



Amplifiers, Comparators, and Special Functions

Data Book
Volume A

Data Book

Amplifiers, Comparators, and Special Functions

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Volume A

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INTRODUCTION

Texas Instruments (TI) offers an extensive line of industry-standard and leadership operational amplifier and comparator products. The technologies represented in this book include traditional bipolar through BiFET, Excalibur, LinCMOS™, Advanced LinCMOS™, and LinBiCMOS™ processes.

The Operational Amplifier/Comparator Data Books (Volumes A and B) provide information on an extensive listing of TI operational amplifier and comparator products:

- Audio Power Amplifiers: Low Voltage, Low Power, High Output Power, and Low Distortion
- Precision, Self-Calibration (Self-Cal]) Amplifiers
- Advanced LinCMOS: Rail-to-Rail Output, High Output Drive, Low Noise, and Low Voltage
- Internally Compensated Amplifiers: Single, Dual, and Quadruple
- Noncompensated Amplifiers: Single and Dual
- Excalibur: High Speed, Low Power, Precision, JFET Input, High Output Drive, and Low Noise
- Various Temperature Ranges: Commercial, Industrial, Automotive, Military, and Extended

AUDIO POWER AMPLIFIERS

Since the release of our last databook, Texas Instruments has introduced several members of our new audio power-amplifier product line. These devices are denoted with the TPA (TI Power Amplifiers) prefix and offer the designer high-fidelity output for low-voltage applications. Several products are optimized for 3-V and 5-V operation and offer shutdown capability for extended life in battery-powered applications. Typical distortion levels are <1% THD+N and along with high ac power supply rejection ratio (PSRR) provide the user with high-fidelity outputs.

FEATURES IN THIS BOOK

- New audio power amplifier product line (TPAxxxx)
- New additions to our low-voltage CMOS rail-to-rail output operational amplifier family
- Amplifier and comparator products available in the SOT-23 package
- Precision Self-Calibration (Self-Cal]) amplifier products
- New family of ultra-fast, low-power comparators
- Expanded product characterization over supply voltage and temperature
- Complete mechanical specifications

The first section of each volume contains an alphanumeric listing, a selection guide, and a cross reference for each type of device. The alphanumeric listing in the book includes all the devices contained in volumes A and B of the Operational Amplifier/Comparator Data Book. The sections in each book are numbered consecutively across volumes (Sections 1, 2, 3, and 4 are in Volume A and sections 5, 6, 7, 8, and 9 are in Volume B). Thus, the reader can easily find the particular volume for a given device.

Due to the great number of devices available from TI, the selection guide for the operational amplifiers is broken down into nine primary categories with a complete alphanumeric listing at the end. The audio power amplifier, comparator and special function selection guides are a complete alphanumeric listing. The cross references in Section 1 help to identify devices that are comparable to other manufacturers and older TI parts.

The last section in each volume contains ordering information and mechanical data for the devices in that particular volume.

While these volumes offer information only on the amplifier and comparator devices available now from TI, complete technical data for upcoming analog or any other TI semiconductor product is available from your nearest TI field sales office, local authorized distributor, or by writing directly to:

Texas Instruments Incorporated Literature Response Center P.O. Box 809066 Dallas, Texas 75380-9066

Also, please visit us on the world wide web at www.ti.com.

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The devices in **BOLD** type are new to this data book.

† This device is in the Advanced Information stage of development.



AUDIO POWER AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per channel) typ	OUTPUT POWER (W)	THD + N @ 1 kHz	PSRR (dB)	ISD (μA)	HEAD- PHONE ENABLE	DESCRIPTION	PAGE NO.
TPA0102†	3 to 5.5	1.9	1.5	0.2%	75	1	Yes	1.5-W stereo audio power amplifier	2–3
TPA302	2.7 to 5.5	4	0.3	0.06%	55	0.6	No	300-mW stereo audio power amplifier	2–9
TPA1517 [†]	6 to 18	40	6	1%	62		No	6-W/ch. stereo audio power amplifier	2-29
TPA4860	2.7 to 5.5	3.5	1	0.2%	56	0.6	Yes	1-W audio power amplifier	2-41
TPA4861	2.7 to 5.5	3.5	1	0.2%	56	0.6	No	1-W audio power amplifier	2-67

[†] This device is in the Advanced Information stage of development.

INTRODUCTION

This selection guide is designed to help you quickly identify which operational amplifiers best suit your needs. This section includes specification tables for each operational amplifier, sorted by the primary performance category; this permits a quick comparison of key specifications, enabling a final decision on which amplifier is best for you. Also included in this section is a complete alphanumerically sorted list of all Texas Instruments advanced linear amplifiers with key specifications.

DEFINITION OF TERMS

This selection guide is broken into eight primary-selection categories:

- DC precision
- Single supply
- Noise
- Low voltage
- High speed
- Low power
- Rail to rail
- High temperature

These categories are then subdivided into secondary and tertiary groups combining performance indices. An understanding of what is meant by each term is helpful when choosing the right amplifier for your application.

DC Precision

Precision refers to an amplifier's inherent dc errors, the input offset voltage (V_{IO}), its temperature coefficient (α_{VIO}), and long-term drift (ΔV_{IO}). In direct-coupled applications, these errors are amplified by the amplifier and carried through the system. The magnitude of the input offset voltage limits the minimum signal level that can be accurately measured. This document defines precision operational amplifiers as those having $V_{IO} \le 1$ mV. In the precision-operational-amplifiers specification table, these operational amplifiers are sorted in ascending order of V_{IO} max at 25°C; the α_{VIO} specification is also provided for comparison.

Single Supply

Single-supply operational amplifiers are those that are designed to operate well with only one power-supply rail, typically 5 V. They are generally characterized as having a common-mode input voltage range (V_{ICR}) that includes ground and outputs that can swing to or very near ground ($V_{OL} \approx 0$ V). Most single-supply operational amplifiers are manufactured using CMOS technology, although some bipolar single-supply amplifiers are available. Single-supply operational amplifiers can be used in systems with split supplies (e.g., ± 5 V), but care must be taken not to exceed the maximum supply voltage across the device. For example, V_{DD} max for CMOS operational amplifiers is 16 V. No more than ± 8 V should be applied to these devices in a split-supply system. Also, some single-supply operational amplifier output stages are not designed to both source and sink current; when used with split supplies, they may exhibit some crossover distortion as the signal passes through midsupply.

Rail to Rail

Rail-to-rail operational amplifiers feature outputs that swing close to both the positive and negative supply rails. To achieve expected results, maintain loading conditions within the specified drive capability of the amplifier; output swing decreases as load increases.



Noise

Noise in operational amplifiers typically has two components: voltage noise and current noise. Current noise is primarily a function of input bias currents (IIB) and is negligible in JFET-input (BiFET) and CMOS amplifiers. Voltage noise (V_n) is noise generated by the amplifier due to the thermal noise of the channel resistance in JFET and CMOS amplifiers or the emitter resistance in bipolar amplifiers. Bipolar technology offers the lowest voltage noise and offers the greatest advantage when interfacing to low-impedance sources. As source impedance increases to about 10 k Ω , system noise is dominated by the thermal noise of the source and feedback resistances and selection of an amplifier is usually driven by other characteristics. At higher source impedances, the noise contribution due to the high-input currents of bipolar amplifiers becomes prohibitive and either a CMOS or BiFET amplifier should be chosen. Amplifiers in the low-noise operational amplifier sections have $V_n \le$ 15 nV/ $\sqrt{\text{Hz}}$. Current noise, though not specified, can be approximated by:

$$I_n \approx \sqrt{(2 \times q \times I_{IB})}$$
, where $q = 1.6 \times 10^{-19}$

Low Voltage

Low-voltage amplifiers operate with V_{CC} or $V_{DD} \le 3$ V. Some CMOS amplifiers operate with $V_{DD} = 1.4$ V. When using any supply voltage, you must ensure that input signals are within the common-mode input voltage range (VICR) of the device. To address the emerging 3-V device market, Texas Instruments has introduced a full line of 3-V operational amplifiers, the TLV series of devices.

High Speed

Speed refers to an operational amplifier's slew rate (SR) and its bandwidth. Slew rate describes the ability of the amplifier's output to follow a large rapidly changing signal at its input, expressed in V/μs. Slew rate is a function of and inversely proportional to supply current (I_{CC} or I_{DD}); increased power consumption must often be traded for faster output response. BiFET amplifiers have traditionally offered the best speed performance, although new complementary bipolar technologies are gaining ground. The high-speed operational amplifiers in this selection guide have a bandwidth ≥ 6 MHz; the amplifiers' slew rate is included in the specification tables for reference.

Low Power

Low power in this document refers to amplifiers whose quiescent currents are less than 500 μA. This category is further broken down to delineate micropower amplifiers, or those with I_{CC} or I_{DD} ≤ 250 µA. The supply current is specified under no-load conditions; the outputs neither sink nor source current. To minimize power consumption, unused amplifiers should be connected as unity-gain followers with their inputs grounded.

High Temperature

High-temperature operational amplifiers are those manufactured using Texas Instruments patent-pending high temperature and high-reliability process. These operational amplifiers perform reliably at temperatures up to 150°C and are well suited for automotive and geophysical (down-hole) applications where temperatures often exceed the industrial or military temperature ranges.



HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per chan- nel) typ max	VIO (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n (nV/√Hz) typ	Slew Rate (V/μs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
LT1013	4 to 44	0.32 to 0.5	0.25 to 0.95	114	-15000	22	0.4		Dual precision low-power	3–51
TLC251(H)	1.4 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Prog. low-voltage: high bias mode	3–357
TLC251(M)	1.4 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Prog. low-voltage: medium bias mode	3–357
TLC251(L)	1.4 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Prog. low-voltage: low bias mode	3-357
TLC252	1.4 to 16	0.7 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Dual low-voltage	3–375
TLC254	1.4 to 16	0.775 to 1.8	2 to 10	80	0.6	25	3.6	1.7	Quad low-voltage	3–395
TLC25L2	1.4 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Dual micropower low-voltage	3–375
TLC25L4	1.4 to 16	0.012 to 0.021	2 to 10	94	0.6	70	0.03	0.085	Quad micropower low-voltage	3–395
TLC25M2	1.4 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Dual low-power low-voltage	3–375
TLC25M4	1.4 to 16	0.125 to 0.32	2 to 10	91	0.6	32	0.43	0.525	Quad low-power low-voltage	3–395
TLC271(H)	3 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Prog. low-power: high bias mode	3-415
TLC271(M)	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Prog. low-power: medium bias mode	3-415
TLC271(L)	3 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Prog. low-power: low bias mode	3–415
TLC272	3 to 16	0.7 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Dual single supply	3-485
TLC274	3 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Quad single supply	3-617
TLC277	3 to 16	0.7 to 1.6	to 0.5	80	0.6	25	3.6	1.7	Dual precision single supply	3-485
TLC279	3 to 16	0.675 to 1.6	to 0.9	80	0.6	25	3.6	1.7	Quad precision single supply	3-617
TLC27L2	3 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Dual precision single supply micropower	3–551
TLC27L4	3 to 16	0.01 to 0.017	2 to 10	94	0.6	70	0.03	0.085	Quad precision single supply micropower	3–669
TLC27L7	3 to 16	0.01 to 0.017	to 0.5	94	0.6	68	0.03	0.085	Dual precision single supply micropower	3–551
TLC27L9	3 to 16	0.01 to 0.017	to 0.9	94	0.6	70	0.03	0.085	Quad precision single supply micropower	3-669
TLC27M2	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Dual precision single supply low-power	3-583
TLC27M4	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Quad precision single supply low-power	3–705
TLC27M7	3 to 16	0.105 to 0.28	to 0.5	91	0.6	32	0.43	0.525	Dual precision single supply low-power	3–583
TLC27M9	3 to 16	0.105 to 0.28	to 0.9	91	0.6	32	0.43	0.525	Quad precision single supply low-power	3–705
TLC1078	1.4 to 16	0.01 to 0.017	1.6 to 0.45	95	0.6	68	0.032	0.085	Dual micropower precision low-voltage	3–741
TLC1079	1.4 to 16	0.01 to 0.017	1.9 to 0.85	95	0.6	68	0.032	0.085	Quad micropower precision low-voltage	3–741
TLC2201	4.6 to 16	1 to 1.5	0.2 to 0.5	110	1	8	2.5	1.8	Low-noise precision rail-to-rail output	3–767
TLC2202	4.6 to 16	0.85 to 1.3	0.5 to 1	110	1	8	2.5	1.9	Dual low-noise precision rail-to-rail	3–767
TLC2252	4.4 to 16	0.035 to 0.0625	0.85 to 1.5	83	1	19	0.12	0.2	Dual rail-to-rail micropower	3–821
TLC2254	4.4 to 16	0.035 to 0.0625	0.85 to 1.5	83	1	19	0.12	0.2	Quad rail-to-rail micropower	3–821
TLC2262	4.4 to 16	0.2 to 0.25	0.95 to 2.5	83	1	12	0.55	0.82	Dual advanced LinCMOS rail-to-rail	3–875

HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS (continued)

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per chan- nel) typ max	VIO (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n (nV/√Hz) typ	Slew Rate (V/µs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
TLC2264	4.4 to 16	0.2 to 0.25	0.95 to 2.5	83	1	12	0.55	0.82	Quad advanced LinCMOS rail-to-rail	3-875
TLC2272	4.4 to 16	1.1 to 1.5	0.95 to 2.5	75	1	9	3.6	2.18	Dual low-noise rail-to-rail	3-931
TLC2274	4.4 to 16	1.1 to 1.5	0.95 to 2.5	75	1	9	3.6	2.18	Quad low-noise rail-to-rail	3-931
TLC2654	±2.3 to ±8	1.5 to 2.4	0.01 to 0.02	125	50	13	3.7	1.9	Low-noise chopper-stabilized	3–1007
TLC4501	4 to 6	1 to 1.5	-0.08 to 0.08	100	1	12	2.5	4.7	Single self-calibrating precision	3-1081
TLC4502	4 to 6	1.25 to 1.75	-0.1 to 0.1	100	1	12	2.5	4.7	Dual self-calibrating precision	3–1107
TLE2021	±2 to ±20	0.2 to 0.3	0.2 to 0.5	115	25000	15	0.65	2	Precision low-power single supply	6–3
TLE2022	±2 to ±20	0.275 to 0.35	0.15 to 0.5	106	35000	15	0.65	2.8	Dual precision low-power single supply	6–3
TLE2024	±2 to ±20	0.2625 to 0.35	0.5 to 1	102	50000	15	0.7	2.8	Quad precision low-power single supply	6–3
TLE2027	±4 to ±22	3.8 to 5.3	0.025 to 0.1	131	15000	2.5	2.8	13	Low-noise precision	6–59
TLE2037	±4 to ±19	3.8 to 5.3	0.025 to 0.1	131	15000	2.5	7.5	50	Low-noise high-speed precision decomp.	6–59
TLE2061	±3.5 to ±19	0.29 to 0.35	0.5 to 3	90	4	40	3.4	2	JFET-input high-output-drive micropower	6–93
TLE2062	±3.5 to ±19	0.3125 to 0.345	1 to 4	90	4	40	3.4	2	Dual JFET-input high-output-drive micropower	6-93
TLE2064	±3.5 to ±19	0.3125 to 0.35	2 to 6	90	4	40	3.4	2	Quad JFET-input high-output-drive micropower	6-93
TLE2071	±2.25 to ±19	1.7 to 2.2	2 to 4	98	20	11.6	45	10	Low-noise high-speed JFET-input	6–155
TLE2072	±2.25 to ±19	1.55 to 1.8	3.5 to 6	98	20	11.6	45	10	Dual low-noise high-speed JFET-input	6-155
TLE2074	±2.25 to ±19	1.425 to 1.875	3 to 5	98	25	11.6	45	10	Quad low-noise high-speed JFET-input	6-155
TLE2081	±2.25 to ±19	1.7 to 2.2	3 to 6	98	20	11.6	45	10	high-speed JFET-input	6-225
TLE2082	±2.25 to ±19	1.55 to 1.8	4 to 7	98	20	11.6	45	10	Dual high-speed JFET-input	6-225
TLE2084	±2.25 to ±19	1.625 to 1.875	4 to 7	98	25	11.6	45	10	Quad high-speed JFET-input	6-225
TLE2141	±2 to ±22	3.5 to 4.5	0.5 to 0.9	108	-700000	10.5	45	5.9	Low-noise high-speed precision single supply	6-287
TLE2142	±2 to ±22	3.45 to 4.5	0.75 to 1.2	108	-700000	10.5	45	5.9	Dual low-noise high-speed precision	6-287
TLE2144	±2 to ±22	3.45 to 4.5	1.5 to 2.4	108	-700000	10.5	45	5.9	Quad low-noise high-speed precision	6-287
TLE2161	±3.5 to ±19	0.29 to 0.35	0.5 to 3	90	4	40	10	6.4	JFET-input high-output-drive low-power decompensated	6–347
TLE2227	±4 to ±19	3.65 to 5.3	0.1 to 0.35	115	15000	2.5	2.5	13	Dual low-noise high-speed precision	6–375
TLE2237	±4 to ±22	3.65 to 5.3	0.1 to 0.35	115	15000	2.5	5	50	Dual low-noise high-speed precision decomp.	6-375
TLE2301	±4.5 to ±22	2.2 to 3.5	0.4 to 10	97	260000	44	14	8	Excalibur 3-state-output wide-bandwidth power	6-405
TLE2662	3.5 to 15	0.3125 to 0.345	1 to 5	90	4	40	3.4	2	Dual μpower JFET-input with switching-capacitor voltage converter	6–427
TLE2682	3.5 to 15	1.55 to 1.8	0.9 to 7.5	98	20	11.3	45	10	High-speed JFET-input dual with switching-ca- pacitor voltage converter	6-465
TLV2211	2.7 to 10	0.013 to 0.025	to 3	83	1	22	0.025	0.065	Single rail-to-rail micropower	6–513

HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS (continued)

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per chan- nel) typ max	V _{IO} (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n (nV/√Hz) typ	Slew Rate (V/μs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
TLV2221	2.7 to 10	0.11 to 0.15	to 3	85	1	19	0.18	0.51	Single rail-to-rail low-power	6-541
TLV2231	2.7 to 10	0.85 to 1.2	to 3	70	1	15	1.6	2	Single rail-to-rail	6–567
TLV2252	2.7 to 8	0.034 to 0.0625	0.85 to 1.5	75	1	19	0.1	0.187	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	2.7 to 8	0.034 to 0.0625	0.85 to 1.5	75	1	19	0.1	0.187	Quad rail-to-rail low-voltage micropower	6–593
TLV2262	2.7 to 8	0.2 to 0.25	0.95 to 2.5	75	1	12	0.55	0.67	Dual rail-to-rail low-voltage low-power	6-639
TLV2264	2.7 to 8	0.2 to 0.25	0.95 to 2.5	75	1	12	0.55	0.67	Quad rail-to-rail low-voltage low-power	6–639
TLV2322	2 to 8	0.006 to 0.017	1.1 to 9	88	0.6	68	0.02	0.027	Dual low-voltage micropower	6687
TLV2324	2 to 8	0.006 to 0.017	1.1 to 10	88	0.6	68	0.02	0.027	Quad low-voltage micropower	6–687
TLV2332	2 to 8	0.08 to 0.25	1.1 to 9	92	0.6	32	0.38	0.3	Dual low-voltage low-power	6–715
TLV2334	2 to 8	0.08 to 0.25	1.1 to 10	92	0.6	32	0.38	0.3	Quad low-voltage low-power	6-715
TLV2341(H)	2 to 8	0.325 to 1.5	1.1 to 8	78	0.6	25	2.1	0.79	Programmable low-voltage: high bias mode	6-743
TLV2341(M)	2 to 8	0.065 to 0.25	1.1 to 8	92	0.6	32	0.38	0.3	Programmable low-voltage: Med bias mode	6–743
TLV2341(L)	2 to 8	0.005 to 0.017	1.1 to 8	88	0.6	68	0.02	0.027	Programmable low-voltage: low bias mode	6-743
TLV2342	2 to 8	0.325 to 1.5	1.1 to 9	78	0.6	25	2.1	0.79	Dual LinCMOS low-voltage high-speed	6–793
TLV2344	2 to 8	0.325 to 1.5	1.1 to 10	78	0.6	25	2.1	0.79	Quad LinCMOS low-voltage high-speed	6–793
TLV2361	±1 to ±2.5	1.75 to 2.5	1 to 6	85	20000	8	3	7	Single high-performanC, low-voltage	6-823
TLV2362	±1 to ±3.5	1.4 to 2.25	1 to 6	75	20000	9	2.5	6	Dual high-performanC, low-voltage	6-823
TLV2432	2.7 to 10	0.1 to 0.125	0.95 to 2	90	1	18	0.25	0.55	Dual wide-input-voltage, high-output-drive	6–839
TLV2442	2.7 to 10	0.75 to 1.1	0.95 to 2	75	1	16	1.4	1.81	Dual wide-input-voltage, high-output-drive	6-875

PRECISION OPERATIONAL AMPLIFIERS

DEVICE	V _{IO} (μV) typ range	V _{IO} (μV) max range	(mA per channel)	CMRR (dB) typ	SLEW RATE (V/µs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
TLC4501	-40 to 40	-80 to 80	1 to 1.5	100	2.5	4.7	Single self-calibrating precision	3–1081
TLC4502	-50 to 50	-100 to 100	1.25 to 1.75	100	2.5	4.7	Dual self-calibrating precision	3–1107
TLE2024		500 to 1000	0.2625 to 0.35	102	0.7	2.8	Quad precision low-power single supply	6–3
TLE2027	10 to 20	25 to 100	3.8 to 5.3	131	2.8	13	Low-noise precision	6–59
TLE2037	10 to 20	25 to 100	3.8 to 5.3	131	7.5	50	Low-noise high-speed precision decompensated	6–59
LT1013	60 to 250	250 to 950	0.32 to 0.5	114	0.4		Dual precision low-power	3-51
TLE2022	70 to 150	150 to 500	0.275 to 0.35	106	0.65	2.8	Dual precision low-power single supply	6–3
TLC2201	80 to 100	200 to 500	1 to 1.5	110	2.5	1.8	Low-noise precision rail-to-rail output	3-767
TLC2202	80 to 100	500 to 1000	0.85 to 1.3	110	2.5	1.9	Dual low-noise precision rail-to-rail	3–767
TLE2021	80 to 120	200 to 500	0.2 to 0.3	115	0.65	2	Precision low-power single supply	6–3
TLC1078	160	450	0.01 to 0.017	95	0.032	0.085	Dual micropower precision low-voltage	3-741
TLE2141	175 to 200	500 to 900	3.5 to 4.5	108	45	5.9	Low-noise high-speed precision single supply	6-287
TLC1079	190	850	0.01 to 0.017	95	0.032	0.085	Quad micropower precision low-voltage	3–741
TLC2252	200	850 to 1500	0.035 to 0.0625	83	0.12	0.2	Dual rail-to-rail micropower	3–821
TLC2254	200	850 to 1500	0.035 to 0.0625	83	0.12	0.2	Quad rail-to-rail micropower	3–821
TLV2252	200	850 to 1500	0.034 to 0.0625	75	0.1	0.187	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	200	850 to 1500	0.034 to 0.0625	75	0.1	0.187	Quad rail-to-rail low-voltage micropower	6–593
TLE2142	275 to 290	750 to 1200	3.45 to 4.5	108	45	5.9	Dual low-noise high-speed precision	6–287
TLC2262	300	950 to 2500	0.2 to 0.25	83	0.55	0.82	Dual advanced LinCMOS rail-to-rail	3–875
TLC2264	300	950 to 2500	0.2 to 0.25	83	0.55	0.82	Quad advanced LinCMOS rail-to-rail	3–875
TLC2272	300	950 to 2500	1.1 to 1.5	75	3.6	2.18	Dual low-noise rail-to-rail	3-931
TLC2274	300	950 to 2500	1.1 to 1.5	75	3.6	2.18	Quad low-noise rail-to-rail	3–931
TLE2161	300 to 600	500 to 3000	0.29 to 0.35	90	10	6.4	JFET-input high-output-drive low-power decompensated	6–347
TLV2262	300	950 to 2500	0.2 to 0.25	. 75	0.55	0.67	Dual rail-to-rail low-voltage low-power	6–639
TLV2264	300	950 to 2500	0.2 to 0.25	75	0.55	0.67	Quad rail-to-rail low-voltage low-power	6–639
TLV2432	300	950 to 2000	0.1 to 0.125	90	0.25	0.55	Dual wide-input-voltage, high-output-drive	6–839
TLV2442	300	950 to 2000	0.75 to 1.1	75	1.4	1.81	Dual wide-input-voltage, high-output-drive	6-875

LOW-NOISE OPERATIONAL AMPLIFIERS

DEVICE	V _n (nV/√Hz) typ	IDD/ICC (mA per channel) typ max	I _{IB} (pA) typ	SLEW RATE (V/µs) typ	GBW (MHz) typ	RAIL-TO-RAIL OUTPUT	DESCRIPTION	PAGE NO.
TLE2027	2.5	3.8 to 5.3	15000	2.8	13		Low-noise precision	6–59
TLE2037	2.5	3.8 to 5.3	15000	7.5	50		Low-noise high-speed precision decompensated	6–59
TLE2227	2.5	3.65 to 5.3	15000	2.5	13		Dual low-noise high-speed precision	6–375
TLE2237	2.5	3.65 to 5.3	15000	5	50		Dual low-noise high-speed precision decompensated	6–375
TLC2201	8	1 to 1.5	1	2.5	1.8	х	Low-noise precision rail-to-rail output	3–767
TLC2202	8	0.85 to 1.3	1	2.5	1.9	X	Dual low-noise precision rail-to-rail	3–767
TLV2361	8	1.75 to 2.5	20000	3	7		single high-performanC, low-voltage	6-823
TLC2272	9	1.1 to 1.5	1	3.6	2.18	Х	Dual low-noise rail-to-rail	3–931
TLC2274	9	1.1 to 1.5	1	3.6	2.18	Х	Quad low-noise rail-to-rail	3–931
TLV2362	9	1.4 to 2.25	20000	2.5	6		Dual high-performanC, low-voltage	6–823
TLE2141	10.5	3.5 to 4.5	-700000	45	5.9		Low-noise high-speed precision single supply	6–287
TLE2142	10.5	3.45 to 4.5	-700000	45	5.9		Dual low-noise high-speed precision	6–287
TLE2144	10.5	3.45 to 4.5	-700000	45	5.9		Quad low-noise high-speed precision	6–287
TLE2071	11.6	1.7 to 2.2	20	45	10		Low-noise high-speed JFET-input	6–155
TLE2072	11.6	1.55 to 1.8	20	45	10		Dual low-noise high-speed JFET-input	6-155
TLE2074	11.6	1.425 to 1.875	25	45	10		Quad low-noise high-speed JFET-input	6–155
TLC2262	12	0.2 to 0.25	1	0.55	0.82	Х	Dual advanced LinCMOS rail-to-rail	3–875
TLC2264	12	0.2 to 0.25	1	0.55	0.82	Х	Quad advanced LinCMOS rail-to-rail	3–875
TLC4501	12	1 to 1.5	1	2.5	4.7	X	Single self-calibrating precision	3–1081
TLC4502	12	1.25 to 1.75	1	2.5	4.7	Х	Dual self-calibrating precision	3–1107
TLV2262	12	0.2 to 0.25	1	0.55	0.67	Х	Dual rail-to-rail low-voltage low-power	6–639
TLV2264	12	0.2 to 0.25	1	0.55	0.67	X	Quad rail-to-rail low-voltage low-power	6–639
TLC2654	13	1.5 to 2.4	50	3.7	1.9	Х	Low-noise chopper-stabilized	3–1007
TLE2021	15	0.2 to 0.3	25000	0.65	2		Precision low-power single supply	6–3
TLE2022	15	0.275 to 0.35	35000	0.65	2.8		Dual precision low-power single supply	6–3
TLE2024	15	0.2625 to 0.35	50000	0.7	2.8		Quad precision low-power single supply	6–3
TLV2231	15	0.850 to 1.2	1	1.6	2	Х	Single rail-to-rail	6–567
TLV2442	16	0.75 to 1.1	1	1.4	1.81	Х	Dual wide-input-voltage, high-output-drive	6–875
TLC2252	19	0.035 to 0.0625	1	0.12	0.2	Х	Dual rail-to-rail micropower	3–821
TLC2254	19	0.035 to 0.0625	1	0.12	0.2	Х	Quad rail-to-rail micropower	3-821

LOW-NOISE OPERATIONAL AMPLIFIERS (continued)

DEVICE	V _n (nV/√Hz) typ	IDD/ICC (mA per channel) typ max	I _{IB} (pA) typ	SLEW RATE (V/μs) typ	GBW (MHz) typ	RAIL-TO-RAIL OUTPUT	DESCRIPTION	PAGE NO.
TLV2221	19	0.110 to 0.15	1	0.18	0.51	Х	single rail-to-rail low-power	6–541
TLV2252	19	0.034 to 0.0625	1	0.1	0.187	х	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	19	0.034 to 0.0625	1	0.1	0.187	Х	Quad rail-to-rail low-voltage micropower	6–593

HIGH-SPEED OPERATIONAL AMPLIFIERS

DEVICE	GBW (Mhz) typ	Slew Rate (V/μs) typ	I _{DD} /I _{CC} (mA per channel) typ max	I _{IB} (pA) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.
TLE2037	50	7.5	3.8 to 5.3	15000	2.5	Low-noise high-speed precision decomp.	6–59
TLE2237	50	5	3.65 to 5.3	15000	2.5	Dual low-noise high-speed precision decomp.	6-375
TLV2361	7	3	1.75 to 2.5	20000	8	single high-performanC, low-voltage	6-823
TLV2362	6	2.5	1.4 to 2.25	20000	9	Dual high-performanC, low-voltage	6-823
TLE2141	5.9	45	3.5 to 4.5	-700000	10.5	Low-noise high-speed precision single supply	6–287
TLE2142	5.9	45	3.45 to 4.5	-700000	10.5	Dual low-noise high-speed precision	6-287
TLE2144	5.9	45	3.45 to 4.5	-700000	10.5	Quad low-noise high-speed precision	6–287
TLE2682	10	45	1.55 to 1.8	20	11.3	Dual high-speed JFET-input with switched-capacitor voltage converter	6-465
TLE2071	10	45	1.7 to 2.2	20	11.6	Low-noise high-speed JFET-input	6–155
TLE2072	10	45	1.55 to 1.8	20	11.6	Dual low-noise high-speed JFET-input	6–155
TLE2074	10	45	1.425 to 1.875	25	11.6	Quad low-noise high-speed JFET-input	6–155
TLE2081	10	45	1.7 to 2.2	20	11.6	High-speed JFET-input	6-225
TLE2082	10	45	1.55 to 1.8	20	11.6	Dual high-speed JFET-input	6–225
TLE2084	10	45	1.625 to 1.875	25	11.6	Quad high-speed JFET-input	6-225

RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (μA per channel) typ max	V _O (V) typ	Slew Rate (V/μs) typ	GBW (MHz) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.
TLC2201	4.6 to 16	1000 to 1500	0 to 4.8	2.5	1.8	8	Low-noise precision rail-to-rail output	3–767
TLC2202	4.6 to 16	850 to 1300	0 to 4.8	2.5	1.9	8	Dual low-noise precision rail-to-rail	3–767
TLC2252	4.4 to 16	35 to 62.5	0.01 to 4.98	0.12	0.2	19	Dual rail-to-rail micropower	3–821
TLC2254	4.4 to 16	35 to 62.5	0.01 to 4.98	0.12	0.2	19	Quad rail-to-rail micropower	3–821
TLC2262	4.4 to 16	200 to 250	0.01 to 4.99	0.55	0.82	12	Dual advanced LinCMOS rail-to-rail	3–875
TLC2264	4.4 to 16	200 to 250	0.01 to 4.99	0.55	0.82	12	Quad advanced LinCMOS rail-to-rail	3-875
TLC2272	4.4 to 16	1100 to 1500	0.01 to 4.99	3.6	2.18	9	Dual low-noise rail-to-rail	3–931
TLC2274	4.4 to 16	1100 to 1500	0.01 to 4.99	3.6	2.18	9	Quad low-noise rail-to-rail	3–931
TLC4501	4 to 6	1000 to 1500	0.01 to 4.99	2.5	4.7	12	Single self-calibrating precision	3–1081
TLC4502	4 to 6	1250 to 1750	0.01 to 4.99	2.5	4.7	12	Dual self-calibrating precision	3–1107
TLV2211	2.7 to 10	13 to 25	0.012 to 4.95	0.025	0.065	22	Single rail-to-rail micropower	6–513
TLV2221	2.7 to 10	110 to 150	0.012 to 4.88	0.18	0.51	19	Single rail-to-rail low-power	6–541
TLV2231	2.7 to 10	850 to 1200	0.08 to 4.9	1.6	2	15	Single rail-to-rail	6–567
TLV2252	2.7 to 8	34 to 62.5	0.01 to 2.98	0.1	0.187	19	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	2.7 to 8	34 to 62.5	0.01 to 2.98	0.1	0.187	19	Quad rail-to-rail low-voltage micropower	6–593
TLV2262	2.7 to 8	200 to 250	0.01 to 2.99	0.55	0.67	12	Dual rail-to-rail low-voltage low-power	6–639
TLV2264	2.7 to 8	200 to 250	0.01 to 2.99	0.55	0.67	12	Quad rail-to-rail low-voltage low-power	6–639
TLV2432	2.7 to 10	100 to 125	0.01 to 4.97	0.25	0.55	18	Dual wide-input-voltage, high-output-drive	6–839
TLV2442	2.7 to 10	750 to 1100	0.01 to 4.97	1.4	1.81	16	Dual wide-input-voltage, high-output-drive	6-875

SINGLE-SUPPLY OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per channel) typ max	V _{IO} (mV) typ max	SLEW RATE (V/µs) typ	GBW (MHz) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.
TLE2021	±2 to ±20	0.2 to 0.3	0.12 to 0.5	0.65	2	15	Precision low-power single supply	6–3
TLE2022	±2 to ±20	0.275 to 0.35	0.15 to 0.5	0.65	2.8	15	Dual precision low-power single supply	6–3
TLE2024	±2 to ±20	0.2625 to 0.35		0.7	2.8	15	Quad precision low-power single supply	6–3
TLE2141	±2 to ±22	3.5 to 4.5	0.2 to 0.9	45	5.9	10.5	Low-noise high-speed precision single supply	6–287
TLE2142	±2 to ±22	3.45 to 4.5	0.29 to 1.2	45	5.9	10.5	Dual low-noise high-speed precision	6–287
TLE2144	±2 to ±22	3.45 to 4.5	0.6 to 2.4	45	5.9	10.5	Quad low-noise high-speed precision	6–287
TLV2211	2.7 to 10	0.013 to 0.025	0.45 to 3	0.025	0.065	22	Single rail-to-rail micropower	6–513
TLV2221	2.7 to 10	0.11 to 0.15	0.61 to 3	0.18	0.51	19	Single rail-to-rail low-power	6–541
TLV2231	2.7 to 10	0.85 to 1.2	0.71 to 3	1.6	2	15	Single rail-to-rail	6–567
TLV2252	2.7 to 8	0.034 to 0.0625	0.2 to 1.5	0.1	0.187	19	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	2.7 to 8	0.034 to 0.0625	0.2 to 1.5	0.1	0.187	19	Quad rail-to-rail low-voltage micropower	6–593
TLV2262	2.7 to 8	0.2 to 0.25	0.3 to 2.5	0.55	0.67	12	Dual rail-to-rail low-voltage low-power	6–639
TLV2264	2.7 to 8	0.2 to 0.25	0.3 to 2.5	0.55	0.67	12	Quad rail-to-rail low-voltage low-power	6-639
TLV2432	2.7 to 10	0.1 to 0.125	0.300 to 2	0.25	0.55	18	Dual wide-input-voltage, high-output-drive	6-839
TLV2442	2.7 to 10	0.75 to 1.1	0.300 to 2	1.4	1.81	16	Dual wide-input-voltage, high-output-drive	6–875
TLC4501	4 to 6	1 to 1.5	0.04 to 0.08	2.5	4.7	12	Single self-calibrating precision	3–1081
TLC4502	4 to 6	1.25 to 1.75	0.05 to 0.1	2.5	4.7	12	Dual self-calibrating precision	3–1107
TLC2252	4.4 to 16	0.035 to 0.0625	0.2 to 1.5	0.12	0.2	19	Dual rail-to-rail micropower	3-821
TLC2254	4.4 to 16	0.035 to 0.0625	0.2 to 1.5	0.12	0.2	19	Quad rail-to-rail micropower	3-821
TLC2262	4.4 to 16	0.2 to 0.25	0.3 to 2.5	0.55	0.82	12	Dual advanced LinCMOS rail-to-rail	3–875
TLC2264	4.4 to 16	0.2 to 0.25	0.3 to 2.5	0.55	0.82	12	Quad advanced LinCMOS rail-to-rail	3–875
TLC2272	4.4 to 16	1.1 to 1.5	0.3 to 2.5	3.6	2.18	9	Dual low-noise rail-to-rail	3–931
TLC2274	4.4 to 16	1.1 to 1.5	0.3 to 2.5	3.6	2.18	9	Quad low-noise rail-to-rail	3–931
TLC2201	4.6 to 16	1 to 1.5	0.1 to 0.5	2.5	1.8	8	Low-noise precision rail-to-rail output	3–767
TLC2202	4.6 to 16	0.85 to 1.3	0.1 to 1	2.5	1.9	8	Dual low-noise precision rail-to-rail	3-767

LOW-VOLTAGE OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (mA per channel) typ max	V _O (V) typ	SLEW RATE (V/μs) typ	GBW (MHz) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.			
TLC1078	1.4 to 16	0.01 to 0.017	0 to 4.1	0.032	0.085	68	Dual micropower precision low-voltage	3–741			
TLC1079	1.4 to 16	0.01 to 0.017	0 to 4.1	0.032	0.085	68	Quad micropower precision low-voltage	3–741			
TLC251(H)	1.4 to 16	0.675 to 1.6	0 to 3.8	3.6	1.7 25 Prog		Prog. low-voltage: high bias mode	3–357			
TLC251(M)	1.4 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Prog. low-voltage: medium bias mode	3–357			
TLC251(L)	1.4 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	68	Prog. low-voltage: low bias mode	3–357			
TLC252	1.4 to 16	0.7 to 1.6	0 to 3.8	3.6	1.7	25	Dual low-voltage	3–375			
TLC254	1.4 to 16	0.775 to 1.8	0 to 3.8	3.6	1.7	25	Quad low-voltage	3–395			
TLC25L2	1.4 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	68	Dual micropower low-voltage	3–375			
TLC25L4	1.4 to 16	0.012 to 0.021	0 to 4.1	0.03	0.085	70	Quad micropower low-voltage	3–395			
TLC25M2	1.4 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Dual low-power low-voltage	3–375			
TLC25M4	1.4 to 16	0.125 to 0.32	0 to 3.9	0.43	0.525	32	Quad low-power low-voltage	3–395			
TLC271(H)	3 to 16	0.675 to 1.6	0 to 3.8	3.6	1.7	25	Prog. low-power: high bias mode	3-415			
TLC271(M)	3 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Prog. low-power: medium bias mode	3–415			
TLC271(L)	3 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	68	Prog. low-power: low bias mode	3–415			
TLC272	3 to 16	0.7 to 1.6	0 to 3.8	3.6	1.7	25	Dual single supply	3–485			
TLC274	3 to 16	0.675 to 1.6	0 to 3.8	3.6	1.7	25	Quad single supply	3–617			
TLC277	3 to 16	0.7 to 1.6	0 to 3.8	3.6	1.7	25	Dual precision single supply	3–485			
TLC279	3 to 16	0.675 to 1.6	0 to 3.8	3.6	1.7	25	Quad precision single supply	3–617			
TLC27L2	3 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	68	Dual precision single supply micropower	3–551			
TLC27L4	3 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	70	Quad precision single supply micropower	3–669			
TLC27L7	3 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	68	Dual precision single supply micropower	3–551			
TLC27L9	3 to 16	0.01 to 0.017	0 to 4.1	0.03	0.085	70	Quad precision single supply micropower	3–669			
TLC27M2	3 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Dual precision single supply low-power	3–583			
TLC27M4	3 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Quad precision single supply low-power	3–705			
TLC27M7	3 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Dual precision single supply low-power	3–583			
TLC27M9	3 to 16	0.105 to 0.28	0 to 3.9	0.43	0.525	32	Quad precision single supply low-power	3–705			
TLV2211	2.7 to 10	0.013 to 0.025	0.012 to 4.95	0.025	0.065	22	Single rail-to-rail micropower	6–513			
TLV2221	2.7 to 10	0.11 to 0.15	0.012 to 4.88	0.18	0.51	19	Single rail-to-rail low-power	6–541			
TLV2231	2.7 to 10	0.85 to 1.2	0.08 to 4.9	1.6	2	15	Single rail-to-rail	6–567			
TLV2252	2.7 to 8	0.034 to 0.0625	0.01 to 2.98	0.1	0.187	19	Dual rail-to-rail low-voltage micropower	6–593			
TLV2254	2.7 to 8	0.034 to 0.0625	0.01 to 2.98	0.1	0.187	19	Quad rail-to-rail low-voltage micropower	6–593			
TLV2262	2.7 to 8	0.2 to 0.25	0.01 to 2.99	0.55	0.67	12	Dual rail-to-rail low-voltage low-power	6-639			
TLV2264	2.7 to 8	0.2 to 0.25	0.01 to 2.99	0.55	0.67	12	Quad rail-to-rail low-voltage low-power	6–639			

LOW-VOLTAGE OPERATIONAL AMPLIFIERS (continued)

DEVICE	V _{DD} /V _{CC} (V) min max	IDD/ICC (mA per channel) typ max	V _O (V) typ	SLEW RATE (V/µs) typ	GBW (MHz) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.
TLV2322	2 to 8	0.006 to 0.017	0.115 to 1.9	0.02	0.027	68	Dual low-voltage micropower	6–687
TLV2324	2 to 8	0.006 to 0.017	0.115 to 1.9	0.02	0.027	68	Quad low-voltage micropower	6–687
TLV2332	2 to 8	0.08 to 0.25	0.115 to 1.9	0.38	0.3	32	Dual low-voltage low-power	6–715
TLV2334	2 to 8	0.08 to 0.25	0.115 to 1.9	0.38	0.3	32	Quad low-voltage low-power	6–715
TLV2341(H)	2 to 8	0.325 to 1.5	0.12 to 1.9	2.1	0.79	25	Programmable low-voltage: high bias mode	6–743
TLV2341(M)	2 to 8	0.065 to 0.25	0.115 to 1.9	0.38	0.3	32	Programmable low-voltage: Med bias mode	6–743
TLV2341(L)	2 to 8	0.005 to 0.017	0.115 to 1.9	0.02	0.027	68	Programmable low-voltage: low bias mode	6–743
TLV2342	2 to 8	0.325 to 1.5	0.12 to 1.9	2.1	0.79	25	Dual LinCMOS low-voltage high-speed	6–793
TLV2344	2 to 8	0.325 to 1.5	0.12 to 1.9	2.1	0.79	25	Quad LinCMOS low-voltage high-speed	6–793
TLV2361	±1 to ±2.5	1.75 to 2.5	-2.4 to 2.4	3	7	8	Single high-performance, low-voltage	6–823 .
TLV2362	±1 to ±3.5	1.4 to 2.25	-1.4 to 1.4	2.5	6	9	Dual high-performanC, low-voltage	6–823
TLV2432	2.7 to 10	0.1 to 0.125	0.01 to 4.97	0.25	0.55	18	Dual wide-input-voltage, high-output-drive	6–839
TLV2442	2.7 to 10	0.75 to 1.1	0.01 to 4.97	1.4	1.81	16	Dual wide-input-voltage, high-output-drive	6–875

LOW-POWER OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	I _{DD} /I _{CC} (μA per channel) typ max	V _{IO} (mV) typ max	SLEW RATE (V/µs) typ	GBW (MHz) typ	V _n (nV/√Hz) typ	DESCRIPTION	PAGE NO.
TLC27L1	3 to 16	10 to 17	1.1 to 10	0.03	1	68	Single LinCMOS	3-521
TLC2252	4.4 to 16	35 to 62.5	0.2 to 1.5	0.12	0.2	19	Dual rail-to-rail micropower	3-821
TLC2254	4.4 to 16	35 to 62.5	0.2 to 1.5	0.12	0.2	19	Quad rail-to-rail micropower	3-821
TLC2262	4.4 to 16	200 to 250	0.3 to 2.5	0.55	0.82	12	Dual advanced LinCMOS rail-to-rail	3–875
TLC2264	4.4 to 16	200 to 250	0.3 to 2.5	0.55	0.82	12	Quad advanced LinCMOS rail-to-rail	3-875
TLE2021	±2 to ±20	200 to 300	0.12 to 0.5	0.65	2	15	Precision low-power single supply	6–3
TLE2022	±2 to ±20	275 to 350	0.15 to 0.5	0.65	2.8	15	Dual precision low-power single supply	6–3
TLE2024	±2 to ±20	262.5 to 350		0.7	2.8	15	Quad precision low-power single supply	6–3
TLE2061	±3.5 to ±19	290 to 350	0.6 to 3	3.4	2	40	JFET-input high-output-drive micropower	6–93
TLE2062	±3.5 to ±19	312.5 to 345	0.9 to 4	3.4	2	40	Dual JFET-input high-output-drive micropower	6–93
TLE2064	±3.5 to ±19	312.5 to 350	0.9 to 6	3.4	2	40	Quad JFET-input high-output-drive micropower	6–93
TLV2211	2.7 to 10	13 to 25	0.45 to 3	0.025	0.065	22	Single rail-to-rail micropower	6–513
TLV2221	2.7 to 10	110 to 150	0.61 to 3	0.18	0.51	19	Single rail-to-rail low-power	6–541
TLV2252	2.7 to 8	34 to 62.5	0.2 to 1.5	0.1	0.187	19	Dual rail-to-rail low-voltage micropower	6–593
TLV2254	2.7 to 8	34 to 62.5	0.2 to 1.5	0.1	0.187	19	Quad rail-to-rail low-voltage micropower	6-593
TLV2262	2.7 to 8	200 to 250	0.3 to 2.5	0.55	0.67	12	Dual rail-to-rail low-voltage low-power	6-639
TLV2264	2.7 to 8	200 to 250	0.3 to 2.5	0.55	0.67	12	Quad rail-to-rail low-voltage low-power	6-639
TLV2432	2.7 to 10	100 to 125	0.3 to 2	0.25	0.55	18	Dual wide-input-voltage, high-output-drive	6-839

GENERAL-PURPOSE BIPOLAR OPERATIONAL AMPLIFIERS

DEVICE	V _{CC} (V) min max	I _{CC} (mA per channel) typ max	V _{IO} (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _{n_} (nV/√Hz) typ	Slew Rate (V/μs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
LM2902	4 to 26	0.175 to 0.3	7	80	-20000	23	0.25	0.4	Quad general-purpose	3–17
LM2904	4 to 26	0.5 to 1	7	80	-20000	23	0.15	0.4	Dual general-purpose	3–29
LM318	±5 to ±20	5 to 10	10	100	150000	23	70	15	Single high-speed	3–13
LM324	4 to 32	0.175 to 0.3	7	80	-20000	23	0.25	0.4	Quad general-purpose	3–17
LM324x2	4 to 32	0.175 to 0.3	7	80	-20000	23	0.15	0.4	Octal general-purpose	3–39
LM348	±4 to ±18	0.6 to 1.125	6	90	30000	23	0.5	1	Quad general-purpose	3–25
LM358	4 to 32	0.5 to 1	3 to 7	80	-20000	23		0.4	Dual general-purpose	3–29
MC1458	±5 to ±15	1.7 to 2.8	6	90	80000	45	0.5	1	Dual general-purpose	3–75
MC3403	5 to 30	0.7 to 1.75	10	90	-200000		0.6	1	Quad low-power general-purpose	3–79
NE5532	3 to 20	4 to 8	4	100	200000	5	9	10	Dual low-noise high-speed audio	3–85
NE5534	3 to 20	4 to 8	4	100	500000	3.5	13	10	Low-noise high-speed audio	3–89
OP07	±3 to ±18	2.7 to 5	0.15	120	1800	9.8	0.3	0.6	Precision	3–95
RC4136	±5 to ±18	1.25 to 2.825	6	90	140000	8	1.7	3	Quad general-purpose	3–101
RC4558	±5 to ±18	1.25 to 2.8	6	90	150000	8	1.7	3	Dual general-purpose	3–105
TL022	±5 to ±18	0.065 to 0.125	5	72	100000	50	0.5	0.5	Dual low-power general-purpose	3–111
TL2828	4 to 30	0.35 to 0.6	7	80	-15000	23	0.15	0.4	Dual high temperature bipolar	3–337
TL2829	4 to 30	0.3 to 0.4	7	75	-15000	23	0.25	0.4	Quad high temperature bipolar	3–343
μΑ741	±3.5 to ±18	1.7 to 2.8	6	90	80000		0.5		General-purpose	6-909

GENERAL-PURPOSE LINCMOS OPERATIONAL AMPLIFIERS

DEVICE	V _{DD} (V) min max	I _{DD} (mA per channel) typ max	V _{IO} (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n (nV/√Hz) typ	SLEW RATE (V/μs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
TLC1078	1.4 to 16	0.01 to 0.017	0.45	95	0.6	68	0.032	0.085	Dual micropower precision low-voltage	3–741
TLC1079	1.4 to 16	0.01 to 0.017	0.85	95	0.6	68	0.032	0.085	Quad micropower precision low-voltage	3–741
TLC251(H)	1.4 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Prog. low-voltage: high bias mode	3–357
TLC251(M)	1.4 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Prog. low-voltage: medium bias mode	3–357
TLC251(L)	1.4 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Prog. low-voltage: low bias mode	3-357
TLC252	1.4 to 16	0.7 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Dual low-voltage	3–375
TLC254	1.4 to 16	0.775 to 1.8	2 to 10	80	0.6	25	3.6	1.7	Quad low-voltage	3–395
TLC25L2	1.4 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Dual micropower low-voltage	3–375
TLC25L4	1.4 to 16	0.012 to 0.021	2 to 10	94	0.6	70	0.03	0.085	Quad micropower low-voltage	3–395
TLC25M2	1.4 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Dual low-power low-voltage	3–375
TLC25M4	1.4 to 16	0.125 to 0.32	2 to 10	91	0.6	32	0.43	0.525	Quad low-power low-voltage	3–395
TLC271(H)	3 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Prog. low-power: high bias mode	3-415
TLC271(M)	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Prog. low-power: medium bias mode	3-415
TLC271(L)	3 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Prog. low-power: low bias mode	3-415
TLC272	3 to 16	0.7 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Dual single supply	3-485
TLC274	3 to 16	0.675 to 1.6	2 to 10	80	0.6	25	3.6	1.7	Quad single supply	3–617
TLC274x2	3 to 16	0.675 to 1.6	10	80	0.6	25	3.6	1.7	Octal single supply	3-653
TLC277	3 to 16	0.7 to 1.6	0.5	80	0.6	25	3.6	1.7	Dual precision single supply	3-485
TLC279	3 to 16	0.675 to 1.6	0.9	80	0.6	25	3.6	1.7	Quad precision single supply	3–617
TLC27L2	3 to 16	0.01 to 0.017	2 to 10	94	0.6	68	0.03	0.085	Dual precision single supply micropower	3–551
TLC27L4	3 to 16	0.01 to 0.017	2 to 10	94	0.6	70	0.03	0.085	Quad precision single supply micropower	3-669
TLC27L7	3 to 16	0.01 to 0.017	0.5	94	0.6	68	0.03	0.085	Dual precision single supply micropower	3–551
TLC27L9	3 to 16	0.01 to 0.017	0.9	94	0.6	70	0.03	0.085	Quad precision single supply micropower	3–669
TLC27M2	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Dual precision single supply low-power	3–583
TLC27M4	3 to 16	0.105 to 0.28	2 to 10	91	0.6	32	0.43	0.525	Quad precision single supply low-power	3–705
TLC27M7	3 to 16	0.105 to 0.28	0.5	91	0.6	32	0.43	0.525	Dual precision single supply low-power	3–583
TLC27M9	3 to 16	0.105 to 0.28	0.9	91	0.6	32	0.43	0.525	Quad precision single supply low-power	3–705
TLC2801	4.6 to 16	1.1 to 1.5	0.5	110	1	8	2.5	1.8	Low-noise precision high temperature	3-1031
TLC2810	4 to 16	0.5 to 1.6	10	90	7	25	3.6	1.7	Dual high temperature	3-1043
TLC2872	4.4 to 16	1.1 to 1.5	2.5	75	1	9	3.6	2.18	Dual low-noise high temperature	3–1065
TLV2322	2 to 8	0.006 to 0.017	9	88	0.6	68	0.02	0.027	Dual low-voltage micropower	6–687
TLV2324	2 to 8	0.006 to 0.017	10	88	0.6	68	0.02	0.027	Quad low-voltage micropower	6-687

GENERAL-PURPOSE LinCMOS OPERATIONAL AMPLIFIERS (continued)

DEVICE	V _{DD} (V) min max	I _{DD} (mA per channel) typ max	V _{IO} (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n (nV/√Hz) typ	SLEW RATE (V/μs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
TLV2332	2 to 8	0.08 to 0.25	9	92	0.6	32	0.38	0.3	Dual low-voltage low-power	6–715
TLV2334	2 to 8	0.08 to 0.25	10	92	0.6	32	0.38	0.3	Quad low-voltage low-power	6–715
TLV2341(H)	2 to 8	0.325 to 1.5	8	78	0.6	25	2.1	0.79	Programmable low-voltage: high bias mode	6–743
TLV2341(M)	2 to 8	0.065 to 0.25	8	92	0.6	32	0.38	0.3	Programmable low-voltage: Med bias mode	6-743
TLV2341(L)	2 to 8	0.005 to 0.017	8	88	0.6	68	0.02	0.027	Programmable low-voltage: low bias mode	6–743
TLV2342	2 to 8	0.325 to 1.5	9	78	0.6	25	2.1	0.79	Dual LinCMOS low-voltage high-speed	6-793
TLV2344	2 to 8	0.325 to 1.5	10	78	0.6	25	2.1	0.79	Quad LinCMOS low-voltage high-speed	6-793

GENERAL-PURPOSE BIFET OPERATIONAL AMPLIFIERS

DEVICE	V _{CC} (V) min max	I _{CC} (mA per channel) typ max	V _{IO} (mV) max range	CMRR (dB) typ	I _{IB} (pA) typ	V _n _ (nV/√Hz) typ	SLEW RATE (V/µs) typ	GBW (MHz) typ	DESCRIPTION	PAGE NO.
LF347	±3.5 to ±18	2 to 3.75	5 to 10	100	50	18	13	3	Quad general-purpose JFET-input	3–3
LF351	±3.5 to ±18	1.8 to 3.4	10	100	. 50	18	13	3	General-purpose JFET-input	3–5
LF353	±3.5 to ±18	1.8 to 3.25	10	100	50	18	13	3	Dual general-purpose JFET-input	3–7
LF411	±3.5 to ±18	2 to 3.4	2	100	50	18	13	3	Precision JFET-input	3–9
LF412	±3.5 to ±18	2.25 to 3.4	3	100	50	18	13	3	Dual JFET-input	3–11
TL031	±5 to ±18	0.217 to 0.28	0.8 to 1.5	94	2	41	5.1	1.1	Enhanced JFET low-power precision	3–115
TL032	±5 to ±18	0.111 to 0.28	0.8 to 1.5	94	2	41	5.1	1.1	Dual enhanced JFET low-power precision	3–115
TL034	±5 to ±18	0.2175 to 0.28	1.5 to 4	94	2	43	5.1	1.1	Quad enhanced JFET low-power precision	3–115
TL051	±5 to ±18	2.7 to 3.2	0.8 to 1.5	93	30	18	20	3.1	Enhanced JFET precision	3–169
TL052	±5 to ±18	2.4 to 2.8	0.8 to 1.5	93	30	19	20.7	3	Dual enhanced JFET precision	3–169
TL054	±5 to ±18	2.1 to 2.8	1.5 to 4	92	30	21	17.8	2.7	Quad enhanced JFET precision	3–169
TL061	±3.5 to ±18	0.2 to 0.25	3 to 15	86	30	42	3.5	1	Low-power JFET-input general-purpose	3–233
TL062	±3.5 to ±18	0.2 to 0.25	3 to 15	86	30	42	3.5	1	Dual low-power JFET-input general-purpose	3–233
TL064	±3.5 to ±18	0.2 to 0.25	3 to 15	86	30	42	3.5	1	Quad low-power JFET-input general-purpose	3–233
TL064x2	±3.5 to ±18	0.2 to 0.25	15	86	30	42	3.5	1	Octal low-power JFET-input general-purpose	3–255
TL070	±3.5 to ±18	1.4 to 2.5	10	100	65	18	13	3	Low-noise JFET-input decompensated	3–265
TL071	±3.5 to ±18	1.4 to 2.5	3 to 10	100	65	18	13	3	Low-noise JFET-input general-purpose	3–279
TL072	±3.5 to ±18	1.4 to 2.5	3 to 10	100	65	18	13	3	Dual low-noise JFET-input general-purpose	3–279
TL074	±3.5 to ±18	1.4 to 2.5	3 to 10	100	65	18	13	3	Quad low-noise JFET-input general-purpose	3–279
TL074x2	±3.5 to ±18	1.4 to 2.5	10	100	65	18	13	3	Octal low-noise JFET-input general-purpose	3–295
TL081	±3.5 to ±18	1.4 to 2.8	3 to 15	86	30	18	13	3	JFET-input general-purpose	3–307
TL082	±3.5 to ±18	1.4 to 2.8	3 to 15	86	30	18	13	3	Dual JFET-input general-purpose	3–307
TL084	±3.5 to ±18	1.4 to 2.8	3 to 15	86	30	18	13	3	Quad JFET-input general-purpose	3–307
TL084x2	±3.5 to ±18	1.4 to 2.8	15	76	30	18	13	3	Octal JFET-input general-purpose	3-327

AMPLIFIERS — PACKAGE AND TEMPERATURE AVAILABILITY

DEVICE	D	DB	DBV	DW	FK	J	JG	N	NE	Р	PW	U	w	Y(CHIP)
LF347	(14)†							(14)†						
LF347B	(14)†							(14)†						
LF351	(8)									(8)†				
LF353	(8)†									(8)†				
LF411	(8)C									(8)C				
LF412	(8)C									(8)C				
LM118					(20)□		(8)□							
LM124					(20)□	(14)□							(14)□	
LM148					(20)□	(14)□							-	
LM158	·				(20)□		(8)□							
LM218	(8)¶									(8)¶				
LM224	(8)¶				1.					(8)¶				
LM248	(14)¶							(14)¶			(14)¶			
LM258	(8)¶									(8)¶				
LM2900								(14)#						
LM2902	(14)*	(14)*						(14)☆			(14)☆			
LM2904	(8)*	(8)★								(8)☆	(8)★		-	
LM318	(8)†									(8)				
LM324	(14)†	(14)†						(14)†			(14)†			. Y
LM324x2		(30)†												
LM348	(14)†							(14)†			(14)†			
LM358	(8)†	(8)†								(8)†	(14)†			Υ
LM3900								(14)†						
LT1013	(8)C,I [‡] ,M				(20)M		M(8)			(8)C,I [‡] ,M				Υ
MC1458	(8)C									(8)C				
MC1558					(20)M		(8)M		-			(10)M		
MC3303	(14)#							(14)#						
MC3403	(14)†							(14)†						
NE5532						1.0				(8)†,1				
NE5534	(8)†									(8)†				
OP07	(8)†									(8)†				Υ
RC4136	(14)†							(14)†						
RC4558	(8)†	(8)								(8)†	(8)†			Υ
SYMBOL	S: Y = 25° ‡ = -40	C, °C to 105°0		= 0°C to 70°0 0°C to 125°C		-20°C to -40°C to			5°C to 85° = -55°C		l or # = -	-40°C to 8	5°C	

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DEVICE	D	DB	DBV	DW	FK	J	JG	N	NE	P	PW	U	W	Y(CHIP)
RM4136					(20)□	(14)□							(14)□	
RM4558							(8)□							
RV4136	(14)#							(14)#						
RV4558	(8)#									(8)#				
SE5534					(20)□		(8)□							
TL022	(8)C						(8)M			(8)C		(10)M		
TL031	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Υ
TL032	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Υ
TL034	(14)C,I,M				(20)M	(14)M		(14)C,I,M			(14)C			Υ
TL051	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Υ
TL052	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Υ
TL054	(14)C,I,M				(20)M	(14)M		(14)C,I,M						Υ
TL061	(8)C,I				(20)M		(8)M			(8)C,I	(8)C	(10)M		Υ
TL062	(8)C,I				(20)M		(8)M			(8)C,I	(8)C	(10)M		Υ
TL064	(14)C,I				(20)M	(14)M		(14)C,I,M			(14)C			Υ
TL064x2		(30)C												
TL070	(8)C,I,M									(8)C,I,M	(8)C			
TL071	(8)C,I				(20)M	-	(8)M			(8)C,I	(8)C			
TL072	(8)C,I				(20)M		(8)M			(8)C,1	(8)C			
TL074	(14)C,I				(20)M	(14)M		(14)C,I,M			(14)C	(10)M		
TL074x2		(30)C												
TL081	(8)C,I				(20)M		(8)M			(8)C,I	(8)C			
TL082	(8)C,I				(20)M		(8)M			(8)C,I	(8)C			Υ
TL084	(14)C,I				(20)M	(14)M		(14)C,I,M			(14)C			Υ
TL084x2	1	(30)C												
TL2828	(8)Z									(8)Z				Υ
TL2829	(14)Z							(14)Z						Υ
TLC251	(8)C									(8)C				Υ
TLC252	(8)C									(8)C				Y
TLC254	(14)C							(14)C			(14)C			Υ
TLC25L2	(8)C									(8)C				Y
TLC25L4	(14)C							(14)C			(14)C			Υ
TLC25M2	(8)C									(8)C				Υ

AMPLIFIERS — PACKAGE AND TEMPERATURE AVAILABILITY (continued)

DEVICE	D	DB	DBV	DW	FK	J	JG	N	NE	Р	PW	·U	W	Y(CHIP)
TLC25M4	(14)C	1						(14)C			(14)C			Y
TLC271	(8)C,I,M				(20)M		(8)M			(8)C,I,M				
TLC272	(8)C,I,M				(20)M		(8)M			(8)C,I,M	(8)C			Y
TLC274	(14)C,I,M				(20)M		(8)M	(14)C,I,M			(14)C			Y
TLC274x2		(30)C												
TLC277	(8)C,I,M				(20)M		(8)M			(8)C,I,M	·			
TLC279	(14)C,I,M				(20)M	(14)M		(14)C,I,M						
TLC27L1	(8)C,I,M						-			(8)C,I,M				
TLC27L2	(8)C,I,M				(20)M		(8)M			(8)C,I,M				
TLC27L4	(14)C,I,M				(20)M	(14)M		(14)C,I,M			(14)C			Y
TLC27L7	(8)C,I,M				(20)M		(8)M			(8)C,I,M				
TLC27L9	(14)C,I,M				(20)M	(14)M		(14)C,I,M						
TLC27M2	(8)C,I,M				(20)M		(8)M			(8)C,I,M				
TLC27M4	(14)C,I,M				(20)M	(14)M		(14)C,I,M			(14)C			Y
TLC27M7	(8)C,I,M				(20)M		(8)M			(8)C,I,M				
TLC27M9	(14)C,I,M				(20)M	(14)M		(14)C,I,M						
TLC1078	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Y
TLC1079	(14)C,I,M				(20)M	(14)M		(14)C,I,M			-			Y
TLC2201	(8)C,I,M				(20)M		(8)M			(8)C,I,M				Y
TLC2202	(14)C,I,M				(20)M		(8)M			(8)C,I,M				Y
TLC2252	(8)C,I				(20)M		M(8)		-	(8)C,I	(8)C,I	(10)M		Y
TLC2254	(14)C,I*				(20)M	(14)M		(14)C,I*			(8)C,I*		(14)M	Y
TLC2262	(8)C,I*				(20)M		(8)M			(8)C,I [★]	(8)C,I [★]	(10)M		Υ
TLC2264	(14)C,I*				(20)M	(14)M		(14)C,I*			(14)C,I*		(14)M	Y
TLC2272	(8)C,I,M									(8)C,I,M	(8)C			Y
TLC2274	(14)C,I,M				(20)M	(14)M	-	(14)C,I,M			(14)C,I		(14)M	Y
TLC2652	(8)C,I,M (14)C,I,M				(20)M	(14)M	(8)M	(14)C,I,M		(8)C,I,M				Υ
TLC2654	(8)C,I,M (14)C,I,M				(20)M	(14)M	(8)M	(14)C,I,M	-	(8)C,I,M				·Y
TLC2801	(8)Z			1						(8)Z				Υ
TLC2810	(8)Z									(8)Z				Y
TLC2872	(8)Z									(8)Z				Y
SYMBOL		C, 0°C to 105°0		= 0°C to 70°0 0°C to 125°C		–20°C to −40°C to			5°C to 85° = -55°C		I or # = -	40°C to 8	5°C	-

AMPLIFIERS — PACKAGE AND TEMPERATURE AVAILABILITY (continued) DEVICE D DB DBV DW FΚ JG NE PW U W Y(CHIP) TLC4501 (8)C,I Υ TLC4502 (8)C,I Υ TLE2021 (8)C,I,M (8)C (20)MM(8) (8)C,I,M Υ (8)C TLE2022 Υ (8)C,I,M (8)C (20)M(8)M (8)C,I,M (8)C TLE2024 (16)C,I,M Υ (20)M(14)M(14)C,I,M TLE2027 (8)C,I[‡],M (8)C,I‡,M Υ (20)M(8)M (8)C,I[‡],M TLE2037 (20)M (8)M (8)C,I‡,M Υ TLE2061 (8)C,I,M (8)C (20)M (8)M (8)C,I,M Υ (8)C TLE2062 (8)C,I,M (20)MM(8) (8)C,I,M Υ TLE2064 (14)C,I,M Υ (20)M(14)M(14)C,I,M TLE2071 (8)C,I (20)M(8)M Υ (8)C,ITLE2072 (8)C,I (20)MM(8) Υ (8)C,I TLE2074 (16)C,I (20)M (14)M(14)C,I Υ TLE2081 (8)C (20)MM(8) (8)C Υ TLE2082 (8)C,I,M (20)MM(8) (8)C,I,M Υ TLE2084 (16)C (20)M(14)M(14)C,I Υ TLE2141 (8)C,I[‡],M (20)MM(8) (8)C,I‡,M Υ (8)C,I[‡],M (8)C,I[‡],M Υ TLE2142 (20)MM(8) (8)C (14)C,I[‡],M TLE2144 (16)C,I‡,M (20)M(14)M Υ TLE2161 (8)C,I,M (20)MM(8) (8)C,I,M TLE2227 (16)C (8)C Υ TLE2237 (16)C (8)C Υ TLE2301 (16)ITLE2662 (16)ITLE2682 (16)ITLV2211 (5)C,I Υ TLV2221 (5)C,I Υ TLV2231 Υ (5)C,I TLV2252 Υ (8) (20)MM(8) (8) (8) (10)MΥ TLV2254 (14)I(20)M (14)M(14)I(14)I(14)MTLV2262 (8) (20)M(8)M (8) (8) (10)MΥ TLV2264 Υ (14)I(20)M(14)M(14)I(14)I(14)MΥ TI V2322 (8)I(8) (8)

§ = -20°C to 85°C

Z = -40°C to 150°C

 $\P = -25^{\circ}\text{C} \text{ to } 85^{\circ}\text{C}$

M or \Box = -55°C to 125°C

I or $\# = -40^{\circ}$ C to 85°C

SYMBOLS:

Y = 25°C.

 $= -40^{\circ}$ C to 105° C

C or \dagger = 0°C to 70°C

 $* = -40^{\circ}$ C to 125°C

AMPLIFIERS — PACKAGE AND TEMPERATURE AVAILABILITY (continued)

DEVICE	D	DB	DBV	DW	FK	J	JG	N	NE	P	PW	U	W	Y(CHIP)
TLV2324	(14)I							(14)I			(14)1			Y
TLV2332	(8)I									(8)	(8)			Y
TLV2334	(14)1							(14)I			(14)I			Y
TLV2341	(8)I									(8)	(8)			Y
TLV2342	(8)I									(8)1	(8)1			Y
TLV2344	(14)I							(14)I			(14)1			Y
TLV2361			(5)C,I											Y
TLV2362	(8)§									(8)§	(8)§			Y
TLV2432	(8)C,I	1			(20)M		(8)M				(8)C,I	(10)M		Y
TLV2442	(8)C,I				(20)M		(8)M				(8)C,I	(10)M		Y
μΑ741	(8)C,I				(20)M	(14)M	(8)M			(8)C,I	(8)C	(10)M		Y
SYMBOLS		°C, 0°C to 105°		= 0°C to 70°C 0°C to 125°C		–20°C to –40°C to			5°C to 85° = -55°C		I or # = -	-40°C to 85	5°C	-

Replacements are based on similarity of electrical and mechanical characteristics shown in currently published data. Interchangeability in particular applications is not guaranteed. Before using a device as a substitute, the user should compare the specifications of the substitute device with the specifications of the original.

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Manufacturers are arranged in alphabetical order.

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SE5534	SE5534		3–89
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TS27L4B		TLC27L4B	3–669
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TS27M4		TLC27M4	3–705
TS27M4A		TLC27M4A	3–705
TS27M4B		TLC27M4B	3-705

α_{IIO} Average Temperature Coefficient of Input Offset Current

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{IIO} = \frac{\left(I_{IO} \text{ at } T_{A(1)}\right) - \left(I_{IO} \text{ at } T_{A(2)}\right)}{T_{A(1)} - T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

α_{VIO} Average Temperature Coefficient of Input Offset Voltage

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range. The dc voltage that must be applied between the input terminals to force the guiescent dc output voltage to zero or other level, if specified.

$$\alpha_{VIO} \ = \ \frac{\left(V_{IO} \ at \ T_{A(1)}\right) \ - \ \left(V_{IO} \ at \ T_{A(2)}\right)}{T_{A(1)} \ - \ T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

∆V_{CC}

See ksvs

 ΔV_{10}

See k_{SVS}

∮_m Phase Margin

The absolute value of the open-loop phase shift between the output and the inverting input at the frequency at which the modulus of the open-loop amplification is unity.

A_m Gain Margin

The reciprocal of the open-loop voltage amplification at the lowest frequency at which the open-loop phase shift is such that the output is in phase with the inverting input.

A_V Large-Signal Voltage Amplification

The ratio of the peak-to-peak output voltage swing to the change in input voltage required to drive the output

A_{VD} Differential Voltage Amplification

The ratio of the change in output to the change in differential input voltage producing it with the common-mode input voltage held constant

B₁ Unity-Gain Bandwidth

The range of frequencies within which the maximum output voltage swing is above a specified value.

BOM Maximum-Output-Swing Bandwidth

The range of frequencies within which the maximum output voltage swing is above the specified value.

c_i Input Capacitance

The capacitance between the input terminals with either input grounded

OPERATIONAL AMPLIFIER **GLOSSARY**

Common-Mode Rejection Ratio

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

F **Average Noise Figure**

The ratio of an ideal current source (having an internal impedance equal to infinity) in parallel with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a current source.

I_{CC+}, I_{CC} Supply Current

The current into the V_{CC+} or V_{CC-} terminal of an integrated circuit

lв **Input Bias Current**

The average of the currents into the two input terminals with the output at the specified level

Input Offset Current lo

The difference between the currents into the two input terminals with the output at the specified level

l_n **Equivalent Input Noise Current**

The current of an ideal current source (having internal impedance equal to infinity) in parallel with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a current source.

loL **Low-Level Output Current**

The current into an output with input conditions applied that according to the product specification will establish a low level at the output.

Short-Circuit Output Current los

The maximum output current available from the amplifier with the output shorted to ground, to either supply, or to a specified point

kCMR

See CMRR

$\begin{array}{c} \mathbf{k_{SVS}}, \Delta \mathbf{V_{CC}}, \Delta \mathbf{V_{IO}} \\ \mathbf{Supply} \ \mathbf{Voltage} \ \mathbf{Sensitivity} \end{array}$

The absolute value of the ratio of the change in supply voltages to the change in input offset voltage.

- NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.
 - 2. This is the reciprocal of supply voltage sensitivity.

Supply Voltage Rejection Ratio kSVR

The absolute value of the ratio of the change in supply voltages to the change in input offset voltage.

- NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.
 - 2. This is the reciprocal of supply voltage sensitivity.

PD **Total Power Dissipation**

The total dc power supplied to the device less any power delivered from the device to a load. NOTE: At no load: $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$



Input Resistance ri

The resistance between the input terminals and either input grounded

rid Differential Input Resistance

The small-signal resistance between two ungrounded input terminals

Output Resistance r_{o}

The resistance between an output terminal and ground

SR Slew Rate

The average time rate of change of the closed-loop amplifier output voltage for a step-signal input

Rise Time tr

The time required for an output voltage step to change from 10% to 90% of its final value

Total Response Time t_{tot}

The time between a step-function change of the input signal and the instant at which the magnitude of the output signal reaches for the last time a specified level range $(\pm \epsilon)$ containing the final output signal level.

٧ı Input Voltage Range

The range of voltage that if exceeded at either input terminal may cause the operational amplifier to cease functioning properly.

Input Offset Voltage VIO

The dc voltage that must be applied between the input terminals to force the quiescent dc output voltage to zero or other level, if specified.

Vic Common-Mode Input Voltage

The average of the two input voltages

Common-Mode Input Voltage Range VICE

The range of common-mode input voltage that if exceeded may cause the operational amplifier to cease functioning properly.

٧n **Equivalent Input Noise Voltage**

The voltage of an ideal voltage source (having internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

V_{O1}/V_{O2} Crosstalk Attenuation

The ratio of the change in output voltage of a driven channel to the resulting change in output voltage of another channel

High-Level Output Voltage VOH

The voltage at an output with input conditions applied that according to the product specification will establish a high level at the output.

Low-Level Output Voltage VOL

The voltage at an output with input conditions applied that according to the product specification will establish a low level at the output.



OPERATIONAL AMPLIFIER GLOSSARY

V_{ID} Differential Input Voltage

The voltage at the noninverting input with respect to the inverting input

VOM Maximum Peak Output Voltage Swing

The maximum positive or negative peak output voltage that can be obtained without waveform clipping when quiescent dc output voltage is zero.

V_{O(PP)} Maximum Peak-to-Peak Output Voltage Swing

The maximum peak-to-peak output voltage that can be obtained without waveform clipping when quiescent dc output voltage is zero.

z_{ic} Common-Mode Input Impedance

The parallel sum of the small-signal impedance between each input terminal and ground

z_o Output Impedance

The small-signal impedance between the output terminal and ground

Overshoot Factor

The ratio of the largest deviation of the output signal value from its final steady-state value after a step-function change of the input signal to the absolute value of the difference between the steady-state output signal values before and after the step-function change of the input signal.

COMPARATOR SELECTION GUIDE

COMPARATORS (Listed Alphanumerically)

DEVICE	V _{DD} /V _{CC} (V) min	V _{DD} /V _{CC} (V) max	(mA per channel) max	VIO (mV) max	VICR (V) min	VICR (V) max	IOL (mA) min	tRESP (μs) low-to-high	DESCRIPTION	PAGE NO.
LM111	3.5	30	6	3	-14.7	13.8		0.115	Single, strobed differential	7–3
LM139	3.5	30	0.8	5	0		6	0.3	Quad, general purpose differential	7–19
LM211	3.5	30	6	3	-14.7	13.8		0.115	Single, strobed differential	7–3
LM239	3.5	30	0.8	5	0		6	0.3	Quad, general purpose differential	7–19
LM306	-6	12	6.8	5	-5	5	100	0.028	Single, strobed, high speed differential	7–33
LM311	3.5	30	7.5	7.5	-14.7	13.8		0.115	Single, strobed differential	7–3
LM339	4	30	0.8	5	0		6	0.3	Quad, general purpose differential	7–19
LM339x2	4	30	0.5	5	0	3.5	6	0.3	Octal, general purpose differential	7–41
LM393	4	36	1	5	0		6	0.3	Dual, general purpose differential	7–27
LM2901	4	30	0.8	7	0		6	0.3	Quad, general purpose differential	7–19
LM2903	2	36	1	7	0		6	0.3	Dual, general purpose differential	7–27
LM3302	2	28	0.2	20	0	3.5	6	0.3	Quad, general purpose differential	7–45
LP111	4	30	0.3	7.5	-14.5	13.5		1.2	Single, low-power, strobed differential	7–49
LP211	4	30	0.3	7.5	-14.5	13.5		1.2	Single, low-power, strobed differential	7-49
LP239	5	30	0.1	±5	0			1.3	Quad, low-power, general purpose differential	7–53
LP311	4	30	0.3	7.5	-14.5	13.5		1.2	Single, low-power, strobed differential	7–49
LP339	5	30	0.1	±5	0			1.3	Quad, low-power, general purpose differential	7–53
LP2901	5	30	0.1	±5	0			1.3	Quad, low-power, general purpose differential	7–53
TL193	2	7	0.8	5	0	3.8	6	0.2	Dual, general purpose differential	7–59
TL293	2	7	0.8	5	0	3.8	6	0.2	Dual, general purpose differential	7–59
TL393	2	7	0.8	5	0	3.8	6	0.2	Dual, general purpose differential	7–59
TL712	4.75	5.25	20	5+	0	5	16	0.025	Differential	7–65
TL714	4.75	5.25	12	10+	0	5	16	0.006	High-speed differential	7–69
TL3016 [†]	-7	7	12.5	3	-3.75	3.5			Ultra-fast low-power precision	7–73
TL3116 [†]	-7	7	14.7	3	-5	2.5			Ultra-fast low-power precision	7–83
TLC139	3	16	0.08	5	0				Quad, micropower, LinCMOS	7–93
TLC339	3	16	0.08	5	0				Quad, micropower, LinCMOS	7–93
TLC352	1.4	16	0.15	5	0	4	6	0.2	Dual, low voltage, LinCMOS differential	7–109
TLC354	1.4	16	0.15	5	0	4	6	0.2	Quad, low voltage, LinCMOS differential	7–117
TLC371	3	16	0.15	5	0	4	6	0.2	Single general purpose LinCMOS differential	7–127
TLC372	3	16	0.15	-5	.0	4	6	0.2	Dual general purpose LinCMOS differential	7–137

† This device is in the Advanced Information stage of development.

COMPARATORS (Listed Alphanumerically) (continued)

DEVICE	V _{DD} /V _{CC} (V) min	V _{DD} /V _{CC} (V) max	(mA per channel)	VIO (mV) max	VICR (V) min	VICR (V) max	IOL (mA) min	^t RESP (μs) low-to-high	DESCRIPTION	PAGE NO.
TLC374	3	16	0.15	,5	0	4	6	0.2	Quad general purpose LinCMOS differential	7–149
TLC393	3	16	0.02	5	0	4	6	1.1	Dual, micropower, LinCMOS voltage	7–161
TLC3702	3	16	0.02	5	0	4	4	1.1	Dual, micropower, push-pull outputs, LinCMOS voltage	7–177
TLC3704	3	16	0.02	5	0	4	4	1.1	Quad, micropower, push-pull outputs, LinCMOS voltage	7–199
TLV1391	2	7	0.150	5	0	3.8	0.600	0.65	Single differential	7–223
TLV1393	2	7	0.125	5	0	1.8	0.5	0.7	Dual low-voltage, low power differential	7-235
TLV2352	2	8	0.125	5	0	2	6	0.2	Dual low voltage LinCMOS differential	7-251
TLV2354	2	8	0.125	5	0	2	6	0.2	Quad low voltage LinCMOS differential	7-265
TLV2393	2	7	0.65	5	0	1.8	4	0.45	Dual low voltage differential	7–235

COMPARATOR SELECTION GUIDE

COMPARATORS — PACKAGE AND TEMPERATURE AVAILABILITY

DEVICE	D	DB	DBV	FK	J	JG	N	P	PW	U	W	Y(CHIP)
LM111				(20)□	(14)□	(8)□				(10)□		
LM139	(14)□				(14)□		(14)□				(14)□	
LM139A	(14)□			(20)□	(14)□		(14)□					
LM193	(8)□			(20)□		(8)□		(8)□				
LM211	(8)							(8)				
LM239	(14)§						(14)§					
LM239A	(14)§						(14)§					
LM2901	(14)☆	(14)☆							(14)☆			
LM2901Q	(14)☆						(14)☆					
LM2903	(8)☆	(8)☆						(8)*	(8)☆			
LM2903Q	(8)☆							(8)☆				
LM293	(8)§							(8)§				
LM293A	(8)§							(8)§				
LM306	(8)†							(8)				
LM311	(8)†	(8)†						(8)	(8)			Y
LM3302	(14)¶				(14)¶		(14)¶					
LM339	(14)†	(14)†					(14)†		(14)†			Υ
LM339A	(14)†						(14)†					Υ
LM339x2		(30)†										
LM393	(8)†	(8)†						(8)	(8)			Υ
LM393A	(8)†				-			(8)				Υ
LP111				(20)□		(8)□						
LP211	(8)§					(8)§		(8)§				
LP239	(14)§				(14)§		(14)§					
LP2901	(14)¶				(14)¶		(14)¶					
LP311	(8)†					(8)†		(8)				
LP339	(14)†				(14)†		(14)†					
TL393	(8)#							(8)#	(8)#			Υ
TL712	(8)C					(8)C		(8)C	(8)C			
TL714	(8)C							(8)C				
TL3016	(8)C,I								(8)C,I			Y
TL3116	(8)C,I								(8)C,I			Υ
TLC139				(20)M	(14)M							

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COMPARATORS — PACKAGE AND TEMPERATURE AVAILABILITY (continued)

DEVICE	D	DB	DBV	FK	J	JG	N	Р	PW	U	W	Y(CHIP)
TLC339	(14)C,I,Q,M						(14)C,I,Q,M					
TLC352	(8)C,I			(20)M		(8)M	-	(8)C,I				
TLC354	(14)C,I,M						(14)C,I,M		(14)C			Υ
TLC371	(8)C,I,M							(8)C,I,M				Y
TLC372	(8)C,I,Q,M			(20)M		(8)M		(8)C,I,Q,M	(8)C			Y
TLC374	(14)C,I,M,Q			(20)M	(14)M		(14)C,I,M,Q		(14)C			
TLC393	(8)C,I,M			(20)M		(8)M	-	(8)C,I,M				
TLC3702	(8)C,I			(20)M		(8)Q,M		(8)C,I				
TLC3704	(14)C,I			(20)M	(14)Q,M		(14)C,I					
TLV1391			(5)C,I				-					Y
TLV1393	(8)#							(8)#	(8)#			Y
TLV2352	(8)I							(8)1	(8)			Υ
TLV2354	(14)I						(14)I		(14)I			Y
TLV2393	(8)#							(8)#	(8)#			Y
SYMB	SYMBOLS: Y = 25°C, # = -40°C to 105°C		105°C	C or $\dagger = 0^{\circ}$ C to 70° C Q or $\star = -40^{\circ}$ C to 125° C			$\$ = -25^{\circ}\text{C to } 85^{\circ}\text{C}$ M or $\square = -55^{\circ}\text{C to } 125^{\circ}\text{C}$			I or ¶ = −40°C to 85°C		

Replacements are based on similarity of electrical and mechanical characteristics shown in currently published data. Interchangeability in particular applications is not guaranteed. Before using a device as a substitute, compare the specifications of the substitute device with the specifications of the original.

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Manufacturers are arranged in alphabetical order.

	LINEAR TECH	NOLOGY									
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L11017		TLC3702	7–177								
LT1018		TLC352	7–109								
LITUTO		TLC3702	7–177								
NATIONAL											
LM311	LM311		7–3								
LM339	LM339		7–19								
		TLC339	7–93								
LM393	LM393		7–27								
LIVIS93		TLC393	7–161								
LM2901	LM2901		7–19								
LMI2901		TLC339	7–93								
LM3302	LM3302		7–45								
LP339	LP339		7–53								
LP339		TLC339	7–93								
	PMI										
		LM339	7–19								
CMD04E		LM2901	7–19								
CMP04F		LM3302	7–45								
V		TLC339	7–93								

COMPARATOR GLOSSARY

Average Temperature Coefficient of Input Offset Current αιιο

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{IIO} = \frac{\left(I_{IO} \text{ at } T_{A(1)}\right) - \left(I_{IO} \text{ at } T_{A(2)}\right)}{T_{A(1)} - T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

Average Temperature Coefficient of Input Offset Voltage ανιο

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{VIO} = \frac{\left(V_{IO} \text{ at } T_{A(1)}\right) - \left(V_{IO} \text{ at } T_{A(2)}\right)}{T_{A(1)} - T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

Differential Voltage Amplification A_{VD}

The ratio of the change in output to the change in differential input voltage producing it with the common-mode input voltage held constant

CMRR

See k_{CMR}

The current into the V_{CC+} or V_{CC-} terminal of an integrated circuit

I_{IH}(S) **High-Level Strobe Current**

The current flowing into or out of the strobe at a high-level voltage

Input Bias Current lıв

The average of the currents into the two input terminals with the output at the specified level

I_{IL(S)} **Low-Level Strobe Current**

The current flowing out of the strobe at a low-level voltage

Input Offset Current lιο

The difference between the currents into the two input terminals with the output at the specified level

IOH **High-Level Output Current**

The current into an output with input conditions applied that according to the product specification will establish a high level at the output.

loL **Low-Level Output Current**

The current into an output with input conditions applied that according to the product specification will establish a low level at the output.

k_{CMR} or CMRR

Common-Mode Rejection Ratio

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

†Current out of a terminal is given as a negative value.



P_D Total Power Dissipation

The total dc power supplied to the device less any power delivered from the device to a load.

NOTE: At no load: $P_D = V_{CC+} \bullet I_{CC+} + V_{CC-} \bullet I_{CC-}$

r_o Output Resistance

The resistance between an output terminal and ground

V_{IC} Common-Mode Input Voltage

The average of the two input voltages

V_{ICR} Common-Mode Input Voltage Range

The range of common-mode input voltage that if exceeded may cause the comparator to cease functioning properly.

V_{ID} Differential Input Voltage

The voltage at the noninverting input with respect to the inverting input

V_{ID} Differential Input Voltage Range

The range of voltage between the two input terminals that if exceeded may cause the comparator to cease functioning properly.

V_I Input Voltage Range

The range of voltage that if exceeded at either input terminal may cause the comparator to cease functioning properly.

V_{IH(S)} High-Level Strobe Voltage

For a device having an active-low strobe, a voltage within that range is guaranteed not to interfere with the operation of the comparator.

V_{IL(S)} Low-Level Strobe Voltage

For a device having an active-low strobe, a voltage within the range that is guaranteed to force the output high or low, as specified, independently of the differential inputs.

V_{IO} Input Offset Voltage

The dc voltage that must be applied between the input terminals to force the quiescent dc output voltage to the specified level.

VOH High-Level Output Voltage

The voltage at an output with input conditions applied that according to the product specification will establish a high level at the output.

VOI Low-Level Output Voltage

The voltage at an output with input conditions applied that according to the product specification will establish a low level at the output.

Response Time

The interval between the application of an input step function and the instant the output crosses the logic threshold voltage.

NOTE: The input step drives the comparator from some initial condition sufficient to saturate the output (or in the case of high-to-low-level response time, to turn the output off) to an input level just barely in excess of that required to bring the output back to the logic threshold voltage. This excess is referred to as the voltage overdrive.

Strobe Release Time

The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from its active logic level to its inactive logic level.



PRECISION TIMERS

DEVICE	IDD/ICC	TIM	ING	+-	DACKACES	DECODIDATION	PAGE
DEVICE	(mA)	то	FROM	T _A	PACKAGES	DESCRIPTION	NO.
NE555	±200	10 μs	Hours	0°C to 70°C	D, P, Y	Single bipolar timer	
NE556	±200	10 μs	Hours	0°C to 70°C	D, N	Dual bipolar timer	
SA555	±200	10 μs	Hours	-40°C to 85°C	D, P	Single bipolar timer	
SA556	±200	10 μs	Hours	-40°C to 85°C	D, N	Dual bipolar timer	
SE555	±200	1 μs	Hours	-55°C to 125°C	D, FK, JG, P	Single bipolar timer	
SE555C	±200	1 μs	Hours	-55°C to 125°C	D, FK, JG, P	Single bipolar timer	
SE556	±200	1 μs	Hours	-55°C to 125°C	D, FK, J, N	Dual bipolar timer	
SE556C	±200	1 μs	Hours	-55°C to 125°C	D, FK, J, N	Dual bipolar timer	
TLC551	100 –10†	1 μs	Hours	0°C to 70°C	D, P, Y	Single LinCMOS high- speed timer	
TLC552	100 -10†	1 μs	Hours	0°C to 70°C	D, N	Dual LinCMOS high-speed timer	
TLC555	100 -10	1 μs	Hours	0°C to 70°C -40°C to 85°C -55°C to 125°C	D, FK, JG, P, Y	Single LinCMOS high- speed timer	
TLC556	100 -10	1 μs	Hours	0°C to 70°C -40°C to 85°C -55°C to 125°C	D, FK, J, N	Dual LinCMOS high-speed timer	

[†] This parameter is at 1-V operation.

VIDEO AMPLIFIERS

DEVICE	V _{DD} /V _{CC} (V) min max	(mA per channel) typ	BW (MHz)	^t r(video) ^{/ t} f(video) (ns)	AV (V/V) (max)	DESCRIPTION	PAGE NO.
TLS1233	11 to 13	84	100	3.5	7.8	video preamplifier system	
TLS1255	11 to 13	110	100	3.5	7.6	Video preamplifier system	
μΑ733			200	2.5	12	Video amplifier with internal frequency compensation	

General Information (Volume A)	1
Audio Power Amplifiers	2,
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Mechanical Data	4
General Information (Volume B)	5
Operational Amplifiers (Continued)	6
Comparators	7
Special Functions	8
Mechanical Data	9

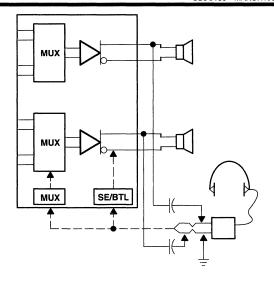
TPA0102 STEREO 1.5-W AUDIO POWER AMPLIFIER

SLOS166 - MARCH1997

- **High Power with PC Power Supply**
 - 1.5 W/Ch at 5 V
 - 600 mW/Ch at 3 V
- **Ultra-Low Distortion**
 - < 0.05% THD+N at 1.5 W and 4- Ω Load
- **Bridge-Tied Load (BTL) or Single Ended** (SE) Modes
- Stereo Input MUX
- **Surface Mount Power Package** 24-Pin TSSOP
- Uncompensated Gains of 1 to 10
- Shutdown Control . . . $-I_{DD}$ < 1 μ A

description

The TPA0102 is a stereo audio power amplifier in a 24-pin TSSOP thermal package capable of delivering greater than 1.5 W of continuous RMS power per channel into $4-\Omega$ loads. This functionality provides a very efficient upgrade path from the TPA4860 and TPA4861 mono amplifiers where two separate devices are



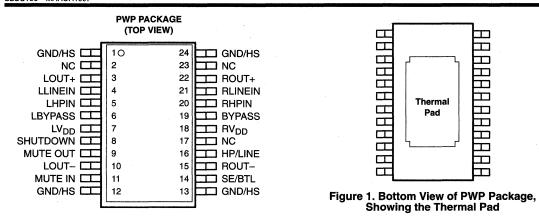
required for stereo speaker-driver applications plus a third device for headphone drive. This implementation simplifies design and frees up board space for other features. Full power distortion levels of 200 m% THD+N from a 5-V supply voltage are typical. This provides significant improvement in fidelity for speech and music over the popular TPA4860/61 series. Low-voltage applications are also well served by the TPA0102 providing 600-mW per channel into $4-\Omega$ loads with a 3.3-V supply voltage.

Amplifier gain is externally configured by means of two resistors per input channel and does not require external compensation for settings of 2 to 20 in BTL mode (1 to 10 in SE mode). An input MUX circuit is integrated to allow two sets of stereo inputs to the amplifier. In notebook applications, where internal speakers are driven as BTL and the line (often headphone drive) outputs are required to be SE, the TPA0102 automatically switches into SE mode when SE/BTL input activated. Connection of the SE/BTL control signal to the HP/LINE select input accomplishes automatic selection of different audio paths for headphone or internal-speaker drive. Using the TPA0102 to drive line outputs, up to 500 mW/Ch into external 4 Ω loads at 200 m% THD is ideal for small non-powered external speakers in portable multimedia systems. The TPA0102 also features a showdown function for power sensitive applications holding the bias current below 1 µA. In speakerphone or other monaural applications, the TPA0102 is configured through the power supply terminals to activate only half of the amplifier which reduces quiescent current by approximately 1/2 for the given voltage.

AVAILABLE OPTIONS

	PACKAGE
T _A	TSSOP† (PWP)
-20°C to 85°C	TPA0102PWP

† See the special instructions for PWP packages.



Terminal Functions

TERMINAL			
NAME	NO.	1/0	DESCRIPTION
GND/HS	1		Provides ground connection for circuitry, directly connected to heat sink pad.
NC	2		No internal connection.
L Out +	.3	0	Left channel + output in BTL mode, + output in SE mode.
L Line In	4	I	Left channel line input, selected when UP/Line pin (16) is held low.
L HP In	.5	ı	Left channel headphone input, selected when IIP/Line pin (16) is held high.
L Bypass	6		Tap to voltage divider for left channel internal mid-supply bias.
L V _{DD}	7	-	Supply voltage input for left channel and for primary bias circuits.
Shutdown	.8	1	Places entire IC in shutdown mode when held high, IDD < I uA.
Mute Out	9	0	Follows Mute In pin (14), provides buffered output.
L Out –	10	0	Left channel – output in BTL mode, high impedance state in SE mode.
Mute In	: 11 .	1	Mute all amplifiers, hold low for normal operation, hold high to mute.
GND/HS	12, 13		Provides ground connection for circuitry, directly connected to heat sink pad.
SE/BTL*	14	-	Hold low for BTL mode, hold high for SE mode.
R Out -	15	0	Left channel – output in BTL mode, high impedance state in SE mode.
BP/Line	16	1.	Input mux control input, hold high to select L/R BP In (5, 20), hold low to select L/R Line In (4, 2 1).
NC	17		No internal connection.
R V _{DD}	18	ı	Supply voltage input for right channel.
R Bypass	19		Tap to voltage divider for right channel internal mid-supply bias.
RBPIn	20	ı	Right channel headphone input, selected when HP/Line pin (16) is held high.
R Line In	21	ı	Fight channel line input, selected when BP/Line pin (16) is held low.
R Out +	22	0	Right channel + output in BTL mode, + output in SE mode.
NC	23		No internal connection.
GND/HS	24		Provides ground connection for circuitry, directly connected to heat sink pad.

TPA0102 STEREO 1.5-W AUDIO POWER AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted) †

Supply voltage, V_{DD} 6 V Continuous total power dissipation internally limited

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply Voltage, V _{DD}			5	5.5	V
Operating free-air temperature, TA		-20	85		°C
Common modelines to altern V	V _{DD} = 5 V	1.25	4.5		.,
Common mode input voltage, V _{ICM}	V _{DD} = 3.3 V	1.25	2.7		V

DC electrical characteristics at specified free-air temperature

	PARAMETER	TE	ST CONDITIONS	MIN TYP	T MAX	UNIT
			ST, BTL		7 25	mA
		V _{DD} = 5 V	ST, SE		9 15	mA
		VDD = 5 V	Mono, BTL		9 15	mA
	Quiescent current		Mono, SE		5 10	mA
IDD	Quiescent current	V 00V	ST, BTL	5	.5 10	mA
			ST, SE	3	.1 5	mA
		$V_{DD} = 3.3 \text{ V}$	Mono, BTL	3	.1 5	mA
			Mono, SE	1	.9 3	mA
V _{odiff}	DC different output voltage	Gain = 2,	See Note 1		5 11	mV
	Supply current in Mute mode	V _{DD} = 5 V	V _{DD} = 5 V		70	
IDD(MUTE)	Supply current in Mute mode	V _{DD} = 3.3 V		45	50	μΑ
ISD	I _{DD} in shutdown				1 10	μА



[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

AC operating characteristic, V_{DD} = 5 V, T_A = 25°C, R_L = 4 Ω

	PARAMETER	TEST CO	ONDITIONS	MIN	TYP	MAX	UNIT
		THD = 0.2%,	BTL		1.25		w
D	Output power (each channel) see Note 2	THD = 1%,	BTL		1.5		VV
P(OUT)	Output power (each channel) see Note 2	THD = 0.2% ,	SE		500		mW
		THD = 1%,	SE		600		IIIVV
THD+N	Total harmonic distortion plus noise	P ₀ = 1 W,	f = 20 – 20 kHz		200		m%
Вом	Maximum output power bandwidth	G = 10,	THD < 5 %		>20		kHz
		BTL		66°	72°		
	Phase margin	Open Load		56°	71°		
		SE		46°	52°		
PSRR	Device comply visual rejection	f = 1 kHz,		70	75		dB
PORK	Power supply ripple rejection	f = 20 - 20 kHz,		55	60		uБ
	Mute attenuation				85		dB
	Channel-to-channel output separation				65		dB
	Line/HP input separation				100		dB
	BTL attenuation in SE mode	1			100		dB
ZĮ	Input impendance	I					MΩ
Vn	Output noise voltage				25		uV(rms)

NOTES: 1. At 3 V < V_{DD} < 5 V the DC output voltage is approximately $V_{DD}/2$. 2. Output power is measured at the output pins of the IC at 1 kHz.

AC operating characteristic, V_{DD} = 3.3 V, T_A = 25°C, R_L = 4 Ω

	PARAMETER	TEST CO	NDITIONS	MIN	TYP	MAX	UNIT	
		THD = 0.2%	BTL		600			
B. S. I	Output newer (each channel) and Note 2	THD = 1%	BTL		750		mW	
P(OUT)	Output power (each channel) see Note 2	THD = 0.2%,	SE		200		11100	
		THD = 1%,	SE		250			
THD+N	Total harmonic distortion plus noise	$P_0 = 600 \text{ mW},$	f = 20 – 20 kHz		250		m%	
ВОМ	Maximum output power bandwidth	G = 10,	THD < 5 %		>20		kHz	
		BTL		78°	92°		deg	
	Phase margin	Open Load		49°	70°			
		SE		52°	57°			
PSRR	Power supply ripple rejection	f = 1 kHz,		65 70			dB	
ronn	rower supply ripple rejection	f = 20 - 20 kHz,		50	55		uБ	
	Mute attenuation				85		dB	
	Channel-to-channel output separation				65		dB	
	Line/HP input separation				100		dB	
	BTL attenuation in SE mode				100		dB	
Z _I	Input impendance						ΜΩ	
Vn	Output noise voltage				25		uV(rms)	

NOTES: 1. At 3 V < V_{DD} < 5 V the DC output voltage is approximately $V_{DD}/2$.

2. Output power is measured at the output pins of the 1 C at 1 kHz.



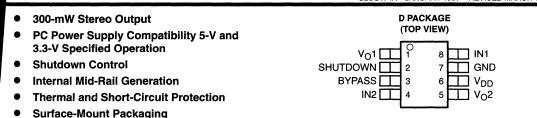
22 21 Line-R MUX **ROUT+** 20 19 RBYPASS ROUT-15 RV_{DD} Cs 14 SE/BTL 11 **MUTE IN** Bias, 9 **MUTE OUT** Clip and MUX 16 **HP/Line Select** 1, 12, 13, 24 Control SHUTDOWN 8 2, 17, 23 NC MUX LOUT+ **LBYPASS** LOUT~ 10 LVDD cs

APPLICATION INFORMATION

Figure 2. Typical Application Circuit

TPA302, TPA302Y 300-mW STEREO AUDIO POWER AMPLIFIER

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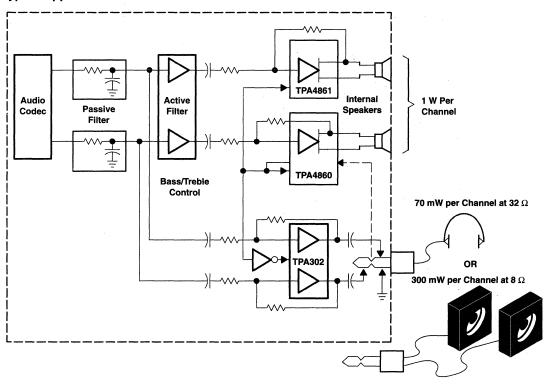


description

The TPA302 is a stereo audio power amplifier capable of delivering 250 mW of continuous average power into an 8- Ω load at less than 0.06% THD+N from a 5-V power supply or up to 300 mW at 1% THD+N. The TPA302 has high current outputs for driving small unpowered speakers at 8 Ω or headphones at 32 Ω . For headphone applications driving $32-\Omega$ loads, the TPA302 delivers 60 mW of continuous average power at less than 0.06% THD+N. The amplifier features a shutdown function for power-sensitive applications as well as internal thermal and short-circuit protection. The amplifier is available in an 8-pin SOIC (D) package that reduces board space and facilitates automated assembly.

typical application circuit

Functional Equivalent of the LM4880



ISTRUMENTS

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AVAILABLE OPTIONS

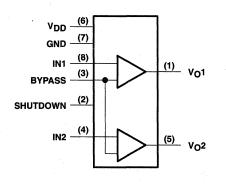
	PACKAGED DEVICES		
TA	SMALL OUTLINE† (D)	CHIP FORM	
-20°C to 85°C	TPA302D	TPA302Y	

[†] The D packages are available taped and reeled. To order a taped and reeled part, add the suffix R (e.g., TPA302DR)

TPA302Y chip information

This chip, when properly assembled, display characteristics similar to the TPA302. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS (6)86 <u> բումագույմության միասակնայարի ան</u>



CHIP THICKNESS: 15 MILS TYPICAL BONDING PADS: 4 × 4 MILS MINIMUM

T_{.i}max = 150°C

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

PIN (7) IS INTERNALLY CONNECTED TO BACKSIDE OF CHIP.

TPA302, TPA302Y 300-mW STEREO AUDIO POWER AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Supply voltage, V _{DD}	
Input voltage , V _I	
Continuous total power dissipation	Internally Limited (See Dissipation Rating Table)
Operating junction temperature range, T _J	–20°C to 150° C
Storage temperature range, T _{stg}	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 sec	onds 260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING	POWER RATING
D	731 mW	5.8 mW/°C	460 mW	380 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{DD}	2.7	5.5	٧
Operating free-air temperature, TA	-20	85	°C

dc electrical characteristics at specified free-air temperature, $V_{DD} = 3.3 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
IDD	Quiescent current			2.25	5	mA
ViO	Offset voltage			5	20	mV
PSRR	Power supply rejection ratio	V _{DD} = 3.2 V to 3.4 V		55		dB
I _{SD}	Quiescent current in shutdown			0.6	20	μΑ

ac operating characteristics, V_{DD} = 3.3 V, T_A = 25°C, R_L = 8 Ω (unless otherwise noted)

PARAMETER			TEST CONDITION		MAX	UNIT
PO	Output power		THD < 0.08%	100		
		Gain = -1,	THD < 1%	125		\4/
		f = 1 kHz	THD < 0.08%, $R_L = 32 \Omega$	25		mW
			THD < 1%, $R_L = 32 \Omega$	35		
ВОМ	Maximum output power bandwidth	Gain = 10,	1% THD	20		kHz
B ₁	Unity gain bandwidth	Open loop		1.5		MHz
	Channel separation	f = 1 kHz		75		dB
ksvr	Supply ripple rejection ratio	f = 1 kHz	· ·	45		dB
٧n	Noise output voltage	Gain = -1		10		μVrms

TPA302, TPA302Y 300-mW STEREO AUDIO POWER AMPLIFIER

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dc electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
loo	Quiescent current			4	10	mΑ
V _{IO}	Offset voltage	See Note 1		5	20	mV
PSRR	Power supply rejection ratio	V _{DD} = 4.9 V to 5.1 V		65		dB
ISD	Quiescent current in shutdown			0.6		μΑ

ac operating characteristics, V_{DD} = 5 V, T_A = 25°C, R_L = 8 Ω (unless otherwise noted)

PARAMETER			TEST CONDITION		TYP	MAX	UNIT
Po	Output power		THD < 0.06%		250		
		Gain = -1,	THD < 1%		300		mW
		f = 1 kHz	THD < 0.06%, $R_L = 32 \Omega$		60		
			THD < 1%, $R_L = 32 \Omega$		80		
Вом	Maximum output power bandwidth	Gain = 10,	1% THD		20		kHz
B ₁	Unity gain bandwidth	Open loop			1.5		MHz
	Channel separation	f = 1 kHz			75		dB
ksvr	Supply ripple rejection ratio	f = 1 kHz			45		dB
Vn	Noise output voltage	Gain = -1			10		μVrms

typical application

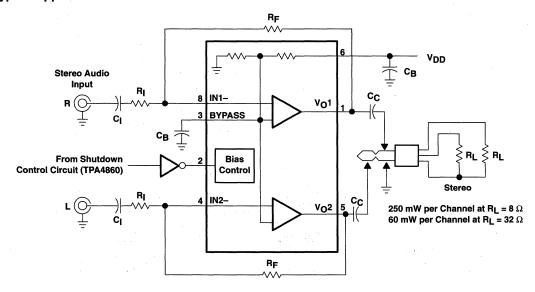


Table of Graphs

			FIGURE
THD+N	Total harmonic distortion plus noise	vs Frequency	1–3, 7–9, 13–15, 19–21
וחט+וא		vs Output power	4–6, 10–12 16–18, 22–24
IDD	Supply current Supply current distribution	vs Supply voltage vs Free-air temperature	25 26
Vn	Output noise voltage	vs Frequency	27, 28
	Maximum package power dissipation	vs Free-air temperature	29
	Power dissipation	vs Output power	30, 31
P _O max	Maximum output power	vs Free-air temperature	32, 33
PO	Output power	vs Load resistance vs Supply voltage	34 35
	Open loop response	vs Frequency	36
	Closed loop response	vs Frequency	37
	Crosstalk	vs Frequency	38, 39
PSRR	Power supply rejection ratio	vs Frequency	40, 41

TOTAL HARMONIC DISTORTION PLUS NOISE

vs

FREQUENCY 8 10 VCC = 5 V PO = 250 mW RL = 8 \(\Omega \) G = -1 VO2 100 1 k 10 k 20 k f - Frequency - Hz

Figure 1

TOTAL HARMONIC DISTORTION PLUS NOISE

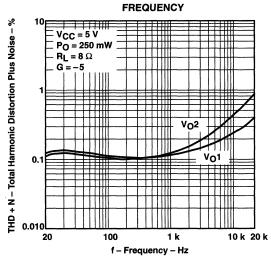
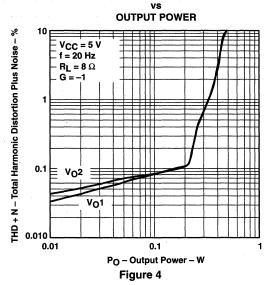


Figure 2

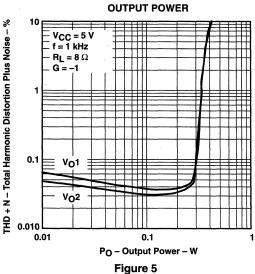
TOTAL HARMONIC DISTORTION PLUS NOISE vs **FREQUENCY** 10 V_{CC} = 5 V THD + N - Total Harmonic Distortion Plus Noise - % PO = 250 mW RL = 8 Ω G = -10V_O2 0.1 0.010 20 10 k 20 k 100 1 k f - Frequency - Hz

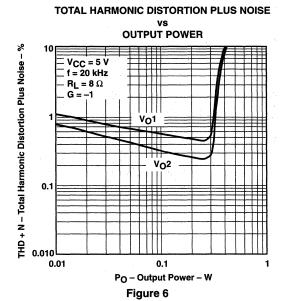


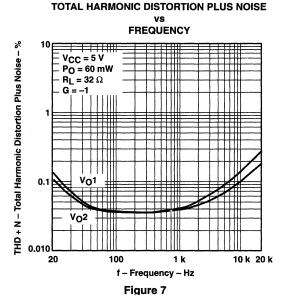
TOTAL HARMONIC DISTORTION PLUS NOISE

TOTAL HARMONIC DISTORTION PLUS NOISE vs

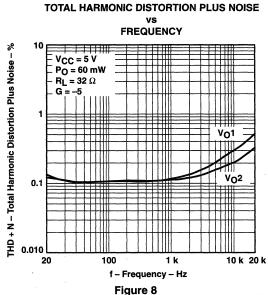
Figure 3



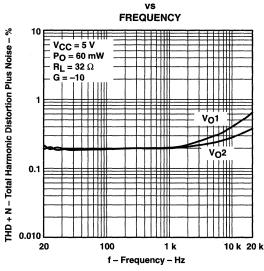


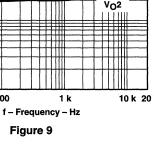


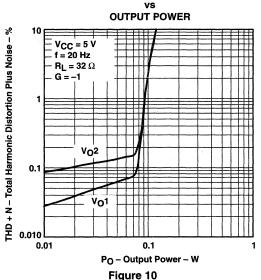
TOTAL HARMONIC DISTORTION PLUS NOISE

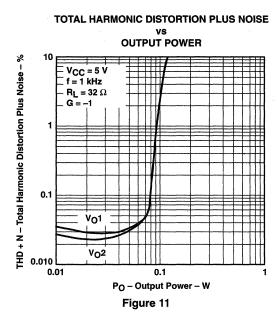


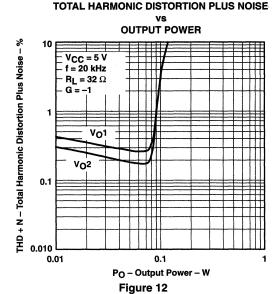
TOTAL HARMONIC DISTORTION PLUS NOISE







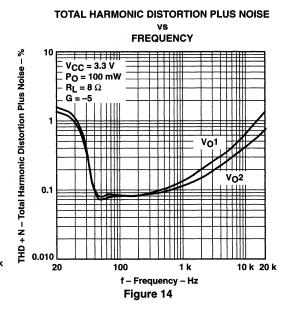


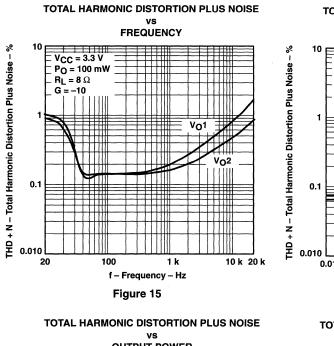


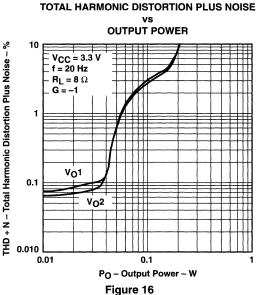
VS FREQUENCY % 10 VCC = 3.3 V PO = 100 mW RL = 8 Ω G = -1 VO1 VO2 VO2 The property of the p

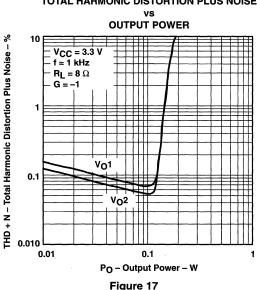
Figure 13

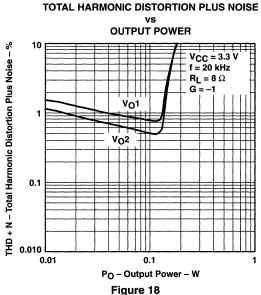
TOTAL HARMONIC DISTORTION PLUS NOISE

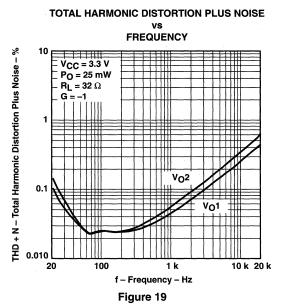


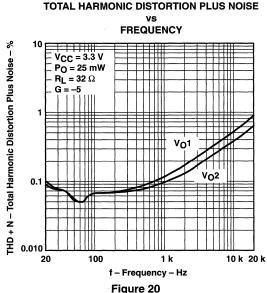


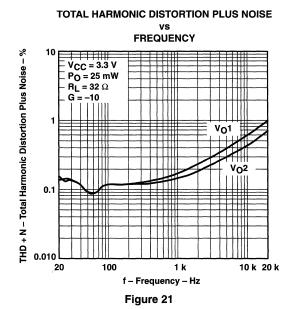


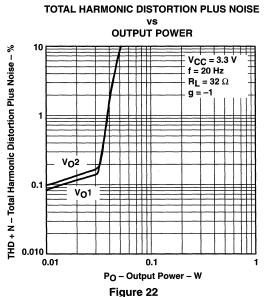












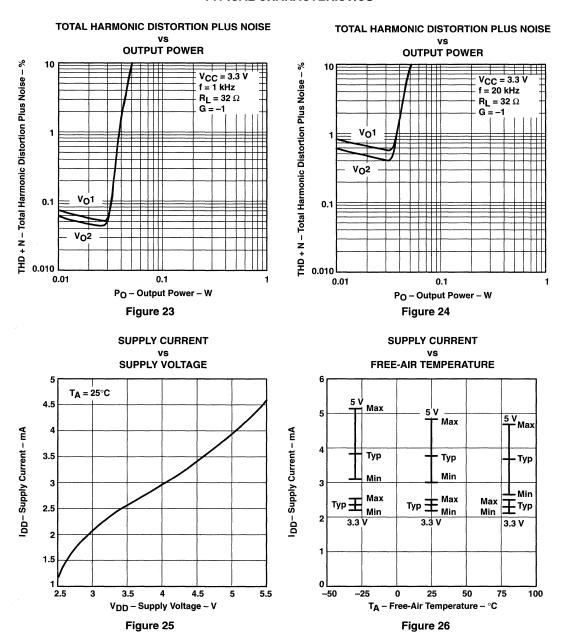


Figure 29

TYPICAL CHARACTERISTICS

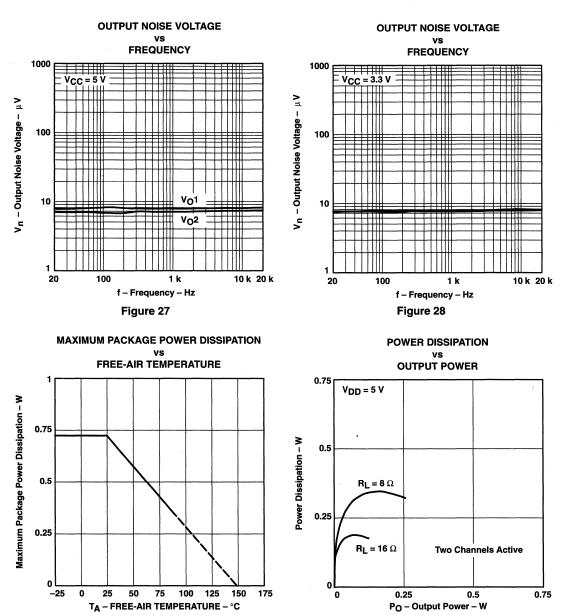


Figure 30

Figure 34

TYPICAL CHARACTERISTICS

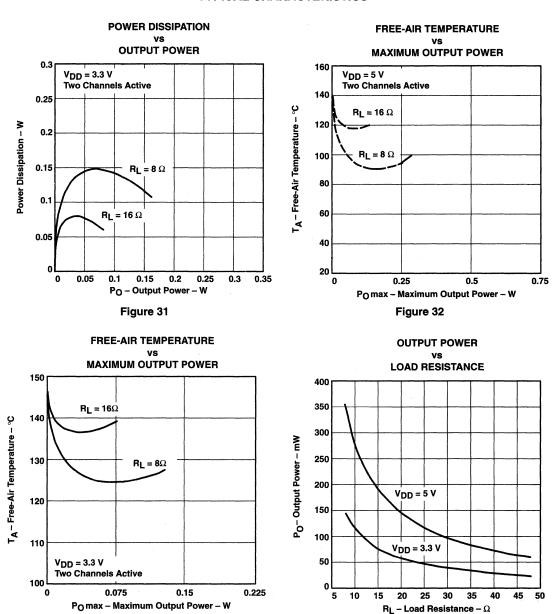
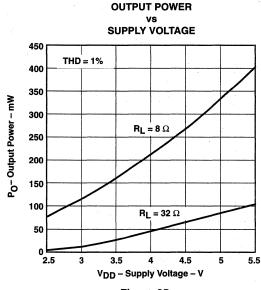


Figure 33



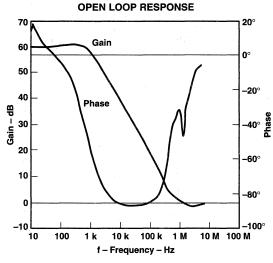
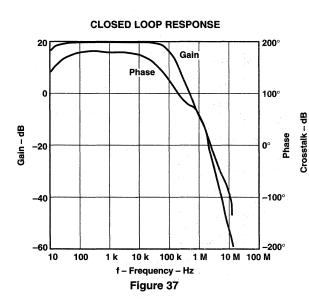
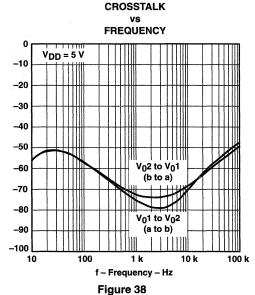


Figure 35



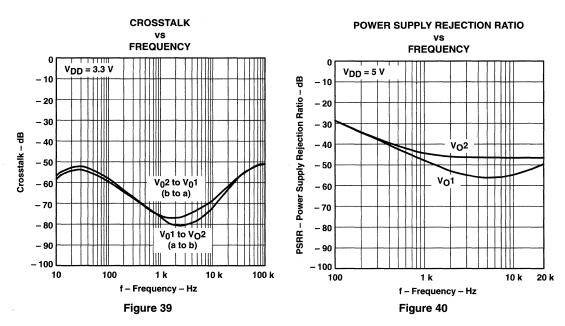




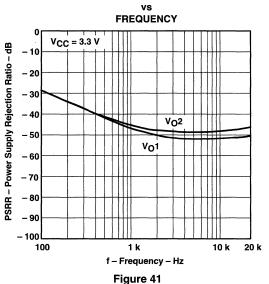
r.

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TYPICAL CHARACTERISTICS



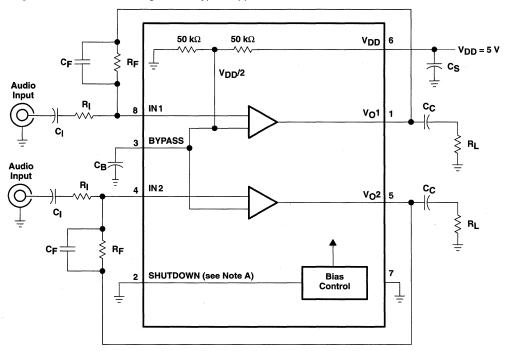
POWER SUPPLY REJECTION RATIO



APPLICATION INFORMATION

selection of components

Figure 42 is a schematic diagram of a typical application circuit.



NOTE A: SHUTDOWN must be held low for normal operation and asserted high for shutdown mode.

Figure 42. TPA302 Typical Notebook Computer Application Circuit

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APPLICATION INFORMATION

gain setting resistors, RF and RI

The gain for the TPA302 is set by resistors R_F and R_I according to equation 1.

$$Gain = -\left(\frac{R_F}{R_I}\right) \tag{1}$$

Given that the TPA302 is a MOS amplifier, the input impedance is very high, consequently input leakage currents are not generally a concern although noise in the circuit increases as the value of R_F increases. In addition, a certain range of R_F values are required for proper startup operation of the amplifier. Taken together it is recommended that the effective impedance seen by the inverting node of the amplifier be set between 5 k Ω and 20 k Ω . The effective impedance is calculated in equation 2.

$$\frac{\text{Effective}}{\text{Impedance}} = \frac{R_F R_I}{R_F + R_I}$$
 (2)

As an example, consider an input resistance of 10 k Ω and a feedback resistor of 50 k Ω . The gain of the amplifier would be -5 and the effective impedance at the inverting terminal would be 8.3 k Ω , which is within the recommended range.

For high performance applications metal film resistors are recommended because they tend to have lower noise levels than carbon resistors. For values of R_F above 50 $k\Omega$ the amplifier tends to become unstable due to a pole formed from R_F and the inherent input capacitance of the MOS input structure. For this reason, a small compensation capacitor of approximately 5 pF should be placed in parallel with R_F . This, in effect, creates a low-pass filter network with the cutoff frequency defined in equation 3.

$$f_{co(lowpass)} = \frac{1}{2\pi R_F C_F}$$
 (3)

For example if R_F is 100 k Ω and C_F is 5 pF then $f_{CO(lowpass)}$ is 318 kHz, which is well outside of the audio range.

input capacitor, C₁

In the typical application an input capacitor, C_I , is required to allow the amplifier to bias the input signal to the proper dc level for optimum operation. In this case, C_I and R_I form a high-pass filter with the corner frequency determined in equation 4.

$$f_{co(highpass)} = \frac{1}{2\pi R_1 C_1}$$
 (4)

The value of C_l is important to consider as it directly affects the bass (low frequency) performance of the circuit. Consider the example where R_l is 10 k Ω and the specification calls for a flat bass response down to 40 Hz. Equation 4 is reconfigured as equation 5.

$$C_{I} = \frac{1}{2\pi R_{I} f_{\text{co(highpass)}}}$$
 (5)

In this example, C_l is 0.40 μF so one would likely choose a value in the range of 0.47 μF to 1 μF . A further consideration for this capacitor is the leakage path from the input source through the input network (R_l, C_l) and the feedback resistor (R_F) to the load. This leakage current creates a dc offset voltage at the input to the amplifier that reduces useful headroom, especially in high-gain applications (> 10). For this reason a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifier input in most applications as the dc level there is held at $V_{DD}/2$, which is likely higher that the source dc level. Please note that it is important to confirm the capacitor polarity in the application.

APPLICATION INFORMATION

power supply decoupling, Cs

The TPA302 is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure that the output total harmonic distortion (THD) is as low as possible. Power supply decoupling also prevents oscillations for long lead lengths between the amplifier and the speaker. The optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μF, placed as close as possible to the device V_{DD} lead, works best. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10 μF or greater placed near the power amplifier is recommended.

midrail bypass capacitor, C_B

The midrail bypass capacitor, CB, serves several important functions. During startup or recovery from shutdown mode, C_B determines the rate at which the amplifier starts up. This helps to push the start-up pop noise into the subaudible range (so slow it can not be heard). The second function is to reduce noise produced by the power supply caused by coupling into the output drive signal. This noise is from the midrail generation circuit internal to the amplifier. The capacitor is fed from a 25-k Ω source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 6 should be maintained.

$$\frac{1}{\left(\mathsf{C}_{\mathsf{B}} \times 25\mathsf{k}\Omega\right)} \le \frac{1}{\left(\mathsf{C}_{\mathsf{I}}\mathsf{R}_{\mathsf{I}}\right)} \tag{6}$$

As an example, consider a circuit where C_B is 0.1 μ F, C_I is 0.22 μ F and R_I is 10 $k\Omega$. Inserting these values into the equation 9 results in:

$$400 \le 454$$

which satisfies the rule. Bypass capacitor, C_B , values of $0.1\,\mu\text{F}$ to $1\,\mu\text{F}$ ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

output coupling capacitor, CC

In the typical single-supply single-ended (SE) configuration, an output coupling capacitor (CC) is required to block the dc bias at the output of the amplifier thus preventing dc currents in the load. As with the input coupling capacitor, the output coupling capacitor and impedance of the load form a high-pass filter governed by equation 7.

$$f_{(out high)} = \frac{1}{2\pi R_L C_C}$$
 (7)

The main disadvantage, from a performance standpoint, is that the load impedances are typically small, which drive the low-frequency corner higher. Large values of CC are required to pass low frequencies into the load. Consider the example where a C_C of 68 μF is chosen and loads vary from 8 Ω , 32 Ω , and 47 $k\Omega$. Table 1 summarizes the frequency response characteristics of each configuration.



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APPLICATION INFORMATION

Table 1. Common Load Impedances Vs Low Frequency Output Characteristics in SE Mode

RL	CC	Lowest Frequency
8Ω	68 μF	293 Hz
32 Ω	68 μF	73 Hz
47,000 Ω	68 μF	0.05 Hz

As Table 1 indicates, most of the bass response is attenuated into $8-\Omega$ loads while headphone response is adequate and drive into line level inputs (a home stereo for example) is very good.

The output coupling capacitor required in single-supply SE mode also places additional constraints on the selection of other components in the amplifier circuit. The rules described earlier still hold with the addition of the following relationship:

$$\frac{1}{\left(C_{\mathsf{R}} \times 25 \text{ k}\Omega\right)} \le \frac{1}{\left(C_{\mathsf{I}}\mathsf{R}_{\mathsf{I}}\right)} \le \frac{1}{\mathsf{R}_{\mathsf{L}}C_{\mathsf{C}}} \tag{8}$$

shutdown mode

The TPA302 employs a shutdown mode of operation designed to reduce quiescent supply current, $I_{DD(q)}$, to the absolute minimum level during periods of nonuse for battery-power conservation. For example, during device sleep modes or when other audio-drive currents are used (i.e., headphone mode), the speaker drive is not required. The SHUTDOWN input terminal should be held low during normal operation when the amplifier is in use. Pulling SHUTDOWN high causes the outputs to mute and the amplifier to enter a low-current state, $I_{DD(q)} < 1 \; \mu A$. SHUTDOWN should never be left unconnected because amplifier operation would be unpredictable.

using low-ESR capacitors

Low-ESR capacitors are recommended throughout this applications section. A real capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this resistor minimizes the beneficial effects of the capacitor in the circuit. The lower the equivalent value of this resistance the more the real capacitor behaves like an ideal capacitor.

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APPLICATION INFORMATION

thermal considerations

A prime consideration when designing an audio amplifier circuit is internal power dissipation in the device. The curve in Figure 43 provides an easy way to determine what output power can be expected out of the TPA302 for a given system ambient temperature in designs using 5-V supplies. This curve assumes no forced airflow or additional heat sinking.

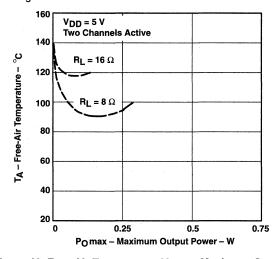


Figure 43. Free-Air Temperature Versus Maximum Output Power

5-V versus 3.3-V operation

The TPA302 was designed for operation over a supply range of 2.7 V to 5.5 V. This data sheet provides full specifications for 5-V and 3.3-V operation since are considered to be the two most common standard voltages. There are no special considerations for 3.3-V versus 5-V operation as far as supply bypassing, gain setting, or stability. Supply current is slightly reduced from 3.5 mA (typical) to 2.5 mA (typical). The most important consideration is that of output power. Each amplifier in the TPA302 can produce a maximum voltage swing of $V_{DD}-1$ V. This means, for 3.3-V operation, clipping starts to occur when $V_{O(PP)}=2.3$ V as opposed when $V_{O(PP)}=4$ V while operating at 5 V. The reduced voltage swing subsequently reduces maximum output power into the load before distortion begins to become significant.

TPA1517, TPA1517Y **6 WATT/CHANNEL STEREO AUDIO POWER AMPLIFIER**

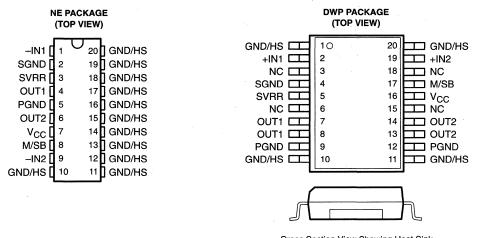
SL0S162 - MARCH1997

- **TDA1517P Compatible**
- **Surface Mount Availability**
- 6-W Stereo Output (10% THD+N)
- Fixed Gain (20 dB)

- **Mute and Standby Operation**
- **Thermal Protection**
- Wide Supply Range (9.5 V 18 V)
- High Power Supply Rejection (65-dB PSRR)

description

The TPA1517 is a stereo audio power amplifier that contains two identical amplifiers capable of delivering 6-W per channel of continuous average power into a 4- Ω load at 10% THD+N or 5-W per channel at 1% THD+N. The gain of each channel is fixed at 20-dB. The amplifier features a mute/standby function for power sensitive applications. The amplifier is available in a special 20-pin surface-mount thermally-enhanced package (DWP) that reduces board space and facilitates automated assembly while maintaining exceptional thermal characteristics.



Cross Section View Showing Heat Sink

NC - No internal connection

AVAILABLE OPTIONS

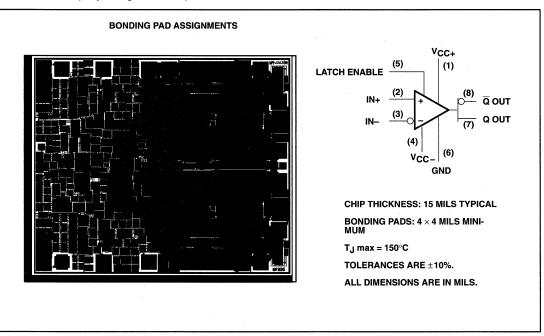
	PACKAG	ED DEVICES	
TA	THERMALLY ENHANCED PLASTIC DIP	THERMALLY ENHANCED SURFACE MOUNT	CHIP FORM (Y)
0°C to 70°C	TPA1517NE	TPA1517DWP	TPA1517Y

TPA1517, TPA1517Y 6 WATT/CHANNEL STEREO AUDIO POWER AMPLIFIER

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TPA1517Y chip information

This chip, when properly assembled, displays characteristics similar to the TPA1517C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TPA1517, TPA1517Y 6 WATT/CHANNEL STEREO AUDIO POWER AMPLIFIER

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DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
DWP	1930 mW	15.5 mW/°C	1233 mW	1000 mW

[‡]With recommended copper heat sink pattern on PCB

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V _{CC}	6		18	V
Operating free-air temperature, TA	0		70	°C

electrical characteristics at specified free-air temperature, V_{CC} = 12 V (unless otherwise noted)

PARAMETER		TEST CONDI	TIONS	MIN	TYP	MAX	UNIT
Icc	Quiescent current				40		mA

NOTE 1: At 6 V < V_{CC} < 18 V the DC output voltage is approximately $V_{CC}/2$.



[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

TPA1517, TPA1517Y 6 WATT/CHANNEL STEREO AUDIO POWER AMPLIFIER

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operating characteristic, V_{CC} = 12 V, R_L = 4 Ω , f = 1 kHz, T_A = 25°C

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
D.	Output nower are Note 2	THD = 0.2%	2.5	3	3.5	W
PO	Output power, see Note 2	THD < 10%	3.75	4	4.25	W
IO(SM)	Non-repetitive peak output current			4		Α
IO(RM)	Repetitive peak output current			2.5		Α
	Low-frequency roll-off	–3 dB		45		Hz
	High-frequency roll-off	-1 dB	20			kHz
	Supply voltage rejection	M/SB = On	48			dB
ΖĮ	Input impedance			60		kΩ
		$R_S = 0$, $M/SB = On$		50		μV(rms)
٧n	Noise output voltage, see Note 3	$R_S = 10$ M/SB = On		70	100	μV(rms)
		M/SB = Mute	T	50		μV(rms)
	Channel separation	$R_S = 10 \text{ k}\Omega$	40	60		dB
	Channel balance			0.1	1	dB

NOTES: 2. Output power is measured at the output pins of the IC.
3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.

operating characteristic, V_{CC} = 12 V, R_L = 4 Ω , f = 1 kHz, T_A = 25°C

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
D-	Outrot never see Note 0	THD = 0.2%	4	4.5	5	W
Po	Output power, see Note 2	THD < 10%	5.5	6	6.5	W
IO(SM)	Non-repetitive peak output current			4		Α
lO(RM)	Repetitive peak output current			2.5		Α
	Low-frequency roll-off	–3 dB		45		Hz
	High-frequency roll-off	–1 dB	20			kHz
	Supply voltage rejection	M/SB = On	48			dB
Ζį	Input impedance			60		kΩ
		$R_S = 0$, $M/SB = On$		50		μV(rms)
v _n	Noise output voltage, see Note 3	$R_S = 10$ M/SB = On		70	100	μV(rms)
		M/SB = Mute		50		μV(rms)
	Channel separation	$R_S = 10 \text{ k}\Omega$	40	60		dB
	Channel balance			0.1	1	dB

NOTES: 3. Output power is measured at the output pins of the IC.

4. Noise voltage is mesured in a bandwidth of 20 Hz to 20 kHz.

TPA1517, TPA1517Y 6 WATT/CHANNEL STEREO AUDIO POWER AMPLIFIER

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TYPICAL CHARACTERISTICS

Table of Graphs

				FIGURE
Icc	Supply current		vs Supply voltage	1
PSSR	Power supply rejection ratio		vs Frequency	2, 3
THD . N	THD + N Total harmonic distortion plus noise		vs Frequency vs Power output	4, 5, 6 10, 11
IND + N	Total narmonic distortion plus noise	V _{CC} = 14.5 V	vs Frequency vs Power output	7, 8, 9 12, 13
	Crosstalk		vs Frequency	14, 15
	Gain margin		vs Frequency	16
	Phase shift		vs Frequency	16
٧N	Noise voltage		vs Frequency	17, 18
PO	Output power		vs Supply voltage vs Load resistance	19 20
PD	Power dissipation		vs Output power	21, 22



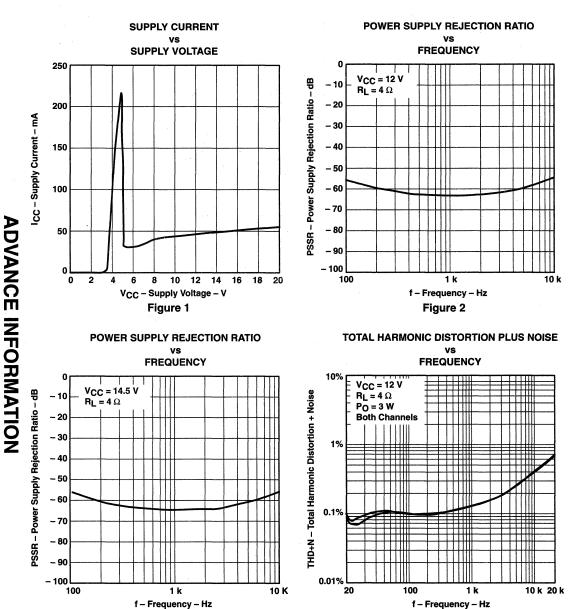




Figure 4

Figure 3

10 k 20 k

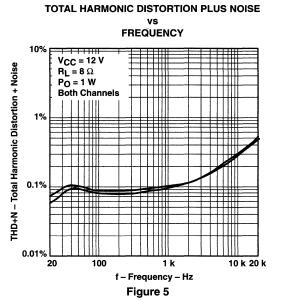
ADVANCE INFORMATION

TYPICAL CHARACTERISTICS

0.01

20

100



VS FREQUENCY

10%

V_{CC} = 12 V

R_L = 32 Ω

P_O = 0.25 W

Both Channels

1%

1%

0.1%

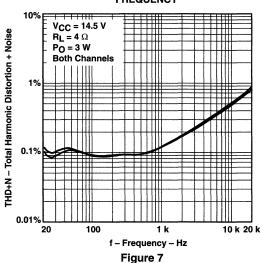
1 k

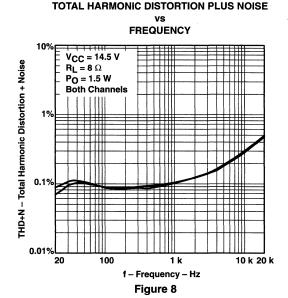
f - Frequency - Hz

Figure 6

TOTAL HARMONIC DISTORTION PLUS NOISE

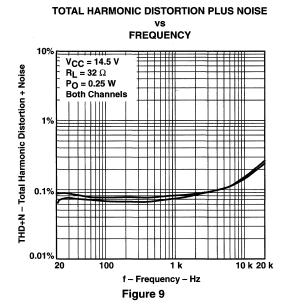
TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

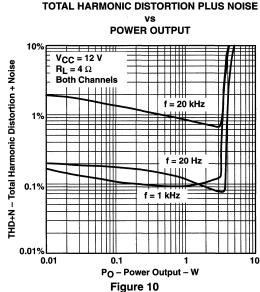




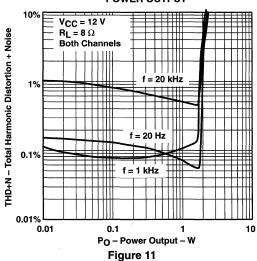
SL0S162 - MARCH1997

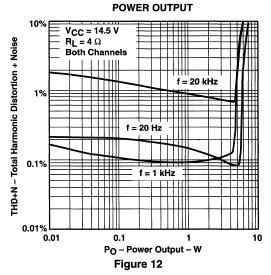
TYPICAL CHARACTERISTICS





TOTAL HARMONIC DISTORTION PLUS NOISE vs
POWER OUTPUT

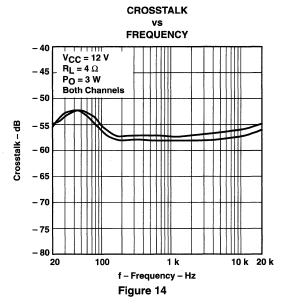




ADVANCE INFORMATION

TYPICAL CHARACTERISTICS

TOTAL HARMONIC DISTORTION PLUS NOISE POWER OUTPUT 10% V_{CC} = 14.5 V THD+N - Total Harmonic Distortion + Noise $R_L = 8 \Omega$ Both Channels Ш f = 20 kHz f = 20 Hz 0.1% f = 1 kHz 0.01% 0.01 0.1 10 Po - Power Output - W Figure 13



CROSSTALK vs **FREQUENCY** - 40 V_{CC} = 14.5 V $R_L = 4 \Omega$ - 45 Po = 5 W **Both Channels** - 50 Crosstalk - dB - 55 - 60 - 65 -70 - 75 - 80 20 100 10 k 20 k 1 k f - Frequency - Hz

Figure 15

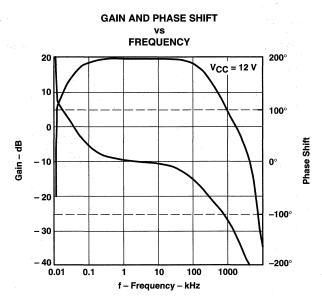
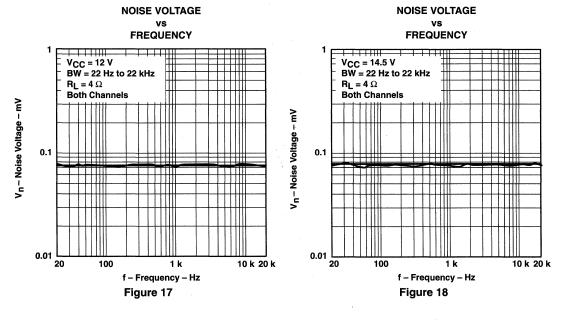
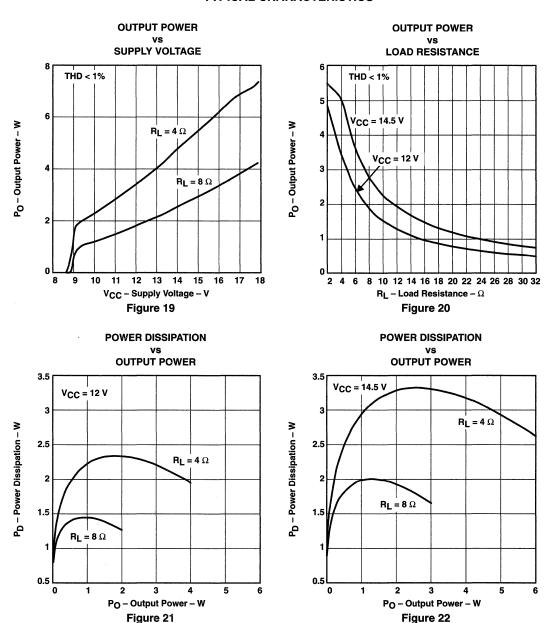


Figure 16



ADVANCE INFORMATION

TYPICAL CHARACTERISTICS





D PACKAGE

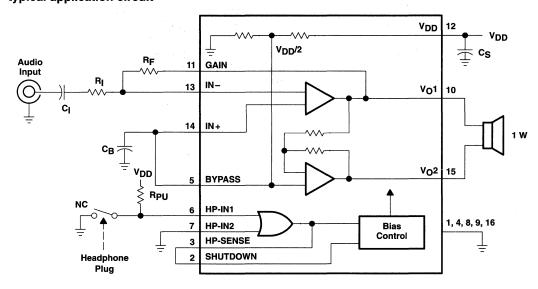
- 1-W BTL Output (5 V, 0.2 % THD+N)
- 3.3-V and 5-V Operation
- No Output Coupling Capacitors Required
- Shutdown Control (I_{DD} = 0.6 μA)
- Headphone Interface Logic
- Uncompensated Gains of 2 to 20 (BTL Mode)
- Surface Mount Packaging
- Thermal and Short-Circuit Protection
- High Power Supply Rejection (56-dB at 1 kHz)
- LM4860 Drop-In Compatible

(TOP VIEW) GND I SHUTDOWN [7] 2 15 HP-SENSE FT 3 T IN+ GND 🖂 T IN-4 13 BYPASS I \square V_{DD} HP-IN1 C 6 ☐ GAIN HP-IN2 I GND □ ☐ GND

description

The TPA4860 is a bridge-tied load (BTL) audio power amplifier capable of delivering 1 W of continuous average power into an 8- Ω load at 0.4 % THD+N from a 5-V power supply in voiceband frequencies (f < 5 kHz). A BTL configuration eliminates the need for external coupling capacitors on the output in most applications. Gain is externally configured by means of two resistors and does not require compensation for settings of 2 to 20. Features of this amplifier are a shutdown function for power-sensitive applications as well as headphone interface logic that mutes the output when the speaker drive is not required. Internal thermal and short-circuit protection increases device reliability. It also includes headphone interface logic circuitry to facilitate headphone applications. The amplifier is available in a 16-pin SOIC surface-mount package that reduces board space and facilitates automated assembly.

typical application circuit



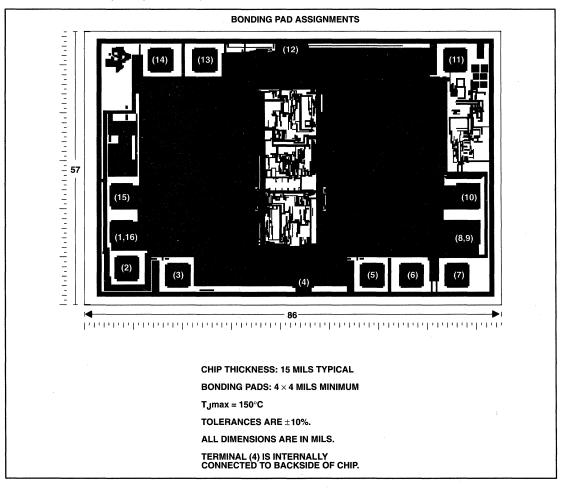
SLOS164 - SEPTEMBER 1996

AVAILABLE OPTIONS

	PACKAGED DEVICE	
TA	SMALL OUTLINE (D)	CHIP FORM
-20°C to 85°C	TPA4860D	TPA4860Y

TPA4860Y chip information

This chip, when properly assembled, displays characteristics similar to the TPA4860C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.



TPA4860, TPA4860Y 1-WATT AUDIO POWER AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD}	6 V
Input voltage, V ₁	
Continuous total power dissipation	internally limited (See Dissipation Rating Table)
Operating free-air temperature range, T _A	–20°C to 85°C
Storage temperature range, T _{stq}	
Lead temperature 1.6 mm (1/16 inch) from case for 10 secon	nds 260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
D	1250 mW	10 mW/°C	800 mW	650 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{DD}		2.7	5.5	V
Common mode input valtage V	V _{DD} = 3.3 V	1.25	2.7	V
Common-mode input voltage, V _{IC}	V _{DD} = 5 V	1.25	4.5	V
Operating free-air temperature, TA		-20	85	°C

TPA4860, TPA4860Y 1-WATT AUDIO POWER AMPLIFIER

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electrical characteristics at specified free-air temperature range, V_{DD} = 3.3 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TPA4860			UNIT
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V ₀₀	Output offset voltage	See Note 1		5	20	mV
ksvr	Supply voltage rejection ratio ($\Delta V_{DD}/\Delta V_{OO}$)	V _{DD} = 3.2 V to 3.4 V		75		dB
I _{DD(q)}	Quiescent current			2.5		mA
I _{DD(m)}	Quiescent current, mute mode			750		μΑ
I _{DD(sd)}	Quiescent current, shutdown mode			0.6		μΑ
V_{IH}	High-level input voltage (HP-IN)			1.7		٧
V_{IL}	Low-level input voltage (HP-IN)			1.7		٧
Vон	High-level output voltage (HP-SENSE)	I _O = 100 μA	2.5	2.8		V
V _{OL}	Low-level output voltage (HP-SENSE)	$I_{O} = -100 \mu\text{A}$		0.2	0.8	V

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristics, V_{DD} = 3.3 V, T_A = 25°C, R_L = 8 Ω

PARAMETER			TEST CONDITIONS	7	TPA4860		
			TEST CONDITIONS	MIN	TYP	MAX	UNIT
PO	Output power, see Note 2		THD = 0.2%, f = 1 kHz, A _V = 2		350		mW
			$THD = 2\%, \qquad f = 1 \text{ kHz},$ $A_V = 2$		500		mW
ВОМ	OM Maximum output power bandwidth		Gain = 10, THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop		1.5		MHz
	Owner to refer the resident to the	BTL	f = 1 kHz		56		dB
	Supply ripple rejection SE		f = 1 kHz		30		dB
Vn	Noise output voltage, see Note 3		Gain = 2		20		μV

NOTES: 2. Output power is measured at the output terminals of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.

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electrical characteristics at specified free-air temperature range, $V_{\mbox{\scriptsize DD}}$ = 5 V (unless otherwise noted)

	DADAMETED	TEST CONDITIONS	TPA4860			
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Voo	Output offset voltage	See Note 1		5	20	mV
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{OO})	V _{DD} = 4.9 V to 5.1 V		70		dB
I _{DD(q)}	Quiescent current			3.5		mA
I _{DD(m)}	Quiescent current, mute mode			750		μА
I _{DD(sd)}	Quiescent current, shutdown mode			0.6		μΑ
VIH	High-level input voltage (HP-IN)			2.5		V
VIL	Low-level input voltage (HP-IN)			2.5		٧
Vон	High-level output voltage (HP-SENSE)	ΙΟ = 500 μΑ	2.5	2.8		V
VOL	Low-level output voltage (HP-SENSE)	$I_{O} = -500 \mu\text{A}$		0.2	0.8	٧

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristic, V_{DD} = 5 V, T_A = 25°C, R_L = 8 Ω

	PARAMETER			TEST CONDITIONS		TPA4860		
						TYP	MAX	UNIT
D-	Output power, see Note 2		THD = 0.2%, A _V = 2	f = 1 kHz,		1000		mW
Ро			THD = 2%, A _V = 2	f = 1 kHz,		1100		mW
Вом	OM Maximum output power bandwidth		Gain = 10,	THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop			1.5		MHz
	Owner to the selection	BTL	f = 1 kHz			56		dB
	Supply ripple rejection SE		f = 1 kHz			30		dB
Vn	Noise output voltage, see Note 3		Gain = 2			20		μV

NOTES: 2. Output power is measured at the output terminals of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.



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electrical characteristics at specified free-air temperature range, V_{DD} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TPA4860Y			UNIT
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V ₀₀	Output offset voltage	See Note 1		- 5		mV
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{OO})	$V_{DD} = 4.9 \text{ V to } 5.1 \text{ V}$		70		dB
IDD(q)	Quiescent current			3.5		mA
I _{DD(m)}	Quiescent current, mute mode			750		μA
I _{DD(sd)}	Quiescent current, shutdown mode			0.6		μΑ
VIH	High-level input voltage (HP-IN)			2.5		٧
VIL	Low-level input voltage (HP-IN)			2.5		٧
Vон	High-level output voltage (HP-SENSE)	ΙΟ = 500 μΑ		2.8		٧
VOL	Low-level output voltage (HP-SENSE)	I _O = -500 μA		0.2		٧

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristic, V_{DD} = 5 V, T_A = 25°C, R_L = 8 Ω

PARAMETER			TEST COMPLETIONS	TPA4860Y			118117
			TEST CONDITIONS	MIN	TYP	MAX	UNIT
D-	Output power, see Note 2		THD = 0.2%, f = 1 kHz, A _V = 2		1000		mW
Po			THD = 2%, f = 1 kHz, A _V = 2		1100	-	mW
ВОМ	OM Maximum output power bandwidth		Gain = 10, THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop		1.5		MHz
		BTL	f = 1 kHz		56		dB
	Supply ripple rejection SE		f = 1 kHz		30		dB
٧n	Noise output voltage, see Note 4		Gain = 2		20		μV

NOTES: 2. Output power is measured at the output terminals of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.

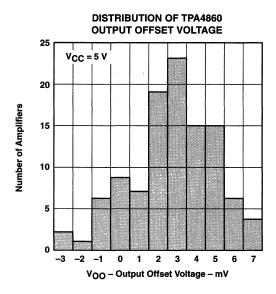
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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
Voo	Output offset voltage	Distribution	1,2
lDD	Supply current distribution	vs Free-air temperature	3,4
THD+N	Total harmonic distortion plus noise	vs Frequency	5,6,7,8,9, 10,11,15, 16,17,18
		vs Output power	12,13,14, 19,20,21
IDD	Supply current	vs Supply voltage	22
Vn	Output noise voltage	vs Frequency	23,24
-	Maximum package power dissipation	vs Free-air temperature	25
	Power dissipation	vs Output power	26,27
	Maximum output power	vs Free-air temperature	28
	Outros to manage	vs Load Resistance	29
	Output power	vs Supply Voltage	30
	Open loop frequency response	vs Frequency	31
PSRR	Power supply rejection ratio	vs Frequency	32,33



DISTRIBUTION OF TPA4860 OUTPUT OFFSET VOLTAGE

25

VCC = 3.3 V

20

15

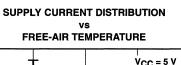
15

0

-3 -2 -1 0 1 2 3 4 5 6 7

VOO - Output Offset Voltage - mV

Figure 1



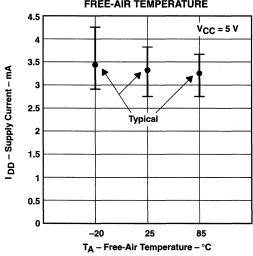


Figure 3

Figure 2

SUPPLY CURRENT DISTRIBUTION

TA - Free-Air Temperature - °C

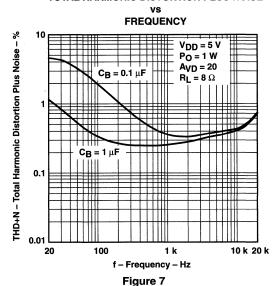
Figure 4

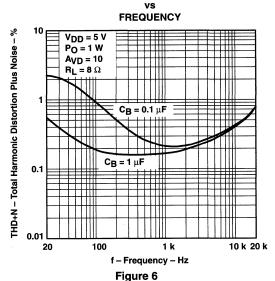
TEXAS INSTRUMENTS

TOTAL HARMONIC DISTORTION PLUS NOISE vs **FREQUENCY** THD+N - Total Harmonic Distortion Plus Noise - % V_{DD} = 5 V Po = 1 W $A_{VD} = 2$ $R_L = 8 \Omega$ $C_B = 0.1 \mu F$ 0.1 $C_B = 1 \mu F$ 0.01 20 100 1 k 10 k 20 k f - Frequency - Hz

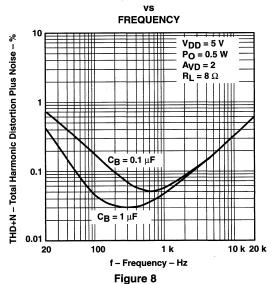
TOTAL HARMONIC DISTORTION PLUS NOISE

Figure 5





TOTAL HARMONIC DISTORTION PLUS NOISE



TOTAL HARMONIC DISTORTION PLUS NOISE

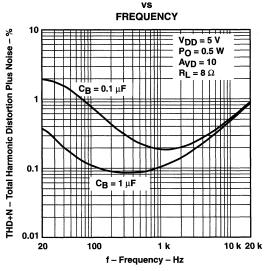


Figure 9

TOTAL HARMONIC DISTORTION PLUS NOISE

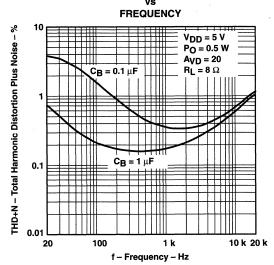


Figure 10

TOTAL HARMONIC DISTORTION PLUS NOISE

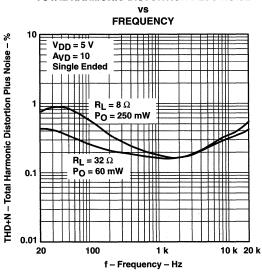


Figure 11

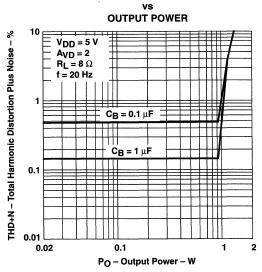
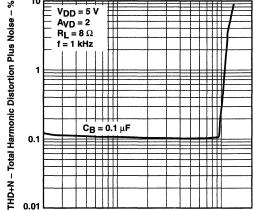


Figure 12

TOTAL HARMONIC DISTORTION PLUS NOISE OUTPUT POWER $V_{DD} = 5 V$ $A_{VD} = 2$ $R_L = 8 \Omega$ f = 1 kHz



0.1

0.02

Po - Output Power - W Figure 13

1

TOTAL HARMONIC DISTORTION PLUS NOISE vs

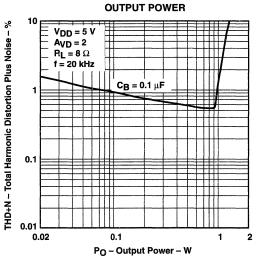


Figure 14

TOTAL HARMONIC DISTORTION PLUS NOISE

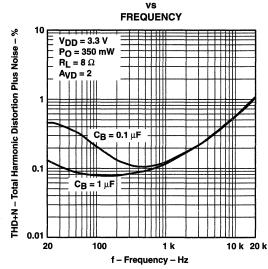


Figure 15

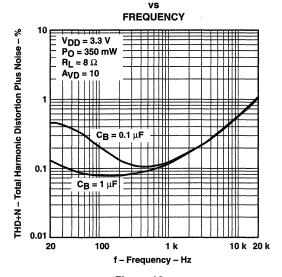


Figure 16

TOTAL HARMONIC DISTORTION PLUS NOISE

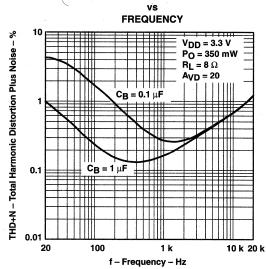


Figure 17

TOTAL HARMONIC DISTORTION PLUS NOISE

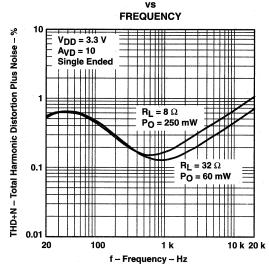
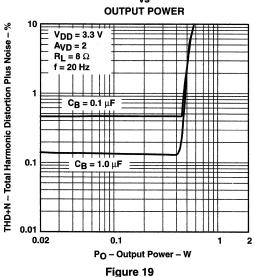
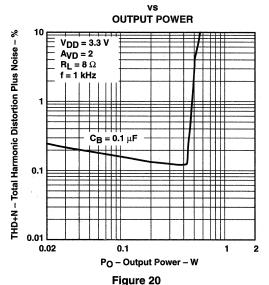


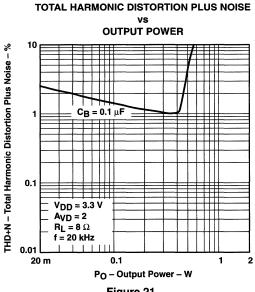
Figure 18

TOTAL HARMONIC DISTORTION PLUS NOISE vs



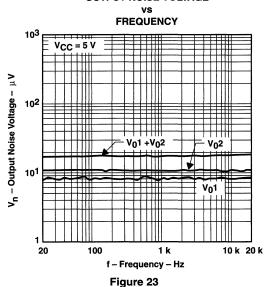


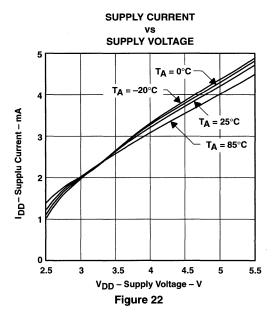
TEXAS INSTRUMENTS

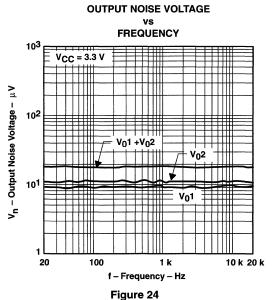


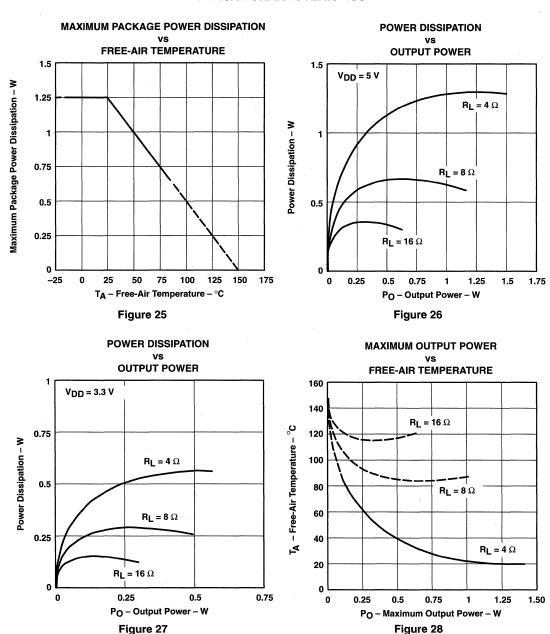
P_O – Output Power – W
Figure 21

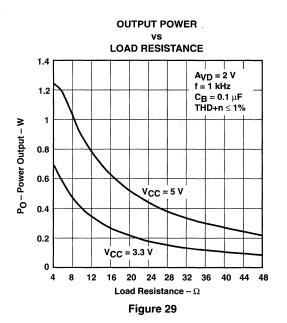
OUTPUT NOISE VOLTAGE

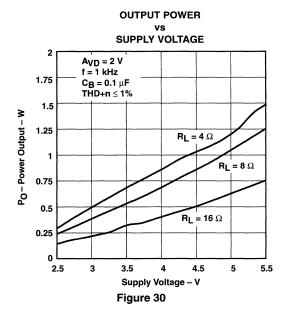






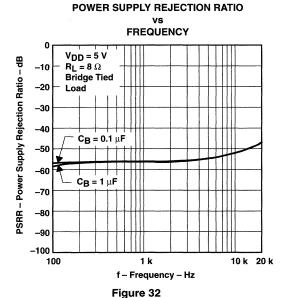






OPEN LOOP FREQUENCY RESPONSE 100 45° $V_{DD} = 5 V$ $R_L = 8 \Omega$ $C_{B} = 0.1 \, \mu F$ 80 60 -45° G - Gain - dB 40 20 –135° 0 -180° -20 -225° 10 100 10 k 100 k 1 M 10 M f - Frequency - Hz

Figure 31



POWER SUPPLY REJECTION RATIO

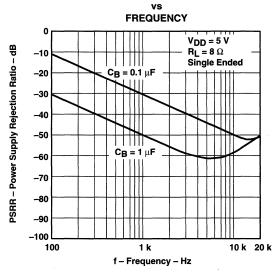


Figure 33

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bridged-tied load versus single-ended mode

Figure 34 shows a linear audio power amplifier (APA) in a bridge tied load (BTL) configuration. A BTL amplifier actually consists of two linear amplifiers driving both ends of the load. There are several potential benefits to this differential drive configuration but initially let us consider power to the load. The differential drive to the speaker means that as one side is slewing up the other side is slewing down and vice versa. This in effect doubles the voltage swing on the load as compared to a ground referenced load. Plugging twice the voltage into the power equation, where voltage is squared, yields 4 times the output power from the same supply rail and load impedance (see equation 1).

$$V_{(rms)} = \frac{V_{O(PP)}}{2\sqrt{2}}$$

$$Power = \frac{V_{(rms)}^{2}}{R_{L}}$$

$$V_{DD}$$

Figure 34. Bridge-Tied Load Configuration

In a typical computer sound channel operating at 5 V, bridging raises the power into a $8-\Omega$ speaker from a singled-ended (SE) limit of 250 mW to 1 W. In sound power that is a 6-dB improvement — which is loudness that can be heard. In addition to increased power there are frequency response concerns, consider the single-supply SE configuration shown in Figure 35. A coupling capacitor is required to block the dc offset voltage from reaching the load. These capacitors can be quite large (approximately 40 μ F to 1000 μ F) so they tend to be expensive, occupy valuable PCB area, and have the additional drawback of limiting low-frequency performance of the system. This frequency limiting effect is due to the high pass filter network created with the speaker impedance and the coupling capacitance and is calculated with equation 2.

$$f_{(corner)} = \frac{1}{2\pi R_1 C_C}$$
 (2)

For example, a $68-\mu F$ capacitor with an $8-\Omega$ speaker would attenuate low frequencies below 293 Hz. The BTL configuration cancels the dc offsets, which eliminates the need for the blocking capacitors. Low-frequency performance is then limited only by the input network and speaker response. Cost and PCB space are also minimized by eliminating the bulky coupling capacitor.

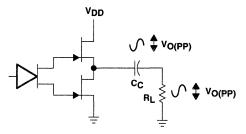


Figure 35. Single-Ended Configuration

Increasing power to the load does carry a penalty of increased internal power dissipation. The increased dissipation is understandable considering that the BTL configuration produces 4 times the output power of the SE configuration. Internal dissipation versus output power is discussed further in the *thermal considerations* section.

BTL amplifier efficiency

Linear amplifiers are notoriously inefficient. The primary cause of these inefficiencies is voltage drop across the output stage transistors. There are two components of the internal voltage drop. One is the headroom or dc voltage drop that varies inversely to output power. The second component is due to the sinewave nature of the output. The total voltage drop can be calculated by subtracting the RMS value of the output voltage from V_{DD} . The internal voltage drop multiplied by the RMS value of the supply current, I_{DD} rms, determines the internal power dissipation of the amplifier.

An easy to use equation to calculate efficiency starts out as being equal to the ratio of power from the power supply to the power delivered to the load. To accurately calculate the RMS values of power in the load and in the amplifier, the current and voltage waveform shapes must first be understood (see Figure 36).

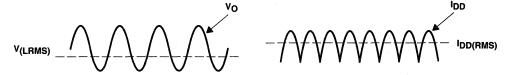


Figure 36. Voltage and Current Waveforms for BTL Amplifiers

Although the voltages and currents for SE and BTL are sinusoidal in the load, currents from the supply are very different between SE and BTL configurations. In an SE application the current waveform is a half-wave rectified shape whereas in BTL it is a full-wave rectified waveform. This means RMS conversion factors are different. Keep in mind that for most of the waveform both the push and pull transistor are not on at the same time, which supports the fact that each amplifier in the BTL device only draws current from the supply for half the waveform. The following equations are the basis for calculating amplifier efficiency.



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$$Efficiency = \frac{P_L}{P_{SUP}}$$
 (3)

where:

$$\begin{split} \text{V}_\text{L}\text{rms} &= \frac{\text{V}_\text{P}}{\sqrt{2}} \\ \text{P}_\text{L} &= \frac{\text{V}_\text{L}\text{rms}^2}{\text{R}_\text{L}} = \frac{\text{V}_\text{p}^2}{2\text{R}_\text{L}} \\ \text{P}_\text{SUP} &= \text{V}_\text{DD} \text{ I}_\text{DD}\text{rms} = \frac{\text{V}_\text{DD} \text{ 2V}_\text{P}}{\pi \text{ R}_\text{L}} \\ \text{I}_\text{DD}\text{rms} &= \frac{2\text{V}_\text{P}}{\pi \text{ R}_\text{L}} \end{split}$$

Efficiency of a BTL Configuration =
$$\frac{\pi V_P}{2V_{DD}} = \frac{\pi \left(\frac{P_L R_L}{2}\right)^{1/2}}{2V_{DD}}$$
 (4)

Table 1 employs equation 4 to calculate efficiencies for four different output power levels. Note that the efficiency of the amplifier is quite low for lower power levels and rises sharply as power to the load is increased resulting in a nearly flat internal power dissipation over the normal operating range. Note that the internal dissipation at full output power is less than in the half power range. Calculating the efficiency for a specific system is the key to proper power supply design. For a stereo 1-W audio system with 8- Ω loads and a 5-V supply, the maximum draw on the power supply is almost 3.25 W.

Table 1. Efficiency Vs Output Power in 5-V 8- Ω BTL Systems

Output Power (W)	Efficiency (%)	Peak-to-Peak Voltage (V)	Internal Dissipation (W)
0.25	31.4	2.00	0.55
0.50	44.4	2.83	0.62
1.00	62.8	4.00	0.59
1.25	70.2	4.47†	0.53

† High peak voltages cause the THD to increase.

A final point to remember about linear amplifiers whether they are SE or BTL configured is how to manipulate the terms in the efficiency equation to utmost advantage when possible. Note that in equation 4, V_{DD} is in the denominator. This indicates that as V_{DD} goes down, efficiency goes up.

For example, if the 5-V supply is replaced with a 10-V supply (TPA4860 has a maximum recommended V_{DD} of 5.5 V) in the calculations of Table 1 then efficiency at 1 W would fall to 31% and internal power dissipation would rise to 2.18 W from 0.59 W at 5 V. Then for a stereo 1-W system from a 10-V supply, the maximum draw would be almost 6.5 W. Choose the correct supply voltage and speaker impedance for the application.

selection of components

Figure 37 is a schematic diagram of a typical notebook computer application circuit.

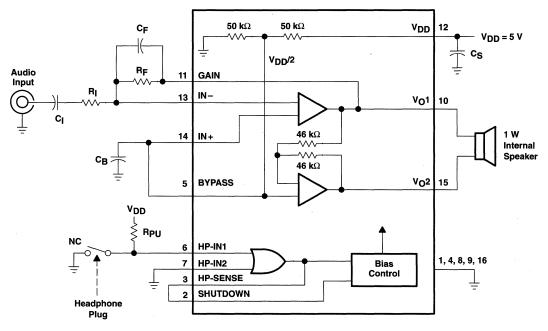


Figure 37. TPA4860 Typical Notebook Computer Application Circuit

gain setting resistors, RF and RI

The gain for the TPA4860 is set by resistors R_F and R_I according to equation 5.

$$Gain = -2\left(\frac{R_F}{R_I}\right) \tag{5}$$

BTL mode operation brings about the factor of 2 in the gain equation due to the inverting amplifier mirroring the voltage swing across the load. Given that the TPA4860 is a MOS amplifier, the input impedance is very high, consequently input leakage currents are not generally a concern although noise in the circuit increases as the value of R_F increases. In addition, a certain range of R_F values are required for proper startup operation of the amplifier. Taken together it is recommended that the effective impedance seen by the inverting node of the amplifier be set between 5 k Ω and 20 k Ω . The effective impedance is calculated in equation 6.

Effective Impedance =
$$\frac{R_F R_I}{R_E + R_I}$$
 (6)

As an example consider an input resistance of 10 k Ω and a feedback resistor of 50 k Ω . The gain of the amplifier would be -10 and the effective impedance at the inverting terminal would be 8.3 k Ω , which is well within the recommended range.



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For high performance applications metal film resistors are recommended because they tend to have lower noise levels than carbon resistors. For values of R_F above 50 $k\Omega$ the amplifier tends to become unstable due to a pole formed from R_F and the inherent input capacitance of the MOS input structure. For this reason, a small compensation capacitor of approximately 5 pF should be placed in parallel with R_F . This, in effect, creates a low pass filter network with the cutoff frequency defined in equation 7.

$$f_{\text{co(lowpass)}} = \frac{1}{2\pi R_F C_F}$$
 (7)

For example, if R_F is 100 k Ω and Cf is 5 pF then f_{CO} is 318 kHz, which is well outside of the audio range.

input capacitor, CI

In the typical application an input capacitor, C_{\parallel} , is required to allow the amplifier to bias the input signal to the proper dc level for optimum operation. In this case, C_{\parallel} and R_{\parallel} form a high-pass filter with the corner frequency determined in equation 8.

$$f_{co(highpass)} = \frac{1}{2\pi R_{|C|}}$$
 (8)

The value of C_l is important to consider as it directly affects the bass (low frequency) performance of the circuit. Consider the example where R_l is 10 k Ω and the specification calls for a flat bass response down to 40 Hz. Equation 8 is reconfigured as equation 9.

$$C_{l} = \frac{1}{2\pi R_{l} f_{co}}$$
 (9)

In this example, C_l is 0.40 μF so one would likely choose a value in the range of 0.47 μF to 1 μF . A further consideration for this capacitor is the leakage path from the input source through the input network (R_l, C_l) and the feedback resistor (R_F) to the load. This leakage current creates a dc offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications. For this reason a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifier input in most applications as the dc level there is held at $V_{DD}/2$, which is likely higher that the source dc level. Please note that it is important to confirm the capacitor polarity in the application.

power supply decoupling, CS

The TPA4860 is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) is as low as possible. Power supply decoupling also prevents oscillations for long lead lengths between the amplifier and the speaker. The optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μ F placed as close as possible to the device V_{DD} lead works best. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10 μ F or greater placed near the power amplifier is recommended.

midrail bypass capacitor, CB

The midrail bypass capacitor, C_B , serves several important functions. During startup or recovery from shutdown mode, C_B determines the rate at which the amplifier starts up. This helps to push the start-up pop noise into the subaudible range (so slow it can not be heard). The second function is to reduce noise produced by the power supply caused by coupling into the output drive signal. This noise is from the midrail generation circuit internal to the amplifier. The capacitor is fed from a 25-k Ω source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 10 should be maintained.

$$\frac{1}{\left(C_{\mathsf{B}} \times 25\mathsf{k}\Omega\right)} \le \frac{1}{\left(C_{\mathsf{I}}\mathsf{R}_{\mathsf{I}}\right)} \tag{10}$$

As an example, consider a circuit where C_B is 0.1 μ F, C_I is 0.22 μ F and R_I is 10 $k\Omega$. Inserting these values into the equation 9 we get:

$$400 \le 454$$

which satisfies the rule. Bypass capacitor, C_B , values of 0.1 μ F to 1 μ F ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

single-ended operation

Figure 38 is a schematic diagram of the recommended SE configuration. In SE mode configurations, the load should be driven from the primary amplifier output (OUT1, terminal 10).

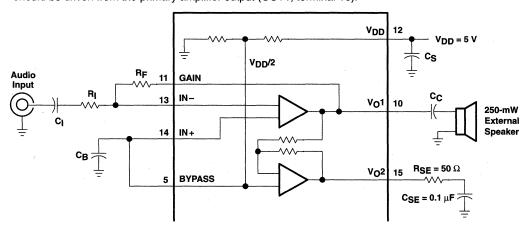


Figure 38. Singled-Ended Mode

Gain is set by the R_F and R_I resistors and is shown in equation 11. Since the inverting amplifier is not used to mirror the voltage swing on the load, the factor of 2 is not included.

$$Gain = -\left(\frac{R_F}{R_I}\right) \tag{11}$$

The phase margin of the inverting amplifier into an open circuit is not adequate to ensure stability, so a termination load should be connected to V_O2 . This consists of a 50- Ω resistor in series with a 0.1- μ F capacitor to ground. It is important to avoid oscillation of the inverting output to minimize noise and power dissipation.



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The output coupling capacitor required in single-supply SE mode also places additional constraints on the selection of other components in the amplifier circuit. The rules described earlier still hold with the addition of the following relationship:

$$\frac{1}{\left(C_{\mathsf{B}} \times 25k\Omega\right)} \le \frac{1}{\left(C_{\mathsf{I}}\mathsf{R}_{\mathsf{I}}\right)} \ll \frac{1}{\mathsf{R}_{\mathsf{L}}C_{\mathsf{C}}} \tag{12}$$

output coupling capacitor, CC

In the typical single-supply SE configuration, an output coupling capacitor (C_C) is required to block the dc bias at the output of the amplifier thus preventing dc currents in the load. As with the input coupling capacitor, the output coupling capacitor and impedance of the load form a high-pass filter governed by equation 13.

$$f_{\text{out high}} = \frac{1}{2\pi R_{\text{L}} C_{\text{C}}} \tag{13}$$

The main disadvantage, from a performance standpoint, is that the load impedances are typically small, which drive the low-frequency corner higher. Large values of C_C are required to pass low frequencies into the load. Consider the example where a C_C of 68 μF is chosen and loads vary from 8 Ω , 32 Ω , and 47 $k\Omega$. Table 2 summarizes the frequency response characteristics of each configuration.

Table 2. Common Load Impedances Vs Low Frequency Output Characteristics in SE Mode

RL	СС	Lowest Frequency
8 Ω	68 μF	293 Hz
32 Ω	68 μF	73 Hz
47,000 Ω	68 μF	0.05 Hz

As Table 2 indicates, most of the bass response is attenuated into $8-\Omega$ loads while headphone response is adequate and drive into line level inputs (a home stereo for example) is very good.

headphone sense circuitry, R_{pu}

The TPA4860 is commonly used in systems where there is an internal speaker and a jack for driving external loads (i.e., headphones). In these applications, it is usually desirable to mute the internal speaker(s) when the external load is in use. The headphone inputs (HP-1, HP-2) and headphone output (HP-SENSE) of the TPA4860 were specifically designed for this purpose. Many standard headphone jacks are available with an internal single-pole single-throw (SPST) switch that makes or breaks a circuit when the headphone plug is inserted. Asserting either or both HP-1 and/or HP-2 high mutes the output stage of the amplifier and causes HP-SENSE to go high. In battery-powered applications where power conservation is critical HP-SENSE can be connected to the shutdown input as shown in Figure 39. This places the amplifier in a very low current state for maximum power savings. Pullup resistors in the range from 1 k Ω to 10 k Ω are recommended for 5-V and 3.3-V operation.

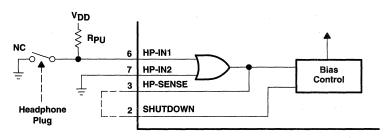


Figure 39. Schematic Diagram of Typical Headphone Sense Application

Table 3 details the logic for the mute function of the TPA4860.

Table 3. Truth table for Headphone Sense and Shutdown Functions

INPUTS†			OUTPUT	AMPLIFIER
HP-1	HP-2	SHUTDOWN	HP-SENSE	STATE
Low	Low	Low	Low	Active
Low	High	Low	High	Mute
High:	Low	Low	High	Mute
High	High	Low	High	Mute
Х	Х	High	Х	Shutdown

[†] Inputs should never be left unconnected.

shutdown mode

The TPA4860 employs a shutdown mode of operation designed to reduce quiescent supply current, $I_{DD(q)}$, to the absolute minimum level during periods of nonuse for battery-power conservation. For example, during device sleep modes or when other audio-drive currents are used (i.e., headphone mode), the speaker drive is not required. The SHUTDOWN input terminal should be held low during normal operation when the amplifier is in use. Pulling SHUTDOWN high causes the outputs to mute and the amplifier to enter a low-current state, $I_{DD(q)} < 1~\mu$ A. SHUTDOWN should never be left unconnected because amplifier operation would be unpredictable.

using low-ESR capacitors

Low-ESR capacitors are recommended throughout this applications section. A real capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this resistor minimizes the beneficial effects of the capacitor in the circuit. The lower the equivalent value of this resistance the more the real capacitor behaves like an ideal capacitor.

thermal considerations

A prime consideration when designing an audio amplifier circuit is internal power dissipation in the device. The curve in Figure 40 provides an easy way to determine what output power can be expected out of the TPA4860 for a given system ambient temperature in designs using 5-V supplies. This curve assumes no forced airflow or additional heat sinking.



X = do not care



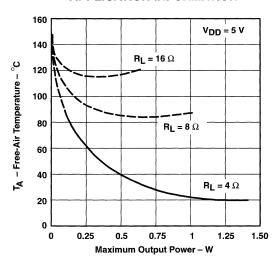


Figure 40. Free-Air Temperature Versus Maximum Continuous Output Power

5-V versus 3.3-V operation

The TPA4860 was designed for operation over a supply range of 2.7 V to 5.5 V. This data sheet provides full specifications for 5-V and 3.3-V operation as these are considered to be the two most common standard voltages. There are no special considerations for 3.3-V versus 5-V operation as far as supply bypassing, gain setting, or stability. Supply current is slightly reduced from 3.5 mA (typical) to 2.5 mA (typical). The most important consideration is that of output power. Each amplifier in TPA4860 can produce a maximum voltage swing of $V_{DD} - 1$ V. This means, for 3.3-V operation, clipping starts to occur when $V_{O(PP)} = 2.3$ V as opposed to when $V_{O(PP)} = 4$ V while operating at 5 V. The reduced voltage swing subsequently reduces maximum output power into an $8-\Omega$ load to less than 0.33 W before distortion begins to become significant.

Operation at 3.3-V supplies, as can be shown from the efficiency formula in equation 4, consumes approximately two-thirds the supply power for a given output-power level than operation from 5-V supplies. When the application demands less than 500 mW, 3.3-V operation should be strongly considered, especially in battery-powered applications.

D PACKAGE (TOP VIEW)

2

3

SHUTDOWN [

BYPASS ET

IN+CI

IN-E

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∇₀2

☐ GND

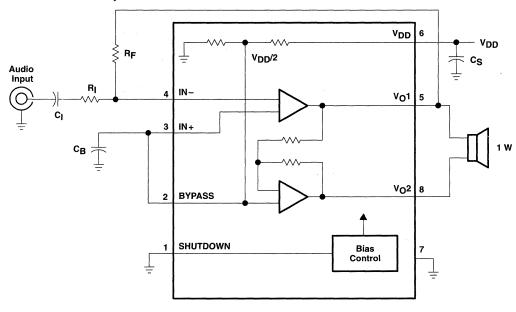
 \Box V_{DD}

□ V_O1

- 1-W BTL Output (5 V, 0.2 % THD+N)
- 3.3-V and 5-V Operation
- No Output Coupling Capacitors Required
- Shutdown Control (I_{DD} = 0.6 μA)
- Uncompensated Gains of 2 to 20 (BTL Mode)
- Surface Mount Packaging
- Thermal and Short-Circuit Protection
- High Power Supply Rejection (56 dB at 1 kHz)
- LM4861 Drop-In Compatible

description

The TPA4861 is a bridge-tied load (BTL) audio power amplifier capable of delivering 1 W of continuous average power into an 8- Ω load at 0.4 % THD+N from a 5-V power supply in voiceband frequencies (f < 5 kHz). A BTL configuration eliminates the need for external coupling capacitors on the output in most applications. Gain is externally configured by means of two resistors and does not require compensation for settings of 2 to 20. Features of the amplifier are a shutdown function for power-sensitive applications as well as internal thermal and short-circuit protection. The TPA4861 works seamlessly with Tl's TPA4860 in stereo applications. The amplifier is available in an 8-pin SOIC surface-mount package that reduces board space and facilitates automated assembly.





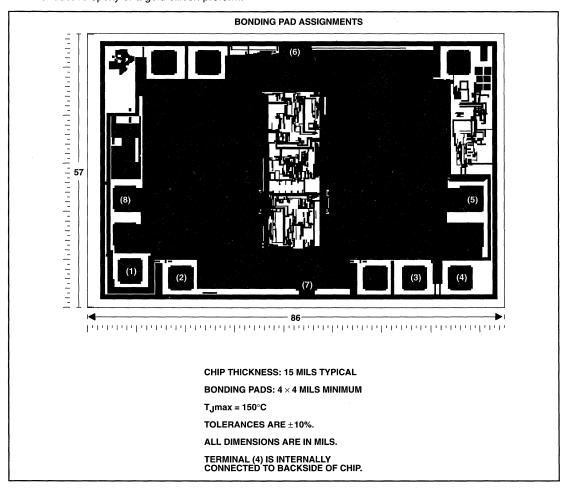
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AVAILABLE OPTIONS

	PACKAGED DEVICE	
™A	SMALL OUTLINE (D)	CHIP FORM
-20°C to 85°C	TPA4861D	TPA4861Y

TPA4861Y chip information

This chip, when properly assembled, displays characteristics similar to the TPA4861C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.



TPA4861, TPA4861Y 1-WATT AUDIO POWER AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD}	
Input voltage, V _I	0.3 V to V _{DD} +0.3 V
Continuous total power dissipation	internally limited (see Dissipation Rating Table)
Operating free-air temperature range, T _A	–20°C to 85°C
Storage temperature range, T _{stq}	–65°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 secon	nds 260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
D	731 mW	5.8 mW/°C	470 mW	383 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{DD}		2.7	5.5	٧
Common-mode input voltage, V _{IC}	V _{CC} = 3 V	1.25	2.7	٧
Common-mode input voltage, vIC	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	4.5	٧	
Operating free-air temperature, TA		-20	85	°C

electrical characteristics at specified free-air temperature, V_{CC} = 3.3 V (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	T	TPA4861		UNIT
	FARAMETER	TEST CONDITIONS	MIN	TYP	MAX 20	UNIT
V ₀₀	Output offset voltage	See Note 1		5	20	mV
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{OO})	$V_{DD} = 3.2 \text{ V to } 3.4 \text{ V}$		75		dB
I _{DD(q)}	Quiescent current			2.5		mA
IDD(sd)	Quiescent current, shutdown mode			0.6		μА

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristics, V_{DD} = 3.3 V, T_{A} = 25°C, R_{L} = 8 Ω

	DADAMETED		TF07.00	TEST CONDITIONS		PA4861		
	PARAMETER		IESI CO	NULLIONS	MIN	TYP	MAX	UNIT
Po	Output power, see Note 2		THD = 0.2%, A _V = 2	f = 1 kHz,	350			mW
			THD = 2%, A _V = 2	f = 1 kHz,		500		mW
ВОМ	Maximum output power bandwidth		Gain = 10,	THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop			1.5		MHz
	Complex simple uniquelity	BTL	f = 1 kHz			56		dB
	Supply ripple rejection	SE	f = 1 kHz			30		dB
Vn	Noise output voltage, see Note 3		Gain = 2			20		μV

NOTES: 2. Output power is measured at the output terminals of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.



TPA4861, TPA4861Y 1-WATT AUDIO POWER AMPLIFIER

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electrical characteristics at specified free-air temperature range, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST CONDITION	TPA4861			UNIT
	PARAMETER	TEST CONDITION		TYP	MAX	UNIT
V00	Output offset voltage	See Note 1		5.	20	mV
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{OO})	V _{DD} = 4.9 V to 5.1 V		70		dB
I _{DD(q)}	Quiescent current			3.5		mA
IDD(sd)	Quiescent current, shutdown mode			0.6		μΑ

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristic, V_{DD} = 5 V, T_A = 25°C, R_L = 8 Ω

	PARAMETER		TEST CO	NDITIONS	Т	PA4861		UNIT
	PARAMETER	(IESI CO	MDITIONS	MIN	TYP	MAX	UNII
D-	Output power, see Note 2		THD = 0.2%, A _V = 2	f = 1 kHz,	1000		mW	
PO			THD = 2%, A _V = 2	f = 1 kHz, 1100			mW	
ВОМ	Maximum output power bandwidth		Gain = 10,	THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop			1.5		MHz
	Country street and a street	BTL	f = 1 kHz			56		dB
	Supply ripple rejection	SE	f = 1 kHz			30		dB
Vn	Noise output voltage, see Note 3		Gain = 2			20		μV

NOTES: 2. Output power is measured at the output terminals of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.

TPA4861, TPA4861Y 1-WATT AUDIO POWER AMPLIFIER

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electrical characteristics at specified free-air temperature range, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CONDITIONS TPA4861Y			UNIT	
	PARAMETER	TEST CONDITIONS	MIN	TYP	Y MAX	UNII
V00	Output offset voltage	See Note 1		5		mV
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{OO})	V _{DD} = 4.9 V to 5.1 V		70		dB
I _{DD(q)}	Quiescent current			3.5		mA
I _{DD(sd)}	Quiescent current, shutdown mode			0.6		μА

NOTE 1: At 3 V < V_{DD} < 5 V the dc output voltage is approximately $V_{DD}/2$.

operating characteristic, V_{DD} = 5 V, T_A = 25°C, R_L = 8 Ω

DADAMETED			TEST CO.	TEST CONDITIONS		TPA4861Y		
	PARAMETER					TYP	MAX	UNIT
Po	Output power, see Note 2		THD = 0.2%, A _V = 2	f = 1 kHz,		1000		mW
			THD = 2%, A _V = 2	f = 1 kHz,		1100		mW
ВОМ	OM Maximum output power bandwidth		Gain = 10,	THD = 2%		20		kHz
B ₁	Unity-gain bandwidth		Open Loop			1.5		MHz
	Supply ripple rejection	BTL	f = 1 kHz			56		dB
		SE	f = 1 kHz			30		dB
٧n	V _n Noise output voltage, see Note 4		Gain = 2			20		μV

NOTES: 2. Output power is measured at the output pins of the device.

3. Noise voltage is measured in a bandwidth of 20 Hz to 20 kHz.

Table of Graphs

			FIGURE
V ₀₀	Output offset voltage	Distribution	1,2
lDD	Supply current distribution	vs Free-air temperature	3,4
THD+N	Total harmonic distortion plus noise	vs Frequency	5,6,7,8,9, 10,11,15, 16,17,18
		vs Output power	12,13,14, 19,20,21
lDD	Supply current	vs Supply voltage	22
Vn	Output noise voltage	vs Frequency	23,24
	Package power dissipation	vs Free-air temperature	25
	Power dissipation	vs Output power	26,27
	Maximum power output	vs Free-air temperature	28
	0.45.4	vs Load Resistance	29
	Output power	vs Supply Voltage	30
	Open loop frequency response	vs Frequency	31
	Power supply rejection ratio	vs Frequency	32,33

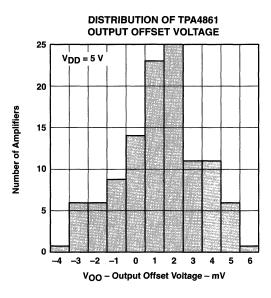
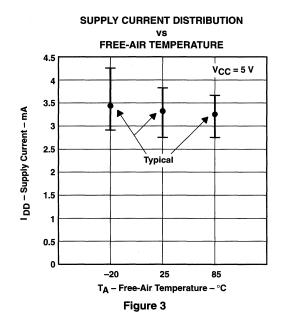
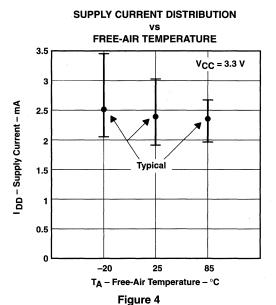


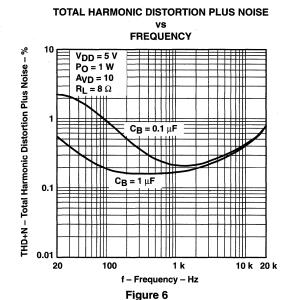
Figure 1







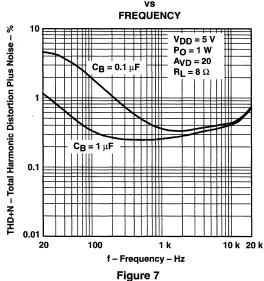
TOTAL HARMONIC DISTORTION PLUS NOISE vs **FREQUENCY** 10 THD+N - Total Harmonic Distortion Plus Noise - % $V_{DD} = 5 V$ Po = 1 W $A_{VD} = 2$ $R_L = 8 \Omega$ $C_B = 0.1 \, \mu F$ 0.1 C_B = 1 μF 0.01 20 100 10 k 20 k 1 k



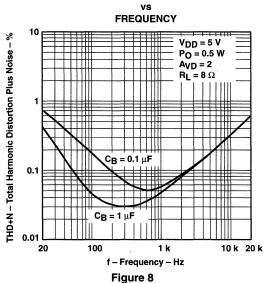
TOTAL HARMONIC DISTORTION PLUS NOISE

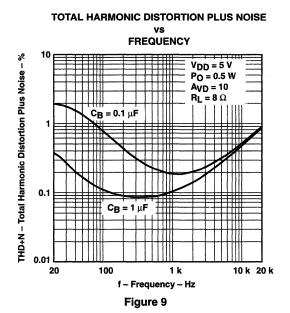
f - Frequency - Hz

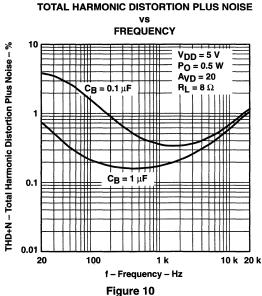
Figure 5



TOTAL HARMONIC DISTORTION PLUS NOISE







TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY 10

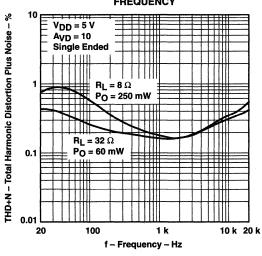
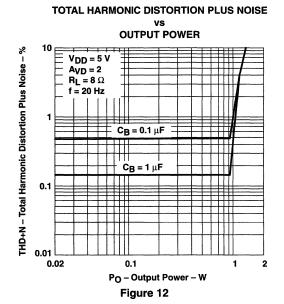
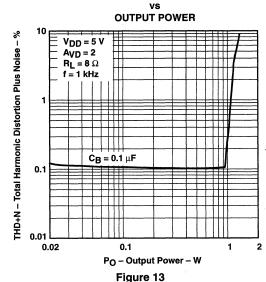


Figure 11



TOTAL HARMONIC DISTORTION PLUS NOISE



TOTAL HARMONIC DISTORTION PLUS NOISE

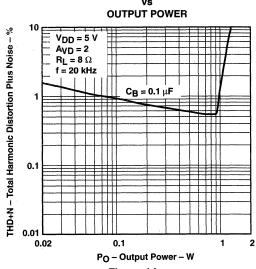
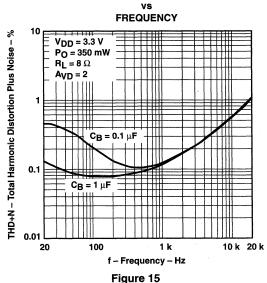
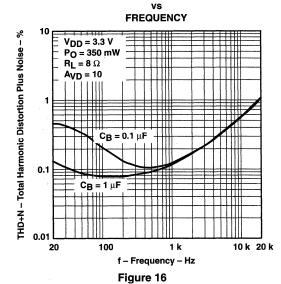


Figure 14

TOTAL HARMONIC DISTORTION PLUS NOISE



TOTAL HARMONIC DISTORTION PLUS NOISE





TOTAL HARMONIC DISTORTION PLUS NOISE

10 k 20 k

TYPICAL CHARACTERISTICS

100 1 k 10 k 20 k f – Frequency – Hz

Figure 17

 $C_B = 1 \mu F$

THD+N - Total Harmonic Distortion Plus Noise - %

0.1

20

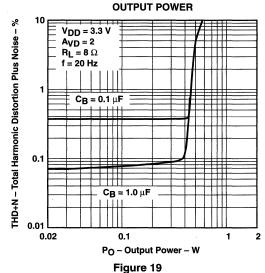
FREQUENCY Total Hamonic Discourse Hamonic Disco

Figure 18

100

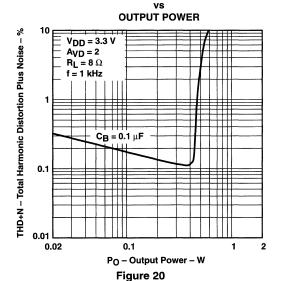
20

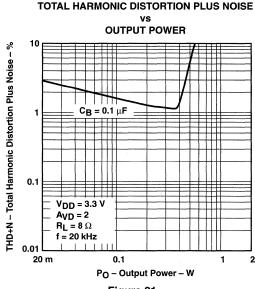
TOTAL HARMONIC DISTORTION PLUS NOISE vs



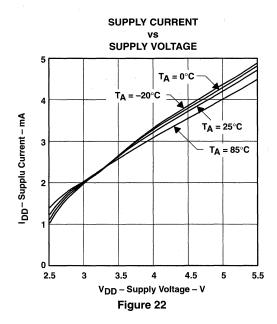
TOTAL HARMONIC DISTORTION PLUS NOISE

f - Frequency - Hz









OUTPUT NOISE VOLTAGE

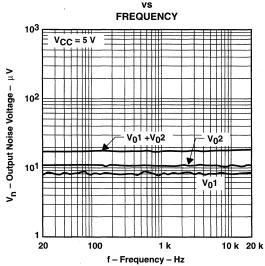


Figure 23

OUTPUT NOISE VOLTAGE vs

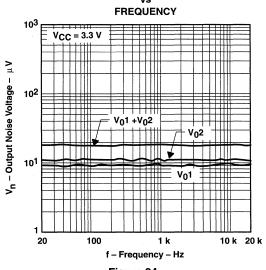


Figure 24

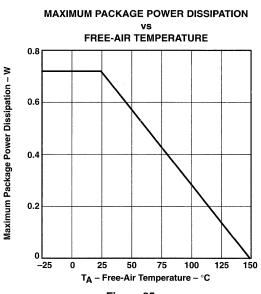
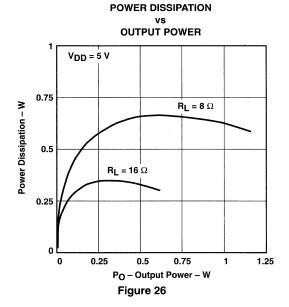


Figure 25



0.5

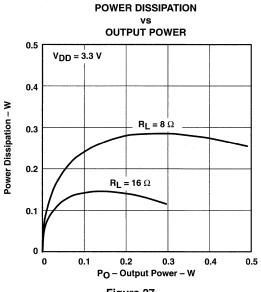


Figure 27

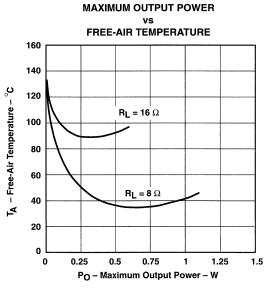
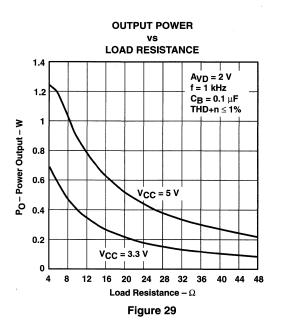
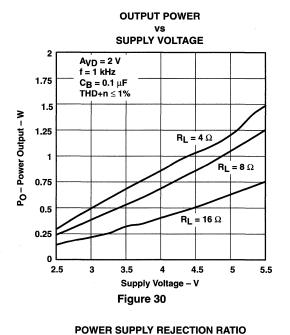
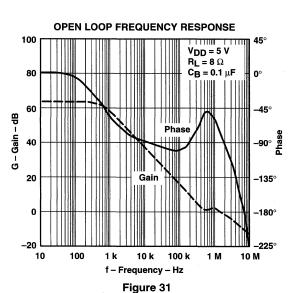
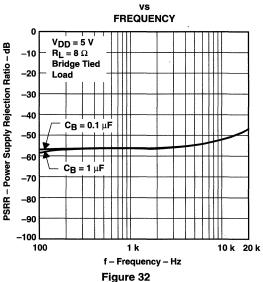


Figure 28









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TYPICAL CHARACTERISTICS

POWER SUPPLY REJECTION RATIO

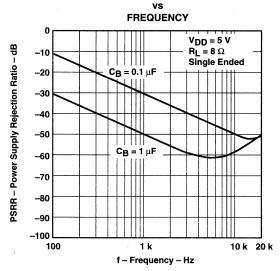


Figure 33

bridged-tied load versus single-ended mode

Figure 34 shows a linear audio power amplifier (APA) in a bridge tied load (BTL) configuration. A BTL amplifier actually consists of two linear amplifiers driving both ends of the load. There are several potential benefits to this differential drive configuration but initially let us consider power to the load. The differential drive to the speaker means that as one side is slewing up the other side is slewing down and vice versa. This in effect doubles the voltage swing on the load as compared to a ground referenced load. Plugging twice the voltage into the power equation, where voltage is squared, yields 4 times the output power from the same supply rail and load impedance (see equation 1).

$$V_{(rms)} = \frac{V_{O(PP)}}{2\sqrt{2}}$$

$$Power = \frac{V_{(rms)}^{2}}{R_{I}}$$
(1)

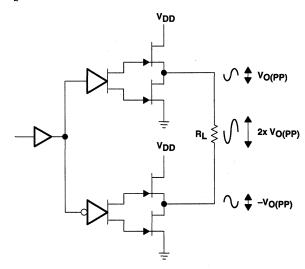


Figure 34. Bridge-Tied Load Configuration

In a typical computer sound channel operating at 5 V, bridging raises the power into a 8- Ω speaker from a singled-ended (SE) limit of 250 mW to 1 W. In sound power that is a 6-dB improvement — which is loudness that can be heard. In addition to increased power there are frequency response concerns, consider the single-supply SE configuration shown in Figure 35. A coupling capacitor is required to block the dc offset voltage from reaching the load. These capacitors can be quite large (approximately 40 µF to 1000 µF) so they tend to be expensive, occupy valuable PCB area, and have the additional drawback of limiting low-frequency performance of the system. This frequency limiting effect is due to the high pass filter network created with the speaker impedance and the coupling capacitance and is calculated with equation 2.



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APPLICATION INFORMATION

bridged-tied load versus single-ended mode (continued)

$$f_{\text{(corner)}} = \frac{1}{2\pi R_1 C_C} \tag{2}$$

For example, a $68-\mu F$ capacitor with an $8-\Omega$ speaker would attenuate low frequencies below 293 Hz. The BTL configuration cancels the dc offsets, which eliminates the need for the blocking capacitors. Low-frequency performance is then limited only by the input network and speaker response. Cost and PCB space are also minimized by eliminating the bulky coupling capacitor.

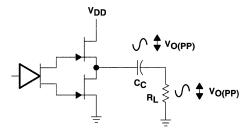


Figure 35. Single-Ended Configuration

Increasing power to the load does carry a penalty of increased internal power dissipation. The increased dissipation is understandable considering that the BTL configuration produces 4 times the output power of the SE configuration. Internal dissipation versus output power is discussed further in the *thermal considerations* section.

BTL amplifier efficiency

Linear amplifiers are notoriously inefficient. The primary cause of these inefficiencies is voltage drop across the output stage transistors. There are two components of the internal voltage drop. One is the headroom or do voltage drop that varies inversely to output power. The second component is due to the sinewave nature of the output. The total voltage drop can be calculated by subtracting the RMS value of the output voltage from V_{DD} . The internal voltage drop multiplied by the RMS value of the supply current, I_{DD} rms, determines the internal power dissipation of the amplifier.

An easy to use equation to calculate efficiency starts out as being equal to the ratio of power from the power supply to the power delivered to the load. To accurately calculate the RMS values of power in the load and in the amplifier, the current and voltage waveform shapes must first be understood (see Figure 36).

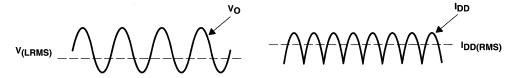


Figure 36. Voltage and Current Waveforms for BTL Amplifiers

BTL amplifier efficiency (continued)

Although the voltages and currents for SE and BTL are sinusoidal in the load, currents from the supply are very different between SE and BTL configurations. In an SE application the current waveform is a half-wave rectified shape whereas in BTL it is a full-wave rectified waveform. This means RMS conversion factors are different. Keep in mind that for most of the waveform both the push and pull transistor are not on at the same time, which supports the fact that each amplifier in the BTL device only draws current from the supply for half the waveform. The following equations are the basis for calculating amplifier efficiency.

Efficiency =
$$\frac{P_L}{P_{SUP}}$$
 (3) where:
$$V_L rms = \frac{V_P}{\sqrt{2}}$$

$$P_L = \frac{V_L rms^2}{R_L} = \frac{V_p^2}{2R_L}$$

$$P_{SUP} = V_{DD} I_{DD} rms = \frac{V_{DD} 2V_P}{\pi R_L}$$

$$I_{DD} rms = \frac{2V_P}{\pi R_L}$$

Effiency of a BTL Configuration
$$=\frac{\pi V_{P}}{2V_{DD}} = \frac{\pi \left(\frac{P_{L}R_{L}}{2}\right)^{1/2}}{2V_{DD}}$$
 (4)

Table 1 employs equation 4 to calculate efficiencies for four different output power levels. Note that the efficiency of the amplifier is quite low for lower power levels and rises sharply as power to the load is increased resulting in a nearly flat internal power dissipation over the normal operating range. Note that the internal dissipation at full output power is less than in the half power range. Calculating the efficiency for a specific system is the key to proper power supply design. For a stereo 1-W audio system with 8- Ω loads and a 5-V supply, the maximum draw on the power supply is almost 3.25 W.

Table 1. Efficiency Vs Output Power in 5-V 8- Ω BTL Systems

Output Power (W)	Efficiency (%)	Peak-to-Peak Voltage (V)	Internal Dissipation (W)
0.25	31.4	2.00	0.55
0.50	44.4	2.83	0.62
1.00	62.8	4.00	0.59
1.25	70.2	4.47†	0.53

[†] High peak voltages cause the THD to increase.



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APPLICATION INFORMATION

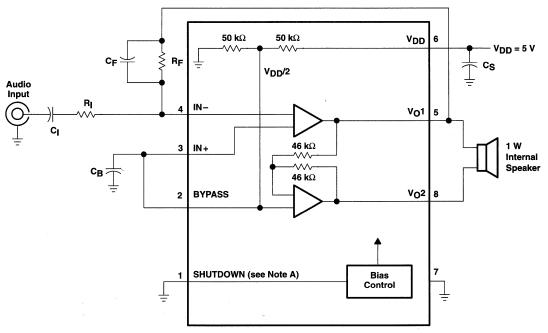
BTL amplifier efficiency (continued)

A final point to remember about linear amplifiers whether they are SE or BTL configured is how to manipulate the terms in the efficiency equation to utmost advantage when possible. Note that in equation 4, V_{DD} is in the denominator. This indicates that as V_{DD} goes down, efficiency goes up.

For example, if the 5-V supply is replaced with a 10-V supply (TPA4861 has a maximum recommended V_{DD} of 5.5 V) in the calculations of Table 1 then efficiency at 1 W would fall to 31% and internal power dissipation would rise to 2.18 W from 0.59 W at 5 V. Then for a stereo 1-W system from a 10-V supply, the maximum draw would be almost 6.5 W. Choose the correct supply voltage and speaker impedance for the application.

selection of components

Figure 37 is a schematic diagram of a typical notebook computer application circuit.



NOTE A: SHUTDOWN must be held low for normal operation and asserted high for shutdown mode.

Figure 37. TPA4861 Typical Notebook Computer Application Circuit

gain setting resistors, RF and RI

The gain for the TPA4861 is set by resistors R_F and R_I according to equation 5.

$$Gain = -2\left(\frac{R_F}{R_I}\right) \tag{5}$$

BTL mode operation brings about the factor of 2 in the gain equation due to the inverting amplifier mirroring the voltage swing across the load. Given that the TPA4861 is a MOS amplifier, the input impedance is very high, consequently input leakage currents are not generally a concern although noise in the circuit increases as the value of $R_{\rm F}$ increases. In addition, a certain range of $R_{\rm F}$ values are required for proper startup operation of the amplifier. Taken together it is recommended that the effective impedance seen by the inverting node of the amplifier be set between 5 k Ω and 20 k Ω . The effective impedance is calculated in equation 6.

Effective Impedance =
$$\frac{R_F R_I}{R_F + R_I}$$
 (6)

As an example consider an input resistance of 10 k Ω and a feedback resistor of 50 k Ω . The gain of the amplifier would be -10 and the effective impedance at the inverting terminal would be 8.3 k Ω , which is well within the recommended range.

For high performance applications metal film resistors are recommended because they tend to have lower noise levels than carbon resistors. For values of R_F above 50 $k\Omega$ the amplifier tends to become unstable due to a pole formed from R_F and the inherent input capacitance of the MOS input structure. For this reason, a small compensation capacitor of approximately 5 pF should be placed in parallel with R_F . This, in effect, creates a low pass filter network with the cutoff frequency defined in equation 7.

$$f_{\text{co(lowpass)}} = \frac{1}{2\pi R_{\text{F}} C_{\text{F}}}$$
 (7)

For example if R_F is 100 k Ω and Cf is 5 pF then f_{CO} is 318 kHz, which is well outside of the audio range.

input capacitor, C_I

In the typical application an input capacitor, C_I , is required to allow the amplifier to bias the input signal to the proper dc level for optimum operation. In this case, C_I and R_I form a high-pass filter with the corner frequency determined in equation 8.

$$f_{co(highpass)} = \frac{1}{2\pi R_1 C_1}$$
 (8)

The value of C_l is important to consider as it directly affects the bass (low frequency) performance of the circuit. Consider the example where R_l is 10 k Ω and the specification calls for a flat bass response down to 40 Hz. Equation 8 is reconfigured as equation 9.

$$C_1 = \frac{1}{2\pi R_1 f_{co}} \tag{9}$$

In this example, C_I is 0.40 μF so one would likely choose a value in the range of 0.47 μF to 1 μF . A further consideration for this capacitor is the leakage path from the input source through the input network (R_I, C_I) and the feedback resistor (R_F) to the load. This leakage current creates a dc offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications. For this reason a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifier input in most applications as the dc level there is held at $V_{DD}/2$, which is likely higher that the source dc level. Please note that it is important to confirm the capacitor polarity in the application.



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APPLICATION INFORMATION

power supply decoupling, CS

The TPA4861 is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) is as low as possible. Power supply decoupling also prevents oscillations for long lead lengths between the amplifier and the speaker. The optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μ F placed as close as possible to the device V_{DD} lead works best. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10 μ F or greater placed near the power amplifier is recommended.

midrail bypass capacitor, C_B

The midrail bypass capacitor, C_B , serves several important functions. During startup or recovery from shutdown mode, C_B determines the rate at which the amplifier starts up. This helps to push the start-up pop noise into the subaudible range (so slow it can not be heard). The second function is to reduce noise produced by the power supply caused by coupling into the output drive signal. This noise is from the midrail generation circuit internal to the amplifier. The capacitor is fed from a 25-k Ω source inside the amplifier. To keep the start-up pop as low as possible, the relationship shown in equation 10 should be maintained.

$$\frac{1}{\left(C_{\mathsf{B}} \times 25k\Omega\right)} \le \frac{1}{\left(C_{\mathsf{I}}\mathsf{R}_{\mathsf{I}}\right)} \tag{10}$$

As an example, consider a circuit where C_B is 0.1 μ F, C_I is 0.22 μ F and R_I is 10 $k\Omega$. Inserting these values into the equation 9 we get:

 $400 \le 454$

which satisfies the rule. Bypass capacitor, C_B , values of 0.1 μ F to 1 μ F ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.



single-ended operation

Figure 38 is a schematic diagram of the recommended SE configuration. In SE mode configurations, the load should be driven from the primary amplifier output (OUT1, terminal 10).

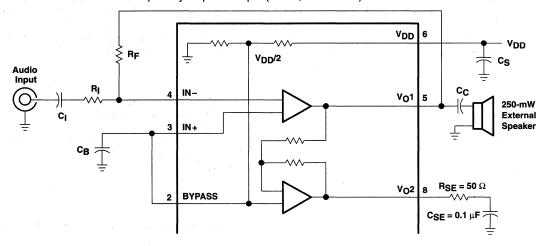


Figure 38. Singled-Ended Mode

Gain is set by the RF and RI resistors and is shown in equation 11. Since the inverting amplifier is not used to mirror the voltage swing on the load, the factor of 2 is not included.

$$Gain = -\left(\frac{R_F}{R_I}\right) \tag{11}$$

The phase margin of the inverting amplifier into an open circuit is not adequate to ensure stability, so a termination load should be connected to V_{Ω} 2. This consists of a 50- Ω resistor in series with a 0.1- μ F capacitor to ground. It is important to avoid oscillation of the inverting output to minimize noise and power dissipation.

The output coupling capacitor required in single-supply SE mode also places additional constraints on the selection of other components in the amplifier circuit. The rules described earlier still hold with the addition of the following relationship:

$$\frac{1}{\left(C_{B} \times 25k\Omega\right)} \le \frac{1}{\left(C_{I}R_{I}\right)} \le \frac{1}{R_{L}C_{C}} \tag{12}$$

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APPLICATION INFORMATION

output coupling capacitor, CC

In the typical single-supply SE configuration, an output coupling capacitor (C_C) is required to block the dc bias at the output of the amplifier thus preventing dc currents in the load. As with the input coupling capacitor, the output coupling capacitor and impedance of the load form a high-pass filter governed by equation 13.

$$f_{\text{out high}} = \frac{1}{2\pi R_L C_C} \tag{13}$$

The main disadvantage, from a performance standpoint, is that the load impedances are typically small, which drive the low-frequency corner higher. Large values of C_C are required to pass low frequencies into the load. Consider the example where a C_C of 68 μF is chosen and loads vary from 8 Ω , 32 Ω , and 47 $k\Omega$. Table 2 summarizes the frequency response characteristics of each configuration.

Table 2. Common Load Impedances Vs Low Frequency Output Characteristics in SE Mode

RL	CC	Lowest Frequency
8 Ω	68 μF	293 Hz
32 Ω	68 μF	73 Hz
47,000 Ω	68 μF	0.05 Hz

As Table 2 indicates, most of the bass response is attenuated into $8-\Omega$ loads while headphone response is adequate and drive into line level inputs (a home stereo for example) is very good.

shutdown mode

The TPA4861 employs a shutdown mode of operation designed to reduce quiescent supply current, $I_{DD(q)}$, to the absolute minimum level during periods of nonuse for battery-power conservation. For example, during device sleep modes or when other audio-drive currents are used (i.e., headphone mode), the speaker drive is not required. The SHUTDOWN input terminal should be held low during normal operation when the amplifier is in use. Pulling SHUTDOWN high causes the outputs to mute and the amplifier to enter a low-current state, $I_{DD(q)} < 1$ μ A. SHUTDOWN should never be left unconnected because amplifier operation would be unpredictable.

using low-ESR capacitors

Low-ESR capacitors are recommended throughout this applications section. A real capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this resistor minimizes the beneficial effects of the capacitor in the circuit. The lower the equivalent value of this resistance the more the real capacitor behaves like an ideal capacitor.

APPLICATION INFORMATION

thermal considerations

A prime consideration when designing an audio amplifier circuit is internal power dissipation in the device. The curve in NO TAG provides an easy way to determine what output power can be expected out of the TPA4861 for a given system ambient temperature in designs using 5-V supplies. This curve assumes no forced airflow or additional heat sinking.

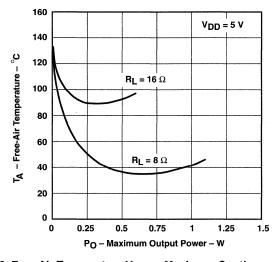


Figure 39. Free-Air Temperature Versus Maximum Continuous Output Power

5-V versus 3.3-V operation

The TPA4861 was designed for operation over a supply range of 2.7 V to 5.5 V. This data sheet provides full specifications for 5-V and 3.3-V operation as these are considered to be the two most common standard voltages. There are no special considerations for 3.3-V versus 5-V operation as far as supply bypassing, gain setting or stability. Supply current is slightly reduced from 3.5 mA (typical) to 2.5 mA (typical). The most important consideration is that of output power. Each amplifier in TPA4861 can produce a maximum voltage swing of $V_{DD}-1$ V. This means, for 3.3-V operation, clipping starts to occur when $V_{O(PP)}=2.3$ V as opposed when $V_{O(PP)}=4$ V while operating at 5 V. The reduced voltage swing subsequently reduces maximum output power into an 8- Ω load to less than 0.33 W before distortion begins to become significant.

Operation at 3.3-V supplies, as can be shown from the efficiency formula in equation 4, consumes approximately two-thirds of the supply power for a given output-power level than operation from 5-V supplies. When the application demands less than 500 mW, 3.3-V operation should be strongly considered, especially in battery-powered applications.

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D OR N PACKAGE (TOP VIEW)

- Low Input Bias Current . . . 50 pA Typ
- Low Input Noise Current
 0.01 pA/√Hz Typ
- Low Total Harmonic Distortion
- Low Supply Current . . . 8 mA Typ
- Gain Bandwidth . . . 3 MHz Typ
- High Slew Rate . . . 13 V/μs Typ
- Pin Compatible With the LM348

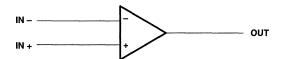
description

These devices are low-cost, high-speed, JFET-input operational amplifiers. They require low supply current yet maintain a large gain-bandwidth product and a fast slew rate. In addition, their matched high-voltage JFET inputs provide very low input bias and offset current.

The LF347 and LF347B can be used in applications such as high-speed integrators, digital-to-analog converters, sample-and-hold circuits, and many other circuits.

The LF347 and LF347B are characterized for operation from 0°C to 70°C.

symbol (each amplifier)



AVAILABLE OPTIONS

	V	PACKA	GE
T _A V _{IO} max AT 25°C		SMALL OUTLINE (D)	PLASTIC DIP (N)
0°C to 70°C	10 mV	LF347D	LF347N
0 0 10 70 0	5 mV	LF347BD	LF347BN

The D packages are available taped and reeled. Add R suffix to the device type (e.g., LF347DR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC +}	18 V
Supply voltage, V _{CC}	
Differential input voltage, V _{ID}	$\dots \dots \pm 30 \ V$
Input voltage, V _I (see Note 1)	±15 V
Duration of output short circuit	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating temperature range	0°C to 70°C
Storage temperature range	65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: Unless otherwise specified, the absolute maximum negative input voltage is equal to the negative power supply voltage.



DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING
D	608 mW	7.6 mW/°C	61°C	608 mW
N ,	680 mW	N/A	N/A	680 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC +}	3.5	18	V
Supply voltage, V _{CC} _	-3.5	-18	٧

electrical characteristics over operating free-air temperature range, $V_{CC\pm}$ = $\pm 15~V$ (unless otherwise specified)

	DADAMETED	TEST			LF347		LF347B			UNIT
	PARAMETER	CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
Via	Input offset voltage	V _{IC} = 0,	25°C		5	10		3	5	mV
VIO	input onset voltage	$R_S = 10 \text{ k}\Omega$	Full range			13			7	IIIV
αVIO	Average temperature coefficient of input offset voltage	$V_{IC} = 0$, R _S = 10 k Ω			18			18		μV/°C
l. a		V 0	25°C		25	100		25	100	pА
ΙO	Input offset current‡	VIC = 0	70°C			4			4	nA
1		V 0	25°C		50	200		- 50	200	pА
IB	Input bias current‡	AIC = 0	70°C			.8			8	nA
VICR	Common-mode input voltage range			±11	-12 to 15		±11	-12 to 15		٧
Vом	Maximum peak output voltage swing	R _L = 10 kΩ		±12	±13.5		±12	±13.5		V
Δ	Lorgo cianol differential voltage	$V_{O} = \pm 10 \text{ V},$	25°C	25	100		50	100		V/mV
AVD	Large-signal differential voltage $R_L = 2 k\Omega$ Full range 15		25			V/IIIV				
rį	Input resistance	T _A = 25°C			1012			1012		Ω
CMRR	Common-mode rejection ratio	R _S ≤ 2 kΩ		70	100		80	100		dB
ksvr	Supply-voltage rejection ratio	See Note 2		70	100		80	100		dB
Icc	Supply current				8	11		8	11	mA

[†] Full range is 0°C to 70°C.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V _{O1} /V _{O2}	Crosstalk attentuation	f = 1 kHz		120		dB
SR	Slew rate		8	13		V/μs
B ₁	Unity-gain bandwidth			3		MHz
V _n	Equivalent input noise voltage	$f = 1 \text{ kHz}, R_S = 20 \Omega$		18		nV/√Hz
I _n	Equivalent input noise current	f = 1 kHz		0.01		pA/√Hz



[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as possible.

NOTE 2: Supply-voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously.

SLOS014B - MARCH 1987 - REVISED AUGUST 1994

- Low Input Bias Current . . . 50 pA Typ
- Low Input Noise Voltage . . . 18 nV/√Hz Typ
- Low Input Noise Current 0.01 pA/√Hz Typ
- Low Supply Current . . . 1.8 mA Typ
- High Input impedance . . . 10¹² Ω Typ
- Low Total Harmonic Distortion
- Internally Trimmed Offset Voltage 10 mV Typ
- High Slew Rate . . . 13 V/μs Typ
- Gain Bandwidth . . . 3 MHz
- Pin Compatible With Standard 741

D OR P PACKAGE (TOP VIEW)

NC - No internal connection

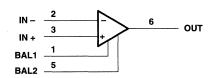
description

This device is a low-cost, high-speed, JFET-input operational amplifier with an internally trimmed input offset voltage. It requires low supply current yet maintains a large gain-bandwidth product and a fast slew rate. In addition, the matched high-voltage JFET input provides very low input bias and offset currents. It uses the same offset voltage adjustment circuits as the 741.

The LF351 can be used in applications such as high-speed integrators, digital-to-analog converters, sample-and-hold circuits, and many other circuits.

The LF351 is characterized for operation from 0°C to 70°C.

symbol (each amplifier)



AVAILABLE OPTIONS

	Viemay	PACKAGE			
T _A V _{IO} max AT 25°C		SMALL OUTLINE (D)	PLASTIC DIP (P)		
0°C to 70°C	10 mV	LF351D	LF351P		

The D packages are available taped and reeled. Add the suffix R to the device type (i.e., LF351DR).



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+}	
Supply voltage, V _{CC}	
Differential input voltage, V _{ID}	
Input voltage, V _I (see Note 1)	±15 V
Duration of output short circuit	unlimited
Continuous total power dissipation	500 mW
Operating temperature range	0°C to 70°C
Storage temperature range	
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	

NOTE 1: Unless otherwise specified, the absolute maximum negative input voltage is equal to the negative power supply voltage.

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC+}	3.5	18	V
Supply voltage, V _{CC} –	-3.5	-18	V

electrical characteristics over operating free-air temperature range, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

	PARAMETER		PARAMETER TEST CONDITIONS			TYP	MAX	UNIT
Vio	Input offset voltage	V10 = 0	R _S = 10 kΩ	25°C		5	10	mV
VIO	Input onset voltage	V _{IC} = 0,	ng = 10 ks2	Full range			13	HIV
ανιο	Average temperature coefficient of input offset voltage	V _{IC} = 0,	R _S = 10 kΩ			10		μV/°C
lio	land affect annual t	V:0 = 0		25°C		25	100	pА
10	Input offset current‡	AIC = 0	VIC = 0				4	nA
lun	land bion of month	V 0		25°C		50	200	pА
lВ	Input bias current‡	VIC = 0		70°C			8	nA
						-12		
VICR	Common-mode input voltage range				±11	to 15		V.
Vом	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$			±12	±13.5		٧
Δ	Large signal differential voltage	V- +10.V	B. 210	25°C	25	200		V/mV
AVD	Large-signal differential voltage $V_O = \pm 10 \text{ V}, R_L = 2 \text{ k}\Omega$	□[= 2 K32	Full range	15	200		V/IIIV	
rį	Input resistance	T _J = 25°C				1012		Ω
CMRR	Common-mode rejection ratio	R _S ≤ 10 kΩ			70	100		dB
ksvr	Supply-voltage rejection ratio	See Note 2			70	100		dB
Icc	Supply current					1:.8	3.4	mA

[†] Full range is 0°C to 70°C.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate		8	13		V/μs
B ₁	Unity-gain bandwidth			3		MHz
٧n	Equivalent input noise voltage	$f = 1 \text{ kHz}$, $R_S = 20 \Omega$		18		nV/√Hz
In	Equivalent input noise current	f = 1 kHz		0.01		pA/√Hz



[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as possible.

NOTE 2: Supply-voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously.

в [] V_{CC+}

6 1 2IN-

2IN+

1 20UT

D OR P PACKAGE (TOP VIEW)

10UT

1IN-

V_{CC}-

1IN+ [] 3

- Low Input Bias Current . . . 50 pA Typ
- Low Input Noise Current 0.01 pA/√Hz Typ
- Low Input Noise Voltage . . . 18 nV/√Hz Typ
- Low Supply Current . . . 3.6 mA Typ
- High Input Impedance . . . 10¹² Ω Typ
- Internally Trimmed Offset Voltage
- Gain Bandwidth . . . 3 MHz Typ
- High Slew Rate . . . 13 V/μs Typ

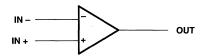
description

This device is a low-cost, high-speed, JFET-input operational amplifier with very low input offset voltage. It requires low supply current yet maintains a large gain-bandwidth product and a fast slew rate. In addition, the matched high-voltage JFET input provides very low input bias and offset currents.

The LF353 can be used in applications such as high-speed integrators, digital-to-analog converters, sample-and-hold circuits, and many other circuits.

The LF353 is characterized for operation from 0°C to 70°C.

symbol (each amplifier



AVAILABLE OPTIONS

	Vmay	PACKAG	GE .
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)
0°C to 70°C	10 mV	LF353D	LF353P

The D packages are available taped and reeled. Add the suffix R to the device type (ie., LF353DR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC +}	
Supply voltage, V _{CC}	–18 V
Differential input voltage, V _{ID}	±30 V
Input voltage, V _I (see Note 1)	±15 V
Duration of output short circuit	unlimited
Continuous total power dissipation	500 mW
Operating temperature range	0°C to 70°C
Storage temperature range	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: Unless otherwise specified, the absolute maximum negative input voltage is equal to the negative power supply voltage.



LF353 JFET-INPUT DUAL OPERATIONAL AMPLIFIER SLOS012B - MARCH 1987 - REVISED AUGUST 1994

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC +}	3.5	18	٧
Supply voltage, V _{CC} _	-3.5	-18	٧

electrical characteristics over operating free-air temperature range, $V_{CC\pm}$ = ± 15 V (unless otherwise specified)

	PARAMETER	TEST CO	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Via	Input offset voltage	V:0 - 0	Po - 10 kO	25°C		5	10	mV
VIO	input onset voitage	$V_{IC} = 0,$	$R_S = 10 \text{ k}\Omega$	Full range			13	IIIV
αΝΙΟ	Average temperature coefficient of input offset voltage	V _{IC} = 0,	R _S = 10 kΩ			10	,	μV/°C
1		V 0		25°C		25	100	pA:
lo ol	Input offset current‡	AIC = 0		70°C			4	nA
l	l	V 0		25°C		50	200	рA
lВ	Input bias current‡	AIC = 0		70°C			8	nA
V _{ICR}	Common-mode input voltage range				±11	-12 to 15		· V
Vом	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$			±12	±13.5		· V
Λ	Large signal differential voltage	V= +10 V	$R_1 = 2 k\Omega$	25°C	25	100		\//m\/
AVD	Large-signal differential voltage	$V_0 = \pm 10 \text{ V},$	0 V, nL = 2 K32	Full range	15			V/mV
rį	Input resistance	T _J = 25°C				1012		Ω
CMRR	Common-mode rejection ratio	R _S ≤ 10 kΩ			70	100		dB
ksvr	Supply-voltage rejection ratio	See Note 2			70	100		dB
Icc	Supply current					3.6	6.5	mA

[†] Full range is 0°C to 70°C.

operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V _{O1} /V _{O2}	Crosstalk attentuation	f = 1 kHz		120		dB
SR	Slew rate		8	13		V/μs
B ₁	Unity-gain bandwidth			3		MHz
Vn	Equivalent input noise voltage	$f = 1 \text{ kHz}, R_S = 20 \Omega$		18		nV/√Hz
In	Equivalent input noise current	f = 1 kHz		0.01		pA/√Hz

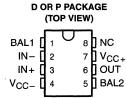
[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as possible.

NOTE 2: Supply-voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously.

LF411C JFET-INPUT OPERATIONAL AMPLIFIER

SLOS011B - MARCH 1987 - REVISED AUGUST 1994

- Low Input Bias Current . . . 50 pA Typ
- Low Input Noise Current 0.01 pA/√Hz Typ
- Low Supply Current . . . 2 mA Typ
- High Input impedance . . . 10¹² Ω Typ
- Low Total Harmonic Distortion
- Low 1/f Noise Corner . . . 50 Hz Typ



NC - No internal connection

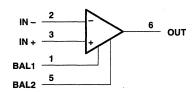
description

This device is a low-cost, high-speed, JFET-input operational amplifier with very low input offset voltage and a maximum input offset voltage drift. It requires low supply current yet maintains a large gain-bandwidth product and a fast slew rate. In addition, the matched high-voltage JFET input provides very low input bias and offset currents.

The LF411C can be used in applications such as high-speed integrators, digital-to-analog converters, sample-and-hold circuits, and many other circuits.

The LF411C is characterized for operation from 0°C to 70°C.

symbol



AVAILABLE OPTIONS

	V may	PACKA	GE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)
0°C to 70°C	2 mV	LF411CD	LF411CP

The D packages are available taped and reeled. Add the suffix R to the device type (ie., LF411CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+}	18 V
Supply voltage, V _{CC}	18 V
Differential input voltage, V _{ID}	±30 V
Input voltage, V _I (see Note 1)	
Duration of output short circuit	unlimited
Continuous total power dissipation	500 mW
Operating temperature range	0°C to 70°C
Storage temperature range	65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: Unless otherwise specified, the absolute maximum negative input voltage is equal to the negative power supply voltage.



LF411C JFET-INPUT OPERATIONAL AMPLIFIER

SLOS011B - MARCH 1987 - REVISED AUGUST 1994

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC +}	3.5	18	٧
Supply voltage, V _{CC} _	-3.5	-18	٧

electrical characteristics over operating free-air temperature range, $V_{CC\pm}$ = ± 15 V (unless otherwise specified)

	PARAMETER	TEST CONDITIONS		T _A †	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _{IC} = 0,	R _S = 10 kΩ	25°C		0.8	2	mV
αVIO	Average temperature coefficient of input offset voltage	V _{IC} = 0,	R _S = 10 kΩ			10	20‡	μV/°C
lio	land offer at a compared 6	V _{IC} = 0		25°C		25	100	pА
ΙΟ	Input offset current§	AIC = 0		70°C			2	nA
1		V 0		25°C		50	200	pΑ
lΒ	Input bias current§	V _{IC} = 0		70°C			4	nA
VICR	Common-mode input voltage range				±11	-11.5 to 14.5		٧
Vом	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$			±12	±13.5		٧
Λ	Large signal differential voltage	ge-signal differential voltage $V_0 = \pm 10 \text{ V}, R_L = 2 \text{ k}\Omega$	D. 010	25°C	25	200		V/mV
AVD	Large-signal differential voltage		H[= 2 K22	Full range	15	200		V/IIIV
rį	Input resistance	T _J = 25°C				1012		Ω
CMRR	Common-mode rejection ratio	R _S ≤ 10 kΩ			70	100		dB
ksvr	Supply-voltage rejection ratio	See Note 2			70	100		dB
lcc	Supply current					2	3.4	mA

[†] Full range is 0°C to 70°C.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C

	PARAMETER	TEST CONDITIONS	MIN	TYP M	AX UNIT
SR	Slew rate		8	13	V/μs
B ₁	Unity-gain bandwidth		2.7	3	MHz
٧n	Equivalent input noise voltage	$f = 1 \text{ kHz}, R_S = 20 \Omega$		18	nV/√Hz
In	Equivalent input noise current	f = 1 kHz		0.01	pA/√Hz

[‡] At least 90% of the devices meet this limit for α_{VIO} .

[§] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as possible.

NOTE 2: Supply-voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously.

DUAL JEET-INPUT OPERATIONAL AMPLIFIER

SLOS010B - MARCH 1987 - REVISED AUGUST 1994

Low Input Bias Current . . . 50 pA Typ

Low Input Noise Current 0.01 pA/√Hz Typ

- Low Supply Current . . . 4.5 mA Typ
- High Input impedance . . . $10^{12} \Omega$ Typ
- **Internally Trimmed Offset Voltage**
- Wide Gain Bandwidth . . . 3 MHz Typ
- High Slew Rate . . . 13 V/µs Typ

D OR P PACKAGE (TOP VIEW) 10UT [8 [] V_{CC+} 1IN – Π 7 N 20UT 1IN+ **∏** 3 6 🛮 2IN-5 N 2IN+ V_{CC}-

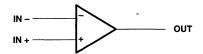
description

This device is a low-cost, high-speed, JFET-input operational amplifier with very low input offset voltage and a specified maximum input offset voltage drift. It requires low supply current yet maintains a large gain bandwidth product and a fast slew rate. In addition, the matched high-voltage JFET input provides very low input bias and offset currents.

The LF412C can be used in applications such as high-speed integrators, digital-to-analog converters, sample-and-hold circuits, and many other circuits.

The LF412C is characterized for operation from 0°C to 70°C.

symbol (each amplifier)



AVAILABLE OPTIONS

I		Viamer	PACKA	GE
	TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)
	0°C to 70°C	3 mV	LF412CD	LF412CP

The D packages are available taped and reeled. Add the suffix R to the device type (ie., LF412CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+}	18 V
Supply voltage, V _{CC}	
Differential input voltage, V _{ID}	
Input voltage, V _I (see Note 1)	
Duration of output short circuit	
Continuous total power dissipation	
Operating temperature range	0°C to 70°C
Storage temperature range	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: Unless otherwise specified, the absolute maximum negative input voltage is equal to the negative power supply voltage.



LF412C DUAL JFET-INPUT OPERATIONAL AMPLIFIER

SLOS010B - MARCH 1987 - REVISED AUGUST 1994

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC +}	3.5	18	V
Supply voltage, V _{CC} _	-3.5	-18	٧

electrical characteristics over operating free-air temperature range, $V_{CC\pm}$ = ± 15 V (unless otherwise specified)

	PARAMETER	TEST C	ONDITIONS	T _A †	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _{IC} = 0,	$R_S = 10 \text{ k}\Omega$	25°C		1	3	mV
αVIO	Average temperature coefficient of input offset voltage	V _{IC} = 0,	R _S = 10 kΩ			10	20‡	μV/°C
lio.	Input offset current§	V _{IC} = 0		25°C		25	100	pА
lio	input offset currents	AIC = 0		70°C			4	nA
lin		V _{IC} = 0		25°C		50	200	pА
lВ	nput bias current§	AIC = 0		70°C			8	nA
VICR	Common-mode input voltage range				±11	-11.5 to 14.5		٧
V _{OM}	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$			±12	±13.5		٧
Λ	Large-signal differential voltage	VO = ±10 V,	D. 040	25°C	25	200		V/mV
AVD	Large-signal differential voltage	VO = ± 10 V,	U[= 2 K22	Full range	15	200		V/IIIV
rį	Input resistance	T _A = 25°C				1012		Ω
CMRR	Common-mode rejection ratio	$R_S \le 10 \text{ k}\Omega$			70	100		dB
ksvr	Supply-voltage rejection ratio	See Note 2			70	100		dB
lcc	Supply current					4.5	6.8	mA

[†] Full range is 0°C to 70°C.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CO	NDITIONS	MIN	TYP	MAX	UNIT
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz			120		dB
SR	Slew rate			8	13		V/μs
B ₁	Unity-gain bandwidth			2.7	3		MHz
٧n	Equivalent input noise voltage	f = 1 kHz,	R _S =20Ω		18		nV/√Hz
In	Equivalent input noise current	f = 1 kHz			0.01		pA/√Hz

 $[\]ddagger$ At least 90% of the devices meet this limit for α_{VIO} .

[§] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as possible.

NOTE 2: Supply-voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously.

LM118, LM218, LM318 FAST GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS063A - JUNE 1976 - REVISED APRIL 1994

- Small-Signal Bandwidth . . . 15 MHz Typ
- Slew Rate . . . 50 V/μs Min
- Bias Current . . . 250 nA Max (LM118, LM218)
- Supply Voltage Range . . . ±5 V to ±20 V
- Internal Frequency Compensation
- Input and Output Overload Protection
- Same Pin Assignments as General-Purpose Operational Amplifiers

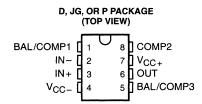
description

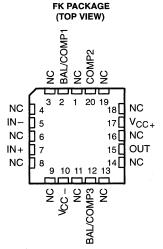
The LM118, LM218, and LM318 are precision, fast operational amplifiers designed for applications requiring wide bandwidth and high slew rate. They feature a factor-of-ten increase in speed over general-purpose devices without sacrificing dc performance.

These operational amplifiers have internal unitygain frequency compensation. This considerably simplifies their application, since no external components are necessary for operation. However, unlike most internally compensated amplifiers, external frequency compensation may be added for optimum performance. For inverting applications, feed-forward compensation boosts the slew rate to over 150 V/µs and almost double the bandwidth. Overcompensation can be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor may be added to reduce the settling time for 0.1% error band to under 1 µs.

The high speed and fast settling time of these operational amplifiers make them useful in A/D converters, oscillators, active filters, sample-and-hold circuits, and general-purpose amplifiers.

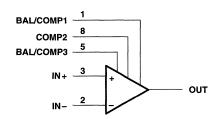
The LM118 is characterized for operation from -55°C to 125°C. The LM218 is characterized for operation from -25°C to 85°C, and the LM318 is characterized for operation from 0°C to 70°C.





NC - No internal connection

svmbol



Pin numbers shown are for the D, JG, and P packages.

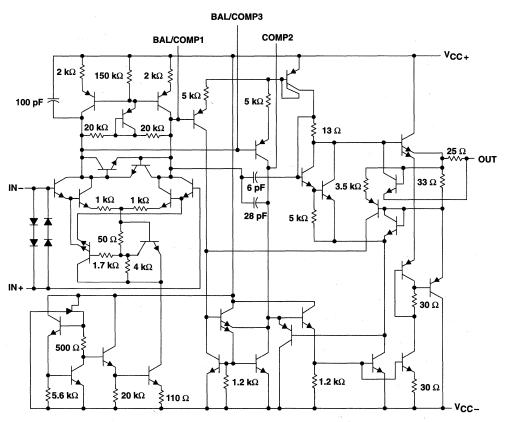
SLOS063A - JUNE 1976 - REVISED APRIL 1994

AVAILABLE OPTIONS

	Vmay		PACKAGE							
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)					
0°C to 70°C	10 mV	LM318D	<u> </u>	_	LM318P					
-25°C to 85°C	4 mV	LM218D	_	-	LM218P					
-55°C to 125°C	4 mV	LM118D	LM118FK	LM118JG	LM118P					

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM318DR).

schematic



Component values shown are nominal.

LM118, LM218, LM318 FAST GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS063A - JUNE 1976 - REVISED APRIL 1994

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM118	LM218	LM318	UNIT	
Supply voltage, V _{CC+} (see Note 1)		20	20	20	٧	
Supply voltage, V _{CC} (see Note 1)	-20	-20	-20	V		
Input voltage, V _I (either input, see Notes 1 and 2)	±15	±15	±15	٧		
Differential input current, VID (see Note 3)			±10	±10	mA	
Duration of output short circuit (see Note 4)			unlimited	unlimited		
Continuous total power dissipation		See Dissipation Rating Table				
Operating free-air temperature range, TA		-55 to 125	-25 to 85	0 to 70	°C	
Storage temperature range		-65 to 150	-65 to 150	-65 to 50	°C	
Case temperature for 60 seconds	FK package	260			°C	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	260	260	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300			°C	

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.

2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.

- 3. The inputs are shunted with two opposite-facing base-emitter diodes for overvoltage protection. Therefore, excessive current flows if a different input voltage in excess of approximately 1 V is applied between the inputs unless some limiting resistance is used.
- 4. The output can be shorted to ground or either power supply. For the LM118 and LM218 only, the unlimited duration of the short circuit applies at (or below) 85°C case temperature or 75°C free-air temperature.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	500 mV	5.8 mW/°C	64°C	464 mW	377 mW	145 mW
FK	500 mV	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
JG	500 mV	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
Р	500 mV	8.0 mW/°C	88°C	500 mW	500 mW	200 mW

SLOS063A - JUNE 1976 - REVISED APRIL 1994

electrical characteristics at specified free-air temperature (see Note 5)

	DADAMETED	TEST		LM1	18, LM2	18		LM318		
	PARAMETER	CONDITIONST	T _A ‡	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V	Innut offeet veltere	V- 0	25°C		2	4		4	10	mV
V _{IO}	Input offset voltage	V _O = 0	Full range			6			15	IIIV
lio	Input offset current	V _O = 0	25°C		6	50		30	200	nA
טי		VO = 0	Full range			100			300	ΠA
l.=	Input bias current	V= 0	25°C		120	250		150	500	nA
lΒ	input bias current	V _O = 0	Full range			500			750	IIA
VICR	Common-mode input voltage range	V _{CC±} = ±15 V	Full range	± 11.5			±11.5			٧
V _{ОМ}	Maximum peak output voltage swing	$V_{CC\pm} = \pm 15 \text{ V},$ $R_L = 2 \text{ k}\Omega$	Full range	±12	±13		±12	±13		٧
A	Large-signal differential	$V_{CC\pm} = \pm 15 \text{ V},$	25°C	50	200		25	200		Mark
AVD	voltage amplification	$V_O = \pm 10 \text{ V},$ $R_L \ge 2 \text{ k}\Omega$	Full range	25			20			V/mV
B ₁	Unity-gain bandwidth	V _{CC±} = ±15 V	25°C		15			15		MHz
rį	Input resistance		25°C	1*	3		0.5	3		MΩ
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	Full range	80	100		70	100		dB
^k SVR	Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO})		Full range	70	80		65	80		dB
lcc	Supply current	V _O = 0, No load	25°C		5	8		5	10	mA

^{*} On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		Т	MIN	TYP	MAX	UNIT		
SR	Slew rate at unity gain	$\Delta V_{I} = 10 \text{ V},$	C _L = 100 pF,	See Figure 1	50*	70		V/µs

^{*} On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

PARAMETER MEASUREMENT INFORMATION

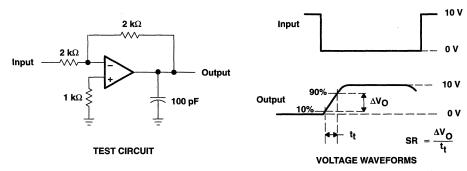


Figure 1. Slew Rate

[†] All characteristics are measured under open-loop conditions with common-mode input voltage unless otherwise specified.

[‡] Full range for LM118 is -55°C to 125°C, full range for LM218 is -25°C to 85°C, and full range for LM318 is 0°C to 70°C. NOTE 5: Unless otherwise noted, $V_{CC} = \pm 5$ V to ± 20 V. All typical values are at $V_{CC} = \pm 15$ V and $T_A = 25$ °C.

LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q **QUADRUPLE OPERATIONAL AMPLIFIERS**

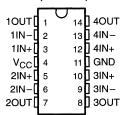
SLOS066E-SEPTEMBER 1975 - REVISED FEBRUARY1997

- Wide Range of Supply Voltages: Single Supply . . . 3 V to 30 V (LM2902 and LM2902Q 3 V to 26 V), or Dual Supplies
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Common-Mode Input Voltage Range **Includes Ground Allowing Direct Sensing Near Ground**
- Low Input Bias and Offset Parameters: Input Offset Voltage . . . 3 mV Typ A Versions . . . 2 mV Typ Input Offset Current . . . 2 nA Typ Input Bias Current . . . 20 nA Tvp A Versions . . . 15 nA Typ
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 32 V (26 V for LM2902 and LM2902Q)
- **Open-Loop Differential Voltage** Amplification . . . 100 V/mV Typ
- Internal Frequency Compensation

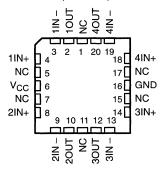
description

These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible when the difference between the two supplies is 3 V to 30 V (for the LM2902 and LM2902Q, 3 V to 26 V) and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

LM124, LM124A . . . J OR W PACKAGE ALL OTHERS . . . D, DB, N OR PW PACKAGE (TOP VIEW)

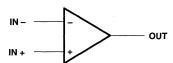


LM124, LM124A . . . FK PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly from the standard 5-V supply that is used in digital systems and easily provides the required interface electronics without requiring additional ± 15 -V supplies.

The LM2902Q is manufactured to demanding automotive requirements.

The LM124 and LM124A are characterized for operation over the full military temperature range of -55°C to 125°C. The LM224 and LM224A are characterized for operation from -25°C to 85°C. The LM324 and LM324A are characterized for operation from 0°C to 70°C. The LM2902 and LM2902Q are characterized for operation from -40°C to 125°C.

LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q QUADRUPLE OPERATIONAL AMPLIFIERS

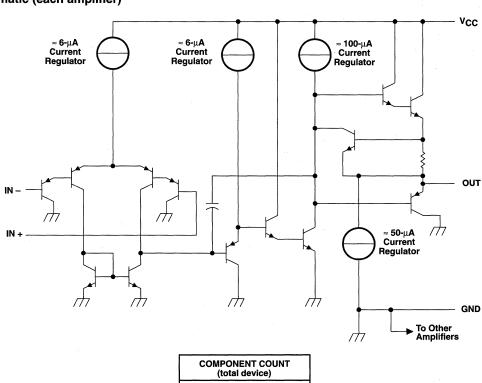
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AVAILABLE OPTIONS

				PACK	AGED DEVIC	ES			
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)†	VERY SMALL OUTLINE (DB)‡	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)‡	FLAT PACK (W)	CHIP FORM (Y)
0°C to	7 mV	LM324D	LM324DBLE	_	_	LM324N	LM324PWLE	_	LM324Y
70°C	3 mV	LM324AD	_			LM324AN	LM324APWLE	_	LIVIOZ41
−25°C to	5 mV	LM224D		_	_	LM224N	_	_	
85°C	3 mV	LM224AD	_	_	_	LM224AN		_	
-40°C to	7 mV	LM2902D	LM2902DBLE	_	_	LM2902N	LM2902PWLE	-	
125°C	7 1110	LM2902QD	LM2902DBLE	_		LM2902QN	LIVI2902PVVLE	_	_
−55°C to	5 mV			LM124FK	LM124J	_		LM124W	
125°C	2 mV			LM124AFK	LM124AJ	_			

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM324DR).

schematic (each amplifier)



COMPONENT COUNT (total device)					
Epi-FET	1				
Transistors	95				
Diodes	4				
Resistors	11				
Capacitors	4				

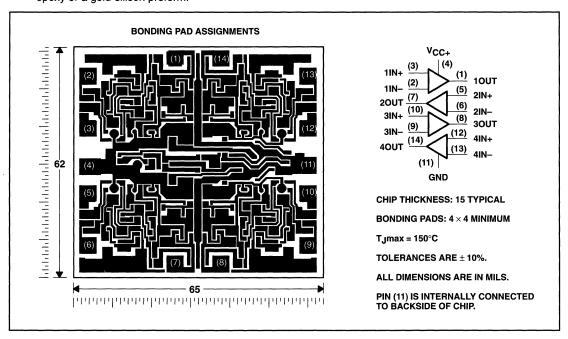


[‡] The DB and PW packages are only available left-end taped and reeled.

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LM324Y chip information

This chip, when properly assembled, displays characteristics similar to the LM324. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS066E-SEPTEMBER 1975 - REVISED FEBRUARY1997

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

	-					
		LM124, LM124A LM224, LM224A LM324, LM324A	LM2902, LM2902Q	UNIT		
Supply voltage, V _{CC} (see Note 1)		32	26	٧		
Differential input voltage, V _{ID} (see Note 2)	±32	±26	٧			
Input voltage, V _I (either input)	-0.3 to 32	-0.3 to 26	٧			
Duration of output short circuit (one amplifier) to ground at (or be $V_{CC} \le 15~V$ (see Note 3)	unlimited	unlimited				
Continuous total dissipation		See Dissipation Rating Table				
	LM124, LM124A	-55 to 125				
On supting from ainternal and the T	LM224, LM224A	-25 to 85		°C		
Operating free-air temperature range, TA	LM324, LM324A	0 to 70		٠٠		
	LM2902, LM2902Q		-40 to 125			
Storage temperature range		-65 to 150	-65 to 150	°C		
Case temperature for 60 seconds	FK package	260		°C		
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J or W package	300	300	°C		
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, DB, N, or PW package	260	260	°C		

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values (except differential voltages and V_{CC} specified for the measurement of I_{OS}) are with respect to the network GND.

- 2. Differential voltages are at IN + with respect to IN -.
- 3. Short circuits from outputs to $V_{\hbox{\scriptsize CC}}$ can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	900 mW	7.6 mW/°C	32°C	611 mW	497 mW	N/A
DB	775 mW	6.2 mW/°C	25°C	496 mW	403 mW	N/A
. FK	900 mW	11.0 mW/°C	68°C	878 mW	713 mW	273 mW
J (LM124_)	900 mW	11.0 mW/°C	68°C	878 mW	713 mW	273 mW
J (all others)	900 mW	8.2 mW/°C	40°C	654 mW	531 mW	N/A
N	900 mW	9.2 mW/°C	52°C	734 mW	596 mW	N/A
PW	700 mW	5.6 mW/°C	25°C	448 mW	364 mW	N/A
w	900 mW	8.0 mW/°C	37°C	636 mW	516 mW	196 mW

electrical characteristics at specified free-air temperature, $V_{CC} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	DITIONET	TA‡	LM	124, LM224			LM324		LM29	02, LM2902	Q.	UNIT
	FARAMETER	TEST CON	DITIONS	'A*	MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNII
VIO	Input offset voltage	V _{CC} = 5 V to MA	λX,	25°C		3	5		3	7		3	7	mV
V10	input onset voltage	V _{IC} ≈ V _{ICR} min,	V _O = 1.4 V	Full range			7			9			10	IIIV
110	Input offset current	V _O = 1.4 V		25°C		2	30		2	50		2	50	nA
1.10	mpat onoct danont	10-1111		Full range			100			150			300	
I _{IB}	Input bias current	V _O = 1.4 V		25°C		-20	-150		-20	-250		-20	-250	nA
10) = 1.4 V			·····	-300			-500			-500	
				25°C	0 to			0 to			0 to			
1	Common-mode input			25 0	V _{CC} - 1.5			V _{CC} - 1.5			V _{CC} -1 .5			
VICR	voltage range	$V_{CC} = 5 \text{ V to MA}$	AX ·		0 to			0 to			0.40			V
				Full range	Vcc-			Vcc-			0 to V _{CC} -2			
ļ		 						2						
		$R_L = 2 k\Omega$		25°C	V _{CC} - 1.5			V _{CC} - 1.5						
l.,		$R_i = 10 \text{ k}\Omega$		25°C							V _{CC} -1			
VOH	riigiri iovor output voitago	<u> </u>		23 0							.5			V
		V _{CC} = MAX,	$R_L = 2 k\Omega$	Full range	26			26			22			
		V _{CC} = MAX,	R _L ≥ 10 kΩ	Full range	27	28		27	28		23	24		
V _{OL}	Low-level output voltage	R _L ≤ 10 kΩ		Full range		5	20		5	20		5	20	mV
AVD	Large-signal differential voltage amplification	$V_{CC} = 15 \text{ V}, V_{O}$ $R_{I} = \ge 2 \text{ k}\Omega$	= 1 V to 11 V,	25°C	50	100		25	100			100		V/mV
ļ		ļ <u> </u>		Full range	25			15			15			
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		25°C	70	80		65	80		50	80		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC}/\Delta V_{IO})$			25°C	65	100		65	100		50	100		dB
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz to 20 kl	Hz	25°C		120			120			120		dB
		V _{CC} = 15 V,	V _{ID} = 1 V,	25°C	-20	-30	-60	-20	-30	-60	-20	-30	-60	
		V _O = 0		Full range	-10			-10			-10			mA
Ю	Output current	V _{CC} = 15 V,	V _{ID} = -1 V,	25°C	10	20		10	20		10	20		IIIA
1		V _O = 15 V		Full range	5			5			5			
L		$V_{ID} = -1 V$,	V _O = 200 mV	25°C	12	30		12	30			30		μА
los	Short-circuit output current	V _{CC} at 5 V, GND at -5 V	V _O = 0	25°C		±40	±60		±40	±60		±40	±60	mA
	V _O =	V _O = 2.5 V,	No load	Full range		0.7	1.2		0.7	1.2		0.7	1.2	
Icc	Supply current (four amplifiers)	V _{CC} = MAX, V _O = 0.5 V _{CC} ,	No load	Full range		1.4	3		1.4	3		1.4	3	mA

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for LM2902 and LM2902Q, 30 V for the others.

[‡] Full range is -55° C to 125° C for LM124, -25° C to 85° C for LM224, 0° C to 70° C for LM324, and -40° C to 125° C for LM2902 and LM2902Q. § All typical values are at $T_A = 25^{\circ}$ C.

electrical characteristics at specified free-air temperature, $V_{CC} = 5 \text{ V}$ (unless otherwise noted)

	24244			_ +	L	M124A		L	M224A		L	M324A		
	PARAMETER	TEST CO	NDITIONS [†]	T _A ‡	MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNIT
.,		V _{CC} = 5 V to 36	O V,	25°C			2		2	3		2	3	mV
VIO	Input offset voltage	V _{IC} = V _{ICR} min	, V _O = 1.4 V	Full range			4			4			5	mv
l	Input offset current	V _O = 1.4 V		25°C			10			2	15	2	30	n/
10	Input onset current	VO = 1.4 V		Full range			30			30			75	11/-
l.m.	Input bias current	VO = 1.4 V		25°C			-50		-15	-80		-15	-100	n/
lв	Input bias current	VO = 1.4 V		Full range			-100			-100			-200	'''
				25°C	0 to			0 to			0 to			
VICR	Common-mode input voltage range	V _{CC} = 30 V		<u> </u>	V _{CC} -1.5	·		V _{CC} -1.5			V _{CC} -1.5			V
	vollage range			Full range	0 to V _{CC} -2			0 to V _{CC} -2			0 to V _{CC} -2			
		$R_1 = 2 k\Omega$		25°C	V _{CC} -1.5			V _{CC} -1.5			V _{CC} -1.5			
Vон	High-level output voltage	V _{CC} = 30 V,	$R_I = 2 k\Omega$	Full range	26			26			26			V
·OH	д	V _{CC} = 30 V,	R _I ≥ 10 kΩ	Full range	27			27	28		27	28		
V _{OL}	Low-level output voltage	R _I ≤ 10 kΩ		Full range	 		20		5	20		5	20	m
AVD	Large-signal differential voltage amplification	$V_{CC} = 15 \text{ V}, V_{C}$ $R_{L} = 2 \text{ k}\Omega$) = 1 V to 11 V,	Full range	25			25			15			· V/n
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	<u></u>	25°C	70			70	80		65	-80		dl
ksvr	Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO})			25°C	65			65	100		65	100		d
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz to 20	kHz	25°C		120			120			120		d
		V _{CC} = 15 V,	V _{ID} = 1 V,	25°C	-20			-20	-30	-60	-20	-30	-60	
		V _O = 0	.5	Full range	-10			-10			-10			
lo	Output current	V _{CC} = 15 V,	V _{ID} = -1 V,	25°C	10			10	20		10	20		m
		V _O = 15 V		Full range	5			5			5			
		$V_{ID} = -1 V$	V _O = 200 mV	25°C	12			12	30		12	30		μ
los	Short-circuit output current	V _{CC} at 5 V, V _O = 0	GND at -5 V,	25°C		±40	±60		±40	±60		±40	±60	m
		$V_0 = 2.5 V$,	No load	Full range		0.7	1.2		0.7	1.2		0.7	1.2	
lcc ·	Supply current (four amplifiers)	V _{CC} = 30 V, No load	V _O = 15 V,	Full range		1.4	3		1.4	3		1.4	3	m

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. ‡ Full range is –55°C to 125°C for LM124A, –25°C to 85°C for LM224A, and 0°C to 70°C for LM324A. § All typical values are at T_A = 25°C.

LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q QUADRUPLE OPERATIONAL AMPLIFIERS SLOS066E – SEPTEMBER 1975 – REVISED FEBRUARY 1997

electrical characteristics, $V_{CC} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

					LN	//324Y		
	PARAMETER	TES	r conditions†		MIN	TYP	MAX	UNIT
VIO	Input offset voltage					3	7	mV
10	Input offset current	$V_{CC} = 5 \text{ V to MAX},$	$V_{IC} = V_{ICR}min,$	$V_0 = 1.4 \text{ V}$		2	50	nA
lв	Input bias current					-20	-250	nA
VICR	Common-mode input voltage range	V _{CC} = 5 V to MAX			0 to V _{CC} -1.5			V
VOH	High-level output voltage	R _L = 10 kΩ			V _{CC} -1.5			٧
VOL	Low-level output voltage	$R_L \le 10 \text{ k}\Omega$				5	20	mV
AVD	Large-signal differential voltage amplification	V _{CC} = 15 V,	V _O = 1 V to 11 V,	R _L ≥2 kΩ	15	100		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min			65	80		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	i.			65	100		dB
		V _{CC} = 15 V,	V _{ID} = 1 V,	V _O = 0	20	-30	-60	
Ю	Output current	V _{CC} = 15 V,	$V_{ID} = -1 V$,	V _O = 15 V	10	20		mA
		V _{ID} = 1 V,	V _O = 200 mV		12	30		
los	Short-circuit output current	V _{CC} at 5 V,	GND at -5 V,	V _O = 0		±40	±60	mA
1	Construction of the construction of	$V_{O} = 2.5 V_{CC}$	No load			0.7	1.2	
Icc	Supply current (four amplifiers) \vdash	V _{CC} = MAX,	V _O = 0.5 V _{CC} ,	No load		1.1	3	mA

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX V_{CC} for testing purposes is 30 V.

LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS058B - OCTOBER 1979 - REVISED AUGUST 1996

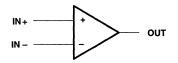
- μΑ741 Operating Characteristics
- Low Supply Current Drain . . . 0.6 mA Typ (per amplifier)
- **Low Input Offset Voltage**
- **Low Input Offset Current**
- **Class AB Output Stage**
- Input/Output Overload Protection
- Designed to Be Interchangeable With National LM148, LM248, and LM348

description

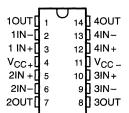
The LM148, LM248, and LM348 are quadruple, independent, high-gain, internally compensated operational amplifiers designed to have operating characteristics similar to the µA741. These amplifiers exhibit low supply current drain, and input bias and offset currents that are much less than those of the uA741.

The LM148 is characterized for operation over the full military temperature range of -55°C to 125°C, the LM248 is characterized for operation from -25°C to 85°C, and the LM348 is characterized for operation from 0°C to 70°C.

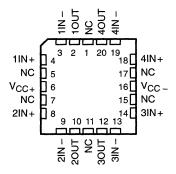
symbol (each amplifier)



LM148...J PACKAGE LM248, LM348 . . . D, N, OR PW PACKAGE (TOP VIEW)



LM148...FK PACKAGE (TOP VIEW)



NC - No internal connection

AVAILABLE OPTIONS

			PACKAGE								
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)					
0°C to 70°C	6 mV	LM348D	_		LM348N	LM348PW					
-25°C to 85°C	6 mV	LM248D	-	_	LM248N	_					
-55°C to 125°C	5 mV	_	LM148FK	LM148J		_					

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM348DR).

LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM148	LM248	LM348	UNIT	
Supply voltage, V _{CC+} (see Note 1)		22	18	18	V	
Supply voltage, V _{CC} _ (see Note 1)	-22	-18	-18	V		
Differential input voltage, V _{ID} (see Note 2)	44	36	36	V		
Input voltage, V _I (either input, see Notes 1 and 3)	±22	±18	±18	V		
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited			
Continuous total power dissipation		See Dissipation Rating Table				
Operating free-air temperature range, TA		-55 to 125	-25 to 85	0 to 70	°C	
Storage temperature range		-65 to 150	-65 to 150	-65 to 150	°C	
Case temperature for 60 seconds	260			°C		
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J package	300			°C	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260	260	°C		

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - The magnitude of the input voltage must never exceed the magnitude of the supply voltage or the value specified in the table, whichever is less.
 - 4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	900 mW	7.6 mW/°C	32°C	611 mW	497 mW	N/A
FK	900 mW	11.0 mW/°C	68°C	878 mW	713 mW	273 mW
J	900 mW	11.0 mW/°C	68°C	878 mW	713 mW	273 mW
N	900 mW	9.2 mW/°C	52°C	734 mW	596 mW	N/A
PW	700 mW	5.6 mW/°C	N/A	448 mW	N/A	N/A

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC+}	4	18	V
Supply voltage, V _{CC} _	-4	-18	V

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

	PARAMETER	_		···ot		LM148			LM248			LM348		
	PARAMETER	''	EST CONDITIO	NS1	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V10	Input offset voltage	Va = 0		25°C		1	5		1	6		1	6	mV
V _{IO}	Input offset voltage	VO = 0		Full range			6			7.5			7.5	mv
lio	Input offset current	V _O = 0		25°C		4	25		4	50		4	50	nA
lio	input onset current	VO = 0	'	Full range			75			125			100	IIA
l.s	Input bias current	V _O = 0		25°C		30	100		30	200		30	200	nA
IB	input bias current	AQ = 0		Full range			325			500			400	IIA
V _{ICR}	Common-mode input voltage range			Full range	±12			±12			±12			V
		$R_L = 10 \text{ k}\Omega$	2	25°C	±12	±13		±12	±13		±12	±13		
V	Maximum peak output voltage	R _L ≥ 10 kΩ	2	Full range	±12			±12			±12			_v
VOM	swing	$R_L = 2 k\Omega$		25°C	±10	±12		±10	±12		±10	±12		,
		$R_L \ge 2 k\Omega$		Full range	±10			±10			±10			
۸	Large-signal differential voltage	V _O = ±10 \	V,	25°C	50	160		25	160		25	160		V/mV
AVD	amplification	R _L = ≥ 2 kΩ F		Full range	25			15			15			V/ITIV
η	Input resistance‡			25°C	0.8	2.5		0.8	2.5		0.8	2.5		MΩ
B ₁	Unity-gain bandwidth	A _{VD} = 1		25°C		1			1			1		MHz
φm	Phase margin	A _{VD} = 1		25°C		60°			60°			60°		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICE}	Amin,	25°C	70	90		70	90		70	90		dB
CIVIAN	Common-mode rejection ratio	V _O = 0	` <u> </u>	Full range	70			70			70			UB
1	Supply-voltage rejection ratio	V _{CC±} = ±	9 V to ± 15 V,	25°C	77	96		77	96		77	96		dB
ksvr	(ΔV _{CC±} /ΔV _{IO})	VO = 0		Full range	77			77			77			Ф
los	Short-circuit output current			25°C		±25			±25			±25		mA
i	C - L (faur amplificus)	V _O	V _O = 0	25.00					2.4	4.5		2.4	4.5	
Icc	Supply current (four amplifiers)	No load	V _O = V _{OM}	25°C		2.4	3.6							mA
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 Hz to	20 kHz	25°C		120			120			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for T_A is -55°C to 125°C for LM148, -25°C to 85°C for LM248, and 0°C to 70°C for LM348.

‡ This parameter is not production tested.

LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

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operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

	PARAMETER	Т	MIN	TYP	MAX	UNIT		
SR	Slew rate at unity gain	$R_L = 2 k\Omega$,	C _L = 100 pF,	See Figure 1		0.5		V/μs

PARAMETER MEASUREMENT INFORMATION

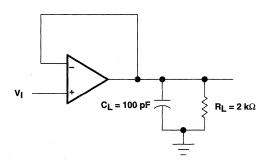


Figure 1. Unity-Gain Amplifier

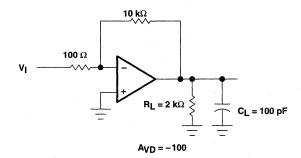


Figure 2. Inverting Amplifier

LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS

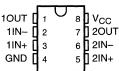
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- Wide Range of Supply Voltages: Single Supply . . . 3 V to 30 V (LM2904 and LM2904Q 3 V to 26 V) or Dual Supplies
- Low Supply Current Drain Independent of Supply Voltage . . . 0.7 mA Typ
- Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing Near Ground
- Low Input Bias and Offset Parameters: Input Offset Voltage . . . 3 mV Typ A Versions . . . 2 mV Typ Input Offset Current . . . 2 nA Typ Input Bias Current . . . 20 nA Typ A Versions . . . 15 nA Typ
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±32 V (±26 V for LM2904 and LM2904Q)
- Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ
- Internal Frequency Compensation

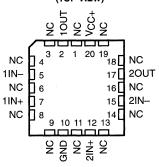
description

These devices consist of two independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supply is also possible so long as the difference between the two supplies is 3 V to 30 V (3 V to 26 V for the LM2904 and LM2904Q), and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

D, DB, JG, P, OR PW PACKAGE (TOP VIEW)

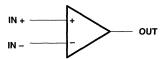


LM158, LM158A . . . FK PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, these devices can be operated directly off of the standard 5-V supply that is used in digital systems and will easily provide the required interface electronics without requiring additional ± 5 -V supplies.

The LM2904Q is manufactured to demanding automotive requirements.

The LM158 and LM158A are characterized for operation over the full military temperature range of –55°C to 125°C. The LM258 and LM258A are characterized for operation from –25°C to 85°C, the LM358 and LM358A from 0°C to 70°C, and the LM2904 and LM2904Q from –40°C to 125°C.

LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS

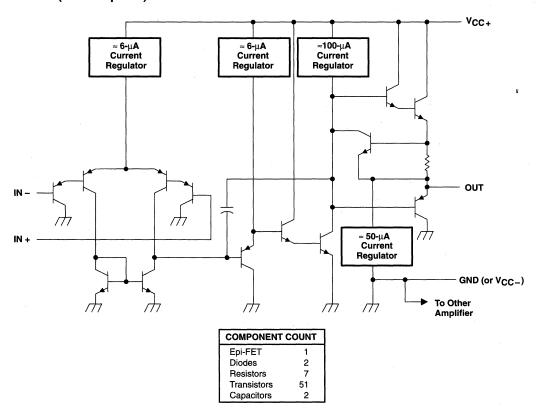
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AVAILABLE OPTIONS

	Viemey	·		PACKAGED	DEVICES			CHIP FORM
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)†	SSOP (DB)‡	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)‡	(Y)
0°C to 70°C	7 mV 3 mV	LM358D	LM358DB			LM358P LM358AP	LM358PW	LM358Y
-25°C to 85°C	5 mV 3 mV	LM258D				LM258P LM258AP	.1.4	
-40°C to 125°C	7 mV	LM2904D LM2904QD	LM2904DB 			LM2904P LM2904QP	LM2904PW —	
-55°C to 125°C	5 mV 2 mV	LM158D		LM158FK LM158AFK	LM158JG LM158AJG	LM158P		

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM358DR).

schematic (each amplifier)

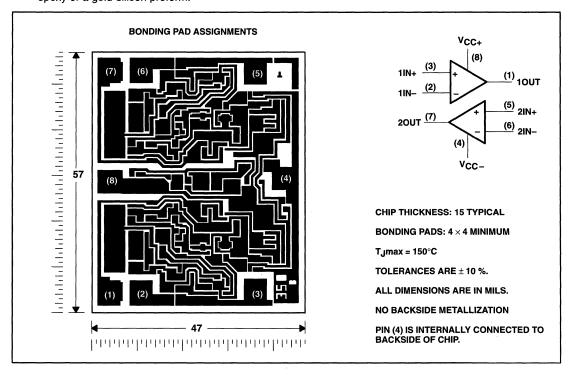


[‡] The DB and PW packages are only available left-end taped and reeled. Add the suffix LE to the device type (e.g., LM358DBLE).

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LM358Y chip information

These chips, when properly assembled, display characteristics similar to the LM358. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM158, LM158A LM258, LM258A LM358, LM358A	LM2904, LM2904Q	UNIT	
Supply voltage V _{CC} (see Note 1)		32	26	V	
Differential input voltage (see Note 2)	±32	±26	V		
Input voltage (either input)	-0.3 to 32	-0.3 to 26	V		
Duration of output short circuit (one amplifier) to ground at (or bettemperature (VCC \leq 15 V) (see Note 3)	low) 25°C free-air	unlimited	unlimited		
Continuous total dissipation		See Dissipation Rating Table			
	LM158, LM158A	-55 to 125			
Operation for a sixtension to the second sec	LM258, LM258A	-25 to 85] _{°C}	
Operating free-air temperature range	LM358, LM358A	0 to 70		1 ~	
	LM2904, LM2904Q		-40 to 125		
Storage tempereture range		-65 to 150	-65 to 150	°C	
Case temperature for 60 seconds	FK package	260		°C	
Lead tempeature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300	300	°C	
Lead tempeature 1,6 mm (1/16 inch) from case for 10 seconds	D, DB, P, or PW package	260	260	°C	

NOTES: 1. All voltage values, except differential voltages and V_{CC} specified for measurement of I_{OS}, are with respect to the network ground terminal

2. Differential voltages are at IN+ with respect to IN-.

3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D.	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
DB	525 mW	4.2 mW/°C	336 mW	273 mW	-
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
. JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW
PW	525 mW	4.2 mW/°C	336 mW	273 mW	_

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	T _A ‡	LM158, LM258			LM358			LM2904, LM2904Q			UNIT	
		1231 CONDITIONS:	'A*	MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNII	
V _{IO}	Input offset voltage	V _{CC} = 5 V to MAX, V _{IC} = V _{ICR} min,	25°C		3	5		3	7		3	7	mV	
		V _O = 1.4 V	Full range			7			9			10	11.14	
αVIO	Average temperature coefficient of input offset voltage		Full range		7			7			7		μV/°C	
110	Input offset current	V _O = 1.4 V	25°C		2	30		2	50		2	50	nA	
,10	mpat oncer current	VO = 1.4 V	Full range			100			150			300	11/4	
αΙΙΟ	Average temperature coefficient of input offset current		Full range		10			10			10		pA/°C	
lin	Input bias current	V _O = 1.4 V	25°C		-20	-150		-20	-250		-20	-250	nA	
IВ	input bias current	VO = 1.4 V	Full range			-300			-500			-500	IIA	
		,	25°C	0 to			0 to			0 to				
VICR	Common-mode	V _{CC} = 5 V to MAX		V _{CC} -1.5			V _{CC} -1	.5		V _{CC} -1	.5		-	
1011	input voltage range		Full range	0 to V _{CC} -2			0 to V _{CC} -2			0 to V _{CC} -2		-		
		RL≥2kΩ	25°C	V _{CC} -1.5			V _{CC} -1	.5						
\v	Lligh level output voltage	R _L ≥ 10 kΩ	25°C								٧c	C-1.5	V	
VOH I	High-level output voltage	$V_{CC} = MAX$, $R_L = 2 k\Omega$	Full range	26			26			26			V	
		$V_{CC} = MAX$, $R_L \ge 10 \text{ k}\Omega$	Full range	27	28		27	28		23	24			
VOL	Low-level output voltage	R _L ≤ 10 kΩ	Full range		5	20		5	20		5	20	mV	
AVD	Large-signal differential	V _{CC} = 15 V, V _O = 1 V to 11 V,	25°C	50	100		25	100		25	100		V/mV	
	voltage amplification	$R_L = \ge 2 k\Omega$	Full range	25			15			15			V/IIIV	
CMRR	Common-mode rejection ratio	V _{CC} = 5 V to MAX, V _{IC} = V _{ICR} min	25°C	70	80		65	80		50	80		dB	
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _{CC} = 5 V to MAX	25°C	65	100		65	100		65	100		dB	
V ₀₁ /V ₀₂	Crosstalk attenuation	f = 1 kHz to 20 kHz	25°C		120			120			120		dB	

[†] All characterisctics are measured under open-loop conditions with zero common-mode input voltage unless otherwise speicifed. MAX V_{CC} for testing purposes is 26 V for LM 2904 and 30 V for others.

‡ Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 125°C for LM2904 and LM2904Q.

§ All typical values are at T_A = 25°C.

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted) (continued)

	PARAMETER Io Output current	TEST CONDITIONS†		T _A ‡	LM158, LM258			LM358			LM2904, LM2904Q			UNIT	
	FARIAMETER		TEST CONDITIONS!		MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNII	
		V _{CC} = 15 V,	V _{ID} = 1 V,	25°C	-20	-30		-20	-30		-20	-30			
		V _O = 0		Full range	-10			-10			-10				
lo		V _{CC} = 15 V,	V _{ID} = -1 V,	25°C	10	20		10	20		10		mA		
		V _O = 15 V	·	Full range	5			5			5				
		$V_{ID} = -1 V$,	V _O = 200 mV	25°C	12	30		12	30			30		μΑ	
los	Short-circuit output current	V _{CC} at 5 V, V _O = 0	GND at −5 V,	25°C		±40	±60		±40	±60		±40	±60	mA _.	
		$V_0 = 2.5 V$,	No load	Full range		0.7	1.2		0.7	1.2		0.7	1.2		
Icc	Supply current (two amplifiers)	V _{CC} = MAX, No load	V _O = 0.5 V,	Full range		1	2		1	2		1	2	mA	

LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS SLOSSGEB - JUNE 1976 - REVISED NOVEMBER 1996

[†] All characterisctics are measured under open-loop conditions with zero common-mode input voltage unless otherwise speicifed. MAX V_{CC} for testing purposes is 26 V for LM 2904 and 30 V for others.

Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 125°C for LM2904 and LM2904Q.

[§] All typical values are at T_A = 25°C.

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER			- +	LM158A			LN	1258A		LM358A			
		TEST CONDITIONS†	T _A ‡	MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNIT
V _{IO}	Input offset voltage	V _{CC} = 5 V to 30 V, V _{IC} = V _{ICR} min,	25°C			2		2	3		2	3	mV
, į	put onost voltago	V _O = 1.4 V	Full range			4			4		_	5	
ανιο	Average temperature coefficient of input offset voltage		Full range		7	15*		7	15		7	20	μV/°C
I _{IO} Input offset current	V _O = 1.4 V	25°C		2	10		2	15		2	30	nA	
10		1.0	Full range			30			30			75	
αιιο	Average temperature coefficient of input offset current		Full range		10	200		10	200		10	300	pA/°C
lun	Input bias current	V _O = 1.4 V	25°C		-15	-50		-15	-80		-15	-100	nA
lВ			Full range			-100			-100			-200	11/4
V	Common-mode input voltage range	V _{CC} = 30 V	25°C	0 to V _{CC} -1.5			0 to V _{CC} -1.5			0 to V _{CC} -1.5			v
VICR			Full range	0 to V _{CC} -2			0 to V _{CC} -2			0 to V _{CC} -2			•
	High-level output voltage	R _L ≥ 2 kΩ	25°C	V _{CC} -1.5			V _{CC} -1.5			V _{CC} -1.5			
VOH		h-level output voltage	Full range	26			26			26			· V
			Full range	27	28		27	28		27	28		
V _{OL}	Low-level output voltage	R _L ≤ 10 kΩ	Full range		5	20		5	20		5	20	mV
AVD	Large-signal differential	V _{CC} = 15 V, V _O = 1 V to 11 V,	25°C	50	100		50	100		25	100		V/mV
1.45	voltage amplification	R _L = ≥ 2 kΩ	Full range	25			25			15			
CMRR	Common-mode rejection ratio		25°C	70	80		70	80		65	80		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		25°C	65	100		65	100		65	100		dB
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz	25°C		120			120			120		dB

^{*}On products compliant to MIL-PRF-38535, this parameter is not production tested.

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

‡ Full range is -55°C to 125°C for LM158A, -25°C to 85°C for LM258A, and 0°C to 70°C for LM358A.

[§] All typical values are at $T_A = 25$ °C.

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted) (continued)

PARAMETER		TEST CO	NDITIONS†	T _A ‡	T T	LM158A			LM258A		LM358A		UNIT	
	PARAMETER	1231 00	COMPITIONS		MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	UNIT
		V _{CC} = 15 V,	V _{ID} = 1 V,	25°C	-20	-30	-60	-20	-30	-60	-20	-30	-60	
IO Output curre		V _O = 0		Full range	-10			-10			-10			
	Output current	V _{CC} = 15 V,	V _{ID} = -1 V,	25°C	10	20		10	20		10	20		mA
		V _O = 15 V		Full range	5			5			5			
		$V_{ID} = -1 V$,	V _O = 200 mV	25°C	12	30		12	30			30		μА
los	Short-circuit output current	V_{CC} at 5 V, $V_{O} = 0$	GND at -5 V,	25°C		±40	±60		±40	±60		±40	±60	mA
		$V_0 = 2.5 V$,	No load	Full range		0.7	1.2		0.7	1.2		0.7	1.2	
Icc	ICC Supply current (two amplifiers)	V _{CC} = MAX, No load	$V_O = 0.5 V$,	Full range		1	2		1	2		1	2	mA

LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS SLOSGERB - JUNE 1976 - REVISED NOVEMBER 1996

[†] All characterisctics are measured under open-loop conditions with zero common-mode input voltage unless otherwise speicifed. MAX V_{CC} for testing purposes is 26 V for LM 2904

[‡] Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 125°C for LM2904 and LM2904Q. § All typical values are at T_A = 25°C.

LM158, LM158A, LM258, LM358 LM258A, LM358A, LM358Y, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS SLOS068B – JUNE 1976 – REVISED NOVEMBER 1996

electrical characteristics $V_{CC} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	DADAMETED				LIV	1358Y	MAX 7 50 -250 -60 ±60 1.2	UNIT	
	PARAMETER	15	ST CONDITIONST		MIN	TYP	MAX	CIVIT	
VIO	Input offset voltage					3	7	mV	
lio	Input offset current	$V_{CC} = 5 \text{ V to MAX},$	$V_{IC} = V_{ICR}min,$	$V_0 = 1.4 \text{ V}$		2	50	nA	
I _{IB}	Input bias current	1				-20	-250	nA	
VICR	Common-mode input voltage range	V _{CC} = 5 V to MAX			0 to V _{CC} -1.5			٧	
V _{OH+}	High-level output voltage	R _L ≥ 10 kΩ			V _{CC} -1.5			٧	
AVD	Large-signal differential voltage amplification	V _{CC} = 15 V,	V _O = 1 V to 11 V,	R _L = ≥ 2 kΩ	15	100		V/mV	
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min			65	80		dB	
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})				65	100		dB	
		V _{CC} = 15 V,	V _{ID} = 1 V,	V _O = 0	-20	-30	-60		
lo	Output current	V _{CC} = 15 V,	V _{ID} = -1 V,	V _O = 15 V	10	20		mA	
		V _{ID} = 1 V,	V _O = 200 mV		12	30			
los	Short-circuit output current	V _{CC} at 5 V,	GND at -5 V,	V _O = 0		±40	±60	mA	
1	County suggest (form amplificate)	V _O = 2.5 V,	No load			0.7	1.2		
ICC	Supply current (four amplifiers)	V _{CC} = MAX,	V _O = 0.5 V,	No load		1	2	mA	

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX V_{CC} for testing purposes is 30 V.

LM324x2 **OCTAL OPERATIONAL AMPLIFIER**

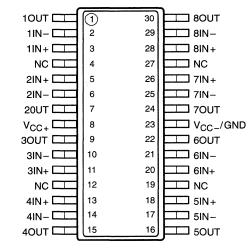
SLOS133A - APRIL 1994 - REVISED AUGUST 1996

- Wide Range of Supply Voltages: Single Supply . . . 3 V to 30 V or Dual Supplies
- Low Supply-Current Drain Independent of Supply Voltage . . . 1.4 mA Typ
- Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing **Near Ground**
- Low Input Bias and Offset Parameters: Input Offset Voltage . . . 3 mV Tvp Input Offset Current . . . 2 nA Typ Input Bias Current . . . -20 nA Typ
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 32 V
- **Open-Loop Differential Voltage** Amplification . . . 100 V/mV Typ
- **Internal Frequency Compensation**

description

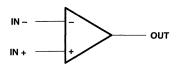
The LM324x2 device consists eiaht of independent, high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible when the difference between the two supplies is 3 V to 30 V and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

DB PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



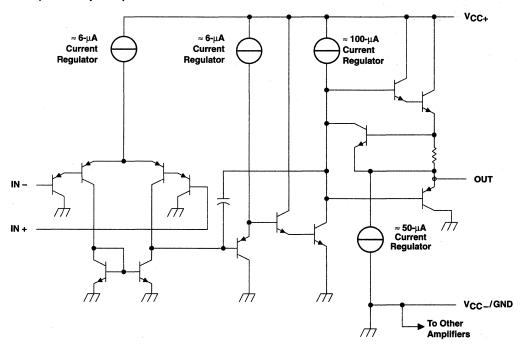
Applications include transducer amplifiers, dc amplification blocks, and all the conventional operationalamplifier circuits that now can be more easily implemented in single-supply-voltage systems.

AVAILABLE OPTION

			PACKAGE
	TA	V _{IO} max AT 25°C	SMALL OUTLINE (DB) [†]
ſ	0°C to 70°C	7 mV	LM324x2DBLE

[†] The DB package is only available left-end taped and reeled.

schematic (each amplifier)



COMPONENT COUNT (total device) Epi-FET 2 Transistors 190

Transistors 190
Diodes 8
Resistors 22
Capacitors 8

LM324x2 OCTAL OPERATIONAL AMPLIFIER

SLOS133A - APRIL 1994 - REVISED AUGUST 1996

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Cumply voltage V (acc Note 1)	20.1/
Supply voltage, V _{CC} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	±32 V
Input voltage range, V _I (any input)	0.3 V to 32 V
Duration of output short circuit to ground (see Note 3)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these conditions beyond those indicated is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages and V_{CC} specified for the measurement of I_{OS}, are with respect to GND.

- 2. Differential voltages are at IN + with respect to IN -.
- 3. Short circuits from outputs to $V_{\hbox{\scriptsize CC}}$ can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING
DB	1024 mW	8.2 mW/° C	655 mW

LM324x2 OCTAL OPERATIONAL AMPLIFIER

SLOS133A - APRIL 1994 - REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{CC} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS†	T _A ‡	MIN	TYP§	MAX	UNIT	
.,	land #	V _{CC} = 5 V to MAX,	V _O = 1.4 V	25°C		3	7		
Vio	Input offset voltage	V _{IC} = V _{ICR} min,		Full range			9	mV	
·				25°C		2	50	4	
١٥٥	Input offset current	V _O = 1.4 V		Full range			150	nA	
1	Input bigg gurrant	V _O = 1.4 V		25°C		-20	-250	nA	
lв	Input bias current	VO = 1.4 V		Full range			-500	IIA	
VICR	Common-mode input	Vaa – E V to MAY		25°C	0 to V _{CC} -1.5			V	
vol	voltage range	V _{CC} = 5 V to MAX	,	Full range	0 to V _{CC} -2			, '	
		$R_L = 2 k\Omega$		25°C	V _{CC} -1.5				
VOH	High-level output voltage	V _{CC} = MAX,	$R_L = 2 k\Omega$	Full range	26			V	
		V _{CC} = MAX,	R _L ≥ 10 kΩ	Full range	27	28			
VOL	Low-level output voltage	R _L ≤ 10 kΩ		Full range		5	20	mV	
Λ.σ	Large-signal differential	V _{CC} = 15 V,	V _O = 1 V to 11 V,	25°C	25	100		V/mV	
AVD	voltage amplification	R _L = ≥ 2 kΩ		Full range	15			V/IIIV	
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		25°C	65	80		dB	
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)			25°C	65	100		dB	
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120		dB	
		V _{CC} = 15 V,	V _{ID} = 1 V,	25°C	-20	-30	-60		
		V _O = 0	· -	Full range	-10			mA	
Ю	Output current	V _{CC} = 15 V,	V _{ID} = -1 V,	25°C	10	20		IIIA	
		V _O = 15 V		Full range	5				
		V _{ID} = −1 V,	V _O = 200 mV	25°C	12	30		μΑ	
los	Short-circuit output current	V _O = 0,	GND = -5 V	25°C		±40	±60	mA	
	Supply current (eight	V _O = 2.5 V,	No load	Full range		1.4	2.4	4	
lcc	amplifiers)	V _{CC} = MAX, No load	$V_O = 0.5 V_{CC}$	Full range		2.2	6	mA	

T All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX V_{CC} for testing purposes is 30 V.

[‡] Full range is 0°C to 70°C.

[§] All typical values are at T_A = 25°C.

LM2900, LM3900 QUADRUPLE NORTON OPERATIONAL AMPLIFIERS

SLOS059 - JULY 1979 - REVISED SEPTEMBER 1990

•	Wide	Range	of Supply	Voltages,	Single	or
	Dual	Supplie	es			

- Wide Bandwidth
- Large Output Voltage Swing
- Output Short-Circuit Protection
- Internal Frequency Compensation
- Low Input Bias Current
- Designed to Be Interchangeable With National Semiconductor LM2900 and LM3900, Respectively

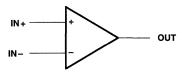
		ACK P VI		_
2IN-[2OUT[1OUT[1 2 3 4 5 6 7	U	13 12 11 10	V _{CC} 3IN+ 4IN+ 4IN- 4OUT 3OUT 3IN-

description

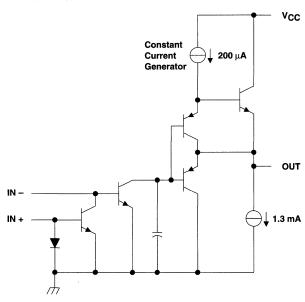
These devices consist of four independent, highgain frequency-compensated Norton operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible. The low supply current drain is essentially independent of the magnitude of the supply voltage. These devices provide wide bandwidth and large output voltage swing.

The LM2900 is characterized for operation from -40°C to 85°C, and the LM3900 is characterized for operation from 0°C to 70°C.

symbol (each amplifier)



schematic (each amplifier)



TEXAS INSTRUMENTS

LM2900, LM3900 QUADRUPLE NORTON OPERATIONAL AMPLIFIERS

SLOS059 - JULY 1979 - REVISED SEPTEMBER 1990

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM2900	LM3900	UNIT
Supply voltage, V _{CC} (see Note 1)	36	36	V
Input current	20	20	mA
Duration of output short circuit (one amplifier) to ground at (or below) 25°C free-air temperature (see Note 2)	unlimited	unlimited	
Continuous total dissipation	See Diss	ipation Rating	Table
Operating free-air temperature range	-40 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
 - 2. Short circuits from outputs to $V_{\hbox{CC}}$ can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_{\mbox{\scriptsize A}} \leq 25^{\circ}\mbox{\scriptsize C}$ POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING
N	1150 mW	9.2 mW/°C	736 mW	598 mW

recommended operating conditions

	LM2	LM2900		LM3900	
	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{CC} (single supply)	4.5	32	4.5	32	٧
Supply voltage, V _{CC+} (dual supply)	2.2	16	2.2	16	V
Supply voltage, V _{CC} (dual supply)	-2.2	-16	-2.2	-16	V
Input current (see Note 3)		-1		-1	mA
Operating free-air temperature, TA	-40	85	0	70	°C

NOTE 3: Clamp transistors are included that prevent the input voltages from swinging below ground more than approximately -0.3 V. The negative input currents that may result from large signal overdrive with capacitive input coupling must be limited externally to values of approximately -1 mA. Negative input currents in excess of -4 mA causes the output voltage to drop to a low voltage. These values apply for any one of the input terminals. If more than one of the input terminals are simultaneously driven negative, maximum currents are reduced. Common-mode current biasing can be used to prevent negative input voltages.

LM2900, LM3900 QUADRUPLE NORTON OPERATIONAL AMPLIFIERS

SLOS059 - JULY 1979 - REVISED SEPTEMBER 1990

electrical characteristics, $V_{CC} = 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	DADAMETED	TTOT COMPUTIONS!			LM2900			LM3900		
	PARAMETER	TEST C	ONDITIONST	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
1	Input bias current (inverting input)	1. 0	T _A = 25°C		30	200		30	200	- 1
IB	input bias current (inverting input)	l ₁₊ = 0	T _A = Full range		300			300		nA
	Mirror gain	l _{j+} = 20 μA t T _A = Full ran		0.9		1.1	0.9		1.1	μ Α /μΑ
	Change in mirror gain	See Note 4	90,		2%	5%		2%	5%	
	Mirror current	V _{I +} = V _I , See Note 4	T _A = Full range,		10	500		10	500	μΑ
AVD	Large-signal differential voltage amplification	V _O = 10 V, f = 100 Hz	$R_L = 10 \text{ k}\Omega$,	1.2	2.8		1.2	2.8		V/mV
rį	Input resistance (inverting input)				1			1		MΩ
ro	Output resistance				8			8		kΩ
B ₁	Unity-gain bandwidth (inverting input)				2.5			2.5		MHz
ksvr	Supply voltage rejection ratio (ΔV _{CC} /ΔV _{IO)}				70			70		. dB
		1. 0	$R_L = 2 k\Omega$	13.5			13.5			
VOH	High-level output voltage	$l_{\parallel +} = 0,$ $l_{\parallel -} = 0$	V _{CC} = 30 V, No load		29.5			29.5		٧
V _{OL}	Low-level output voltage	$I_{I+} = 0$, $R_L = 2 k\Omega$	I _I _= 10 μA,		0.09	0.2		0.09	0.2	٧
los	Short-circuit output current (output internally high)	I _{I+} = 0, V _O = 0	I _I _= 0,	-6	-18		-6	-10		mA
	Pulldown current			0.5	1.3		0.5	1.3		mA
lOL	Low-level output current‡	I _{I —} = 5 μA	V _{OL} = 1 V	-	5			5		mA
ICC	Supply current (four amplifiers)	No load			6.2	10		6.2	10	mA

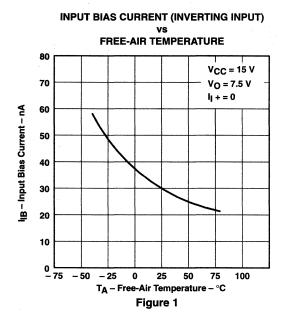
[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for T_A is -40°C to 85°C for LM2900 and 0°C to 70°C for LM3900.

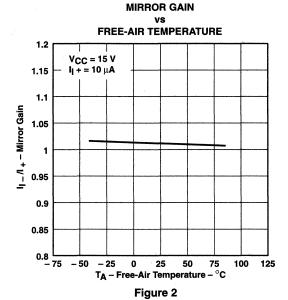
NOTE 4: These parameters are measured with the output balanced midway between V_{CC} and GND.

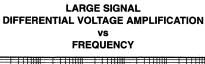
operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

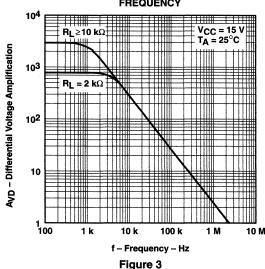
	PARAMETER	7	TEST CONDITION	MIN	TYP	MAX	UNIT		
SR	Claureta at unity gain	Low-to-high output	V- 10 V	C: 100 pF	D. 040		0.5		V/us
l on	Slew rate at unity gain	High-to-low output	$V_0 = 10 V$,	$C_L = 100 pF,$	$R_L = 2 k\Omega$		20		V/μS

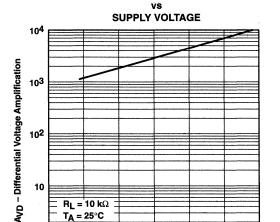
[‡] The output current-sink capability can be increased for large-signal conditions by overdriving the inverting input.











TA = 25°C

5

10

15

V_{CC} - Supply Voltage - V

Figure 4

25

30

0

LARGE SIGNAL

DIFFERENTIAL VOLTAGE AMPLIFICATION

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

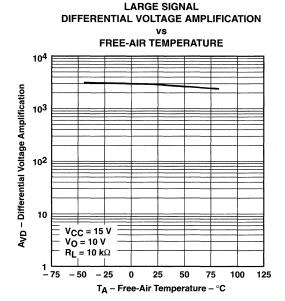


Figure 5

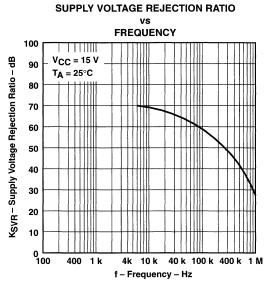
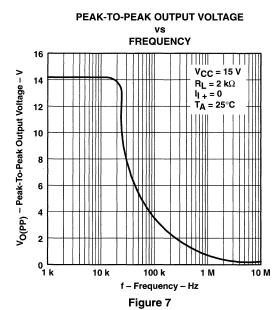
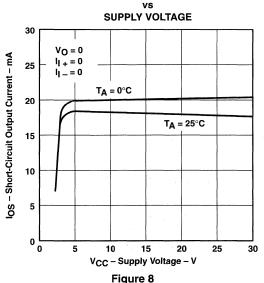


Figure 6

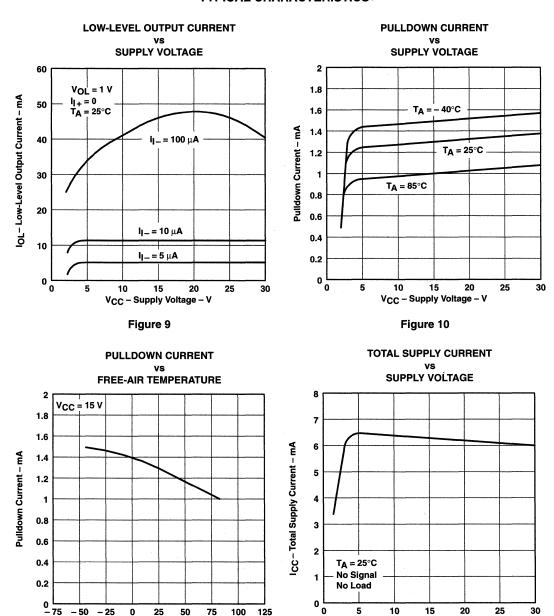


SHORT-CIRCUIT OUTPUT CURRENT (OUTPUT INTERNALLY HIGH)



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





V_{CC} - Supply Voltage - V

Figure 12

125

 T_A – Free-Air Temperature – $^{\circ}$ C

Figure 11



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

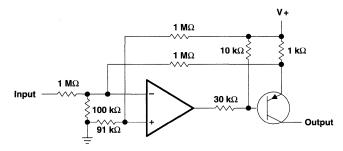
SLOS059 - JULY 1979 - REVISED SEPTEMBER 1990

APPLICATION INFORMATION

Norton (or current-differencing) amplifiers can be used in most standard general-purpose operational amplifier applications. Performance as a dc amplifier in a single-power-supply mode is not as precise as a standard integrated-circuit operational amplifier operating from dual supplies. Operation of the amplifier can best be understood by noting that input currents are differenced at the inverting input terminal and this current then flows through the external feedback resistor to produce the output voltage. Common-mode current biasing is generally useful to allow operating with signal levels near (or even below) ground.

Internal transistors clamp negative input voltages at approximately -0.3 V but the magnitude of current flow has to be limited by the external input network. For operation at high temperature, this limit should be approximately -100 μ A.

Noise immunity of a Norton amplifier is less than that of standard bipolar amplifiers. Circuit layout is more critical since coupling from the output to the noninverting input can cause oscillations. Care must also be exercised when driving either input from a low-impedance source. A limiting resistor should be placed in series with the input lead to limit the peak input current. Current up to 20 mA will not damage the device, but the current mirror on the noninverting input will saturate and cause a loss of mirror gain at higher current levels, especially at high operating temperatures.



I_O ≈ 1 mA per input volt

Figure 13. Voltage-Controlled Current Source

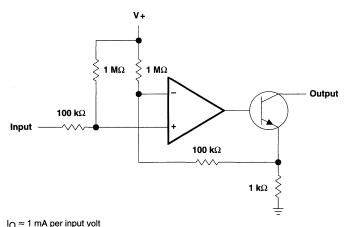


Figure 14. Voltage-Controlled Current Sink



LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

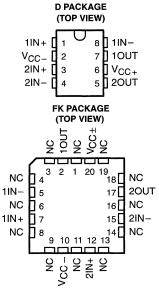
SLOS018B - MAY 1988 - REVISED OCTOBER 1996

- Single-Supply Operation: Input Voltage Range Extends to Ground Output Swings to Ground While Sinking Current
- Input Offset Voltage
 150 μV Max at 25°C for LT1013A
- Offset Voltage Temperature Coefficient 2.5 μV/°C Max for LT1013A
- Input Offset Current
 0.8 nA Max at 25°C for LT1013A
- High Gain . . . 1.5 V/ μ V Min (R_L = 2 kΩ), 0.8 V/ μ V Min (R_I = 600 kΩ) for LT1013A
- Low Supply Current . . . 0.5 mA Max at T_Δ = 25°C for LT1013A
- Low Peak-to-Peak Noise Voltage 0.55 μV Tvp
- Low Current Noise . . . 0.07 pA/√HZ Typ

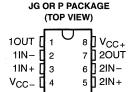
description

The LT1013 is a dual precision operational amplifier featuring low offset voltage temperature coefficient, high gain, low supply current, and low noise.

The LT1013 can be operated from a single 5-V power supply; the common-mode input voltage range includes ground, and the output can also swing to within a few millivolts of ground. Crossover distortion is eliminated. The LT1013 can be operated with both dual ± 15 -V and single 5-V supplies.



NC - No internal connection



The LT1013C and LT1013AC, and LT1013D are characterized for operation from 0° C to 70° C. The LT1013I and LT1013AI, and LT1013DI are characterized for operation from -40° C to 105° C. The LT1013M and LT1013AM, and LT1013DM are characterized for operation over the full military temperature range of -55° C to 125° C.

LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

SLOS018B - MAY 1988 - REVISED OCTOBER 1996

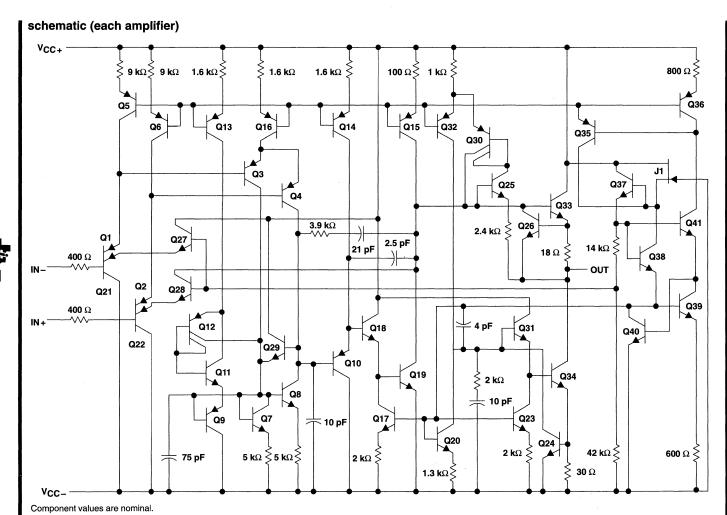
AVAILABLE OPTIONS

			WAILABLE OF HORO			
	V _{IO} max		PACKAGE	DEVICES		CHIP FORM
TA	AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	(Y)
	150 μV	_		_	LT1013ACP	
0°C to 70°C	300 μV	_	_	_	LT1013CP	LT1013Y
	800 μV	LT1013DD			LT1013DP	
	150 μV	_	_		LT1013AIP	
-40°C to 105°C	300 μV	_		_	LT1013IP	-
	800 μV	LT1013DID	_	_	LT1013DIP	
	150 μV	_	LT1013AMFK	_	LT1013AMP	
-55°C to 125°C	300 μV	_	LT1013MFK	LT1013MJG	LT1013MP	l -
	800 μV	LT1013DMD	_	LT1013DMJG	LT1013DMP	

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LT1013DDR).

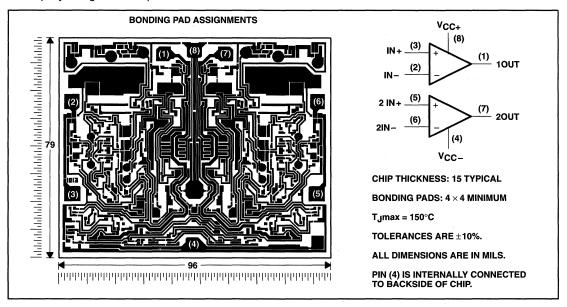
LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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LT1013Y chip information

This chip, when properly assembled, displays characteristics similar to the LT1013. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+} (see Note 1)	22 V
Supply voltage, V _{CC} (see Note 1)	
Differential input voltage (see Note 2)	
Input voltage range, V _I (any input, see Note 1)	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Operating free-air temperature range, T _A : LT1013C, LT1013AC, LT1013D	0 °C to 70°C
LT1013I, LT1013AI, LT1013DI –40	0°C to 105°C
LT1013M, LT1013AM, LT1013DM –55	°C to 125°C
Storage temperature range –65	°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds: JG package	300°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VCC+ and VCC-.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The output may be shorted to either supply.

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V, V_{IC} = 0 (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	T. +	ı	LT1013C		Ľ	T1013AC	;	L	T1013DC	:	UNIT
	PARAMETER	1231 00	MULLIONS	T _A †	MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	UNII
VIO	Input offset voltage	$R_S = 50 \Omega$		25°C		60	300		40	150		200	800	μV
VIO		115 = 30 12		Full range			400			240			1000	μν
ανιο	Temperature coefficient of input offset voltage			Full range		0.4	2.5		0.3	2		0.7	5	μV/°C
	Long-term drift of input offset voltage			25°C		0.5			0.4			0.5		μV/mo
lio	Input offset current			25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
טוי	input onset current			Full range			2.8			1.5			2.8	шА
I _{IB}	Input bias current			25°C		-15	-30		-12	-20		15	-30	nA
'IB	mput pias current			Full range			-38			-25			-38	ш
1					-15	-15.3		-15	-15.3		-15	-15.3		
				25°C	13.5	to 13.8		to 13.5	to 13.8		to 13.5	to 13.8		
VICR	Common-mode input voltage range				-15	10.0		-15			-15	10.0		٧
			Full range	to			to			to				
					13			13			13			
VOM	Maximum peak output voltage swing	$R_1 = 2 k\Omega$		25°C	±12.5	±14		±13	±14		±12.5	±14		V
VOM	waxiindiii peak odipat voitage swilig	11L - 2 K32		Full range	±12			±12.5			±12			•
	Love simple differential voltage	$V_0 = \pm 10 \text{ V},$	$R_L = 600 \Omega$	25°C	0.5	0.2		0.8	2.5		0.5	2		
AVD	Large-signal differential voltage amplification	$V_{O} = \pm 10 \text{ V},$	Br = 2 kO	25°C	1.2	7		1.5	8		1.2	7		V/µV
		VO = ± 10 V,	11[= 2 1/22	Full range	0.7			1			0.7			
CMRR	Common-mode rejection ratio	$V_{IC} = -15 V$	to 13.5 V	25°C	97	114		100	117		97	114		dB
Civil II I		$V_{IC} = -14.9$	V to 13 V	Full range	94			98			94			<u> </u>
KSVR	Supply-voltage rejection ratio	V _{CC+} = ±2 \	/ to + 18 V	25°C	100	117		103	120	ut.	100	117		dB
OVII	(ΔV _{CC} /ΔV _{IO})	VCC+	7 to ± 10 V	Full range	97			101			97			ub_
	Channel separation	$V_0 = \pm 10 \text{ V},$	$R_L = 2 k\Omega$	25°C	120	137		123	140		120	137		dB
^r id_	Differential input resistance			25°C	70	300		100	400		70	300		МΩ
r _{ic}	Common-mode input resistance			25°C		4			5			4		GΩ
lcc	Supply current per amplifier			25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
1.00	Supply surrout per uniphilor			Full range			0.7			0.55			0.6	****

[†] Full range is 0°C to 70°C. ‡ All typical values are at T_A = 25°C.

electrical characteristics at specified free-air temperature, $V_{CC+} = 5 \text{ V}$, $V_{CC-} = 0$, $V_{O} = 1.4 \text{ V}$, $V_{IC} = 0$ (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	TAT	L	.T1013C		L	T1013A0	;	Lī	1013DC	;	UNIT
	PANAMETEN	TEST CON	DITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
Via	Input offset voltage	R _S = 50 Ω		25°C		90	450		60	250		250	950	μV
VIO	input onset voltage	HS = 50 12		Full range			570			350			1200	μν
10	Input offset current			25°C		0.3	2		0.2	1.3		0.3	2	nA
10	input onset ourient		·	Full range			6			3.5			6	11/4
I _{IB}	Input bias current			25°C		-18	-50		-15	-35		-18	-50	nA
'IB	input blue current			Full range			-90			-55			-90	
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	Common-mode input voltage	·		25°C	0 to 3.5	-0.3 to 3.8		0 to 3.5	-0.3 to 3.8		0 to 3.5	0.3 to 3.8		
VICR	range			Full range	0 to 3			0 to 3			0 to 3			V
		Output low,	No load	25°C		15	25		15	25		15	25	
		Output low,		25°C		5	10		5	10		5	10	mV
İ	Marchaelland	$R_L = 600 \Omega$ to GNI	D	Full range			13			13			13	1114
V _{OM}	Maximum-peak output voltage swing	Output low,	I _{sink} = 1 mA	25°C		220	350		220	350		220	350	
		Output high,	No load	25°C	4	4.4		4	4.4		4	4.4		
1 .		Output high,		25°C	3.4	4		3.4	4		3.4	- 4		V
		$R_L = 600 \Omega$ to GNI)	Full range	3.2			3.3			3.2			
A _{VD}	Large-signal differential voltage amplification	$V_O = 5 \text{ mV to 4 V},$	$R_L = 500 \Omega$	25°C		1			1			1		V/μV
laa	Supply current per amplifier			25°C		0.32	0.5		0.31	0.45		0.32	0.5	mA
lcc	Supply current per ampliner			Full range			0.55			0.5			0.55	ША

[†] Full range is -0°C to 70°C.

operating characteristics, $V_{CC\pm}$ =±15 V, V_{IC} = 0, T_A = 25°C

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate		0.2	0.4		V/μs
V	Equivalent input noise voltage	f = 10 Hz		24		nV/√Hz
V _n	Equivalent input noise voitage	f = 1 kHz		22		nv/vHz
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.55		μV
In	Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

OS018B - MAY 1988 - REVISED OCTOBER 1996

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V, V_{IC} = 0 (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	T. +		LT1013I		L	T1013A		L	T1013D		UNIT
	PARAMETER	1231 CONDITIONS	T _A †	MIN	TYP‡	MAX	MIN	ТҮР‡	MAX	MIN	TYP‡	MAX	UNIT
VIO	Input offset voltage	R _S = 50 Ω	25°C		60	300		40	150		200	800	μV
VIO	input onset voltage	115 = 30 32	Full range			550			300			1000	μν
αVIO	Temperature coefficient of input offset voltage		Full range		0.4	2.5		0.3	2		0.7	5	μV/°C
	Long-term drift of input offset voltage		25°C		0.5			0.4			0.5		μ V/m o
1	Input offset surrent		25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
lio -	Input offset current		Full range			2.8			1.5			2.8	nA
lun	Input bias current		25°C		-15	-30		-12	-20		-15	-30	nA
lВ	input bias current		Full range			-38			-25			-38	11/4
			25°C	-15 to 13.5	-15.3 to 13.8		-15 to 13.5	-15.3 to 13.8		-15 to 13.5	-15.3 to 13.8		
VICR	Common-mode input voltage range		Full range	-15 to 13		:	-15 to 13			-15 to 13			V
V _{ОМ}	Maximum peak output voltage swing	R _L = 2 kΩ	25°C Full range	±12.5	±14		±13	±14		±12.5	±14		٧
		$V_{O} = \pm 10 \text{ V}, R_{I} = 600 \Omega$	25°C	0.5	0.2		0.8	2.5		0.5	2		
AVD	Large-signal differential voltage amplification		25°C	1.2	7		1.5	8		1.2	7		V/μV
	amplification	$V_O = \pm 10 \text{ V}, \qquad R_L = 2 \text{ k}\Omega$	Full range	0.7			1			0.7			
CMRR	Common-mode	V _{IC} = -15 V to 13.5 V	25°C	97	114		100	117		97	114		dB
CIVIAN	rejection ratio	V _{IC} = -14.9 V to 13 V	Full range	94			97			94			UВ
ksvr	Supply-voltage rejection ratio	$\dot{V}_{CC+} = \pm 2 \text{ V to } \pm 18 \text{ V}$	25°C	100	117		103	120		100	117		dB
"SVA	(ΔVCC/ΔVIO)	ACC = 15 A 10 1 19 A	Full range	97			101			97			UB
	Channel separation	$V_0 = \pm 10 \text{ V}, R_L = 2 \text{ k}\Omega$	25°C	120	137		123	140		120	137		dB
rid	Differential input resistance		25°C	70	300		100	400		70	300		MΩ
ric	Common-mode input resistance		25°C		4			5			4		GΩ
Icc	Supply current per amplifier		25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
	- Spp., ca		Full range			0.7			0.55			0.6	

[†] Full range is -40°C to 105°C. ‡ All typical values are at T_A = 25°C.

	DADAMETED	TEST CON	IDITIONS	- +		T1013I		Ľ	T1013AI		Ľ	T1013DI		UNIT
	PARAMETER	TEST CON	IDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
Ţ,	l	D- 50.0		25°C		90	450		60	250		250	950	μV
VIO	Input offset voltage	R _S = 50 Ω		Full range			570			350			1200	μν
lio	Input offset current			25°C		0.3	2		0.2	1.3		0.3	2	nA
10	input onset current			Full range			6			3.5			6	
li-	Input bias current			25°C		-18	-50		-15	-35		-18	-50	nA
IВ	input bias current			Full range			-90			-55			-90	
					0	-0.3		0	-0.3		0	0.3		
				25°C	to 3.5	to 3.8		to 3.5	to 3.8		to 3.5	to 3.8		
VICR	Common-mode input voltage range					3.0			3.0			3.0		· v
	range			Full range	0 to			0 to			0 to			
					3			3			3		<i>'</i>	
		Output low,	No load	25°C		15	25		15	25		15	25	
		Output low,		25°C		5	10		5	10		5	10	mV
		$R_L = 600 \Omega$ to GN	ID	Full range			13			13			13	"""
Vом	Maximum-peak output voltage swing	Output low,	I _{sink} = 1 mA	25°C		220	350		220	350		220	350	
	Swing	Output high,	No load	25°C	4	4.4		4	4.4		4	4.4		
		Output high,		25°C	3.4	4		3.4	4		3.4	4		ν
		$R_L = 600 \Omega$ to GN	D	Full range	3.2			3.3			3.2			
AVD	Large-signal differential voltage amplification	$V_O = 5 \text{ mV to 4 V},$	R _L = 500 Ω	25°C		1			1			1		V /μ V
loo	Supply current per amplifier			25°C		0.32	0.5		0.31	0.45		0.32	0.5	mA
Icc	Supply current per ampliner			Full range			0.55			0.5			0.55	111/4
t Eull ron	nge is _40°C to 105°C													

† Full range is -40°C to 105°C.

operating characteristics, $V_{CC\pm}$ = ± 15 V, V_{IC} = 0, T_A = $25^{\circ}C$

	PARAMETER TEST CO	ONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate		0.2	0.4		V/μs
V	f = 10 Hz			24		nV/√Hz
V _n	Equivalent input noise voltage f = 1 kHz			22		Π V /∀HZ
V _{N(PP)}	Peak-to-peak equivalent input noise voltage f = 0.1 Hz	to 10 Hz		0.55		μV
In	Equivalent input noise current f = 10 Hz			0.07		pA/√Hz

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V, V_{IC} = 0 (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS	- +	ī	.T1013M		Ľ	Γ1013AN	ı	Ľ	T1013DN	1	UNIT
	PARAMETER	I ESI CON	ADITIONS	TA [†]	MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	UNII
V-0	Input offset voltage	$R_S = 50 \Omega$		25°C		60	300		40	150		200	800	μV
VIO	input onset voltage	ng = 50 12		Full range			550			300			1000	μν
ανιο	Temperature coefficient of input offset voltage			Full range		0.5	2.5*		0.4	2*		0.5	2.5*	μV/°C
	Long-term drift of input offset voltage			25°C		0.5			0.4			0.5		μV/mo
li a	Input offset current			25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
lio	input onset current			Full range			5			2.5			5	nA.
1	Input bias current			25°C		-15	-30		-12	-20		-15	-30	nA
lВ	input bias current			Full range			-45			-30			-45	IIA
					-15	-15.3		-15	-15.3		-15	-15.3		
1	!			25°C	to	to		to 13.5	to		to	to		
VICR	Common-mode input voltage range				13.5	13.8			13.8		13.5	13.8		V
	ł			Full range	-14.9 to			-14.9 to			-14.9 to			
	l				13			13			13			
V		D: 040		25°C	±12.5	±14		±13	±14		±12.5	±14		V
VOM	Maximum peak output voltage swing	R _L = 2 kΩ		Full range	±11.5			±12			±11.5			V
		$V_0 = \pm 10 \text{ V},$	$R_L = 600 \Omega$	25°C	0.5	2		0.8	2.5		0.5	2		
AVD	Large-signal differential voltage amplification	V _O = +10 V,	D: 0 k0	25°C	1.2	7		1.5	8		1.2	7		√/μ√
	amplification	VO = + 10 V,	HL = 2 K12	Full range	0.25			0.5			0.25			
CMRR	Common-mode rejection ratio	V _{IC} = -15 V to	o 13.5 V	25°C	97	117		100	117		97	114		dB
CIVIAN	Common-mode rejection ratio	V _{IC} = -14.9 V	' to 13 V	Full range	94			97			94			uБ
kay ra	Supply-voltage rejection ratio	V _{CC+} = ±2 V	to ±10 \/	25°C	100	117		103	120		100	117		dB
ksvr	(ΔVCC/ΔVIO)	ACC = TS A	10 ± 10 V	Full range	97			100			97			uБ
	Channel separation	$V_{O} = \pm 10 \text{ V},$	$R_L = 2 k\Omega$	25°C	120	137		123	140		120	137		dB
rid	Differential input resistance			25°C	70	300		100	400		70	300		MΩ
ric	Common-mode input resistance			25°C		4			5			4		GΩ
loo	Supply current per amplifier			25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
lcc .	Supply culterit per ampliner			Full range			0.7			0.6			0.7	""

^{*} On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested. † Full range is –55°C to 125°C. ‡ All typical values are at T_A = 25°C.

electrical characteristics at specified free-air temperature, $V_{CC+} = 5 \text{ V}$, $V_{CC-} = 0$, $V_{O} = 1.4 \text{ V}$, $V_{IC} = 0$ (unless otherwise noted)

	•		•	, 00	-	-		•		•				
	DADAMETED	TEST COND	UTIONS	T. +	L	T1013M		Lī	1013AN	A	Lī	1013DN	٨	UNIT
	PARAMETER	IEST CONL	IIIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
		Po - 50.0		25°C		90	450		60	250		250	950	
VIO	Input offset voltage	$R_S = 50 \Omega$		Full range		400	1500		250	900		800	2000	μV
		$R_S = 50 \Omega$,	V _{IC} = 0.1 V	125°C		200	750		120	450		560	1200	
l. a	Input offset current			25°C		0.3	2		0.2	1.3		0.3	2	nA
lio	input onset current			Full range			10			6			10	IIA
	Input bias current			25°C		-18	-50		-15	-35		-18	-50	nA
lВ	input bias current	-		Full range			-120			-80			-120	IIA
-					0	-0.3		0	-0.3		0	-0.3		
				25°C	to	to		to	to		to	to	ŀ	ĺ
VICR	Common-mode input voltage				3.5	3.8		3.5	3.8		3.5	3.8		v
1011	range			Full range	0			0			0		ļ	ĺ
				Full range	to 3			to 3			to 3			1
		Output low,	No load	25°C		15	25		15	25		15	25	
		Output low,		25°C		5	10		5	10		5	10	mV
		$R_L = 600 \Omega$ to GNI)	Full range			18			15			18	mv
VOM	Maximum-peak output voltage swing	Output low,	I _{sink} = 1 mA	25°C		220	350		220	350		220	350	ĺ
	Swilly	Output high,	No load	25°C	4	4.4		4	4.4		4	4.4		
		Output high,		25°C	3.4	4		3.4	4		3.4	4		√/μ√
		$R_L = 600 \Omega$ to GNI		Full range	3.1			3.2			3.1			-
A _{VD}	Large-signal differential voltage amplification	$V_O = 5 \text{ mV to 4 V},$	R _L = 500 Ω	25°C		1			1			1		
	0 1 1:5			25°C		0.32	0.5		0.31	0.45		0.32	0.5	mA
Icc	Supply current per amplifier			Full range			0.65			0.55			0.65	ĺ

[†] Full range is -55°C to 125°C.

operating characteristics, $V_{CC\pm}$ = ± 15 V, V_{IC} = 0, T_A = $25^{\circ}C$

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate		0.2	0.4		V/μs
.,		f = 10 Hz		24		nV/√ Hz
V _n	Equivalent input noise voltage	f = 1 kHz		22		nv/√Hz
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.55		μV
In	Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

SLOS018B - MAY 1988 - REVISED OCTOBER 199

LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at $V_{CC+} = 5 \text{ V}$, $V_{CC-} = 0$, $V_O = 1.4 \text{ V}$, $V_{IC} = 0$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		LT1013Y			
		IESI CC	TEST CONDITIONS		TYP	MAX	UNIT
VIO	Input offset voltage	$R_S = 50 \Omega$			250	950	μV
10	Input offset current				0.3	2	nA
Iв	Input bias current				-18	-50	nA
VICR	Common-mode input voltage range			0 to 3.5	0.3 to 3.8		٧
V _{ОМ}	Maximum peak output voltage swing	Output low,	No load		15	25	mV
		Output low,	$R_L = 600 \Omega$ to GND		5	10	
		Output low,	I _{sink} = 1 mA		220	350	
		Output high,	No load	4	4.4		V
		Output high,	$R_L = 600 \Omega$ to GND	3.4	4		
A _{VD}	Large-signal differential voltage amplification	$V_0 = 5 \text{ mV to 4 V},$	R _L = 500 Ω		1		V/µV
Icc	Supply current per amplifier				0.32	0.5	mA

electrical characteristics at $V_{CC+}=\pm15$ V, $V_{IC}=0$, $T_A=25^{\circ}C$ (unless otherwise noted)

PARAMETER		TEST COL	TEST CONDITIONS		LT1013Y		
		IESI COI			TYP	MAX	UNIT
VIO	Input offset voltage	$R_S = 50 \Omega$			200	800	μV
	Long-term drift of input offset voltage				0.5		μV/mo
lo	Input offset current				0.2	1.5	nA
lв	Input bias current				-15	-30	nA
ViCR	Common-mode input voltage range			-15 to 13.5	-15.3 to 13.8		V
VOM	Maximum peak output voltage swing	$R_L = 2 k\Omega$	$R_L = 2 k\Omega$		±14		٧
۸. ۲۵	Large-signal differential voltage amplification	$V_{O} = \pm 10 \text{ V},$	$R_L = 600 \Omega$	0.5	2		V/µV
AVD		VO = ± 10 V,	$R_L = 2 \Omega$	1.2	7		dB
CMRR	Common-mode rejection ratio	V _{IC} = -15 V to	V _{IC} = -15 V to 13.5 V		114		l ub
ksvr	Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO})	V _{CC±} = ±2 V	to ±18 V	100	117		dB
	Channel separation	$V_0 = \pm 10 \text{ V},$	R _L = 2 Ω	120	137		dB
^r id	Differential input resistance			70	300		MΩ
ric	Common-mode input resistance				4		GΩ
ICC	Supply current per amplifier				0.35	0.55	mA

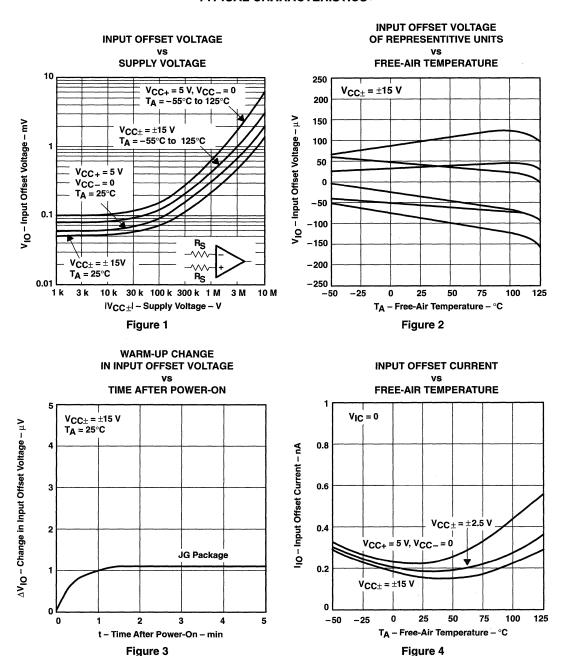
operating characteristics, $V_{CC}\pm=\pm15$ V, $V_{IC}=0$, $T_A=25^{\circ}C$

PARAMETER		TEST CONDITIONS	LT1013Y			UNIT
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate		0.2	0.4		V/μs
Vn	Equivalent input noise voltage	f = 10 Hz		24		nV/√Hz
		f = 1 kHz		22		nv/√Hz
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.55		μV
In	Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

Table of Graphs

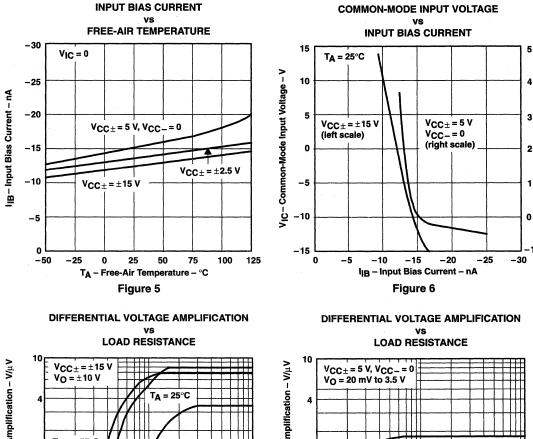
		FIGURE	
V _{IO}	Input offset voltage	vs Source resistance vs Temperature	1 2
ΔVΙΟ	Change in input offset voltage	vs Time	3
lο	Input offset current	vs Temperature	4
IB	Input bias current	vs Temperature	. 5
V _{IC}	Common-mode input voltage	vs Input bias current	6
AVD	Differential voltage amplification	vs Load resistance vs Frequency	7, 8 9, 10
	Channel separation	vs Frequency	11
	Output saturation voltage	vs Temperature	12
CMRR	Common-mode rejection ratio	vs Frequency	13
ksvr	Supply voltage rejection ratio	vs Frequency	14
ICC	Supply current	vs Temperature	15
los	Short-circuit output current	vs Time	16
Vn	Equivalent input noise voltage	vs Frequency	17
In	Equivalent input noise current	vs Frequency	17
V _{n(PP)}	Peak-to-peak input noise voltage	vs Time	18
	Pulse response	Small signal Large signal	19, 21 20, 22, 23
	Phase shift	vs Frequency	9

TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





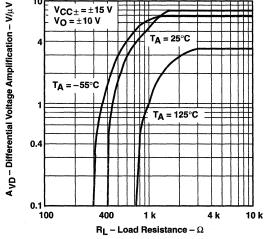
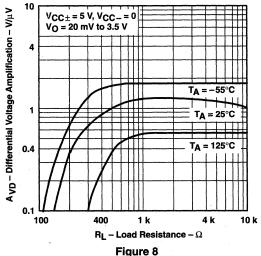


Figure 7

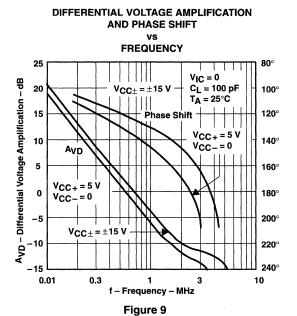


Common-Mode Input Voltage -

VIC-

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



vs **FREQUENCY** 140 $C_L = 100 pF$ Avp - Differential Voltage Amplification - dB TA = 25°C 120 100 V_{CC+} = 5 V V_{CC±} = ±15 V $V_{CC} = 0$ 80 60 40 20 0

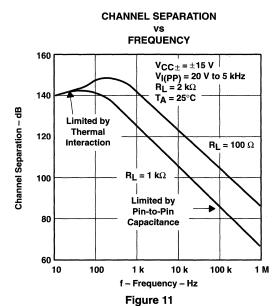
DIFFERENTIAL VOLTAGE AMPLIFICATION

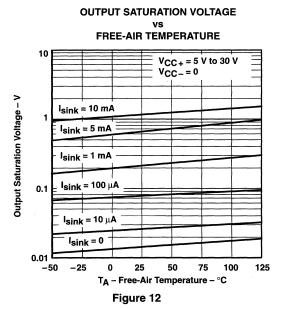
Figure 10

f - Frequency - Hz

1 k 10 k 100 k 1 M 10 M

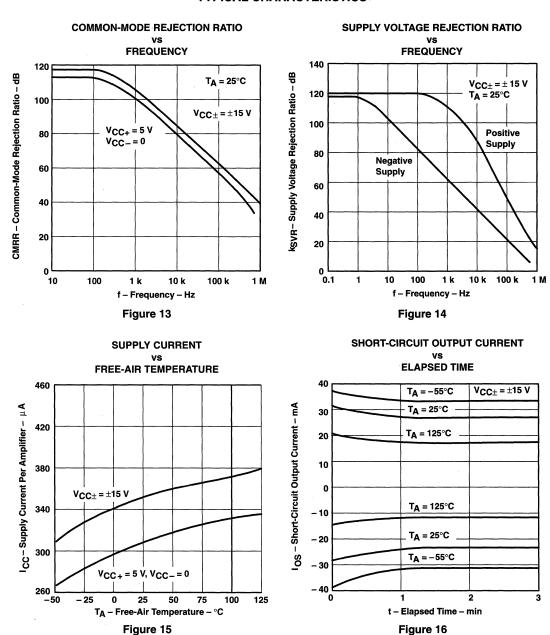
0.01 0.1





† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



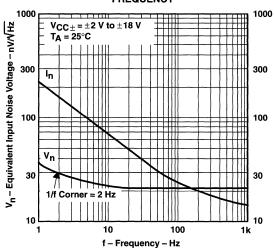


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



EQUIVALENT INPUT NOISE VOLTAGE AND EQUIVALENT INPUT NOISE CURRENT

vs **FREQUENCY**



PEAK-TO-PEAK INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD

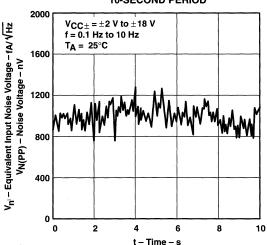


Figure 17

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

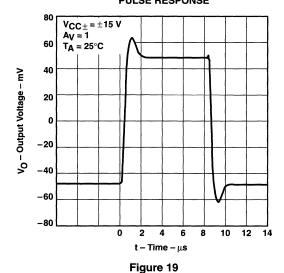


Figure 18

VOLTAGE-FOLLOWER LARGE-SIGNAL **PULSE-RESPONSE**

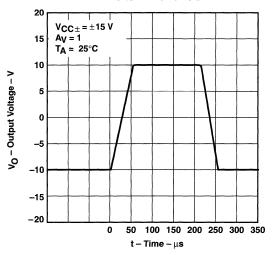
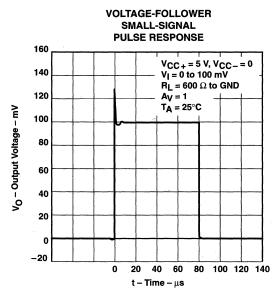


Figure 20





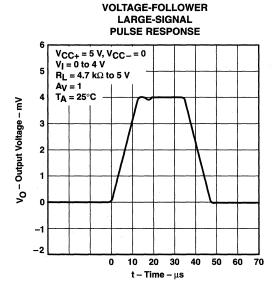


Figure 21

Figure 22



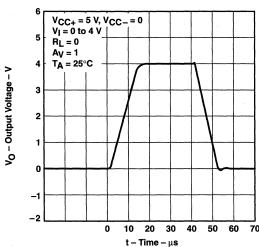


Figure 23

APPLICATION INFORMATION

single-supply operation

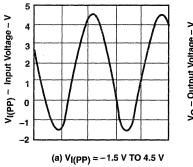
The LT1013 is fully specified for single-supply operation (V_{CC} = 0). The common-mode input voltage range includes ground, and the output swings to within a few millivolts of ground.

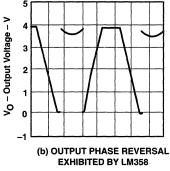
Furthermore, the LT1013 has specific circuitry that addresses the difficulties of single-supply operation, both at the input and at the output. At the input, the driving signal can fall below 0 V, either inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, the LT1013 is designed to deal with the following two problems that can occur:

- On many other operational amplifiers, when the input is more than a diode drop below ground, unlimited current will flow from the substrate (V_{CC} terminal) to the input, which can destroy the unit. On the LT1013, the 400- Ω resistors in series with the input (see schematic) protect the device even when the input is 5 V below ground.
- 2. When the input is more than 400 mV below ground (at T_A = 25°C), the input stage of similar type operational amplifiers saturates and phase reversal occurs at the output. This can cause lock up in servo systems. Because of a unique phase-reversal protection circuitry (Q21, Q22, Q27, and Q28), the LT1013 outputs do not reverse, even when the inputs are at -1.5 V (see Figure 24).

This phase-reversal protection circuitry does not function when the other operational amplifier on the LT1013 is driven hard into negative saturation at the output. Phase-reversal protection does not work on amplifier 1 when 2's output is in negative saturation or on amplifier 2 when 1's output is in negative saturation.

At the output, other single-supply designs either cannot swing to within 600 mV of ground or cannot sink more than a few microproamperes while swinging to ground. The all-NPN output stage of the LT1013 maintains its low output resistance and high gain characteristics until the output is saturated. In dual-supply operations, the output stage is free of crossover distortion.





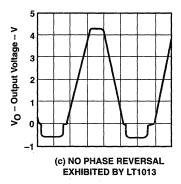
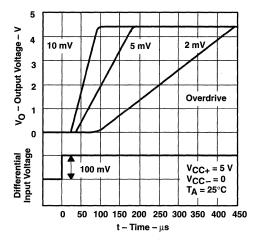


Figure 24. Voltage-Follower Response With Input Exceeding the Negative Common-Mode Input Voltage Range

APPLICATION INFORMATION

comparator applications

The single-supply operation of the LT1013 lends itself for use as a precision comparator with TTL-compatible output. In systems using both operational amplifiers and comparators, the LT1013 can perform multiple duties. Refer to Figures 25 and 26.



V_{CC}+ = 5 V V_{CC}- = 0 T_A = 25°C 10 mV 5 mV 2 mV 0 50 100 150 200 250 300 350 400 450 t - Time - µs

Figure 25. Low-to-High-Level Output Response for Various Input Overdrives

Figure 26. High-to-Low-Level Output Response for Various Input Overdrives

low-supply operation

The minimum supply voltage for proper operation of the LT1013 is 3.4 V (three Ni-Cad batteries). Typical supply current at this voltage is 290 µA; therefore, power dissipation is only 1 mW per amplifier.

offset voltage and noise testing

The test circuit for measuring input offset voltage and its temperature coefficient is shown in Figure 30. This circuit with supply voltages increased to ± 20 V is also used as the burn-in configuration.

The peak-to-peak equivalent input noise voltage of the LT1013 is measured using the test circuit shown in Figure 27. The frequency response of the noise tester indicates that the 0.1-Hz corner is defined by only one zero. The test time to measure 0.1-Hz to 10-Hz noise should not exceed 10 seconds, as this time limit acts as an additional zero to eliminate noise contribution from the frequency band below 0.1 Hz.

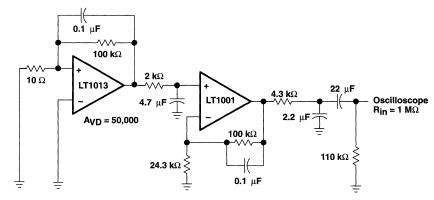
An input noise voltage test is recommended when measuring the noise of a large number of units. A 10-Hz input noise voltage measurement correlates well with a 0.1-Hz peak-to-peak noise reading because both results are determined by the white noise and the location of the 1/f corner frequency.

Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.



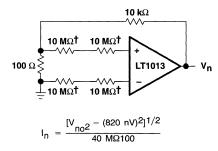
APPLICATION INFORMATION

offset voltage and noise testing (continued)



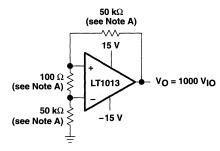
NOTE A: All capacitor values are for nonpolarized capacitors only.

Figure 27. 0.1-Hz to 10-Hz Peak-to-Peak Noise Test Circuit



† Metal-film resistor

Figure 28. Noise-Current Test Circuit and Formula

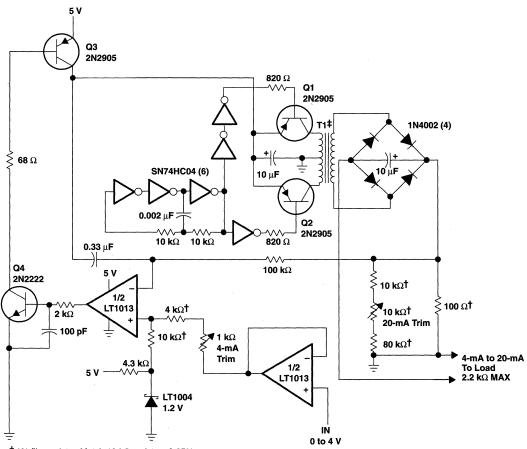


NOTE A: Resistors must have low thermoelectric potential.

Figure 29. Test Circuit for V_{IO} and αV_{IO}

APPLICATION INFORMATION

typical applications



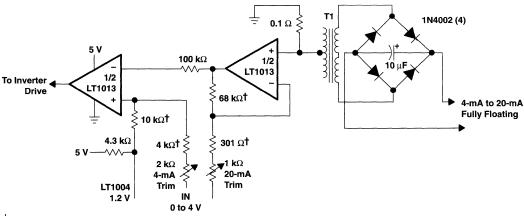
^{† 1%} film resistor. Match 10-k Ω resistors 0.05%.

Figure 30. 5-V 4-mA - 20-mA Current Loop Transmitter With 12-Bit Accuracy

[‡]T1 = PICO-31080

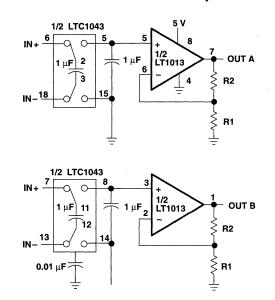
SLOS018B - MAY 1988 - REVISED OCTOBER 1996

APPLICATION INFORMATION



† 1% film resistor

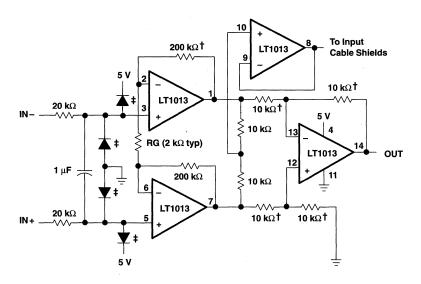
Figure 31. Fully Floating Modification to 4-mA – 20-mA Current Loop Transmitter With 8-Bit Accuracy



NOTE A: V_{IO} = 150 μ V, A_{VD} = (R1/R2) + 1, CMRR = 120 dB, V_{ICR} = 0 to 5 V

Figure 32. 5-V Single-Supply Dual Instrumentation Amplifier

APPLICATION INFORMATION



^{† 1%} film resistor. Match 10-k Ω resistors 0.05%.

NOTE A: $A_{VD} = (400,000/RG) + 1$

Figure 33. 5-V Precision Instrumentation Amplifier

[‡] For high source impedances, use 2N2222 as diodes.

MC1458, MC1558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS069 - FEBRUARY 1971 - REVISED OCTOBER 1990

- Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-Up
- Designed to Be Interchangeable With Motorola MC1558/MC1458 and Signetics \$5558/N5558

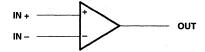
description

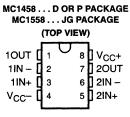
The MC1458 and MC1558 are dual general-purpose operational amplifiers with each half electrically similar to the μ A741 except that offset null capability is not provided.

The high-common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

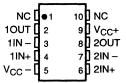
The MC1458 is characterized for operation from 0°C to 70°C. The MC1558 is characterized for operation over the full military temperature range of –55°C to 125°C.

symbol (each amplifier)

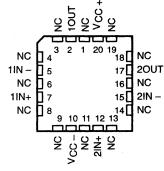




MC1558...U PACKAGE (TOP VIEW)



MC1558...FK PACKAGE (TOP VIEW)



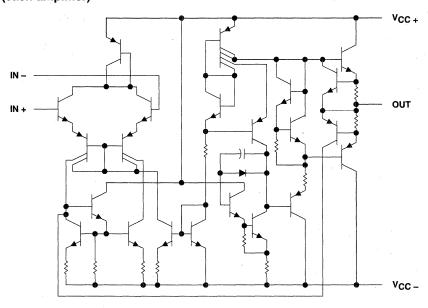
NC - No internal connection

AVAILABLE OPTIONS

ı				PACKAGE							
	TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	CERAMIC FLAT PACK (U)				
	0°C to 70°C	6 mV	MC1458CD	_		MC1458CP	<u> </u>				
I	-55°C to 125°C	5 mV	_	MC1558MFK	MC1558MSG	_	MC1558MU				

The D packages are available taped and reeled. Add the suffix R to the device type (i.e., MC1458DR)

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

,		MC1458	MC1558	UNIT	
Supply voltage V _{CC} + (see Note 1)		18	22	V	
Supply voltage V _{CC} – (see Note 1)		-18	-22	V	
Differential input voltage (see Note 2)		±30	±30	V	
Input voltage at either input (see Notes 1 and 3)		±15	±15	٧	
Duration of output short circuit (see Note 4)		unlimited	unlimited		
Continuous total dissipation		See Diss	See Dissipation Rating Tab		
Operating free-air temperature range		0 to 70	-55 to 125	°C	
Storage temperature range		65 to 150	-65 to 150	°C	
Case temperature for 60 seconds: FK package			260	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG or U package		300	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260		, °C	

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC} + and V_{CC} -.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- 4. The output can be shorted to ground or either power supply. For the MC1558 only, the unlimited duration of the short circuit applies at (or below) 125°C case temperature or 70°C free-air temperature.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 125°C POWER RATING
D	680 mW	5.8 mW/°C	33°C	464 mW	
FK	680 mW	11.0 mW/°C	88°C	880 mW	275 mW
JG	680 mW	8.4 mW/°C	69°C	672 mW	210 mW
Р	680 mW	8.0 mW/°C	65°C	640 mW	
U	675 mW	5.4 mW/°C	25°C	432 mW	135 mW



MC1458, MC1558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

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recommended operating conditions

	MIN	NOM MAX	UNIT
Supply voltage, V _{CC±}	±5	±15	V

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = $\pm 15~V$

	DADAMETED			+	ı	MC1458		ı	AC1558		UNIT
	PARAMETER	IESI	CONDITIONS	51	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V	Innut offeet veltoes	V- 0		25°C		1	6		1	5	mV
V _{IO}	Input offset voltage	VO = 0		Full range			7.5			6	mv
1	In	\\- 0		25°C		20	200		20	200	^
ΙO	Input offset current	VO = 0		Full range			300			500	nA
1	In a state of a summer	\\- 0		25°C		80	500		- 80	500	nA
lΒ	Input bias current	VO = 0		Full range			800			1500	11/
V	Common-mode input			25°C	±12	±13		±12	±13		٧
VICR	voltage range			Full range	±12			±12			v
		$R_L = 10 \text{ k}\Omega$		25°C	±12	±14		±12	±14		
\ /	Maximum peak output	R _L ≥ 10 kΩ		Full range	±12			±12			v
νом	voltage swing	$R_L = 2 k\Omega$		25°C	±10	±13		±10	±13		V
		R _L ≥ 2 kΩ		Full range	±10			±10			
۸	Large-signal differential	$R_L \ge 2 k\Omega$,		25°C	20	200		50	200		V/mV
AVD	voltage amplification	$V_0 = \pm 10 \text{ V}$		Full range	15			25			V/mV
ВОМ	Maximum-output-swing bandwidth (closed loop)	$R_L = 2 k\Omega,$ $V_O \ge \pm 10 V,$ $AV_D = 1,$ $THD \ge 5\%$		25°C		14			14		kHz
B ₁	Unity-gain bandwidth			25°C		1			1		MHz
φm	Phase margin	A _{VD} = 1		25°C		65			65		°C
	Gain margin			25°C		11			11		dB
rį	Input resistance			25°C	0.3*	2		0.3*	2		MΩ
ro	Output resistance	V _O = 0,	See Note 5	25°C		75			75		Ω
Cį	Input capacitance			25°C		1.4			1.4		pF
z _{ic}	Common-mode input impedance	f = 20 Hz		25°C		200			200		МΩ
CMRR	Common-mode rejection	VIC = VICE mi	n,	25°C	70	90		70	90		4D
CIVINN	ratio	VO = 0		Full range	70			70			dB
karra	Supply voltage sensitivity	$V_{CC} = \pm 9 \text{ V to}$	±15 V,	25°C		30	150		30	150	μV/V
ksvs	$(\Delta V_{IO}/\Delta V_{CC})$	V _O = 0	•	Full range			150			150	μν/ν
Vn	Equivalent input noise voltage (closed loop)		R _S = 0, BW = 1 Hz	25°C		45			45		nV/√Hz

^{*}This parameter is not production tested.



[†] All characteristics are specified under open-loop operating conditions with zero common-mode input voltage unless otherwise specified. Full range for MC1458 is 0°C to 70°C and for MC1558 is –55°C to 125°C.

NOTE 5: This typical value applies only at frequencies above a few hundred hertz because of the effect of drift and thermal feedback.

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electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (continued)

	PARAMETER		TEST CONDITIONS†		MC1458			MC1558			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	UNII
los	Short-circuit output current			25°C		±25	±40		±25	±40	mA
loo	Cumply ourrant (both amplifiara)	V _O = 0,	No load	25°C		3.4	5.6		3.4	5	mA
lcc	Supply current (both amplifiers)			Full range			6.6			6.6	
Po	Total power dissipation	V= 0	No load	25°C		100	170		100	150	-l mW l
PD	(both amplifiers)	$V_O = 0$,	No load	Full range			200			200	
V _{O1} /V _{O2}	Crosstalk attenuation			25°C		120			120		dB

[†] All characteristics are specified under open-loop operating conditions with zero common-mode input voltage unless otherwise specified. Full range for MC1458 is 0°C to 70°C and for MC1558 is -55°C to 125°C.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CO	NULTIONS	MC1458			MC1558			UNIT	
PAHAMETER		lesi co	TEST CONDITIONS		TYP	MAX	MIN	TYP	MAX	UNII	
t _r	Rise time	$V_{I} = 20 \text{ mV},$	$V_{l} = 20 \text{ mV}, \qquad R_{L} = 2 \text{ k}\Omega,$		0.3			0.3		μs	
	Overshoot factor	C _L = 100 pF,	See Figure 1		5%			5%			
SR	Slew rate at unity gain	V _I = 10 V, C _L = 100 pF,	R _L = 2 kΩ, See Figure 1		0.5			0.5		V/μs	

PARAMETER MEASUREMENT INFORMATION

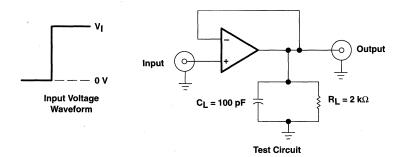
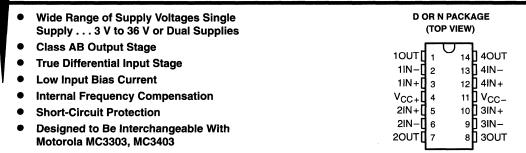


Figure 1. Rise Time, Overshoot, and Slew Rate Waveform and Test Circuit

MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

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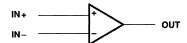


description

The MC3303 and the MC3403 are quadruple operational amplifiers similar in performance to the μ A741 but with several distinct advantages. They are designed to operate from a single supply over a range of voltages from 3 V to 36 V. Operation from split supplies is also possible provided the difference between the two supplies is 3 V to 36 V. The common-mode input range includes the negative supply. Output range is from the negative supply to $V_{CC} = 1.5$ V. Quiescent supply currents are less than one-half those of the μ A741.

The MC3303 is characterized for operation from -40° C to 85° C, and the MC3403 is characterized for operation from 0° C to 70° C.

symbol (each amplifier)

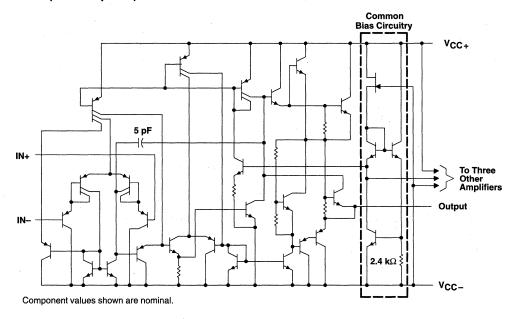


AVAILABLE OPTIONS

	V	PACK	AGE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (N)
0°C to 70°C	10 mV	MC3403D	MC3403N
-40°C to 85°C	8 mV	MC3303D	MC3303N

The D packages are available taped and reeled. Add R suffix to the device type (e.g., MC3403DR).

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	MC3303	MC3403	UNIT
Supply voltage V _{CC+} (see Note 1)	18	18	V
Supply voltage V _{CC} (see Note 1)	-18	-18	٧
Supply voltage V _{CC+} with respect to V _{CC-}	36	36	V
Differential input voltage (see Note 2)	±36	±36	٧
Input voltage (see Notes 1 and 3)	±18	±18	V
Continuous total power dissipation	See Diss	sipation Rating T	able
Operating free-air temperature range	- 40 to 85	0 to 70	°C
Storage temperature range	- 65 to 150	- 65 to 150 - 65 to 150	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

NOTES: 1. These voltage values are with respect to the midpoint between V_{CC+} and V_{CC-}.

2. Differential voltages are at IN+ with respect to IN-.

3. Neither input must ever be more positive then V_{CC+} or more negative than V_{CC-} .

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW

MC3303, MC3403 **QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS**

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recommended operating conditions

	MIN	MAX	UNIT
Single-supply voltage, V _{CC}	5	30	٧
Dual-supply voltage, V _{CC+}	2.5	15	V
Dual-supply voltage, V _{CC} _	-2.5	-15	V

electrical characteristics at specified free-air temperature, V_{CC+} = 14 V, V_{CC-} = 0 V for MC3303, $V_{CC\pm}$ = ±15 V for MC3403 (unless otherwise noted)

	DADAMETED				MC3303			MC3403		
	PARAMETER	TEST CONDITIO	INSI	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	See Note 4	25°C		2	8		2	10	mV
10		000 11010 4	Full range			10			12	
αVIO	Temperature coefficient of input offset voltage	See Note 4	Full range		10			10		μV/°C
lio	Input offset current	See Note 4	25°C		30	75		30	50	nA
10	input onset current	Gee Note 4	Full range			250			200	. 114
αΙΙΟ	Temperture coefficient of input offset current	See Note 4	Full range		50			50		pA/C
lim	Input bias current	See Note 4	25°C		-0.2	-0.5		-0.2	-0.5	μА
ΪΒ	input bias current	See Note 4	Full range			-1			-0.8	μζ
V _{ICR}	Common-mode input voltage range‡		25°C		V _{CC} - to 12.5			V _{CC} - to 13.5		٧
		$R_L = 10 \text{ k}\Omega$	25°C	12	12.5		±12	±13.5		
Vом	Peak output voltage swing	$R_L = 2 k\Omega$	25°C	10	12		±10	±13		V
		$R_L = 2 k\Omega$	Full range	10			±10			
AVD	Large-signal differential	$V_0 = \pm 10 \text{ V},$	25°C	20	200		20	200	V/mV	\//m\/
AVD	voltage amplification	$R_L \approx 2 k\Omega$	Full range	15			15			V/IIIV
ВОМ	Maximum-output-swing bandwidth	$V_{OPP} = 20 \text{ V},$ $A_{VD} = 1,$ $THD \le 5\%,$ $R_L = 2 \text{ k}\Omega$	25°C		9			9		kHz
B ₁	Unity-gain bandwidth	$V_O = 50 \text{ mV},$ $R_L = 10 \text{ k}\Omega$	25°C		1			1		MHz
φm	Phase margin	$C_L = 200 \text{ pF},$ $R_L = 2 \text{ k}\Omega$	25°C		60°			60°		
η	Input resistance	f = 20 Hz	25°C	0.3	1		0.3	. 1		MΩ
ro	Output resistance	f = 20 Hz	25°C		75			75		Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	25°C	70	90		70	90		dB
ksvs	Supply voltage sensitivity (ΔV _{IO} /ΔV _{CC})	$V_{CC\pm} = \pm 2.5 \text{ to } \pm 15 \text{ V}$	25°C		30	150		30	150	μV/V
los	Short-circuit output current§		25°C	±10	±30	±45	±10	±30	±45	mA
lcc	Total supply current	No load, See Note 4	25°C		2.8	7		2.8	7	mĄ

TAll characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for TA is -40°C to 85°C for MC3303, and 0°C to 70°C for MC3403.



[‡] The V_{ICR} limits are directly linked volt-for-volt to supply voltage; the positive limit is 2 V less than V_{CC+}.

[§] Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

NOTE 4: V_{IO}, I_{IO}, I_{IB}, and I_{CC} are defined at V_O = 0 for MC3403 and V_O = 7 V for MC3303.

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electrical characteristics, $V_{CC+} = 5 \text{ V}$, $V_{CC-} = 0 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	PARAMETER	TEGT COMPLETIONS	1	MC3303		ı	MC3403		
PANAMETER		TEST CONDITIONS†	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	V _O = 2.5 V			10	•	2	10	mV
lo	Input offset current	V _O = 2.5 V			75		30	50	nA
I _{IB}	Input bias current	V _O = 2.5 V			-0.5		-0.2	-0.5	pА
		R _L = 10 kΩ	3.3	3.5		3.3	3.5		
VOM	Peak output voltage swing‡	$R_L = 10 \text{ k}\Omega,$ V _{CC+} = 5 V to 30 V	V _{CC+} -	-1.7		V _{CC+} -	-1.7		٧
AVD	Large-signal differential voltage amplification	$V_O = 1.7 \text{ V to } 3.3 \text{ V},$ $R_L = 2 \text{ k}\Omega$	20	200		20	200		V/mV
ksvs	Supply voltage sensitivity $(\Delta V_{IO}/\Delta V_{CC\pm})$	$V_{CC\pm} = \pm 2.5 \text{ V to } \pm 15 \text{ V}$			150			150	μV/V
lcc	Supply current	V _O = 2.5 V, No load		2.5	7		2.5	7	mA
V _{O1} /V _{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		120			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics, V_{CC+} = 14 V, V_{CC-} = $\,0$ V for MC3303, $V_{CC\pm}$ = ±15 V for MC3403, T_A = 25°C, A_{VD} = 1 (unless otherwise noted)

PARAMETER TEST CONDITIONS				MIN	TYP	MAX	UNIT		
SR	Slew rate at unity gain	$V_{ } = \pm 10 \text{ V},$	C _L = 100 pF,	$R_L = 2 k\Omega$,	See Figure 1		0.6		V/μs
t _r	Rise time						0.35		μs
tf	Fall time	$\Delta V_{O} = 50 \text{ mV},$	$C_{L} = 100 \text{ pF},$	pF, $R_L = 10 \text{ k}\Omega$, See Figure	See Figure 1		0.35		μs
	Overshoot factor						20%		
	Crossover distortion	$V_{I(PP)} = 30 \text{ mV},$	V _{OPP} = 2 V,	f = 10 kHz	,		1%		

PARAMETER MEASUREMENT INFORMATION

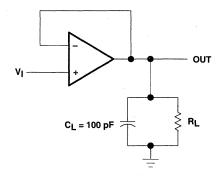


Figure 1. Unity-Gain Amplifier

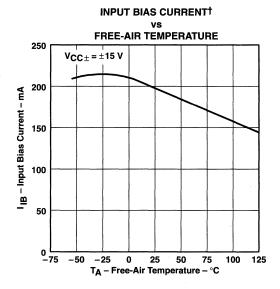
[‡] Output will swing essentially to ground.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
1	Innuit him a	vs Free-air temperature	2
IB	Input bias current	vs Supply voltage	3
.,	Maximum made to made autout valtage	vs Supply voltage	4
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	5
AVD	Large-signal differential voltage amplification	vs Frequency	6
	Large-signal pulse response	vs Time	7



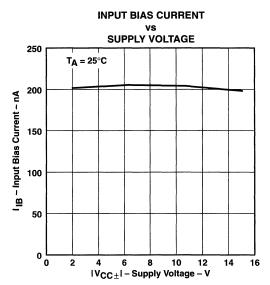


Figure 2 Figure 3

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE

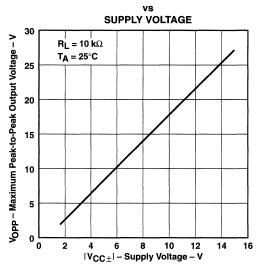


Figure 4

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs **FREQUENCY** 30 $V_{CC\pm} = \pm 15 \text{ V}$ Vopp – Maximum Peak-to-Peak Output Voltage CL = 0 $R_L = 10 \text{ k}\Omega$ 25 T_A = 25°C See Figure 1 20 15 10 5 0 └ 1 k 10 k 100 k 1 M

f - Frequency - Hz Figure 5

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION**

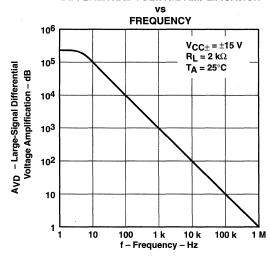


Figure 6

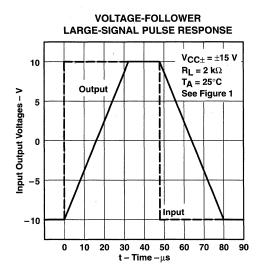


Figure 7

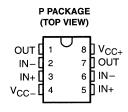
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



NE5532, NE5532A, NE5532I, NE5532AI **DUAL LOW-NOISE OPERATIONAL AMPLIFIERS**

SLOS075A - NOVEMBER 1979 - REVISED SEPTEMBER 1990

- **Equivalent Input Noise Voltage** 5 nv/√Hz Typ at 1 kHz
- Unity-Gain Bandwidth . . . 10 MHz Typ
- **Common-Mode Rejection Ratio** 100 dB Typ
- High DC Voltage Gain . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing 32 V Typ With $V_{CC+} = \pm 18$ V and $R_L = 600 \Omega$
- High Slew Rate . . . 9 V/us Tvp
- Wide Supply Voltage Range . . . ±3 V
- Designed to Be Interchangeable With Signetics NE5532 and NE5532A

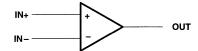


description

The NE5532 and NE5532A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. They feature very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, high slew rate, input-protection diodes, and output short-circuit protection. These operational amplifiers are internally compensated for unity-gain operation. The NE5532A has specified maximum limits for equivalent input noise voltage.

The NE5532 and NE5532A are characterized for operation from 0°C to 70°C. The NE5532I and NE5532AI are characterized for operation from -40°C to 85°C.

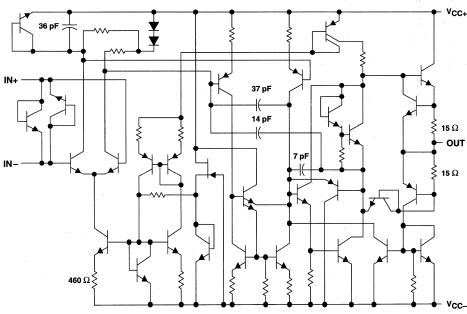
symbol (each amplifier)



NE5532, NE5532A, NE5532I, NE5532AI **DUAL LOW-NOISÉ OPERATIONAL AMPLIFIERS**

SLOS075A - NOVEMBER 1979 - REVISED SEPTEMBER 1990

schematic (each amplifier)



Component values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+} (see Note 1)	22 V
Supply voltage, V _{CC} (see Note 1)	–22 V
Input voltage, either input (see Notes 1 and 2)	V _{CC±}
Input current (see Note 3)	±10 mA
Duration of output short circuit (see Note 4)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Continuous total power dissipation	
Operating free-air temperature range: NE5532, NE5532A	
Operating free-air temperature range: NE5532, NE5532A	0°C to 70°C40°C to 85°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
 - 2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
 - 3. Excessive input current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
 - 4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	OPERATING FACTOR	T _A = 70°C	T _A = 85°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING	POWER RATING
Р	1000 mW	8 mW/°C	640 mW	520 mW



NE5532, NE5532A, NE5532I, NE5532AI DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

SLOS075A - NOVEMBER 1979 - REVISED SEPTEMBER 1990

recommended operating conditions

	MIN	NOM MAX	UNIT
Supply voltage, V _{CC+}	5	1	
Supply voltage, V _{CC} _	-5	-15	

electrical characteristics, $V_{CC\pm}$ = +15 V, T_A = 25°C (unless otherwise noted)

	PARAMETER TEST CONDITIONS†			MIN	TYP	MAX	UNIT	
V10	Input offset voltage	V _O = 0	T _A = 25°C			0.5	4	mV
VIO	Input offset voltage	AQ = 0	T _A = Full range				5	mv
li a	Input offset current	T _A = 25°C			10	150	nA	
lio	input onset current	T _A = Full range					200	na .
1	Input bias current	T _A = 25°C				200	800	nA
lВ	input bias current	T _A = Full range					1000	nA
VICR	Common-mode input voltage range		-		±12	±13		V
V	Maximum peak-to-peak output voltage	R _I ≥ 600 Ω	$V_{CC\pm} = \pm 15 \text{ V}$		24	26		٧
VOPP	swing	H ≥ 600 22	V _{CC±} = ±18 V		30	32		V
		$R_1 \ge 600 \Omega$	T _A = 25°C		15	50		
A	Large-signal differential voltage	V _O = ±10 V	T _A = Full range		10			V/mV
AVD	amplification	$R_L \ge 2 k\Omega$	T _A = 25°C		25	100		v/mv
		$V_{O} = \pm 10 \text{ V}$	T _A = Full range		15			
A _{vd}	Small-signal differential voltage amplification	f = 10 kHz				2.2		V/mV
Б.	Manifest and the state of the s	R _L = 600 Ω	V _O = ±10 V			140		
ВОМ	Maximum-output-swing bandwidth		$V_{CC\pm} = \pm 18 \text{ V},$	V _O = ±14 V		100		kHz
B ₁	Unity-gain bandwidth	R _L = 600 Ω,	C _L = 100 pF			10		MHz
rį	Input resistance				30	300		kΩ
z _o	Output impedance	$A_{VD} = 30 \text{ dB},$	R _L = 600 Ω,	f = 10 kHz		0.3		Ω
CMRR	Common-mode rejection ratio	VIC = VICR min			70	100		dB
ksvr	Supply voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	V _{CC±} = ±9 V to ±	15 V,	VO = 0	80	100		dB
los	Output short-circuit current					38		mA
Icc	Total supply curent	V _O = 0,	No load			8	16	mA
	Crosstalk attenuation (VO1/VO2)	V ₀₁ = 10 V peak,	f = 1 kHz			110	,	dB

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for T_A is 0°C to 70°C for NE5532/NE5532A and -40°C to 85°C for NE5532I/NE5532AI.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CONDIT	TEST CONDITIONS -		NE5532/NE5532I		NE5532A/NE5532AI			UNIT
		TEST CONDIT			TYP	MAX	MIN	TYP	MAX	ONI
SR	Slew rate at unity gain				9			9		V/µs
	Overshoot factor	$V_I = 100 \text{ mV}, \qquad A_{V_I} = 100 \text{ mV}, \qquad C_{L} = 600 \Omega, \qquad C_{L} = 600 \Omega$) = 1, = 100 pF		10%			10%		
V	Equivalent input noise voltage	f = 30 Hz			8			8	10	- N// (TT-
Vn	Equivalent input noise voltage	f = 1 kHz			5			5	6	nV/√Hz
In	Equivalent input noise current	f = 30 Hz			2.7			2.7		pA/√Hz
	Equivalent input noise current	f = 1 kHz			0.7			0.7		₽ΑV∀⊓Z



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- Equivalent Input Noise Voltage 3.5 nV/√Hz
- Unity-Gain Bandwidth . . . 10 MHz Typ
- Common-Mode Rejection Ratio 100 dB Typ
- High DC Voltage Gain . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing 32 V Typ With $V_{CC+} = \pm 18$ V and $R_L = 600 \Omega$
- High Slew Rate . . . 13 V/μs Typ
- Wide Supply Voltage Range ±3 V to ±20 V
- Low Harmonic Distortion
- Designed to Be Interchangeable With Signetics NE5534, NE5534A, SE5534, and SE5534A

description

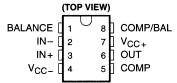
The NE5534, NE5534A, SE5534, and SE5534A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. Some of the features include very low noise, high output drive capability, high unitygain and maximum-output-swing bandwidths, low distortion, and high slew rate.

These operational amplifiers are internally compensated for a gain equal to or greater than three. Optimization of the frequency response for various applications can be obtained by use of an external compensation capacitor between COMP and COMP/BAL. The devices feature input-protection diodes, output short-circuit protection, and offset-voltage nulling capability.

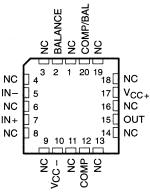
For the NE5534A, a maximum limit is specified for equivalent input noise voltage.

The NE5534 and NE5534A are characterized for operation from 0°C to 70°C. The SE5534 and SE5534A are characterized for operation over the full military temperature range of – 55°C to 125°C.

NE5534, NE5534A . . . D OR P PACKAGE SE5534, SE5534A . . . JG PACKAGE

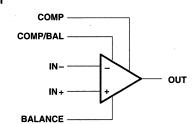


SE5534, SE5534A . . . FK PACKAGE (TOP VIEW)



NC - No internal connection

symbol



SE5534A FROM TI NOT RECOMMENDED FOR NEW DESIGNS

AVAILABLE OPTIONS

	V _{IO} max		PACK	AGE	
TA	AT 25°C	SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	4 mV	NE5534D NE5534AD	- .		NE5534P NE5534AP
- 55°C to 125°C	2 mV		SE5534FK SE5534AFK	SE5534JG SE5534AJG	_

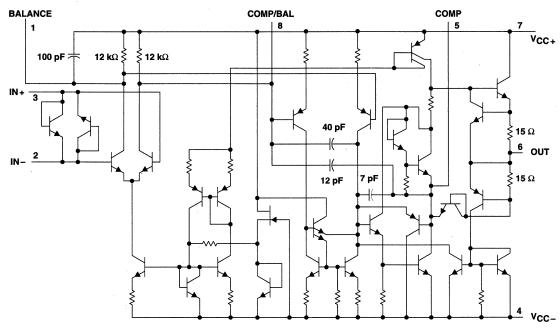
The D package is available taped and reeled. Add the suffix R to the device type (e.g., NE5534DR).



NE5534, NE5534A, SE5534, SE5534A LOW-NOISE OPERATIONAL AMPLIFIERS

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schematic



All component values shown are nominal. Pin numbers shown are for D, JG, and P packages.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+} (see Note 1)	22 V
Supply voltage, V _{CC} (see Note 1)	– 22 V
Input voltage either input (see Notes 1 and 2)	V _{CC+}
Input current (see Note 3)	±10 mA
Duration of output short circuit (see Note 4)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range: NE5534, NE5534A	0°C to 70°C
SE5534, SE5534A	– 55°C to 125°C
Storage temperature range	– 65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature range 1,6 mm (1/16 inch) from case for 60 seconds: JG pac	kage 300°C
Lead temperature range 1,6 mm (1/16 inch) from case for 10 seconds: D or P	package 260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.

- 2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
- 3. Excessive current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
- 4. The output may be shorted to ground or to either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

NE5534, NE5534A, SE5534, SE5534A LOW-NOISE OPERATIONAL AMPLIFIERS

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DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	N/A
FK (see Note 5)	1375 mW	11.0 mW/°C	880 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	N/A

NOTE 5: For the FK package, power rating and derating factor will vary with actual mounting technique used. The values stated here are believed to be conservative.

recommended operating conditions

	MIN	NOM MAX	UNIT
Supply voltage, V _{CC+}	5	15	٧
Supply voltage, V _{CC} _	-5	– 15	V

electrical characteristics, $V_{\mbox{CC}}\,\pm$ = ±15 V, $T_{\mbox{A}}$ = 25°C (unless otherwise noted)

PARAMETER				NE55	34, NE5	534A	SE5534, SE5534A			UNIT
	PARAMETER	TEST COND	DITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage	V _O = 0,	T _A = 25°C		0.5	4		0.5	2	mV
۷IO	input onset voltage	$R_S = 50 \Omega$	T _A = Full range			5			3	IIIV
lia	Input offset current	V _O = 0	T _A = 25°C		20	300		10	200	nA
lo	input onset current	VO = 0	T _A = Full range			400			500	ПА
lin	Input bias current	V _O = 0	T _A = 25°C		500	1500		400	800	nA
^I IB	input bias current	VO = 0	T _A = Full range			2000			1500	IIA
VICR	Common-mode input voltage range			±12	±13		±12	±13		٧
V	Maximum peak-to-peak	D. > 600 O	$V_{CC\pm} = \pm 15 \text{ V}$	24	26		24	26		٧
V _{O(PP)}	output voltage swing	R _L ≥ 600 Ω	V _{CC±} = ±18 V	30	32		30	32		V
Δ	Large-signal differential	$V_0 = \pm 10 \text{ V},$	T _A = 25°C	25	100		50	100		V/mV
AVD	voltage amplification	R _L ≥ 600 Ω	T _A = Full range	15			25			V/IIIV
Δ.	Small-signal differential	f = 10 kHz	C _C = 0		6			6		V/mV
A _{vd}	voltage amplification	T = TO KHZ	C _C = 22 pF		2.2			2.2		V/111V
		$V_0 = \pm 10 \text{ V},$	C _C = 0		200			200		
ВОМ	Maximum-output-swing	$V_0 = \pm 10 \text{ V},$	$C_C = 22 pF$		95			95		kHz
DOW	bandwidth	$V_{CC\pm} = \pm 18 \text{ V},$ $R_L \ge 600 \Omega,$	$V_O = \pm 14 \text{ V},$ $C_C = 22 \text{ pF}$		70			70		NI IZ
B ₁	Unity-gain bandwidth	C _C = 22 pF,	C _L = 100 pF		10			10		MHz
rj	Input resistance			30	100		50	100		kΩ
z _o	Output impedance	$A_{VD} = 30 \text{ dB},$ $C_{C} = 22 \text{ pF},$	$R_L \ge 600 \Omega$, f = 10 kHz		0.3			0.3		Ω
CMRR	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	V _{IC} = V _{ICR} min,	70	100		80	100		dB
ksvr	Supply voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	$V_{CC+}=\pm 9 \text{ V to } \pm 15 \text{ V},$ $V_{O}=0,$	R _S = 50 Ω	80	100		86	100		dB
los	Output short-circuit current				38			38		mA
loo	Supply current	V _O = 0,	T _A = 25°C		4	8		4	6.5	mA
CC	Supply culteril	No load	T _A = Full range						9	IIIA

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is TA = 0°C to 70°C for NE5534 and NE5534A and - 55°C to 125°C for SE5534 and SE5534A.



NE5534, NE5534A, SE5534, SE5534A LOW-NOISE OPERATIONAL AMPLIFIERS

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operating characteristics, $V_{CC} \pm = \pm 15$ V, $T_A = 25^{\circ}C$

	PARAMETER		TEST CONDITIONS		34, NE5	534	SE553	4A, NE5	534A	
	PARAMETER	IESI			TYP	MAX	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	C _C = 0			13			13		V/μs
οn	Siew rate at unity gain	C _C = 22 pF			6			6		ν/μ5
tr	Rise time	V _I = 50 mV,	A _{VD} = 1, C _C = 22 pF,		20			20		ns
	Overshoot factor	$R_L = 600 \Omega$, $C_L = 100 pF$	OC = 22 pr,		20%			20%		
t _r	Rise time	V _I = 50 mV,	A _{VD} = 1, C _C = 47 pF,		50			50		ns
	Overshoot factor	$R_L = 600 \Omega$, $C_L = 500 pF$	OC = 47 pr,		35%			35%		
W	Equivalent input paice veltage	f = 30 Hz			7			5.5	7	
٧n	Equivalent input noise voltage	f = 1 kHz			4			3.5	4.5	nV/√Hz
	Facilitation of pains account	f = 30 Hz			2.5			1.5		
In	Equivalent input noise current	f = 1 kHz			0.6			0.4		pA/√Hz
F	Average noise figure	$R_S = 5 k\Omega$,	f = 10 Hz to 20 kHz					0.9		dB

TYPICAL CHARACTERISTICS[†]

NORMALIZED INPUT BIAS CURRENT AND INPUT OFFSET CURRENT

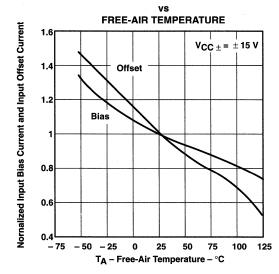


Figure 1

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE

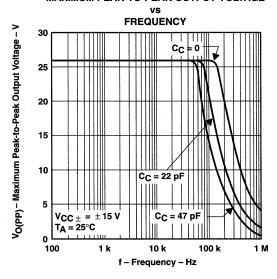


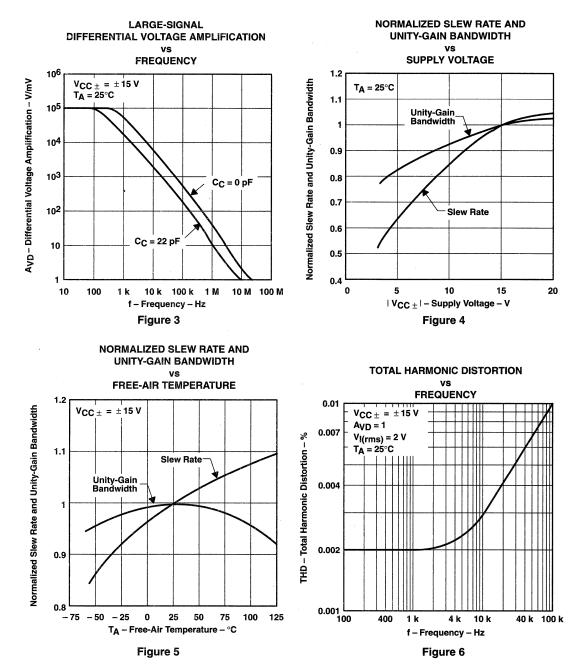
Figure 2

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS

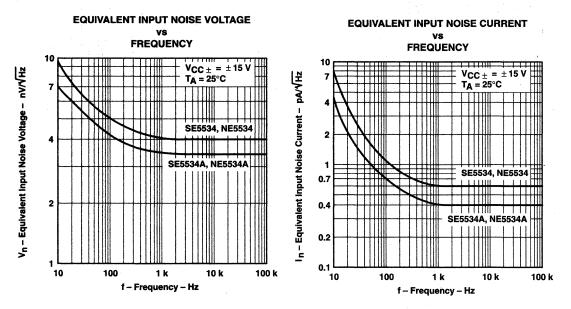
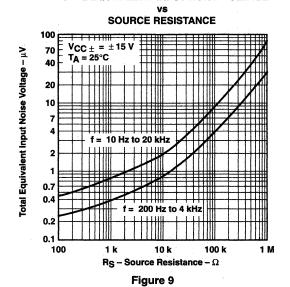


Figure 7

Figure 8

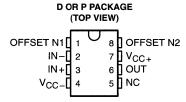
TOTAL EQUIVALENT INPUT NOISE VOLTAGE



OP07C, OP07D, OP07Y PRECISION OPERATIONAL AMPLIFIERS

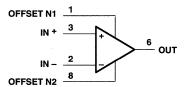
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- Low Noise
- No External Components Required
- Replaces Chopper Amplifiers at a Lower Cost
- Single-Chip Monolithic Fabrication
- Wide Input Voltage Range 0 to ±14 V Typ
- Wide Supply Voltage Range ±3 V to ±18 V
- Essentially Equivalent to Fairchild μΑ714
 Operational Amplifiers
- Direct Replacement for PMI OP07C and OP07D



NC-No internal connection

symbol



description

These devices represent a breakthrough in operational amplifier performance. Low offset and long-term stability are achieved by means of a low-noise, chopperless, bipolar-input-transistor amplifier circuit. For most applications, external components are not required for offset nulling and frequency compensation. The true differential input, with a wide input voltage range and outstanding common-mode rejection, provides maximum flexibility and performance in high-noise environments and in noninverting applications. Low bias currents and extremely high input impedances are maintained over the entire temperature range. The OP07 is unsurpassed for low-noise, high-accuracy amplification of very low-level signals.

These devices are characterized for operation from 0°C to 70°C.

AVAILABLE OPTIONS

	Viemov	PACKAGED	CHIP FORM		
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)	(Y)	
0°C to 70°C	150 μV	OP07CD OP07DD	OP07CP OP07DP	OP07Y	

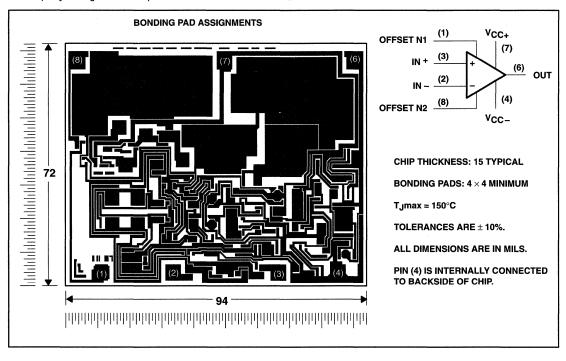
The D package is available taped and reeled. Add the suffix R to the device type (e.g., OP07CDR). The chip form is tested at $T_A = 25$ °C.

3-95

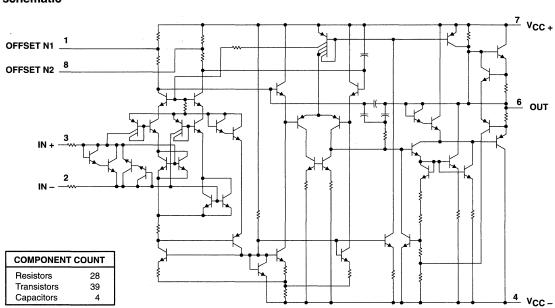
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OP07Y chip information

These chips, properly assembled, display characteristics similar to the OP07. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.







absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V _{CC+} (see Note 1)	22 V
Supply voltage, V _{CC}	22 V
Differential input voltage (see Note 2)	
Input voltage, V _I (either input, see Note 3)	±22 V
Duration of output short circuit (see Note 4)	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5) .	
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	65°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- 4. The output may be shorted to ground or either power supply.
- 5. For operation above 64°C free-air temperature, derate the D package to 464 mW at 70°C at the rate of 5.8 mW/°C.

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{CC±}		±3	±18	V
Common-mode input voltage, V _{IC}	V _{CC±} = ±15 V	-13	13	V
Operating free-air temperature, T _A		0	70	°C



electrical characteristics at specified free-air temperature, $V_{CC} \pm = \pm 15 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST SS	NOTIONS	т.		OP07C			OP07D		UNIT
	PARAMETER	TEST CO	NDITIONS†	TA	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V	Innuit offert veltere	V- 0	D- 50.0	25°C		60	150		60	150	
VIO	Input offset voltage	$V_O = 0$,	$R_S = 50 \Omega$	0°C to 70°C		85	250		85	250	μV
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	0°C to 70°C		0.5	1.8		0.7	2.5	μV/°C
	Long-term drift of input offset voltage	See Note 6				0.4			0.5		μV/mo
	Offset adjustment range	$R_S = 20 \text{ k}\Omega$,	See Figure 1	25°C		±4			±4		mV
lio.	Input offset current			25°C		0.8	6		0.8	6	nΑ
lio	input onset current			0°C to 70°C		1.6	8		1.6	8	nA
αΙΙΟ	Temperature coefficient of input offset current			0°C to 70°C		12	50		12	50	pA/°C
lun	Input bias current			25°C		±1.8	±7		±2	±12	nA
lв	input bias current			0°C to 70°C		±2.2	±9		±3	±14	114
αIIB	Temperature coefficient of input bias current			0°C to 70°C		18	50		18	50	pA/°C
VICR	Common-mode input voltge range			25°C	±13	±14		±13	±14		V
VICH	Common-mode input voitge range			0°C to 70°C	±13	±13.5		±13	±13.5		· ·
		$R_L \ge 10 \text{ k}\Omega$		į	±12	±13		±12	±13		
VOM	Peak output voltage	$R_L \ge 2 k\Omega$			±11.5	±12.8		±11.5	±12.8		v
VOM	r eak output voltage	$R_L \ge 1 \ k\Omega$				±12			±12		·
		$R_L \ge 2 k\Omega$		0°C to 70°C	±11	±12.6		±11	±12.6		
		$V_{CC\pm} = \pm 3 \text{ V},$ $R_L \ge 500 \text{ k}\Omega$	$V_0 = \pm 0.5 \text{ V},$	25°C	100	400			400		
AVD	Large-signal differential voltage amplification	V _O = ±10 V,	$R_1 = 2 k\Omega$	25°C	120	400		120	400		V/mV
		VO = ± 10.V,	HL = 2 KS2	0°C to 70°C	100	400		100	400		
B ₁	Unity-gain bandwidth			25°C	0.4	0.6		0.4	0.6		MHz
rj	Input resistance			25°C	8	33		7	31		МΩ
CMRR	Common-mode rejection ratio	V _{IC} = ±13 V,	Po - 50 O	25°C	100	120		94	110		dB
CIVINN	Common-mode rejection ratio	VIC = ± 13 V,	ng = 50 s2	0°C to 70°C	97	120		94	106		иБ
kovo	Supply voltage sensitivity (ΔV _{IO} /ΔV _{CC})	V _{CC±} = ±3 V t	o ± 18 V,	25°C		7	32		7	32	μV/V
ksvs	Subbit sourage sensitivity (\(\Pi\)\(\D\)\(\Pi\)\(\C)	$R_S = 50 \Omega$		0°C to 70°C		10	51		10	51	μ ν/ν
		V _O = 0,	No load			80	150		80	150	
PD	Power dissipation	V _{CC±} = ±3 V, No load	V _O = 0,	25°C		4	8		4	8	mW

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise noted.

NOTE 6: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a warranty. It is an engineering estimate of the averaged trend line of drift versus time over extended periods after the first thirty days of operation.

OP07C, OP07D, OP07Y PRECISION OPERATIONAL AMPLIFIERS

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operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

	PARAMETER	TEST		OP07C			OP07D		UNIT
	PARAMETER	CONDITIONS†	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
-		f = 10 Hz		10.5			10.5		
V _n	Equivalent input noise voltage	f = 100 Hz		10.2			10.3		nV/√Hz
		f = 1 kHz		9.8			9.8		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.38			0.38		μV
		f = 10 Hz		0.35			0.35		
In	Equivalent input noise current	f = 100 Hz		0.15			0.15		pA/√Hz
		f = 1 kHz		0.13			0.13		
IN(PP)	Peak-to-peak equivalent input noise current	f = 0.1 Hz to 10 Hz		15			15		рA
SR	Slew rate	R _L ≥2 kΩ		0.3			0.3		V/μs

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise noted.

electrical characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

	DADAMETED					OP07Y		
	PARAMETER] TE	ST CONDITION	IST	MIN	TYP	MAX	UNIT
VIO	Input offset voltage	$R_S = 50 \Omega$				60	150	μV
	Long-term drift of input offset voltage	See Note 6				0.5		μV/mo
	Offset adjustment range	$R_S = 20 \text{ k}\Omega$,	See Figure 1			±4		mV
lio	Input offset current					0.8	6	nA
lв	Input bias current					±2	±12	nA
VICR	Common-mode input voltage range				±13	±14		V
		R _L ≤ 10 kΩ	-		±12	±13		
Vом	Peak output voltage	$R_L \le 2 k\Omega$			±11.5	±12.8		V
		R _L ≤ 1 kΩ				±12		
Δ	Large signal differential valters complification	$V_{CC\pm} = \pm 3 \text{ V},$	$V_O = \pm 0.5 V$,	R _L ≤ 500 kΩ		400		
AVD	Large-signal differential voltage amplification	$V_0 = \pm 10 \text{ V},$	$R_L = 2 k\Omega$		120	400		
B ₁	Unity-gain bandwidth				0.4	0.6		MHz
η	Input resistance				7	31		МΩ
CMRR	Common-mode input resistance	$V_{IC} = \pm 13 \text{ V},$	$R_S = 50 \Omega$		94	110		dB
ksvs	Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO})	V _{CC±} = ±3 V t	o ± 18 V,	R _S = 50 Ω		7	32	μV/V
D-	Dougas discination	V _O = 0,	No load			80	150	MO
P_{D}	Power dissipation	$V_{CC\pm} = \pm 3 \text{ V},$	V _O = 0,	No load		4	8	МΩ

NOTE 6: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a warranty.

It is an engineering estimate of the averaged trend line of drift versus time over extended periods after the first thirty days of operation.

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operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = 25°C

	DADAMETED	TEST CONDITIONST				UNIT
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNII
		f = 10 Hz		10.5		
V _n	Equivalent input noise voltage	f = 1 kHz		10.3		nV/√Hz
		f = 0.1 Hz to 10 Hz	9.8			
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.38		μV
		f = 10 Hz		0.35		
In	Equivalent input noise current	f = 100 Hz	0.15			pA/√Hz
		f = 1 kHz	f = 1 kHz 0.13			
N(PP)	Peak-to-peak equivalent input noise current	f = 0.1 Hz to 10 Hz		15		pА
SR	Slew rate	$R_L = 2 k\Omega$		0.3		V/μs

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise noted.

APPLICATION INFORMATION

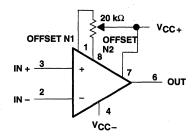


Figure 1. Input Offset Voltage Null Circuit

RC4136, RM4136, RV4136 QUAD GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS072 - MARCH 1978 - REVISED SEPTEMBER 1990

- Continuous-Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-Up
- Unity Gain Bandwidth . . . 3 MHz Typ
- Gain and Phase Match Between Amplifiers
- Designed To Be Interchangeable With Raytheon RC4136, RM4136, and RV4136
- Low Noise . . . 8 nV√Hz Typ at 1 kHz

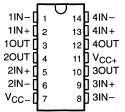
description

The RC4136, RM4136, and RV4136 are quad general-purpose operational amplifiers with each amplifier electrically similar to the µA741 except that offset null capability is not provided.

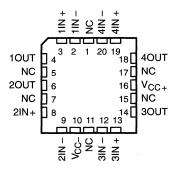
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short circuit protected and the internal frequency compensation ensures stability without external components.

The RC4136 is characterized for operation from 0°C to 70°C, the RM4136 is characterized for operation over the full military temperature range of -55°C to 125°C, and the RV4136 is characterized for operation from -40°C to 85°C.

RM4136...J OR W PACKAGE ALL OTHERS...D OR N PACKAGE (TOP VIEW)

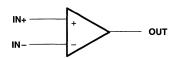


RM4136 . . . FK PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



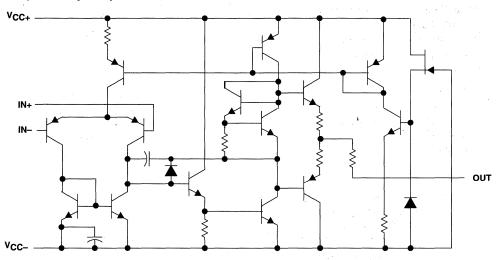
AVAILABLE OPTIONS

			P	ACKAGE		
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	FLAT (W)
0°C to 70°C	6 mV	RC4136D	_		RC4136N	_
-40°C to 85°C	6 mV	RV4136D	_	-	RV4136N	
-55°C to 125°C	4 mV	-	RM4136FK	RM4136J	_	RM4136W

The D packages are available taped and reeled. Add the suffix R to the device type (e.g., RC4136DR).

SLOS072 - MARCH 1978 - REVISED SEPTEMBER 1990

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	RC4136	RM4136	RV4136	UNIT		
	18	22	18	V		
Supply voltage V _{CC} - (see Note 1)						
Differential input voltage (see Note 2)						
	±15	±15	±15	V.		
Duration of output short circuit to ground, one amplifier at a time (see Note 4)						
	See Dissipation Rating Table					
	0 to 70	-55 to 125	-40 to 85	°C		
	-65 to 150	-65 to 150	-65 to 150	°C		
FK package		260	_	°C		
J or W package	_	300	_	°C		
D or N package	260	_	260	°C		
	FK package J or W package	18 -18 ±30 ±15 ee Note 4) unlimited Se 0 to 70 -65 to 150 FK package — J or W package —	18 22 -18 -22 ±30 ±30 ±15 ±15 ee Note 4) unlimited unlimited See Dissipation 0 to 70 −55 to 125 -65 to 150 −65 to 150 FK package − 260 J or W package − 300	18		

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC-} and V_{CC-} .
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - 4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	800 mW	7.6 mW/°C	45°C	608 mW	494 mW	
FK	800 mW	11.0 mW/°C	77°C	800 mW	715 mW	275 mW
J	800 mW	11.0 mW/°C	77°C	800 mW	715 mW	275 mW
N	800 mW	9.2 mW/°C	63°C	736 mW	598 mW	_
W	800 mW	8.0 mW/°C	50°C	640 mW	520 mW	200 mW

RC4136, RM4136, RV4136 QUAD GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS072 - MARCH 1978 - REVISED SEPTEMBER 1990

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC+}	5	15	V
Supply voltage, V _{CC} _	-5	-15	V

electrical characteristics at specified free-air temperature, $V_{CC+} = 15 \text{ V}$, $V_{CC-} = -15 \text{ V}$

				F	RC4136	;	F	RM4136	;	RV4136			T
F	PARAMETER	TEST CONDITIONS†		MIN TYP MAX		MIN TYP MAX		MAX	MIN TYP MAX			UNIT	
			25°C		0.5	6		0.5	4		0.5	6	
VIL	Input offset voltage	V _O = 0	Full range			7.5			6			7.5	mV
			25°C		5	200		5	1.50		5	200	
110	Input offset current	V _O = 0	Full range			300			500			500	nA
			25°C		140	500		140	400		140	500	<u> </u>
IB	Input bias current	V _O = 0	Full range			800			1500			1500	nA
Vį	Input voltage range		25°C	±12	±14		±12	±14		±12	±14		٧
		$R_L = 10 \text{ k}\Omega$	25°C	±12	±14		±12	±14		±12	±14		l
Vola	Maximum peak output voltage	R _L = 2 kΩ	25°C	±10	±13		±10	±13		±10	±13		v
VOM	swing	R _L ≥ 2 kΩ	Full range	±10			±10			±10			
	Large-signal	V _O = ±10 V,	25°C	20	300		50	350		20	300		
AVD	differential voltage amplification	$R_L \ge 2 k\Omega$	Full range	15			25			15			V/mV
B ₁	Unity-gain bandwith		25°C		3			3.5			3		MHz
rį	Input resistance		25°C	0.3*	5		0.3*	5		0.3*	5	-	MΩ
CMRR	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	25°C	70	90		70	90		70	90		dB
ksvs	Supply voltage sensitivity (ΔV _{IO} /ΔV _{CC})	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ $V_{O} = 0$	25°C		30	150		30	150		30	150	μV/V
V _n	Equivalent input noise voltage (closed-loop)	A _{VD} = 100, BW = 1 Hz, f = 1 kHz, R _S = 100 Ω	25°C		8			8			8		nV√Hz
			25°C		5	11.3		5	11.3		5	11.3	
Icc	Supply current (all four amplifiers)	V _O = 0, No load	MIN T _A		6	13.7		6	13.3		6	13.7	mA
	(an rour ampimers)		MAX T _A		4.5	10		4.5	10		4.5	10	
	Total power		25°C		150	340		150	340		150	340	
PD	dissipation (all four amplifiers)	V _O = 0, No load	MIN T _A		180	400		180	400		180	400	mW
			MAX T _A		135	300		135	300		135	300	
	Crosstalk attenuation (VO1/VO2)	AVD = 100, f = 10 kHz, $R_S = 1 \text{ k}\Omega$	25°C		105	:		105			105		dB

^{*} This parameter is not production tested.

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is 0°C to 70°C for RC4136, -55°C to 125°C for RM4136, and -40°C to 85°C for RV4136. Minimum T_A is 0°C for RC4136, -55°C for RM4136, and -40°C for RV4136. Maximum T_A is 70°C for RC4136, 125°C for RM4136, and 85°C for RV4136.



RC4136, RM4136, RV4136 QUAD GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS072 - MARCH 1978 - REVISED SEPTEMBER 1990

operating characteristics, $V_{CC+} = 15 \text{ V}$, $V_{CC-} = -15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CONDITIONS	RC4136, RV4136			RM4136			UNIT
		TEST CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
t _r	Rise time	$V_{\parallel} = 20 \text{ mV}, R_{\perp} = 2 \text{ k}\Omega,$		0.13			0.13		
	Overshoot factor	C _L = 100 pF		5%			5%		μs
SR	Slew rate at unity gain	$\begin{aligned} V_I &= 10 \text{ V}, & R_L &= 2 \text{ k}\Omega, \\ C_L &= 100 \text{ pF} \end{aligned}$		1.7			1.7		V/µs

RC4558, RC4558Y, RM4558, RV4558 **DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS**

SLOS073 - MARCH 1976 - REVISED AUGUST 1991 D. DB. JG, P. OR PW PACKAGE

- **Continuous-Short-Circuit Protection**
- Wide Common-Mode and Differential **Voltage Ranges**
- No Frequency Compensation Required
- **Low Power Consumption**
- No Latch-Up
- Unity Gain Bandwidth . . . 3 MHz Typ
- **Gain and Phase Match Between Amplifiers**
- Low Noise . . . 8 nV√Hz Typ at 1 kHz
- **Designed To Be Interchangeable With** Raytheon RC4558, RM4558, and RV4558

(TOP VIEW) **10UT** 8 V_{CC}+ 1IN- Π **1**1 20UT 2 6 1 2IN-1IN+ [] 3 1 2 IN+ $V_{CC}-$

description

The RC4558, RM4558, and RV4558 are dual general-purpose operational amplifiers with each half electrically similar to the µA741 except that offset null capability is not provided.

The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The RC4558 is characterized for operation from 0°C to 70°C, the RM4558 is characterized for operation over the full military temperature range of -55°C to 125°C, and the RV4558 is characterized for operation from -40°C to 85°C.

AVAILABLE OPTIONS

	Viomax	PACKAGED DEVICES						
TA	AT 25°C	SMALL OUTLINE (D)	SSOP (DBLE)	CERAMIC DIP (JG)	PLASTIC DIP (P)	SSOP (PWLE)	CHIP FORM (Y)	
0°C to 70°C	6 mV	RC4558D	RC4558DBLE		RC4558P	RC4558PWLE	RC4558Y	
-40°C to 85°C	6 mV	RV4558D	_	_	RV4558P	-	_	
-55 °C to 125°C	6 mV			RM4558JG		_		

The D package is available taped and reeled. Add the suffix R to the device type (e.g., RC4558DR). The DB and PW packages are available only left-end taped and reeled. RC4558Y is tested at 25°C.

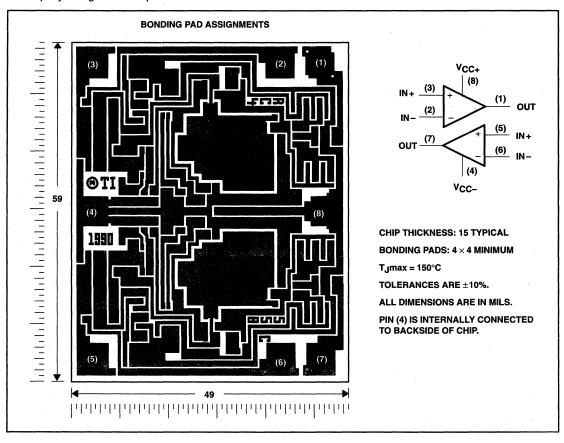


RC4558, RC4558Y, RM4558, RV4558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS073 - MARCH 1976 - REVISED AUGUST 1991

RC4558Y chip information

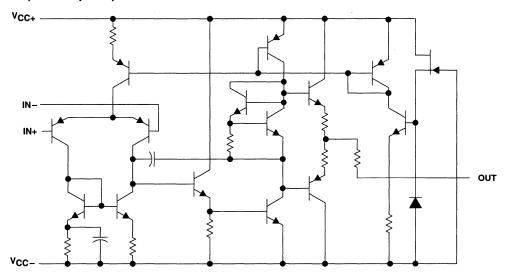
These chips, properly assembled, display characteristics similar to the RC4558. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



RC4558, RC4558Y, RM4558, RV4558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS073 - MARCH 1976 - REVISED AUGUST 1991

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

·	RC4558	RM4558	RV4558	UNIT	
Supply voltage V _{CC+} (see Note 1)	18	22	18	٧	
Supply voltage V _{CC} (see Note 1)	-18	-22	-18	٧	
Differential input voltage (see Note 2)	±30	±30	±30	٧	
Input voltage (any input, see Notes 1 and 3)	±15	±15	±15	٧	
Duration of output short circuit to ground, one amplifier at a time (see Note 4)	unlimited	unlimited	unlimited		
Continuous total dissipation	ntinuous total dissipation See Dissipation Rating Table				
Operating free-air temperature range	0 to 70	-55 to 125	-40 to 85	°C	
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package		300		°C	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DB, P, or PW package	260	·	260	°C	

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.

2. Differential voltages are at IN+ with respect to IN-.

3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.

4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

	T _A ≤ 25°C	DERATING FACTOR	DERATE	T _A = 70°C	T _A = 85°C	T _A = 125°C
PACKAGE	POWER RATING	ABOVE T _A = 25°C	ABOVE TA	POWER RATING	POWER RATING	POWER RATING
D	680 mW	5.8 mW/°C	33°C	464 mW	377 mW	N/A
DB or PW	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
JG	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
Р	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A



RC4558, RC4558Y, RM4558, RV4558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS073 - MARCH 1976 - REVISED AUGUST 1991

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC+}	5	15	٧
Supply voltage, V _{CC} _	-5	-15	٧

electrical characteristics at specified free-air temperature, $V_{CC+} = 15 \text{ V}$, $V_{CC-} = -15 \text{ V}$

						RC4558			RM4558			RV4558		
	PARAMETER	l .	TEST CON	DITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
				25°C		0.5	6		0.5	5		0.5	6	
V_{IO}	Input offset vol	tage .	V _O = 0	Full range	-		7.5			6	-	-	7.5	mV
				25°C		5	200		5	200		5	200	_
l _{IO}	Input offset cur	rent	V _O = 0	Full range			300			500			500	nA
			., .	25°C		150	500		140	500		140	500	
I _{IB}	Input bias curre	ent	V _O = 0	Full range			800			1500			1500	nA
V _{ICR}	Common-mode voltage range	e input		25°C	±12	±14	i	±12	±14		±12	±14		٧
			$R_L = 10 \text{ k}\Omega$	25°C	±12	±14		±12	±14		±12	±14		
V_{OM}	Maximum outp swing	ut voltage	$R_L = 2 k\Omega$	25°C	±10	±13		±10	±13		±10	±13		V
	Swing		$R_L \ge 2 k\Omega$	Full range	±10			±10			±10			
Λ	Large-signal di	fferential	$R_L \ge 2 k\Omega$,	25°C	20	300		50	350		20	300		V/mV
A _{VD}	voltage amplific	cation	$V_0 = \pm 10 \text{ V}$	Full range	15			25	144.5	2.15	15			V/IIIV
B ₁	Unity-gain band	dwith		25°C	, , , , , , , , , , , , , , , , , , ,	3		2	3.5			3		MHz
rį	Input resistance	е		25°C	0.3	5		0.3	5		0.3	5		MΩ
CMRR	Common-mode ratio	e rejection		25°C	70	90		70	90		70	. 90		dB
k _{SVS}	Supply voltage (ΔV _{IO} /ΔV _{CC})	sensitivity	V _{CC} = ±15 V to ±9 V	25°C		30	150		30	150		30	150	μV/V
V _n	Equivalent inpu		$\begin{aligned} A_{VD} &= 100, \\ R_S &= 100 \ \Omega, \\ f &= 1 \ \text{kHz}, \\ BW &= 1 \ \text{Hz} \end{aligned}$	25°C		8			8			8		nV√Hz
				25°C		2.5	5.6		2.5	5.6		2.5	5.6	
Icc	Supply current amplifiers)	(both	V _O = 0, No load	MIN T _A		3	6.6		3	6.6		3	6.6	mA
	ampilioro)		110 1000	MAX T _A		2.3	5		2	5		2.3	5	
				25°C		75	170		75	170		75	170	
P_D	Total power dis (both amplifiers		V _O = 0, No load	MIN T _A		90	200		90	200		90	200	mW
	(= 20. G	-, 		MAX T _A		70	150		60	150		. 70	150	
V _{O1} /V _O	Crosstalk	Open loop	$R_S = 1 k\Omega$,	25°C		85			85			85		dB
2	attenuation	A _{VD} = 100	f = 10 kHz	250		105			105			105		ub

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is 0°C to 70°C for RC4558, –55°C to 125°C for RM4558, and –40°C to 85°C for RV4558. Minimum T_A is 0°C for RC4558, –55°C for RM4558, and –40°C for RV4558. Maximum T_A is 70°C for RC4558, 125°C for RM4558, and 85°C for RV4558.

RC4558, RC4558Y, RM4558, RV4558 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

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operating characteristics, $V_{CC+} = 15 \text{ V}$, $V_{CC-} = -15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT	
t _r	Rise time	V. 00 mV D. 0100 C. 100 mF			0.13		ns	
	Overshoot	v = 20 mv,	$V_{\parallel} = 20 \text{ mV}, \qquad R_{\parallel} = 2 \text{ k}\Omega, \qquad C_{\parallel} = 100 \text{ pF}$			5%		
SR	Slew rate at unity gain	V _I = 10 V,	$R_L = 2 k\Omega$,	C _L = 100 pF	1.1	1.7		V/μs

electrical characteristics, $V_{CC+} = 15 \text{ V}$, $V_{CC-} = -15 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	DADAMETED			ET CONDITION	o.t	R	C4558Y		UNIT
	PARAMETER		16	ST CONDITION	51	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage		V _O = 0				0.5	6	mV
lo lo	Input offset current		V _O = 0				5	200	nA
lв	Input bias current		V _O = 0				150	500	nA
VICR	Common-mode input voltage rang	je				±12	±14		٧
V	Maximum autout valtage aving		$R_L = 10 \text{ k}\Omega$			±12	±14		V
VOM	Maximum output voltage swing		$R_L = 2 k\Omega$			±12	±13		V
AVD	Large-signal differential voltage ar	nplification	$R_L = 2 k\Omega$,	V _O = ±10 V		20	300		V/mV
B ₁	Unity-gain bandwidth						3		MHz
rį	Input resistance					0.3	5		MΩ
CMRR	Common-mode rejection ratio					70	90		dB
ksvs	Supply voltage sensitivity (ΔV _{IO} /Δ	V _{CC})	$V_{CC} = \pm 15 \text{ V}$	to ±9 V			30	150	μV/V
Vn	Equivalent input noise voltage (clo	sed-loop)	A _{VD} = 100, BW = 1 Hz	$R_S = 100 \Omega$,	f = 1 kHz,		8		nV√ Hz
Icc	Supply current (both amplifiers)		V _O = 0,	No load			2.5	5.6	mA
P_{D}	Total power dissipation (both amp	lifiers)	$V_{O} = 0$,	No load			75	170	mW
V/V	Crootally attentivation	Open loop	D- 110	f 101/H-			85		dB
V _{O1} /V _{O2}	Crosstalk attentuation	A _{VD} = 100	$R_S = 1 k\Omega$,	f = 10 kHz			105		uВ

T All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics, V_{CC+} = 15 V, V_{CC-} = -15 V, T_A = 25°C

	PARAMETER		MIN	TYP	MAX	UNIT		
t _r	Rise time	Vı = 20 mV.	D. Oko	C: 100 pF		0.13		ns
	Overshoot	vj = 20 mv,	$R_L = 2 k\Omega$,	C _L = 100 pF		5%		
SR	Slew rate at unity gain	V _I = 10 V,	$R_L = 2 k\Omega$,	C _L = 100 pF	1.1	1.7		V/μs

TL022C, TL022M DUAL LOW-POWER OPERATIONAL AMPLIFIERS

SLOS076 - SEPTEMBER 1973 - REVISED SEPTEMBER 1990

- Very Low Power Consumption
- Power Dissipation With ±2-V Supplies 170 μW Typ
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low input Offset Voltage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- Popular Dual Operational Amplifier Pinout

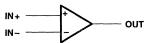
TL022M IS NOT RECOMMENDED FOR NEW DESIGNS

description

The TL022 is a dual low-power operational amplifier designed to replace higher power devices in many applications without sacrificing system performance. High input impedance, low supply currents, and low equivalent input noise voltage over a wide range of operating supply voltages result in an extremely versatile operational amplifier for use in a variety of analog applications including battery-operated circuits. Internal frequency compensation, absence of latch-up, high slew rate, and output short-circuit protection assure ease of use.

TL022M . . . JG PACKAGE TL022C...D OR P PACKAGE (TOP VIEW) 10UT 8 D V_{CC} 1IN- [] 2 7 1 20UT 1IN+ **∏** 3 6 1 2 IN-5 1 2IN+ GND TL022M . . . U PACKAGE (TOP VIEW) NC[] •1 10 NC 10UT[2 9 VCC+ 1IN-∏ 3 8 20UT 7 2IN-1IN+[] 4 6 2IN+ Vcc -[] 5

symbol (each amplifier)



The TL022C is characterized for operation from 0° C to 70° C. The TL022M is characterized for operation over the full military temperature range of -55° C to 125° C.

AVAILABLE OPTIONS

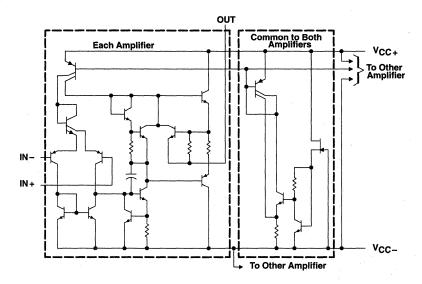
	Viemay		PAC	KAGE	
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CERAMIC DIP (JG)	PLASTIC DIP (P)	CERAMIC FLAT PACK (U)
0°C to 70°C	5 mV	TL022CD		TL022CP	_ :
-55°C to 125°C	5 mV	_	TL022MJG	_	TL022MU

The D package is available taped and reeled. Add the suffix R to the device type (i.e. TL022CDR).

TL022C, TL022M DUAL LOW-POWER OPERATIONAL AMPLIFIERS

SLOS076 - SEPTEMBER 1973 - REVISED SEPTEMBER 1990

schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		TL022C	TL022M	UNIT
Supply voltage, V _{CC+} (see Note 1)		18	22	٧
Supply voltage, V _{CC} (see Note 1)		-18	-22	٧
Differential input voltage (see Note 2)		±30	±30	٧
Input voltage (any input, see Notes 1 and 3)		±15	±15	V
Duration of output short circuit (see Note 4)		unlimited	unlimited	
Continuous total dissipation		See Dissi	pation Rating	Table
Operating free-air temperature range		0 to 70	-55 to 125	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG or U package		300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260		°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - 4. The output may be shorted to ground or either power supply. For the TL022M only, the unlimited duration of the short circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 125°C POWER RATING
D	680 mW	5.8 mW/°C	33°C	464 mW	_
JG	680 mW	8.4 mW/°C	69°C	672 mW	210 mW
Р	680 mW	8.0 mW/°C	65°C	640 mW	_
υ	675 mW	5.4 mW/°C	25°C	432 mW	135 mW



TL022C, TL022M DUAL LOW-POWER OPERATIONAL AMPLIFIERS

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recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{CC+}	5	15	V
Supply voltage, V _{CC} _	-5	-15	V

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = $\pm 15\,V$ (unless otherwise noted)

	PARAMETER	TEST CONDITION	uet		TL022C		1	L022M		UNIT
	ranaweten	TEST CONDITION	101	MIN	TYP	MAX	MIN	TYP	MAX	CIVIT
ViO	Input offset voltage	V _O = 0,	25°C		1	5		1	5	mV
VIO	mput onset voltage	$R_S = 50 \Omega$	Full range			7.5			6	1110
l _I O	Input offset current	V _O = 0	25°C		15	80		5	40	nA
טוי	mput onset current	VO = 0	Full range			200			100	11/4
I _{IB}	Input bias current	V _O = 0	25°C		100	250		50	100	nA
чв	input bias current	VO = 0	Full range			400			250	11/4
VICR	Common-mode input		25°C	±12	±13		±12	±13		V
VICH	voltage range		Full range	±12			±12			V
Vocan	Maximum peak-to-peak	R _L = 10 kΩ	25°C	20	26		20	26		V
VO(PP)	output voltage swing	R _L ≥ 10 kΩ	Full range	20			20			٧
AVD	Large-signal differential	R _L ≥ 10 kΩ,	25°C	60	80		72	86		dB
~VD	voltage amplification	$V_0 = \pm 10 \text{ V}$	Full range	60			66			uБ
B ₁	Unity-gain bandwidth		25°C		0.5			0.5		MHz
CMRR	Common-mode rejection	V _{IC} = V _{ICR} min,	25°C	60	72		60	72		dB
CIVINN	ratio	$R_S = 50 \Omega$	Full range	60			60			ub.
kovo	Supply voltage sensitivity	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$	25°C		30	200		30	150	μV/V
ksvs	(ΔVIO/ΔVCC)	$R_S = 50 \Omega$	Full range			200			150	μν/ν
V _n	Equivalent input noise voltage	AVD = 20 dB, B = 1 Hz, f = 1 kHz	25°C		50			50		nV/Hz
los	Short-circuit output current		25°C		±6			±6		mA
laa	Supply current (both	Va O Na laad	25°C		130	250		130	250	
ICC	amplifiers)	$V_O = 0$, No load	Full range			250			250	μΑ
D-	Total dissipation	Va - 0 No load	25°C		3.9	7.5		3.9	6	mW
P_D	(both amplifiers)	$V_O = 0$, No load	Full range			7.5			6	11100

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for TL022C is 0°C to 70°C and for TL022M is -55°C to 125°C.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C

	PARAMETER		TEST CONDITIONS						UNIT
t _r	Rise time	Vı = 20 mV.	D 10 kO	C: - 100 pF	Coo Eiguro 1		0.3		μs
	Overshoot factor	ν ₁ = 20 mν,	n_ = 10 ksz,	C _L = 100 pF,	See Figure 1		5%		
SR	Slew rate at unity gain	V _I = 10 V,	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,	See Figure 1		0.5		V/μs

PARAMETER MEASUREMENT INFORMATION

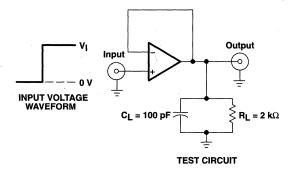


Figure 1. Rise Time, Overshoot Factor, and Slew Rate

TYPICAL CHARACTERISTICS

TOTAL POWER DISSIPATION

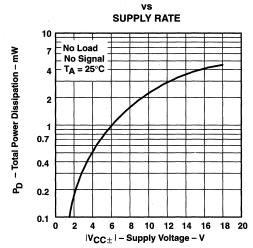


Figure 2

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- Direct Upgrades for the TL06x Low-Power BiFETs
- Low Power Consumption 6.5 mW/Channel Typ
- On-Chip Offset Voltage Trimming For Improved DC Performance (1.5 mV, TL031A)
- Higher Slew Rate And Bandwidth Without Increased Power Consumption
- Available in TSSOP For Small Form-Factor Designs

description

The TL03x series of JFET-input operational amplifiers offer improved dc and ac characteristics over the TL06x family of low power BiFET operational amplifiers. On-chip zener trimming of offset voltage yields precision grades as low as 1.5 mV (TL031A) for greater accuracy in dc-coupled applications. Texas Instruments improved BiFET process and optimized designs also yield improved bandwidths and slew rates without increased power consumption. The TL03x devices are pin-compatible with the TL06x and can be used to upgrade existing circuits or for optimal performance in new designs.

BiFET operational amplifiers offer the inherently higher input impedance of the JFET-input transistors, without sacrificing the output drive associated with bipolar amplifiers. This higher input impedance makes the TL3x amplifiers better suited for interfacing with high-impedance sensors or very low-level ac signals. These devices also feature inherently better ac response than bipolar or CMOS devices having comparable power consumption.

The TL03x family has been optimized for micropower operation, while improving on the performance of the TL06x series. Designers requiring significantly faster ac response should consider the Excalibur TLE206x family of low power BiFET operational amplifiers.

AVAILABLE OPTIONS

				AVAILABLE .					
				PAC	KAGED DEVIC	ES			01.11B
TA	V _{IO} max AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	TSSOP (PW)	CHIP FORM [‡] (Y)
	0.8 mV	TL031ACD TL032ACD		_	_		TL031ACP TL032ACP	_	
0°C to 70°C	1.5 mV	TL031CD TL032CD TL034ACD	_	_	_	TL034ACN	TL031CP TL032CP	_	TL031Y TL032Y TL034Y
	4 mV	TL034CD	_	_	_	TL034CN		TL034CPW	
	0.8 mV	TL031AID TL032AID			-	_	TL031AIP TL032AIP	_	_
-40°C t0 85°C	1.5 mV	TL031ID TL032ID TL034AID	_	_	_	TL034AIN	TL031IP TL032IP		_
	4 mV	TL034ID	_	_	_	TL034IN	_	_	_
	0.8 mV	TL031AMD TL032AMD	TL031AMFK TL032AMFK	_	TL031AMJG TL032AMJG	_	TL031AMP TL032AMP	_	-
-55°C to 125°C	1.5 mV	TL031MD TL032MD TL034AMD	TL031MFK TL032MFK TL034AMFK	TL034AMJ	TL031MJG TL032MJG	TL034AMN	TL031MP TL032MP	_	-
	4 mV	TL034MD	TL034MFK	TL034MJ	_	TL034MN		_	_

[†]The D packages are available taped and reeled and is indicated by adding an R suffix to device type (e.g., TL034CDR).



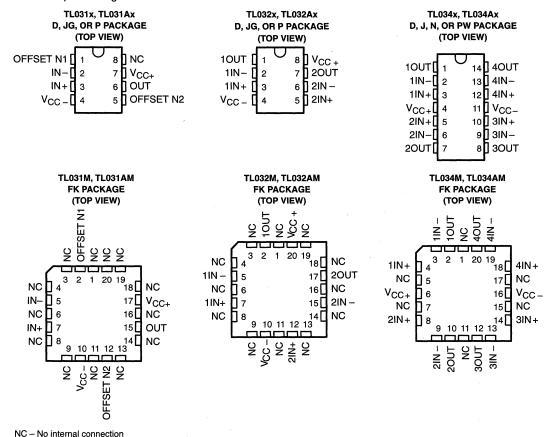
[‡] Chip forms are tested at 25°C.

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description (continued)

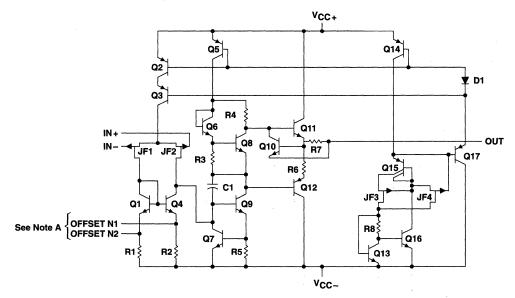
Because BiFET operational amplifiers are designed for use with dual power supplies, care must be taken to observe common-mode input voltage limits and output swing when operating from a single supply. DC biasing of the input signal is required and loads should be terminated to a virtual ground node at mid-supply. Texas Instruments TLE2426 integrated virtual ground generator is useful when operating BiFET amplifiers from single supplies.

The TL03x are fully specified at ± 15 V and ± 5 V. For operation in low-voltage and/or single-supply systems, Texas Instruments LinCMOS families of operational amplifiers (TLC-prefix) are recommended. When moving from BiFET to CMOS amplifiers, particular attention should be paid to slew rate and bandwidth requirements, and output loading.



symbol (each amplifier)

equivalent schematic (each amplifier)

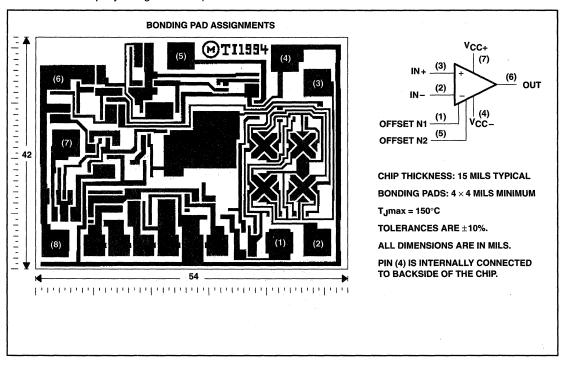


NOTE A: OFFSET N1 and OFFSET N2 are only available on the TL031.

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TL031Y chip information

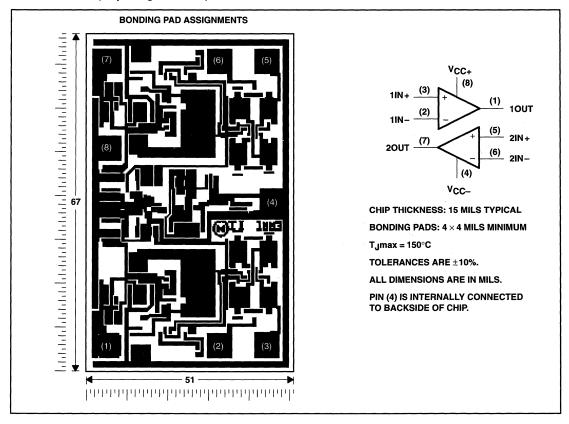
This chip, when properly assembled, displays characteristics similar to the TL031C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. These chips may be mounted with conductive epoxy or a gold-silicon preform.



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TL032Y chip information

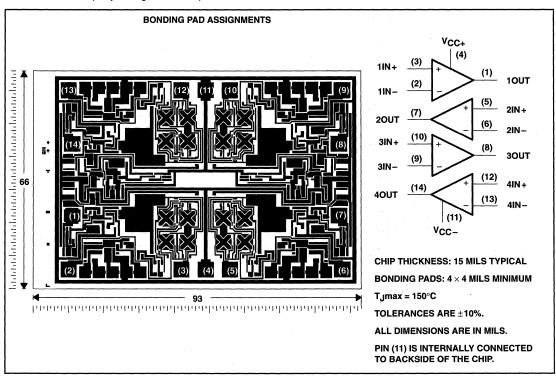
This chip, when properly assembled, displays characteristics similar to the TL032C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. These chips may be mounted with conductive epoxy or a gold-silicon preform.



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TL034Y chip information

This chip, when properly assembled, displays characteristics similar to the TL034C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. These chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	
Supply voltage, V _{CC} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage, V _I (any input) (see Notes 1 and 3)	±15 V
Input current, I _I (each input)	±1 mA
Output current, IO (each output)	±40 mA
Total current into V _{CC+}	
Total current out of V _{CC} -	
Duration of short-circuit current at (or below) 25°C (see Note 4)	unlimited
Continuous total power dissipation	
	Coo bicolpation nating rabic
Operating free-air temperature, T _A : C suffix	
	0°C to 70°C
Operating free-air temperature, TA: C suffix	0°C to 70°C 40°C to 85°C
Operating free-air temperature, T _A : C suffix	
Operating free-air temperature, T _A : C suffix	0°C to 70°C -40°C to 85°C -55°C to 125°C -65°C to 150°C
Operating free-air temperature, T _A : C suffix I suffix M suffix Storage temperature range, T _{stg}	0°C to 70°C -40°C to 85°C -55°C to 125°C -65°C to 150°C 260°C
Operating free-air temperature, T _A : C suffix I suffix M suffix Storage temperature range, T _{stg} Case temperature for 60 seconds: FK package	

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	230 mW
P	1100 mW	8.0 mW/°C	640 mW	520 mW	200 mW
PW	700 mW	5.6 mW/°C	448 mW	N/A	N/A

recommended operating conditions

		C SU	FFIX	I SUF	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{CC±}		±5	±15	±5	±15	±5	±15	V
Q	V _{CC±} = ±5 V	-1.5	4	-1.5	4	-1.5	4	,,
Common-mode input voltage, V _{IC}	V _{CC±} = ±15 V	-11.5	14	-11.5	14	-11.5	14	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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TL031C and TL031AC electrical characteristics at specified free-air temperature

						Т	L031C,	TL031AC	>		
	PARAMETER	TEST CO	NDITIONS	T _A †	VC)± = ±5	V	Vcc)± = ±18	5 V	UNIT
]		, ,	MIN	TYP	MAX	MIN	TYP	MAX	
			7.0040	25°C		0.54	3.5		0.5	1.5	
	I	3	TL031C	Full range			4.5			2.5	
VIO	Input offset voltage	Ì	TI 00440	25°C		0.41	2.8		0.34	0.8	mV
		\	TL031AC	Full range			3.8			1.8	
ST 11.0	Temperature coefficient of	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL031C	25°C to 70°C		7.1			5.9		μV/°C
αVIO	input offset voltage‡		TL031AC	25°C to 70°C		7.1			5.9	25	μν/ Ο
	Input offset voltage long-term drift§	i		25°C		0.04			0.04		μV/mo
2	Input offset current	$V_{O} = 0$,	V _{IC} = 0,	25°C		1	100		1	100	рA
lo lo	mpat onset current	See Figure 5	5	70°C		9	200		12	200	PΑ
lum.	Input bias current	$V_{O} = 0$,	V _{IC} = 0,	25°C		2	200		2	200	pA
ΙΒ	mput bias current	See Figure 5	5	70°C		50	400		80	400	PΛ
	Common-mode input	,		25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		
VICR	voltage range			Full range	-1.5 to .4			-11.5 to 14			V
				25°C	3	4.3		13	14		
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	3	4.2		13	14		٧
				70°C	3	4.3	٠.	13	14		
				25°C	-3	-4.2		-12.5	-13.9		
VOM-	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	-3	-4.1		-12.5	-13.9		٧
				70°C	-3	-4.2		-12.5	-14		
	l avec simual differential			25°C	4	12		5	14.3		
AVD	Large-signal differential voltage amplification¶	$R_L = 10 \text{ k}\Omega$		0°C	3	11.1		4	13.5		V/mV
	J			70°C	4	13.3		5	15.2		
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		5			4		pF
	0	J., ,,		25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	VIC = VICRI VO = 0,	nin, $R_S = 50 \Omega$	0°C	70	87		75	94		dB
		1.0 = 4,	3 = 00 11	70°C	70	87		75	94		
	Supply voltage rejection retin			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio (ΔVCC±/ΔVIO)	$V_{O} = 0$,	$R_S = 50 \Omega$	0°C	75	96		75	96		dB
	. 551 10/			70°C	75	96		75	96		<u></u>

[†] Full range is 0°C to 70°C.

[‡] This parameter is tested on a sample basis for the TL031A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

[¶] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = \pm 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

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TL031C and TL031AC electrical characteristics at specified free-air temperature (continued)

				TL031C, TL031AC											
	PARAMETER	TEST CONDITIONS		TEST CONDITIONS		TEST CONDITIONS		TA	Vcc)± = ±5	٧	Vcc	± = ±1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX					
				25°C		1.9	2.5		6.5	8.4					
PD	Total power dissipation	$V_{O} = 0$,	No load	0°C		1.8	2.5		6.3	8.4	mW				
				70°C		1.9	2.5		6.3	8.4					
				25°C		192	250		217	280					
lcc	Supply current	$V_{O} = 0$,	No load	0°C		184	250		211	280	μΑ				
		l		70°C		189	250		210	280					

TL031C and TL031AC operating characteristics at specified free-air temperature

							Т	L031C,	TL031AC	;		
	PARAMETER		TEST CO	NDITIONS	TA	Vcc)±=±5	٧	VCC			UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9 .		
SR+	Positive slew rate unity gain†	at			0°C		1.8		1	2.6		V/μs
	unity ganti		$R_L = 10 \text{ k}\Omega$	$C_L = 100 pF$,	70°C		2.2	,	1.5	3.2		
			See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rat	e at			0°C		3.7		1.5	5		V/μs
	unity gain			70°C			4		1.5	5		
			$V_{I(PP)} = \pm 10 \text{ mV},$		25°C		138			132		
tr	Rise time		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	0°C		134			127		ns
			See Figures 1	and 2	70°C		150			142		
			V _{I(PP)} = ±10 i	mV.	25°C		138			132		
t _f	Fall time		$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,	0°C		134			127		ns
			See Figure 1		70°C		150			142		
		,	V _{I(PP)} = ±10 i	mV.	25°C		11%			5%		
	Overshoot factor		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	0°C		10%			4%		
			See Figures 1	and 2	70°C		12%			6%		
		TL031C		f = 10 Hz	0500		61			61		
.,	Equivalent input	110310	$R_S = 20 \Omega$	f = 1 kHz	25°C		41			41		
Vn	noise voltage‡	TI 00440	See Figure 3	f = 10 Hz	0500		61			61		nV/√Hz
		TL031AC	l	f = 1 kHz	25°C		41			41	60	
In	Equivalent input i current	noise	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B ₁	Unity-gain bandw	ridth	$V_1 = 10 \text{ mV},$ $C_1 = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	0°C		1			1.1		MHz
			OL = 25 pr,	See Figure 4	70°C		1			1		
					25°C		61°			65°		
φm	Phase margin at	unity gain	$V_{\parallel} = 10 \text{ mV}, R_{\perp} = 10 \text{ k}\Omega,$	0°C		61°			65°			
		C _L = 25 pF, See Figure 4	See Figure 4	70°C		60°			64°			

[†] For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V. ‡ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL031I and TL031AI electrical characteristics at specified free-air temperature

							ΓL031I,	TL031AI			
	PARAMETER	TEST CO	NDITIONS	T _A †	VCC)± = ±6	5 V	Vcc	0± = ±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			TL031I	25°C		0.54	3.5		0.5	1.5	
V _{IO}	Input offset voltage		110311	Full range			5.3			3.3	mV
VIO	input onset voltage		TL031AI	25°C		0.41	2.8		0.34	0.8	IIIV
],, ,	TEOSTAI	Full range			4.6			2.6	
	Temperature coefficient of	$V_O = 0$, $V_{IC} = 0$, $R_S = 50 \Omega$	TL031I	25°C to 85°C		6.5			6.2		μV/°C
αNIO	input offset voltage‡		TL031AI	25°C to .85°C		6.5			6.2	25	μν/ Ο
	Input offset voltage long-term drift§			25°C		0.04			0.04	:	μV/mo
1	I	V _O = 0,	V _{IC} = 0,	25°C		1	100		1	100	pА
ΙΟ	Input offset current	See Figure 9		85°C		0.02	0.45		0.02	0.45	nA
lın	Input bigs ourrent	V _O = 0,	V _{IC} = 0,	25°C		2	200		2	200	pА
lB	Input bias current	See Figure 8	5	85°C		0.2	0.9		0.2	0.9	nA
	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		
VICR	voltage range			Full range	-1.5 to 4			-11.5 to 14			V
				25°C	3	4.3		13	14		
v_{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$		-40°C	3	4.1		13	14		V
				85°C	3	4.4		13	14		
	Mandanana			25°C	-3	-4.2		-12.5	-13.9		
$^{VOM-}$	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		-40°C	-3	-4.1		-12.5	-13.8		V
				85°C	-3	-4.2		-12.5	-14		
	Large-signal differential			25°C	4	12		5	14.3		
AVD	voltage amplification¶	$R_L = 10 \text{ k}\Omega$		-40°C	3	8.4		4	11.6		V/mV
				85°C	4	13.5		5	15.3		
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		5			4		pF
	0	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	!	25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ $V_{O} = 0$,	min, $R_S = 50 \Omega$	-40°C	70	87		75	94		dB
	• • • • • • • • • • • • • • • • • • • •			85°C	70	87		75	94		
	Cumply voltage rejection			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$,	$R_S = 50 \Omega$	-40°C	75	96		75	96		dB
	. 00± 10/			85°C	75	96		75	96		

[†] Full range is -40°C to 85°C.

[‡] This parameter is tested on a sample basis for the TL031A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

[¶] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = \pm 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

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TL031I and TL031AI electrical characteristics at specified free-air temperature (continued)

						1	ΓL031I, 1	LO31AI			
l	PARAMETER	TEST C	ONDITIONS	TA	Vcc)±= ±5	5 V	Vcc	± = ±1	5 V	UNIT
				•	MIN	TYP	MAX	MIN	TYP	MAX	
1				25°C		1.9	2.5		6.5	8.4	
PD	Total power dissipation	$V_{O} = 0$,	No load	-40°C		1.4	2.5		5.4	8.4	mW
1				85°C		1.9	2.5		6.2	8.4	
				25°C		192	250		217	280	
Icc	Supply current	$V_O = 0$	No load	-40°C		144	250		181	280	μΑ
1				85°C		189	250		207	280	ĺ

TL031I and TL031AI operating characteristics at specified free-air temperature

		·····						ΓL031I, 1	TL031AI			
1	PARAMETER		TEST CO	NDITIONS	TA	VC	C±=±5	٧	Vcc	;±=±15	٧	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate unity gain†	at			-40°C		1.6		1	2.1		V/μs
	unity gant		$R_L = 10 \text{ k}\Omega$,	CL = 100 pF,	85°C		2.3		1.5	3.3		
			See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rat unity gain†	e at			-40°C		3.3		1.5	4.8		V/μs
	unity gairi				85°C		4.1		1.5	4.9		
			$V_{I(PP)} = \pm 10 \text{ r}$	nV.	25°C		138			132		
tr	Rise time		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	-40°C		132			123		ns
			See Figures 1	and 2	85°C		154			146		
			V _{I(PP)} = ±10 r	nV	25°C		138			132		
tf	Fall time		$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,	-40°C		132			123		ns
			See Figure 1		85°C		154			146		
			V _I (PP) = ±10 r	nV	25°C		11%			5%		
	Overshoot factor		$R_L = 10 \text{ k}\Omega$,	$C_{L} = 100 pF$,	-40°C		12%			5%		
			See Figures 1	and 2	85°C		13%			7%		
		TL0311		f = 10 Hz	25°C		61			61		
	Equivalent input	120311	$R_S = 20 \Omega$,	f = 1 kHz	25.0		41			41		
v _n	noise voltage‡	TL031AI	See Figure 3	f = 10 Hz	25°C		61			61		nV/√Hz
		ILUSTAI		f = 1 kHz	25.0		41			41	60	
In	Equivalent input r current	noise	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B ₁	Unity-gain bandw	idth	$V_I \approx 10 \text{ mV},$ $C_L = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	-40°C		1			1.1		MHz
			OL = 20 pr,	OUE Figure 4	85°C		0.9			1		
			10 1	D 401-0	25°C		61°			65°		
φm	Phase margin at t	unity gain	$V_{\parallel} \approx 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	-40°C		60°			65°	65°	}
				222guio 1	85°C		60°			64°]

[†] For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V. ‡ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL031M and TL031AM electrical characteristics at specified free-air temperature

					,	Т	L031M,	TL031A	VI		
	PARAMETER	TEST CO	NDITIONS	T _A †	٧c	C ± = ± 5	V	Vc	C±=±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			TI 00414	25°C		0.54	3.5		0.5	1.5	
W -	land affect wells as		TL031M	Full range			6.5			4.5	
VIO	Input offset voltage		TLOOTANA	25°C		0.41	2.8		0.34	0.8	mV
		J _V ₂ = 0	TL031AM	Full range			5.8	,		3.8	
	Temperature coefficient of	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL031M	25°C to 125°C		5.1			4.3		
αVIO	input offset voltage		TL031AM	25°C to 125°C		5.1			4.3		μV/°C
	Input offset voltage long-term drift‡			25°C		0.04			0.04		μV/mo
1	lancet affect account	V _O = 0,	V _{IC} = 0,	25°C		1	100		1	100	pА
ΙO	Input offset current	See Figure 5		125°C		0.2	10		0.2	10	nA
1	land bing somet	V _O = 0,	V _{IC} = 0,	25°C		2	200		2	200	pА
İΒ	Input bias current	See Figure 5		125°C		7	20		8	20	nÅ
					-1.5	-3.4		-11.5	-13.4		
	0			25°C	to 4	to 5.4		to 14	to 15.4		
VICR	Common-mode input voltage range	·		Full range	-1.5 to	0.1		-11.5 to	10.1		V
		 		25°C	3	4.3		13	14		
V _{OM} +	Maximum positive peak	$R_{\rm I} = 10 \rm k\Omega$		_55°C	3	4.1		13	14		v
OWI +	output voltage swing			125°C	3	4.4		13	14		
				25°C	-3	-4.2		-12.5	-13.9		
V _{OM} –	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		−55°C	-3	-4		-12.5	-13.8		v
	output voltage swing	-		125°C	-3	-4.3		-12.5	-14		
				25°C	4	12		5	14.3		
AVD	Large-signal differential voltage amplification§	$R_L = 10 \text{ k}\Omega$		-55°C	3	7.1		4	10.4		V/mV
	voltage amplifications	İ		125°C	3	12.9		4	15		
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		5			4		pF
		VIC = VICE	min	25°C	70	87		75	94		l -
CMRR	Common-mode rejection ratio		$R_S = 50 \Omega$	–55°C	70	87		70	94		dB
	rejection ratio		-	125°C	70	87		70	94		1
	_			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{O}=0$,	$R_S = 50 \Omega$	−55°C	75	96		75	95		dB
	14.10 (AVCC±/AVIC)			125°C	75	96		75	96		
				25°C		1.9	2.5		6.5	8.4	
P_{D}	Total power dissipation	$V_O = 0$,	No load	−55°C		1.1	2.5		4.7	8.4	mW
				125°C		1.8	2.5		5.8	8.4	L

[†] Full range is – 55°C to 125°C.

[‡] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to $T_A=25^{\circ}C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV. § At V_{CC±} = ±5 V, V_O = ±2.3 V; at V_{CC±} = ±15 V, V_O = ±10 V.

TL03x, TL03xA, TL03xY **ENHANCED-JFET LOW-POWER LOW-OFFSET** OPERATIONAL AMPLIFIERS SLOS180 - FEBRUARY 1997

TL031M and TL031AM electrical characteristics at specified free-air temperature (continued)

[PARAMETER		TEST CONDITIONS		VC	C ± = ± 5	v	V _{CC±} = ±15 V			UNIT
.[MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		192	250		217	280	1
Icc	Supply current	$V_{O} = 0$,	No load	−55°C		114	250		156	280	μΑ
		1		125°C		178	250		197	280	

TL031M and TL031AM operating characteristics at specified free-air temperature

							Т	L031M,	TL031AN	1		
	PARAMETER		TEST CO	NDITIONS	TA	Vcc) ± = ± 5	٧	Vcc	;±=±1	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate unity gain†	at			−55°C		1.4		1	1.9		V/µs
	unity gain		RL = 10 kΩ,	CL = 100 pF,	125°C		2.4		1	3.5		
			See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rate unity gain†	e at			_55°C		3.2		1	4.6		V/µs
	unity gain		i		125°C		4.1		1	4.7		
			$V_{I(PP)} = \pm 10 \text{ mV},$ $R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF},$ See Figures 1 and 2 $V_{I(PP)} = \pm 10 \text{ mV},$		25°C		138			132		
t _r	Rise time				-55°C		142			123		ns
					125°C		166			158		
					25°C		138			132		
tf	Fall time		$R_L = 10 \text{ k}\Omega$	C _L = 100 pF,	−55°C		142			123		ns
			See Figure 1		125°C		166			158		
			V _{I(PP)} = ±10	mV.	25°C		11%			5%		
	Overshoot factor		$R_L = 10 \text{ k}\Omega$	$C_L = 100 pF$,	−55°C		16%			6%		
			See Figures 1	and 2	125°C		14%			8%		
		TL031 M		f = 10 Hz	25°C		61			61		
\ <i>\</i>	Equivalent input	ILOSTW	$R_S = 20 \Omega$,	f = 1 kHz	25°0		41			41		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Vn	noise voltage	TL031AM	See Figure 3	f = 10 Hz	25°C		61			61		nV/√Hz
		ILUSTAM		f = 1 kHz	25-0		41			41		
In	Equivalent input r	oise	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B ₁	Unity-gain bandw	idth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	R _L = 10 kΩ, See Figure 4	–55°C		1		1.1		MHz	
			OL - 25 pr,	Jee i igule 4	125°C		0.9					
					25°C		61°			65°		
φm	Phase margin at u	unity gain	in $V_I = 10 \text{ mV}$, $R_L = 10 \text{ k}\Omega$, $C_I = 25 \text{ pF}$, See Figure 4		–55°C		57°			64°		
	Phase margin at unity ga		OL - 23 pr,	Gee i igule 4	125°C		59°			62°		

[†] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{I(PP)} = \pm 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{I(PP)} = \pm 5 \text{ V}$.

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TL031Y electrical characteristics, $T_A = 25^{\circ}C$

						TLO	31Y			
	PARAMETER	TEST COND		VC	C± = ±5	5 V	Vcc	± = ±1	5 V	UNIT
		1.		MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V 0			0.54			0.5		mV
αΛΙΟ	Temperature coefficient of input offset voltage	$V_O = 0,$ $R_S = 50 \Omega$	AIC = 0,		7.1			5.9		μV/°C
lo	Input offset current	$V_{O} = 0$,	V _{IC} = 0,		1			1		pΑ
I _{IB}	Input bias current	See Figure 5			2			2		pΑ
VICR	Common-mode input voltage range				-3.4 to 5.4			-13.4 to 15.4		٧
V _{OM+}	Maximum positive peak output voltage swing	R _L = 10 kΩ			4.3			14		٧
V _{OM} -	Maximum negative peak output voltage swing	R _L = 10 kΩ			-4.2			-13.9		٧
AVD	Large-signal differential voltage amplification	R _L = 10 kΩ			12			14.3		V/mV
rį	Input resistance				1012			1012		Ω
cį	Input capacitance				5			4		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}^{min}$, R _S = 50 Ω	V _O = 0,		87			94		dB
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	V _O = 0,	R _S = 50 Ω		96			96		dB
PD	Total power dissipation	V- 0	Nolond		1.9			6.5		mW
Icc	Supply current	V _O = 0,	No load		192			217		μА

[†] At $V_{CC\pm} = \pm 5$ V, $V_{O} = \pm 2.3$ V; at $V_{CC\pm} = \pm 15$ V, $V_{O} = \pm 10$ V.

TL031Y operating characteristics, T_A = 25°C

						TL0	31Y			
	PARAMETER	TEST CO	NDITIONS	VC	C±=±5	V	VCC)± = ±15	5 V	UNIT
		l		MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain†	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,		2			2.9		V/μs
SR-	Negative slew rate at unity gain†	See Figure 1	- ;		3.9			5.1		V/μs
tŗ	Rise time	V _{I(PP)} = ±10 r	mV,		138			132		ns
t _f	Fall time	$R_L = 10 k\Omega$	$C_L = 100 pF$,		138			132		ns
	Overshoot factor	See Figures 1	and 2		11%			5%		
···	Environment in the control of the control of	$R_S = 20 \Omega$,	f = 10 Hz		61			61		nV/√Hz
Vn	Equivalent input noise voltage‡	See Figure 3	f = 1 kHz		41			41		nv/√Hz
In	Equivalent input noise current	f = 1 kHz			0.003			0.003		pA/√Hz
В1	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	R _L = 10 kΩ, See Figure 4		1			1.1		MHz
φm	Phase margin at unity gain	V _I = 10 mV, C _I = 25 pF,	$R_L = 10 \text{ k}\Omega$, See Figure 4		61°			65°		

[†] For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V. ‡ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL032C and TL032AC electrical characteristics at specified free-air temperature

						Т	L032C,	TL032A0	;		
	PARAMETER	TEST CON	NDITIONS	T _A †	VC	C±=±5	٧	VC	C± = ±15	5 V	UNIT
		j			MIN	TYP	MAX	MIN	TYP	MAX	
			T	25°C		0.69	3.5		0.57	1.5	
	1		TL032C	Full range			4.5			2.5	
VIO	Input offset voltage		TI 00040	25°C		0.53	2.8		0.39	0.8	mV
			TL032AC	Full range			3.8			1.8	
an # 0	Temperature coefficient	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL032C	25°C to 70°C		11.5			10.8		μV/°C
αVIO	of input offset voltage‡		TL032AC	25°C to 70°C		11.5			10.8	25	μν/ Ο
	Input offset voltage long- term drift§			25°C		0.04			0.04		μV/mo
lio.	Input offset current	$V_{O} = 0$,	V _{IC} = 0,	25°C		1	100		1	100	Aq
10	mput onset current	See Figure 5		70°C		9	200		12	200	PΑ
lin	Input bias current	$V_{O} = 0$,	V _{IC} = 0,	25°C		2	200		2	200	рA
lВ	mput bias current	See Figure 5		70°C		50	400		80	400	рA
	Common-mode input		τ	25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		
VICR	voltage range			Full range	-1.5 to 4			-11.5 to 14			٧
				25°C	3	4.3		13	14		
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	3	4.2		13	14		V
	output voltage swing			70°C	3	4.3		13	14		
				25°C	-3	-4.2	,	-12.5	-13.9		
V _{OM} -	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	-3	-4.1		-12.5	-13.9		V
	- Culput Voltage Owing			70°C	-3	-4.2		-12.5	-14		
				25°C	4	12		5	14.3		
AVD	Large-signal differential voltage amplification	$R_L = 10 \text{ k}\Omega$		0°C	3	11.1		4	13.5		V/mV
	voltage amplification			70°C	4	13.3		5	15.2		
rį	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		5			14		pF
	0	, ,	•	25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR} m$ $V_{C} = 0$	$R_S = 50 \Omega$	0°C	70	87		75	94		dB
	. 5,550077 1000	.0 = 0,		70°C	70	87		75	94		
	Cumply voltoge releast:	Van 15V	to ±15.1/	25°C	75	96		75	96		
ksvR	Supply-voltage rejection ratio ($\Delta V_{CC+}/\Delta V_{IO}$)	$V_{CC\pm} = \pm 5 V$ $V_{CC\pm} = 0$	$R_S = 50 \Omega$	0°C	75	96		75	96		dB
	. 55± 10,	L		70°C	75	96		75	96		

[†] Full range is 0°C to 70°C.

[‡] This parameter is tested on a sample basis for the TL032A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

Stypical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

At V_{CC±} = ±5 V, V_O = 2.3 V; at V_{CC±} = ±15 V, V_O = ±10 V.

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TL032C and TL032AC electrical characteristics at specified free-air temperature (continued)

						Ţ	L032C, 1	L032AC			
	PARAMETER	TEST C	ONDITIONS	TA	VC	C±=±5	٧	Vcc	;± = ±15	V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			,	25°C	·	3.8	5		13	17	
PD	Total power dissipation (two amplifiers)	$V_{O} = 0$,	No load	0°C		3.7	5		12.7	17	mW
	(Wo ampiniors)	1		70°C		3.8	5		12.6	17	
	Supply current	V- 0	Nalaad	0°C		368	500		422	560	A
lcc	(two amplifiers)	V _O = 0,	No load	70°C		378	500		420	560	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100	dB	25°C		120			120		dB

TL032C and TL032AC operating characteristics at specified free-air temperature

							Т	L032C, 1	TL032AC	;				
	PARAMETER		TEST CO	NDITIONS	TA	Vcc	C±=±5	٧	Vcc)±=±15	5 V	UNIT		
						MIN	TYP	MAX	MIN	TYP	MAX			
					25°C		12		1.5	2.9				
SR+	Positive slew rate a gain†	t unity			0°C		1.8		1	2.6		V/μs		
	gairr		$R_1 = 10 \text{ k}\Omega$	$C_1 = 100 pF$	70°C		2.2		1.5	3.2				
			See Figure 1		25°C		3.9		1.5	5.1				
SR-	Negative slew rate gain†	at unity			0°C		3.7		1.5	5		V/µs		
	gaiii		·		70°C		4		1.5	5				
					25°C		138			132				
tr	Rise time			Į.	0°C		134			127		ns		
			1		70°C		150			142				
			V _{I(PP)} = ±10	V.	25°C		138			132				
tf	Fall time		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	0°C		134			127		ns		
			See Figures 1	and 2	70°C		150			142				
			8.3		25°C		11%			5%				
	Overshoot factor				0°C		10%			4%				
					70°C		12%			6%				
		TL032C		f = 10 Hz	25°C		49			49				
v	Equivalent input	110320	$R_S = 20 \Omega$	f = 1 kHz	25.0		41			41		nV/√Hz		
V _n	noise voltage‡	TL032AC	See Figure 3	f = 10 Hz	25°C		49			49		nv/√HZ		
		ILUSZAC		f = 1 kHz	25.0		41			41	60			
In	Equivalent input no	ise current	f = 1 kHz		25°C		0.003			0.003		pA/√Hz		
					25°C		1			1.1				
B ₁	Unity-gain bandwid	th	$V_1 = 10 \text{ mV},$ $C_1 = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	0°C		1			1.1		MHz		
,			OL = 23 pr,	See rigule 4	70°C		1			1				
			10 -11	D 401-0	25°C		61°			65°				
φm	Phase margin at un	ity gain	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$			iV, RL = 10 kΩ, ├−	0°C		61°			65°		
-			,	230ga.0 4	70°C		60°			64°				

[†] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{I(PP)} = \pm 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{I(PP)} = \pm 5 \text{ V}$.



[‡] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL032I and TL032AI electrical characteristics at specified free-air temperature

							TL0321,	TL032AI			
	PARAMETER	TEST COND	ITIONS	TAT	٧c	C± = ±5	٧	VC	C±=±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			<u> </u>	25°C		0.69	3.5	l	0.57	1.5	
		<u> </u>	TL032I	Full range	-		5.3			3.3	
VIO	Input offset voltage	1		25°C		0.53	2.8		0.39	0.8	mV
		_	TL032AI	Full range			4.6			2.6	
	Temperature coefficient	$V_O = 0$, $V_{IC} = 0$, $R_S = 50 \Omega$	TL032I	25°C to 85°C		11.4			10.8		
αVIO	of input offset voltage‡		TL032AI	25°C to 85°C		11.4			10.8	25	μV/°C
	Input offset voltage long-term drift§			25°C		0.04			0.04		μV/mo
l	Innut officet oursent	V _O = 0,	V _{IC} = 0,	25°C		1	100		1	100	pА
lo	Input offset current	See Figure 5		85°C		0.02	0.45		0.02	0.45	nA
l	land this a summer	V _O ≈ 0,	V _{IC} = 0,	25°C		2	200		2	200	pА
IB	Input bias current	See Figure 5		85°C		0.2	0.9		0.3	0.9	nA
VICR	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4	0.9	v
VICH	voltage range			Full range	-1.5 to 4		-	-11.5 to 14			V
				25°C	3	4.3		13	14		
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$		-40°C	3	4.2		13	14		٧
	output voltage swilig			85°C	3	4.4		13	14		
				25°C	-3	-4.2		-12.5	-13.9		
V _{OM} –	Maximum negative peak output voltage swing	R _L = 10 kΩ		-40°C	-3	-4.1		-12.5	-13.8		٧
				85°C	-3	-4.2		-12.5	-14		
AVD	Large-signal differential	$R_{l} = 10 \text{ k}\Omega$		−40°C	3	8.4		4	11.6		V/mV
~VD	voltage amplification¶	11 - 10 K22		85°C	4	13.5		5	15.3		V/IIIV
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		5			4		pF
	0			25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min $V_{CI} = 0$, Re	$S_1 = 50 \Omega$	-40°C	70	87		75	94		dB
		.0 - 5,	,	85°C	70	87		75	94		
	Cupply valtage rejection	$V_{CC\pm} = \pm 5 \text{ V to}$	2 + 15 V	25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	•CC± = ±5 • €	∪ ± 1∪ V ,	-40°C	75	96		75	96		dB
	(= 100±1=10)	V _O = 0, R _S	$S = 50 \Omega$	85°C	75	96		75	96		

[†] Full range is -40°C to 85°C.

[‡] This parameter is tested on a sample basis for the TL032A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

[¶] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

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TL032I and TL032AI electrical characteristics at specified free-air temperature (continued)

							TL032I,	TL032AI			
	PARAMETER	TEST CON	DITIONS	TA	ν _C	C± = ±5	٧	VCC	± = ±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		3.8	5		13	17	
P_{D}	Total power dissipation (two amplifiers)	$V_O = 0$,	No load	-40°C		2.9	5		10.9	17	mW
	(two ampliners)			85°C		3.7	5		12.4	17	
				25°C		384	500		434	560	
lcc	Supply current (two amplifiers)	$V_O = 0$,	No load	-40°C		288	500		362	560	μΑ
	(tiro ampimoro)			85°C		372	500		414	560	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100 dB		25°C		120			120		dB

TL032I and TL032AI operating characteristics at specified free-air temperature

							-	TL0321,	L032AI			
	PARAMETER		TEST CO	NDITIONS	TA	VCC)±=±5	٧	VCC	± = ±18	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate at gain†	unity			-40°C		1.6		1	2.1		V/μs
	gaiiii		D. 1010	C _I = 100 pF	85°C		2.3		1.5	3.3		
			n[= 10 k22,	C[= 100 pr	25°C		3.9		1.5	5.1		
SR-	Negative slew rate a gain†	unity			-40°C		3.3		1.5	4.8		V/μs
	gain	:			85°C		4.1		1.5	4.9		
			$V_{I(PP)} = \pm 10$	V.	25°C		138			132		
t _r	Rise time		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	-40°C		132		7 1 1	123		ns
			See Figures 1	and 2	85°C		154			146		
			V _{I(PP)} = ±10	V.	25°C		138			132		
tf	Fall time		$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,	-40°C		132			123		ns
			See Figure 1		85°C		154			146		
			V _{I(PP)} = ±10	V.	25°C		11%			5%		
	Overshoot factor		$R_L = 10 \text{ k}\Omega$,	$C_L = 100 pF$,	-40°C		12%			5%		
			See Figures 1	and 2	85°C		13%			7%		
		TL032i		f = 10 Hz	25°C		49			49		
V _n	Equivalent input	110321	$R_S = 20 \Omega$	f = 1 kHz	250		41			41		
٧n	noise voltage‡	TL032AI	See Figure 3	f = 10 Hz	25°C		49			49		nV/√Hz
		ILUSZAI		f = 1 kHz	25 0		41			41	60	
In	Equivalent input nois	e current	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1		-	1.1		
В1	Unity-gain bandwidth	1	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	-40°C		1			1.1	1.1	MHz
			OL = 23 pr,	Gee i igule 4	85°C		0.9			1		
			V 40 - V	D 4010	25°C		61°		. j. i	65°		
φm	Phase margin at unit	rgin at unity gain $V_I = 10 \text{ mV}, R_L = 10 \text{ k}\Omega,$ $C_I = 25 \text{ pF}, See Figure 4}$	61°			65°						
			J = 20 pr,	ccc, iguio 4	85°C		60°			64°	60	1

[†] For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V. † This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS SLOS180 – FEBRUARY 1997

TL032M and TL032AM electrical characteristics at specified free-air temperature

						Т	L032M,	TL032A	М		
	PARAMETER	TEST CON	IDITIONS	T _A †	٧c	C± = ±5	V	٧c	C± = ±15	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			TI 00014	25°C		0.69	3.5		0.57	1.5	
.,			TL032M	Full range			6.5			4.5	
VIO	Input offset voltage		Ti 000414	25°C		0.53	2.8		0.39	0.8	mV
		1,, ,	TL032AM	Full range			5.8			3.8	
	Temperature coefficient of	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL032M	25°C to 125°C		9.7			9.7		μV/°С
αVIO	input offset voltage		TL032AM	25°C to 125°C		9.7			9.7		μν/٠
	Input offset voltage long-term drift‡			25°C		0.04			0.04		μ V/m o
1	land offers and	$V_{O} = 0$	V _{IC} = 0,	25°C		1	100		1	100	pА
lΟ	Input offset current	See Figure 5		125°C		0.2	10		0.2	10	nA
l	Input bigg gurrent	V _O = 0,	V _{IC} = 0,	25°C		2	200		2	200	pА
IB	Input bias current	See Figure 5		125°C		7	20		8	20	nA
	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		.,
VICR	voltage range			Full range	-1.5 to 4			-11.5 to 14			V
				25°C	3	4.3		13	14		
V _{OM+}	Maximum positive peak output voltage swing	R _L ≈ 10 kΩ		−55°C	3	4.1		13	14		٧
	output voltage swing			125°C	3	4.4		13	14		
				25°C	-3	-4.2		-12.5	-13.9		
V _{OM} -	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		-55°C	-3	-4		-12.5	-13.8		V
	odipat voltage swing			125°C	-3	-4.3		-12.5	-14		
				25°C	4	12		5	14.3		
A_{VD}	Large-signal differential voltage amplification§	$R_L = 10 \text{ k}\Omega$		–55°C	3	7.1		4	10.4		V/mV
	voltago ampilioationi			125°C	3	12.9		4	15		
rį	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		5			4		pF
	0	V 17		25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}m$ $V_{O} = 0$,	in, R _S = 50 Ω	−55°C	70	87		. 70	94		dB
				125°C	70	87		70	94		
	Cupply voltage rejection	V00 - +5 V	to ±15 V	25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio (ΔV _{CC+} /ΔV _{IO})	$V_{CC\pm} = \pm 5 \text{ V}$ $V_{CC\pm} = 0$	$10 \pm 15 \text{ V},$ $R_S = 50 \Omega$	-55°C	75	95		75	95		dB
	. 00± 10/		•	125°C	75	96		75	96		

[†] Full range is -55°C to 125°C.

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TL032M and TL032AM electrical characteristics at specified free-air temperature (continued)

						TI	L032M, 1	L032AN	1		
	PARAMETER	TEST CO	NDITIONS	TA	VC	C±=±5	V	٧cc)± = ±15	٧ 5	UNIT
	4 N				MIN	TYP	MAX	MIN	TYP	MAX	*
				25°C		3.8	5		13	17	
PD ·	Total power dissipation (two amplifiers)	$V_{O} = 0$,	No load	-55°C		2.3	. 5		9.4	17	mW
	(two ampiliors)			125°C		3.6	5		11.8	17	
				25°C		384	500		434	560	
lcc	Supply current (two amplifiers)	$V_{O} = 0,$	No load	-55°C		228	500		312	560	μΑ
	(two ampimers)			125°C		356	500		394	560	
V _{O1} /V _{O2}	Crosstalk attenuation	$A_{VD} = 100 \text{ dB}$		25°C		120			120		dB

TL032M and TL032AM operating characteristics at specified free-air temperature

							Т	L032M,	TL032AN	1		
	PARAMETER	ì	TEST COI	NDITIONS	TA	٧c	C±=±5	V	VCC)± = ±15	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate at unity gain [†])			-55°C		1.4		1	1.9		V/μs
	at unity gain		$R_L = 10 \text{ k}\Omega$		125°C		2.4		1	3.5		
			C _L = 100 pF, See and Figure	e 1	25°C		3.9		1.5	5.1		
SR-	Negative slew rat	e at unity			−55°C		3.2		1	4.6		V/μs
	ganr				125°C		4.1		1	4.7		
			$V_{I(PP)} = \pm 10 \text{ V}$	',	25°C		138			132		
t _r	Rise time		R_L = 10 kΩ, C ₁ = 100 pF,		-55°C		142			123		ns
			See Figures 1	and 2	125°C		166			58		
			V _{I(PP)} = ±10 V	',	25°C		138			132		
t _f	Fall time		R_L = 10 kΩ, C_L = 100 pF,		-55°C		142			123		ns
			See Figure 1		125°C		166			158		
			V _{I(PP)} = ±10 V	<u>'</u> ,	25°C	†	11%		-	5%		
	Overshoot factor		R_L = 10 kΩ, C_L = 100 pF.		-55°C		16%			6%		
			See Figures 1	and 2	125°C		14%			8%		
		TI 00014		f = 10 Hz	0500		49			49		
.,	Equivalent input	TL032M	$R_S = 20 \Omega$	f = 1 kHz	25°C		41			41		
٧n	noise voltage	TLOCOANA	See Figure 3	f = 10 Hz	0500		49			49		nV/√Hz
		TL032AM		f = 1 kHz	25°C		41			41		
۱ _n	Equivalent input r current	noise	f = 1 kHz	N	25°C		0.003			0.003		pA/√Hz
					25°C		1			1,1		
B1	Unity-gain bandw	ridth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	R_L = 10 kΩ, See Figure 4	−55°C		1			1.1		MHz
					125°C		0.9			0.9		
			\/- 10 m\/	D 10 kO	25°C		61°			65°		
ϕ_{m}	Phase margin at	unity gain	$V_1 = 10 \text{ mV},$ $C_1 = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	−55°C		57°			64°		
			,		125°C		59°			62°		

 $tag{For V_{CC\pm} = \pm 5 \text{ V}, V_{I(PP)} = \pm 1 \text{ V}; for V_{CC\pm} = \pm 15 \text{ V}, V_{I(PP)} = \pm 5 \text{ V}.}$

TL032Y electrical characteristics, $T_A = 25^{\circ}C$

	`		T		TL0	32Y			
	PARAMETER	TEST CONDITIONS	VC	C±=±5	٧	VCC)± = ±16	5 V	UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V- 0 V- 0		0.69			0.57		mV
αVIO	Temperature coefficient of input offset voltage	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$		11.5			10.8		μV/°C
IIO	Input offset current	V _O = 0, V _{IC} = 0, See Figure 5		1			1		pA
IB	Input bias current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		2			2		рA
VICR	Common-mode input voltage range			-3.4 to 5.4			-13.4 to 15.4		٧
V _{OM+}	Maximum positive peak output voltage swing	R _L = 10 kΩ		4.3			14		V
V _{OM} –	Maximum negative peak output voltage swing	R _L = 10 kΩ		-4.2			-13.9		V
AVD	Large-signal differential voltage amplification	R _L = 10 kΩ		12			14.3		V/mV
rį	Input resistance			1012			1012		Ω
cį	Input capacitance			5			14		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $V_{O} = 0$, $R_{S} = 50 \Omega$		87			94		dB
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC\pm} = \pm 5 \text{ V to } \pm 15 \text{ V},$ $V_{O} = 0,$ $R_{S} = 50 \Omega$		96			96		dB
PD	Total power dissipation (two amplifiers)	V _O = 0, No load		3.8			13		mW
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100 dB	T	120			120		dB

[†] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

TL032Y operating characteristics, $T_A = 25^{\circ}C$

						TL03	32Y			
	PARAMETER	TEST CO	NDITIONS	VC	C± = ±5	V	Vcc	;± = ±15	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain [†]	$R_L = 10 \text{ k}\Omega$	C _L = 100 pF,		12			2.9		V/μs
SR-	Negative slew rate at unity gain†	See Figure 1	and Note 8		3.9			5.1		V/μs
t _r	Rise time	V _{I(PP)} = ±10	V.		138			132		ns
t _f	Fall time	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,			138			132		ns
	Overshoot factor	See Figures 1	and 2		11%			5%	MAX	
V	Equivalent input noise voltage‡	$R_S = 20 \Omega$,	f = 10 Hz		49			49		nV/√Hz
Vn	Equivalent input noise voltage+	See Figure 3	f = 1 kHz		41			41		IIV/VIIZ
In	Equivalent input noise current	f = 1 kHz			0.003			0.003		pA/√Hz
B ₁	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	R_L = 10 kΩ, See Figure 4		1			1.1		MHz
φm	Phase margin at unity gain	V _I = 10 mV, C _L = 25 pF,	R_L = 10 kΩ, See Figure 4		61°			65°		

[†] For $V_{CC\pm} = \pm 5$ V, $V_{I(PP)} = \pm 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{I(PP)} = \pm 5$ V. † This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TL034C and TL034AC electrical characteristics at specified free-air temperature

						Т	L034C,	TL034A0	>		
	PARAMETER	TEST CO	NDITIONS	TA [†]	٧c	C±=±5	٧	٧c	C±=±15	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		0.91	6		0.79	4	
			TL034C	Full range			8.2			6.2	١.,
V _{IO}	Input offset voltage		TI 00440	25°C		0.7	3.5		0.58	1.5	mV
		$V_O = 0,$ $V_{IC} = 0,$	TL034AC	Full range			5.7			3.7	
	Temperature coefficient of	$R_S = 50 \Omega$	TL034C	25°C to 70°C		11.6			12		μV/°C
αVIO	input offset voltage‡		TL034AC	25°C to 70°C		11.6			12	25	μν/-C
	Input offset voltage long- term drift§			25°C		0.04			0.04		μV/mo
lio	Input offset current	V _O = 0,	V _{IC} = 0,	25°C		1	100		1	100	рA
JIO OIL	Input onset current	See Figure 5	5	70°C		9	200		12	200	PA
lв	Input bias current	$V_{O} = 0$,	$V_{IC} = 0$,	25°C		2	200		2	200	pА
110	Input bias current	See Figure 5	; 	70°C		50	400		80	400	PA
Vian	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		V
VICR	voltage range			Full range	-1.5 to 4	· · ·		-11.5 to 14			V
				25°C	3	4.3	,	13	14		
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	3	4.2		13	14		V
				70°C	3	4.3		13	14		
				25°C	-3	-4.2		-12.5	-13.9		
V _{OM} -	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		0°C	-3	-4.1		-12.5	-13.9		V
				70°C	-3	-4.2		-12.5	-14		
				25°C	4	12		5	14.3		
AVD	Large-signal differential voltage amplification¶	$R_L = 10 \text{ k}\Omega$		0°C	3	11.1		4	13.5		V/mV
	vokago ampilioation			70°C	4	13.3		5	15.2		
rį	Input resistance			25°C		10 ¹²			1012		Ω
Cį	Input capacitance			25°C		5			14		pF
	Common-mode	VIC = VICR	nin,	25°C	70	87		75	94		
CMRR	rejection ratio	$V_{O} = 0$		0°C	70	87		75	94	***************************************	dB
	•	$R_S = 50 \Omega$		70°C	70	87		75	94		
	Cumply voltage rejection			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$,	$R_S = 50 \Omega$	0°C	75	96		75	96		dB
	. 55± 15,			70°C	75	96		75	96		L

[†] Full range is 0°C to 70°C.

[‡] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. ¶ At $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V; at $V_{CC\pm}$ = ±15 V, V_O = ±10 V.

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TL034C and TL034AC electrical characteristics at specified free-air temperature (continued)

						T	L034C, 7	L034AC	:		
	PARAMETER	TEST CO	ONDITIONS	TA	VC	C±=±5	v	VCC)±=±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		7.7	10		26	34	
P_{D}	Total power dissipation (two amplifiers)	$V_{O} = 0$,	No load	0°C		7.4	10		25.3	34	mW
	(two ampiniors)			70°C		7.6	10		25.2	34	
				25°C		0.77	1		0.87	1.12	
Icc	Supply current (four amplifiers)	$V_{O} = 0$,	No load	0°C		0.74	1		0.85	1.12	mA
	(ioui umpimolo)			70°C		0.76	1		0.84	1.12	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

TL034C and TL034AC operating characteristics at specified free-air temperature

							Т	L034C, 1	L034AC	:		
	PARAMETER		TEST CON	NDITIONS	TA	VC	C±=±5	٧	٧cc)± = ±18	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate at gain†	unity			0°C		1.8		1	2.6		V/μs
	gann		$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,		70°C		2.2		1.5	3.2		
			See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rate a gain†	it unity			0°C		3.7		1.5	5		V/μs
					70°C		4		1.5	5		
			V _{I(PP)} = ±10 V	/ ,	25°C		138			132		
t _r	Rise time		R_L = 10 kΩ, C_L = 100 pF,		0°C		134			127		ns
			See Figures 1	and 2	70°C		150			142		
			V _{I(PP)} = ±10 V	<i>I</i> ,	25°C		138			132		
tf	Fall time		$R_L = 10 kΩ$, $C_L = 100 pF$		0°C		134			127		ns
			See Figure 1		70°C		150			142		
			V _{I(PP)} = ±10 V	Ι,	25°C		11%			5%		
	Overshoot factor		$R_L = 10 \text{ k}Ω$, $C_L = 100 \text{ pF}$,		0°C		10%			4%		
			See Figures 1	and 2	70°C		12%			6%		
		TL034C		f = 10 Hz	25°C		83			83		
v_n	Equivalent input	120340	$R_S = 20 \Omega$	f = 1 kHz	25 0		43			43		nV/√ Hz
l vn	noise voltage‡	TL034AC	See Figure 3	f = 10 Hz	25°C		83			83		11 V / \ \ \ \ \
		TL034AC		f = 1 kHz	25 0		43			43	60	
In	Equivalent input nois	se current	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B ₁	Unity-gain bandwidt	h		$R_L = 10 \text{ k}\Omega$, See Figure 4	0°C		1			1.1		MHz
			о_ 20 р.,	- Coo i iguio i	70°C		1			1		
			V 40V	D 4016	25°C		61°			65°		
φm	Phase margin at uni	ty gain	$V_{ } = 10 \text{ mV},$ $C_{ } = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	0°C		61°			65°		
					70°C		60°			64°		

[†] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{I(PP)} = \pm 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{I(PP)} = \pm 5 \text{ V}$. † This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TL034I and TL034AI electrical characteristics at specified free-air temperature

						•	TL034I,	TL034AI			,
	PARAMETER	TEST CO	NDITIONS	TAT	ν _C	C±=±5	٧	VC	C±=±15	V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			TI 00 41	25°C		0.91	36		0.79	4	
V	Innut official voltage		TL034I	Full range			9.3			7.3	
VIO	Input offset voltage		TI 00 4 4 1	25°C		0.7	3.5		0.58	1.5	mV
		V _O = 0, V _{IC} = 0,	TL034AI	Full range			6.8			4.8	
	Temperature coefficient	$R_S = 50 \Omega$	TL0341	25°C to 85°C		11.5			11.6		μV/°C
αΛΙΟ	of input offset voltage‡		TL034AI	25°C to 85°C		11.5			11.6	25	μν/°C
	Input offset voltage long- term drift§			25°C		0.04			0.04		μV/mo
	11	$V_{O} = 0$,	V _{IC} = 0,	25°C		1	100		1	100	рA
liO	Input offset current	See Figure	5	85°C		0.02	0.45		0.02	0.45	nA
1	land bion or mark	V _O = 0,	V _{IC} = 0,	. 25°C		2	200		2	200	рA
lВ	Input bias current	See Figure	5	85°C		0.2	0.9		0.3	0.9	nA
.,	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4		-11.5 to 14	-13.4 to 15.4		v
VICR	voltage range			Full range	-1.5 to 4			-11.5 to 14			V
				25°C	3	4.3		13	14		
V _{OM+}	Maximum positive peak output voltage swing	R _L = 10 kΩ		-40°C	3	4.1		13	14		V
	odiput voltage swilig			85°C	3	4.4		13	14		
				25°C ,	-3	-4.2		-12.5	-13.9		
V_{OM-}	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		-40°C	-3	-4.1		-12.5	-13.8		V
				85°C	-3	-4.2		-12.5	-14		
A _{VD}	Large-signal differential	R _L = 10 kΩ		-40°C	4	12		5	14.3		V/mV
~VD	voltage amplification¶	11[= 10 KS2		85°C	3	8.4		4	11.6		V/111V
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		5			4		pF
	Common mode	V _{IC} = V _{ICR}	min,	25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{O} = 0$,		-40°C	70	87		75	94		dB
		$R_S = 50 \Omega$		85°C	70	87		75	94		
	Supply voltage rejection			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{O} = 0,$	$R_S = 50 \Omega$	-40°C	75	96		75	96		dB.
	(= 100 <u>1</u> ; = 10)			85°C	75	96		75	96		

[†] Full range is -40°C to 85°C.

[‡] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

¶ At V_{CC±} = ±5 V, V_O = ±2.3 V; at V_{CC±} = ±15 V, V_O = ±10 V.

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TL034I and TL034AI electrical characteristics at specified free-air temperature (continued)

							ΓL034I, Ί	L034AI			
	PARAMETER	TEST C	ONDITIONS	TA	VC	C±=±5	٧	٧cc	;± = ±15	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		7.7	10		26	34	
PD	Total power dissipation (four amplifiers)	$V_{O} = 0$,	No load	-40°C		5.8	10		21.7	34	mW
	(rour amplificio)			85°C		7.4	10		24.8	34	
	• • •			25°C		0.77	1		0.87	1.12	
Icc	Supply current (four amplifiers)	$V_{O} = 0$,	No load	−40°C		0.58	1		0.72	1.12	mA
	(rour amplificio)			85°C		0.74	1		0.83	1.12	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

TL034I and TL034AI operating characteristics

								TL034I, 1	ΓL034AI			
	PARAMETER		TEST CO	NDITIONS	T _A	Vcc)±=±5	V	Vcc) ± = ±15	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate at u	unity gain†			-40°C		1.6		1	2.1		V/μs
			$R_L = 10 \text{ k}\Omega$	C _L = 100 pF,	85°C		2.3		1.5	3.3		
			See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rate at gain†	unity			-40°C		3.3		1.5	4.8		V/μs
	gann				85°C		4.1		1.5	4.9		
					25°C		138			132		
t _r	Rise time				-40°C		132			123		ns
] .		85°C		154			146		
			$V_{I(PP)} = \pm 10$	V,	25°C		138			132		
tf	Fall time		$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,		-40°C		132			123		ns
			See Figures 1	and 2	85°C		154			146		
]		25°C		11%			5%		
	Overshoot factor		1		-40°C		12%			5%		
					85°C		13%			7%		
		TL034I		f = 10 Hz	25°C		83			83		
۷n	Equivalent input	110341	$R_S = 20 \Omega$	f = 1 kHz	25 C		43			43		nV/√Hz
٧n	noise voltage‡	TL034AI	See Figure 3	f = 10 Hz	25°C		83			83		ΠV/γHZ
		TEOGRAI		f = 1 kHz	25 0		43			43	60	
In	Equivalent input noise	current	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B ₁	Unity-gain bandwidth		$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 10 kΩ$, See Figure 4	−40°C		1			1.1		MHz
			- 20 pr,	JJJ i iguio T	85°C		0.9			1		
				5 1015	25°C		61°			65°		
φm	Phase margin at unity	gain	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$		−40°C		61°			65°		
			C = 25 pi ,	COOT Iguic 4	85°C		60°			64°		

[†] For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V. † This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL034M and TL034AM electrical characteristics at specified free-air temperature

		1				Т	L034M,	TL034AI	И		
	PARAMETER	TEST CO	NDITIONS	T _A †	ν _C	C±=±5	٧	VC	C±=±16	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			T	25°C		0.91	3.6		0.78	4	
.,	1		TL034M	Full range			-11			9	.,
VIO	Input offset voltage		TI 00 1111	25°C		0.7	3.5		0.58	1.5	mV
		$V_O = 0,$ $V_{IC} = 0,$	TL034AM	Full range			8.5			6.5	
	Temperature coefficient of	$R_S = 50 \Omega$	TL034M	25°C to 125°C		10.6			10.9	-	
αVIO	input offset voltage		TL034AM	25°C to 125°C		10.6			10.9		μV/°C
	Input offset voltage long-term drift‡			25°C		0.04			0.04		μV/mo
lia	Input offset current	V _O = 0,	V _{IC} = 0,	25°C		1	100		1	100	pА
lo	input onset current	See Figure	5	125°C		0.2	10		0.2	10	nA
l	Input bigg ourrent	V _O = 0,	V _{IC} = 0,	25°C		2	200		2	200	pА
IB	Input bias current	See Figure	5	125°C		7	20		8	20	nA
	Common-mode input			25°C	-1.5 to 4	-3.4 to 5.4	,	-11.5 to 14	-13.4 to 15.4		
VICR	voltage range			Full range	-1.5 to 4			-11.5 to 14			V
				25°C	3	4.3		13	14		
Vом+	Maximum positive peak output voltage swing	R _L = 10 kΩ		-55°C	3	4.1		13	14		V
				125°C	3	4.4		13	14		
				25°C	-3	-4.2		-12.5	-13.9		
V _{OM} -	Maximum negative peak output voltage swing	R _L = 10 kΩ		–55°C	-3	-4		-12.5	-13.8		٧
				125°C	-3	-4.3		-12.5	-14		
	1			25°C	4	12		5	14.3		
AVD	Large-signal differential voltage amplification§	$R_L = 10 \text{ k}\Omega$		–55°C	3	7.1		4	10.4		V/mV
				125°C	3	12.9		4	15		
rį	Input resistance			25°C		1012			1012		Ω
Cį	Input capacitance			25°C		5			4		pF
	Common mode	V V.	min	25°C	70	87		75	94		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ $V_{O} = 0$,	$R_S = 50 \Omega$	−55°C	70	87		70	94		dB
	•	<u> </u>	J	125°C	70	87		70	94		
	Supply voltage rejection			25°C	75	96		75	96		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$,	$R_S = 50 \Omega$	-55°C	75	95		75	95		dB
t =	100± 107	1		125°C	75	96		75	96		<u> </u>

[†] Full range is -55°C to 125°C.

[‡] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

[§] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = \pm 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

TL034M and TL034AM electrical characteristics at specified free-air temperature (continued)

						T	L034M, 1	L034AN	1		
	PARAMETER	TEST CONDITI	ONS	TA	VC	C±=±5	V	VCC)± = ±15	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		7.7	10		26	34	
P_{D}	Total power dissipation (two amplifiers)	$V_O = 0$, No lo	ad	−55°C		4.6	12		18.7	45	mW
	(two ampiniers)			125°C		7.1	12		23.6	45	
				25°C		0.77	1		0.87	1.12	
Icc	Supply current (two amplifiers)	$V_O = 0$, No lo	ad	–55°C		0.46	1.2		0.62	1.5	mA
	(tho displace)			125°C		0.71	1.2		0.79	1.5	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

TL034M and TL034AM operating characteristics at specified free-air temperature

							Т	L034M,	TL034AN			
	PARAMETER		TEST CO	NDITIONS	TA	٧c	C±=±5	٧	Vcc	;± = ±15	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
					25°C		2		1.5	2.9		
SR+	Positive slew rate at	t unity gain†			−55°C		1.4		1	1.9		V/μs
			$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,		125°C		2.4		1	3.5		
	Name the state of the state of		See Figure 1		25°C		3.9		1.5	5.1		
SR-	Negative slew rate a	at unity			−55°C		3.2		1	4.6		V/μs
					125°C		4.1		1	4.7		
			$V_{I(PP)} = \pm 10$	V,	25°C		138		-	132		
t _r	Rise time		$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,		−55°C		142			123		ns
			See Figures 1	and 2	125°C		166			58		,
			$V_{I(PP)} = \pm 10$	V,	25°C		138			132		
tf	Fall time		$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$,		−55°C		142			123		ns
			See Figure 1		125°C		166			158		
			$V_{I(PP)} = \pm 10$	V,	25°C		11%			5%		
	Overshoot factor		$R_L = 10 kΩ$, $C_L = 100 pF$,		-55°C		16%			6%		
			See Figures 1	and 2	125°C		14%			8%		
		TL034M		f = 10 Hz	25°C		83			83		
Vn	Equivalent input	I LU34IVI	$R_S = 20 \Omega$	f = 1 kHz	25 0		43			43		nV/√Hz
٧n	noise voltage	TL034AM	See Figure 3	f = 10 Hz	25°C		83			83		110/17
		1 LOOTAIVI		f = 1 kHz	23 0		43			43		
In	Equivalent input noi	se current	f = 1 kHz		25°C		0.003			0.003		pA/√Hz
					25°C		1			1.1		
B1	Unity-gain bandwidt	h	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$		−55°C		1			1.1		MHz
			-L = 20 pr,	2.3. iguio 4	125°C		0.9			0.9		
			10	D 401-C	25°C		61°			65°		
φm	Phase margin at uni	ity gain	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$		−55°C		57°			64°		
					125°C		59°			62°		

[†] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{I(PP)} = \pm 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{I(PP)} = \pm 5 \text{ V}$.

TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS SLOS180 – FEBRUARY 1997

TL034Y electrical characteristics, $T_A = 25^{\circ}C$

					TL0	34Y		***************************************	
	PARAMETER	TEST CONDITIONS	ν _C	C±=±5	v	VCC)± = ±18	5 V	UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V- 0 V- 0		0.91			0.79		mV
αVIO	Temperature coefficient of input offset voltage	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$		11.6			12		μV/°C
lia	Input offset current	$V_{O} = 0, V_{IC} = 0,$		1			1		рA
lio .	input oliset current	See Figure 5		2			2		pА
li-	Input his surrent	$V_{O} = 0$, $V_{IC} = 0$,		2			2		pА
IB	Input bias current	See Figure 5		7			8		nA
				-3.4			-13.4		
VICR	Common-mode input voltage range			to			to		٧
				5.4			15.4		
V _{OM+}	Maximum positive peak output voltage swing	R _L = 10 kΩ		4.3			14		٧
V _{OM} -	Maximum negative peak output voltage swing	R _L = 10 kΩ		-4.2			-13.9		٧
AVD	Large-signal differential voltage amplification†	R _L = 10 kΩ		12			14.3		V/mV
rį	Input resistance		<u> </u>	1012	·		1012		Ω
Cį	Input capacitance			5			4		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $V_{O} = 0$, $R_{S} = 50 \Omega$		87			94		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_O = 0$, $R_S = 50 \Omega$		96			96		dB
PD	Total power dissipation (four amplifiers)	V _O = 0, No load		7.7			26		mW
Icc	Supply current (four amplifiers)	V _O = 0, No load		0.77			0.87		mA
V _{O1} /V _{O2}	Crosstalk attenuation	AVD = 100		120			120		dB

[†] At $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = \pm 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

TL034Y operating characteristics, T_A = 25°C

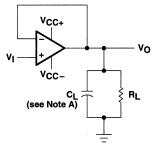
						TLO	34Y			
	PARAMETER	TEST CO	NDITIONS	VC	C± = ±5	٧	Vcc)± = ±15	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF,		2		1.5	2.9		V/μs
SR-	Negative slew rate at unity gain	See Figure 1	_		3.9		1.5	5.1		V/μs
t _r	Rise time	V _{I(PP)} = ±10	V		138			132		ns
tf	Fall time	$R_L = 10 \text{ k}\Omega$	$C_L = 100 pF$,		138			132		ns
	Overshoot factor	See Figures 1	and 2		11%			5%		
V	F	$R_S = 20 \Omega$,	f = 10 kHz		83			83		
٧n	Equivalent input noise voltage†	See Figure 3	f = kHz		43			43		nV/√Hz
In	Equivalent input noise current	f = 1 kHz			0.003			0.003		pA/√Hz
В1	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	R _L = 10 kΩ, See Figure 4		1			1.1		MHz
φm	Phase margin at unity gain	V _I = 10 mV, C _L = 25 pF,			61°			65°		

This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew-Rate and Overshoot Test Circuit

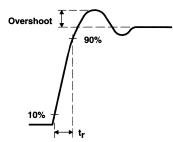


Figure 2. Rise Time and Overshoot Waveform

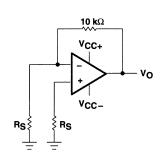
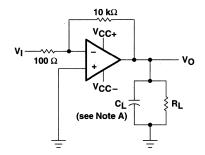


Figure 3. Noise-Voltage Test Circuit



NOTE A: CL includes fixture capacitance.

Figure 4. Unity-Gain Bandwidth and Phase-Margin Test Circuit

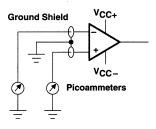


Figure 5. Input-Bias and Offset-Current Test Circuit

TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

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PARAMETER MEASUREMENT INFORMATION

typical values

Typical values presented in this data sheet represent the median (50% point) of device parametric performance.

input bias and offset current

At the picoampere bias current level typical of the TL03x and TL03xA, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

noise

Because of the increasing emphasis on low noise levels in many of today's applications, the input noise voltage density is sample tested at f = 1 kHz. Texas Instruments also has additional noise testing capability to meet specific application requirements. Contact the factory for details.

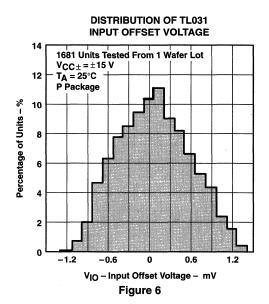


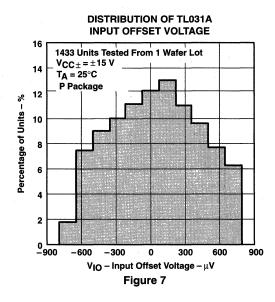
TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	6 – 11
αVIO	Input offset voltage temperature coefficient	Distribution	12, 13, 14
10	Input offset current	vs Free-air temperature	15
lв	Input bias current	vs Common-mode input voltage vs Free-air temperature	15 16
VIC	Common-mode input voltage range	vs Supply voltage vs Free-air temperature	17 18
VID	Output voltage	vs Differential input voltage	19, 20
V _{OM}	Maximum peak output voltage	vs Supply voltage vs Output current vs Free-air temperature	21 23, 24 25, 26
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	22
A _{VD}	Large-signal differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	27 28 29
z _O	Output impedance	vs Frequency	30
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	31, 32 33
ksvr	Supply voltage rejection ratio	vs Free-air temperature	34
los	Short-circuit output current	vs Supply voltage vs Time vs Free-air temperature	35 36 37
٧n	Equivalent input noise voltage	vs Frequency	38, 39, 40
lcc	Supply current	vs Supply voltage vs Free-air temperature	41, 42, 43 44, 45, 46
SR	Slew rate	vs Load resistance vs Free-air temperature	47, 48 49, 50
	Overshoot factor	vs Load capacitance	51
THD	Total harmonic distortion	vs Frequency	52
В1	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	53 54
φm	Phase margin	vs Supply voltage vs Load capacitance vs Free-air temperature	55 56 57
	Voltage-follower small signal pulse response	vs Time	58
	Voltage-follower large-signal pulse response	vs Time	59, 60
	Phase shift	vs Frequency	28

TYPICAL CHARACTERISTICS





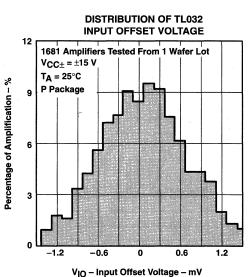
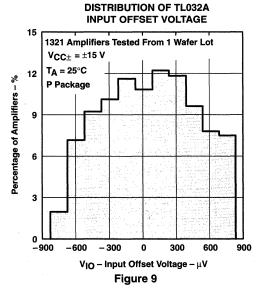


Figure 8



DISTRIBUTION OF TL034A

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1.8

1.2

TYPICAL CHARACTERISTICS

0

-1.8

-1.2

0.6

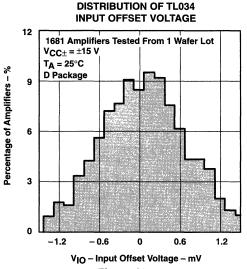
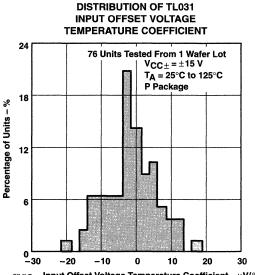
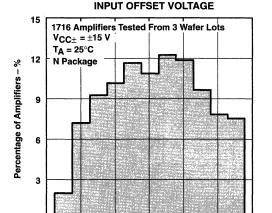


Figure 10



 α_{VIO} – Input Offset Voltage Temperature Coefficient – μ V/°C Figure 12



V_{IO} – Input Offset Voltage – mV Figure 11

0.6

DISTRIBUTION OF TL032 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

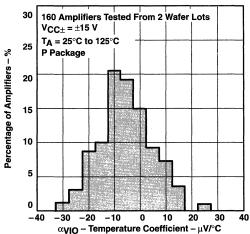
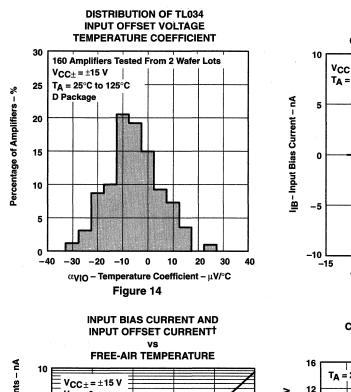
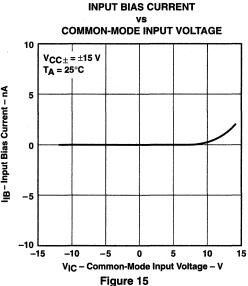
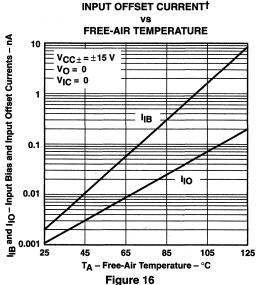
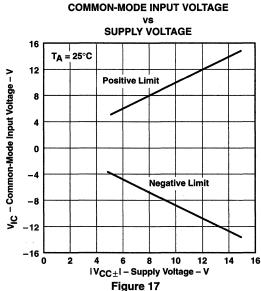


Figure 13

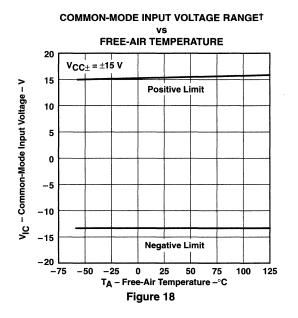


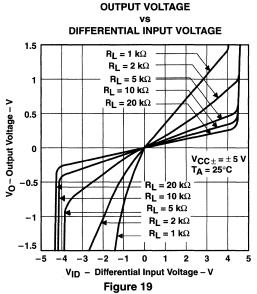


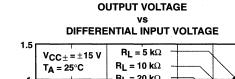


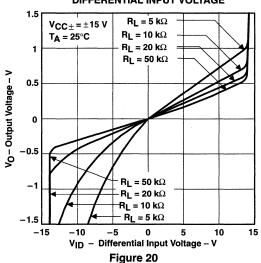


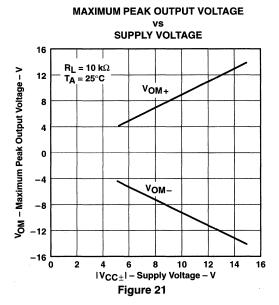
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



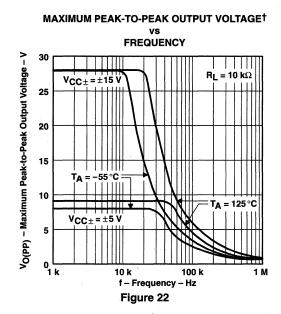


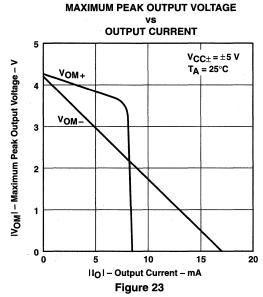


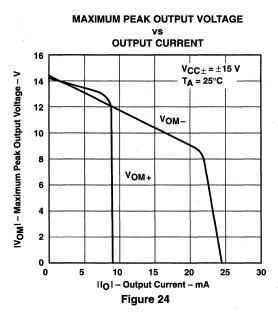


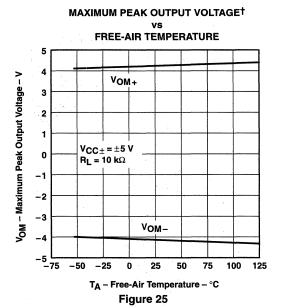


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





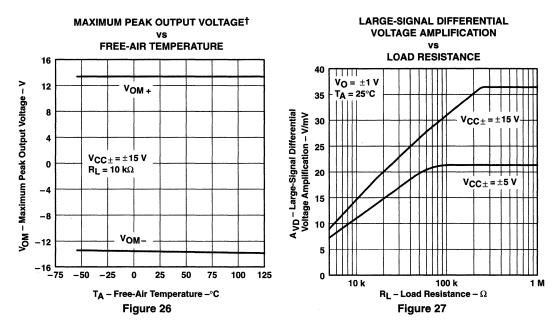




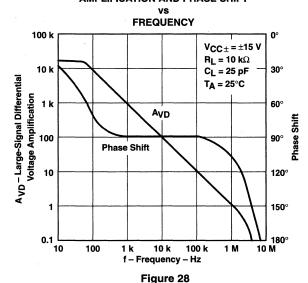
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



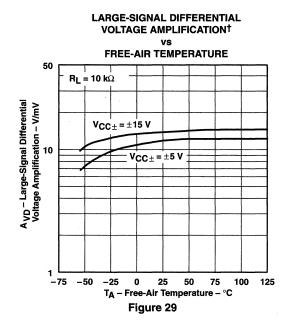
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

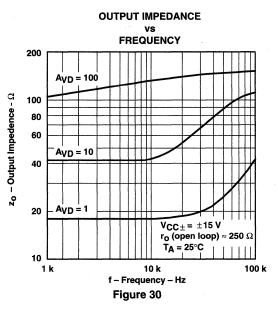


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

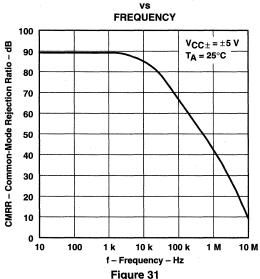


TYPICAL CHARACTERISTICS

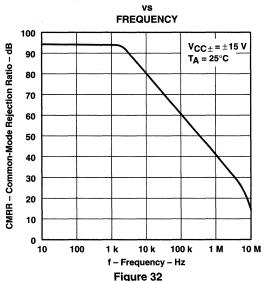




COMMON-MODE REJECTION RATIO



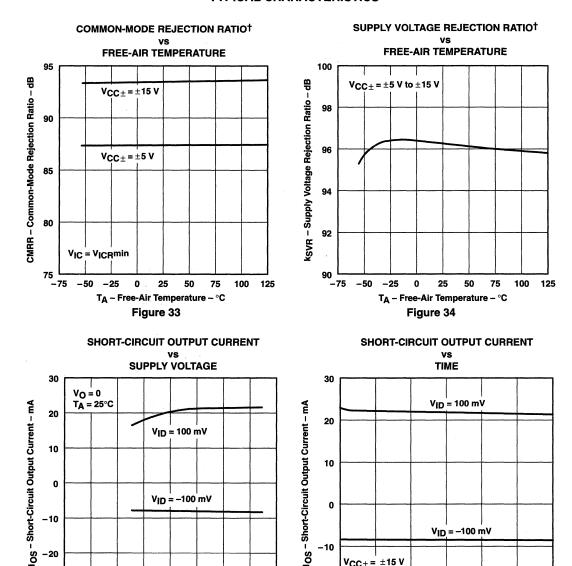
COMMON-MODE REJECTION RATIO



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



-20

-30

2

8

IV_{CC±}I - Supply Voltage - V

Figure 35

10 12 14 16



V_{CC±} = ±15 V T_A = 25°C

5

10

15

t - Time - s

Figure 36

20

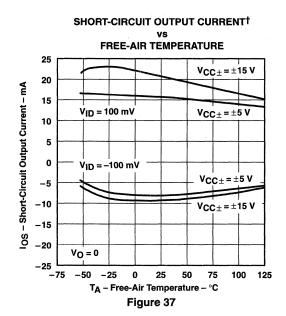
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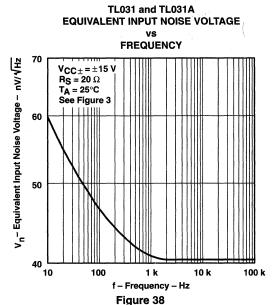
30

-20

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS





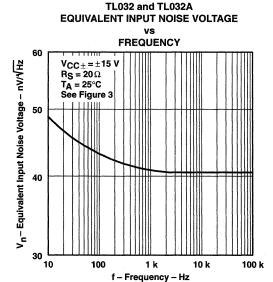
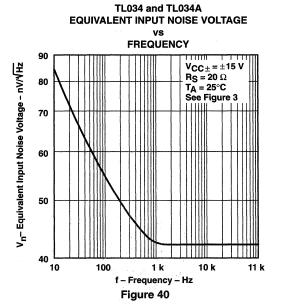
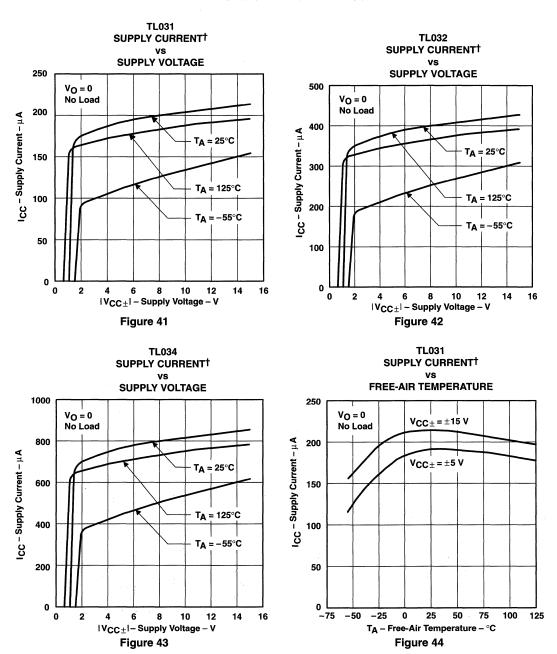


Figure 39



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

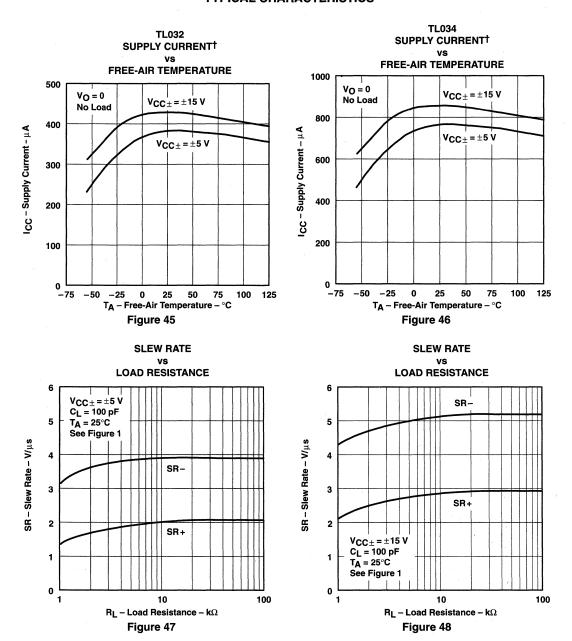




[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



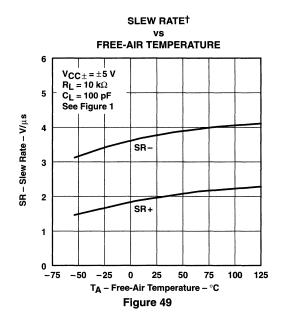
TYPICAL CHARACTERISTICS

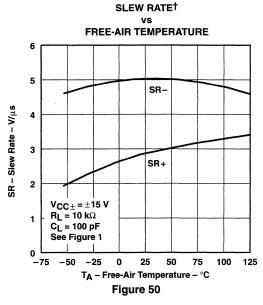


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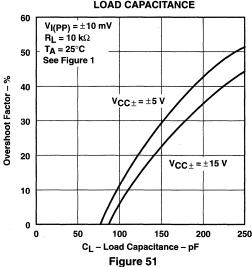


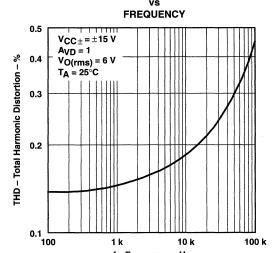
TYPICAL CHARACTERISTICS





OVERSHOOT FACTOR LOAD CAPACITANCE 60 $V_{I(PP)} = \pm 10 \text{ mV}$





f - Frequency - Hz

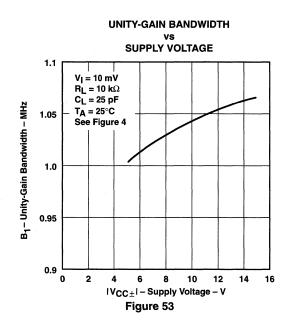
Figure 52

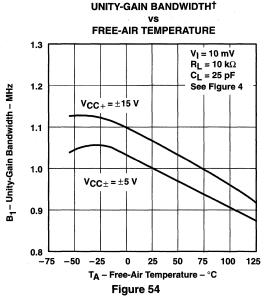
TOTAL HARMONIC DISTORTION

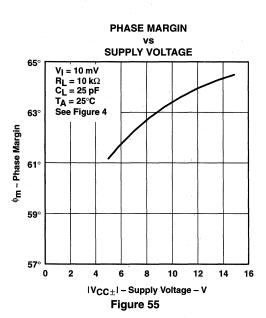
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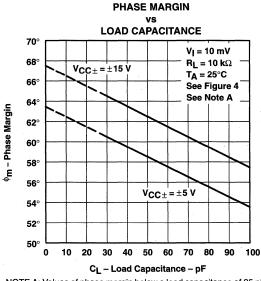


TYPICAL CHARACTERISTICS







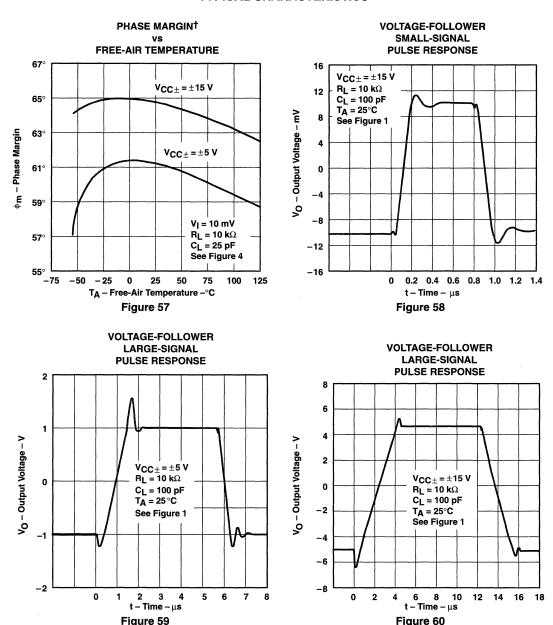


NOTE A: Values of phase margin below a load capacitance of 25 pF were estimated.

Figure 56

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



APPLICATION INFORMATION

input characteristics

The TL03x and TL03xA are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Due to of the extremely high input impedance and resulting low bias current requirements, the TL03x and TL03xA are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 61). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

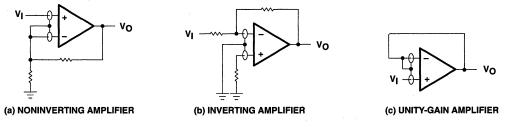


Figure 61. Use of Guard Rings

APPLICATION INFORMATION

output characteristics

All operating characteristics (except bandwidth and phase margin) are specified with 100-pF load capacitance. The TL03x and TL03xA drive higher capacitive loads; however, as the load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation. The value of the load capacitance at which oscillation occurs varies with production lots. If an application appears to be sensitive to oscillation due to load capacitance, adding a small resistance in series with the load should alleviate the problem (see Figure 63). Capacitive loads of 1000 pF and larger may be driven if enough resistance is added in series with the output (see Figure 62).

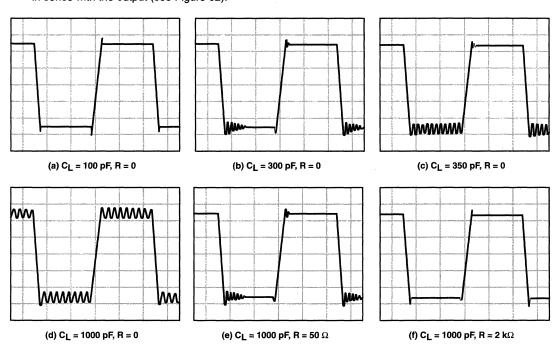


Figure 62. Effect of Capacitive Loads

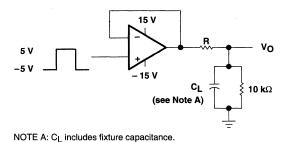


Figure 63. Test Circuit for Output Characteristics



APPLICATION INFORMATION

high-Q notch filter

In general, Texas Instruments enhanced-JFET operational amplifiers serve as excellent filters. The circuit in Figure 64 provides a narrow notch at a specific frequency. Notch filters are designed to eliminate frequencies that are interfering with the operation of an application. For this filter, the center frequency can be calculated as:

$$f_O = \frac{1}{2\pi R1C1}$$

With the resistors and capacitors shown in Figure 64, the center frequency is 1 kHz. C1 = C3 = C2 + 2 and $R1 = R3 = 2 \times R2$. The center frequency can be modified by varying these values. When adjusting the center frequency, ensure that the operational amplifier has sufficient gain at the frequency required.

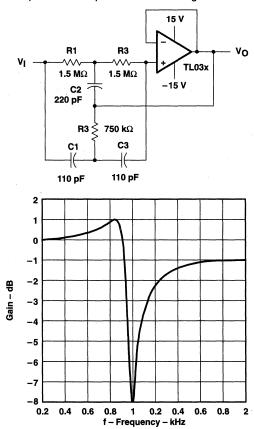


Figure 64. High-Q Notch Filter

APPLICATION INFORMATION

transimpedance amplifier

The low-power precision TL03x allows accurate measurement of low currents. The high input impedance and low offset voltage of the TL03xA greatly simplify the design of a transimpedance amplifier. At room temperature, this design achieves 10-bit accuracy with an error of less than 1/2 LSB.

Assuming that R2 is much less than R1 and ignoring error terms, the output voltage can be expressed as:

$$V_O = -I_{IN} \times R_F \left(\frac{R1 + R2}{R2} \right)$$

Using the resistor values shown in the schematic for a 1-nA input current, the output voltage equals -0.1 V. If the V_O limit for the TL03xA is measured at \pm 12 V, the maximum input current for these resistor values is \pm 120 nA. Similarly, one LSB on a 10-bit scale corresponds to 12 mV of output voltage, or 120 pA of input current.

The following equation shows the effect of input offset voltage and input bias current on the output voltage:

$$V_{O} = -\left[V_{IO} + R_{F}\left(I_{IO} + I_{IB}\right)\right]\left(\frac{R1 + R2}{R2}\right)$$

If the application requires input protection for the transimpedance amplifier, do not use standard PN diodes. Instead, use low-leakage Siliconix SN4117 JFETs (or equivalent) connected as diodes across the TL03xA inputs as shown in Figure 65.

As with all precision applications, special care must be taken to eliminate external sources of leakage and interference. Other precautions include using high-quality insulation, cleaning insulating surfaces to remove fluxes and other residue, and enclosing the application within a protective box.

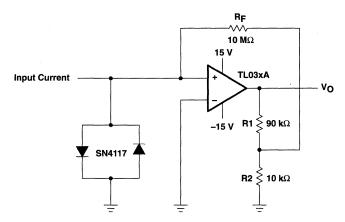


Figure 65. Transimpedance Amplifier

APPLICATION INFORMATION

4-mA to 20-mA current loops

Often, information from an analog sensor must be sent over a distance to the receiving circuitry. For many applications, the most feasible method involves converting voltage information to a current before transmission. The following circuits give two variations of low-power current loops. The circuit in Figure 66 requires three wires from the transmitting to receiving circuitry while the second variation in Figure 67 requires only two wires but includes an extra integrated circuit. Both circuits benefit from the high input impedance of the TL03xA since many inexpensive sensors do not have low output impedance.

Assuming that the voltage at the noninverting input of the TL03xA is zero, the following equation determines the output current:

$$I_O = V_I \left(\frac{R3}{R1 \times R_S} \right) + 5V \left(\frac{R3}{R2 \times R_S} \right) = 0.16 \times V_I + 4 \text{ mA}$$

The circuits presently provide 4-mA to 20-mA output for an input voltage of 0 to 100 mV. By modifying R1, R2, and R3, the input voltage range or the output current range can be adjusted.

Including the offset voltage of the operational amplifier in the above equation clearly illustrates why the low offset TL03xA was chosen:

$$I_{O} = V_{I} \left(\frac{R3}{R1 \times R_{S}} \right) + 5V \left(\frac{R3}{R2 \times R_{S}} \right) - V_{I} \left(\frac{R3}{R1 \times R_{S}} + \frac{R3}{R2 \times R_{S}} + \frac{R1}{R_{S}} \right)$$

$$= 0.16 \times V_{I} + 4mA - 0.17 \times V_{I}$$

For example, an offset voltage of 1 mV decreases the output current by 0.17 mA.

Due to the low power consumption of the TL03xA, both circuits have at least 2 mA available to drive the actual sensor from the 5-V reference node.

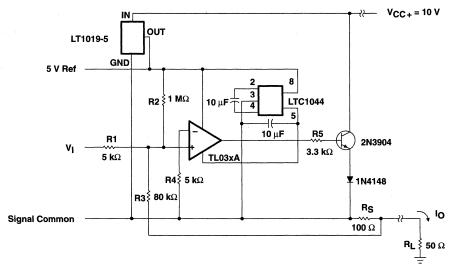


Figure 66. Two-Wire 4-mA to 20-mA Current Loop



APPLICATION INFORMATION

4-mA to 20-mA current loops (continued)

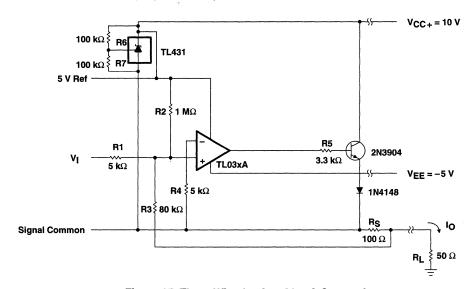


Figure 67. Three-Wire 4-mA to 20-mA Current Loop

APPLICATION INFORMATION

low-level light detector preamplifier

Applications that need to detect small currents require high input-impedance operational amplifiers; otherwise, the bias currents of the operational amplifier camouflage the current being monitored. Phototransistors provide a current that is proportional to the light reaching the transistor. The TL03x allows even the small currents resulting from low-level light to be detected.

In Figure 68, if there is no light, the phototransistor is off and the output is high. As light is detected, the operational amplifier output begins pulling low. Adjusting R4 both compensates for offset voltage of the amplifier and adjusts the point of light detection by the amplifier.

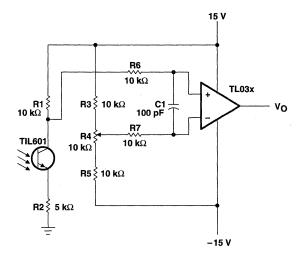


Figure 68. Low-Level Light Detector Preamplifier

APPLICATION INFORMATION

audio-distribution amplifier

This audio-distribution amplifier (see Figure 69) feeds the input signal to three separate output channels. U1A amplifies the input signal with a gain of 10, while U1B, U1C, and U1D serve as buffers to the output channels. The gain response of this circuit is very flat from 20 Hz to 20 kHz. The TL03x allows quick response to the input signal while maintaining low power consumption.

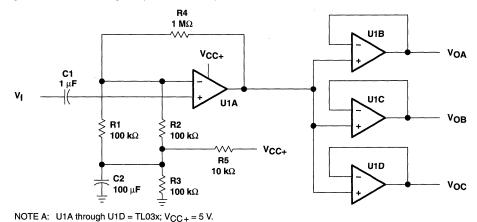


Figure 69. Audio-Distribution Amplifier Circuit

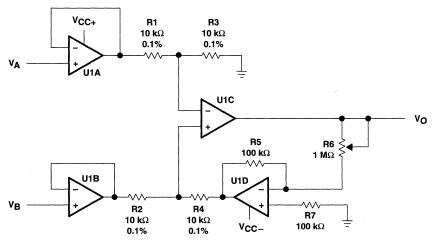
APPLICATION INFORMATION

instrumentation amplifier with linear gain adjust

The low offset voltage and low power consumption of the TL03x provide an accurate but inexpensive instrumentation amplifier (see Figure 70). This particular configuration offers the advantage that the gain can be linearly set by one resistor:

$$V_O = \frac{R6}{R5} \times (V_B - V_A)$$

Adjusting R6 varies the gain. The value of R6 should always be greater or equal to the value of R5 in order to ensure stability. The disadvantage of this instrumentation amplifier topology is the high degree of CMRR degradation resulting from mismatches between R1, R2, R3, and R4. For this reason, these four resistors should be 0.1% tolerance resistors.



NOTE A: U1A through U1D = TL03x; $V_{CC\pm} = \pm 15 \text{ V}$.

Figure 70. Instrumentation Amplifier With Linear Gain-Adjust Circuit

SLOS178 - FEBRUARY 1997

- Direct Upgrades to TL07x and TL08x BiFET Operational Amplifiers
- Faster Slew Rate (20 V/μs Typ) Without Increased Power Consumption
- On-Chip Offset Voltage Trimming for Improved DC Performance and Precision Grades Are Available (1.5 mV, TL051A)
- Available in TSSOP for Small Form-Factor Designs

description

The TL05x series of JFET-input operational amplifiers offers improved dc and ac characteristics over the TL07x and TL08x families of BiFET operational amplifiers. On-chip zener trimming of offset voltage yields precision grades as low as 1.5 mV (TL051A) for greater accuracy in dc-coupled applications. Texas Instruments improved BiFET process and optimized designs also yield improved bandwidth and slew rate without increased power consumption. The TL05x devices are pin-compatible with the TL07x and TL08x and can be used to upgrade existing circuits or for optimal performance in new designs.

BiFET operational amplifiers offer the inherently higher input impedance of the JFET-input transistors, without sacrificing the output drive associated with bipolar amplifiers. This makes them better suited for interfacing with high-impedance sensors or very low-level ac signals. They also feature inherently better ac response than bipolar or CMOS devices having comparable power consumption.

The TL05x family was designed to offer higher precision and better ac response than the TL08x with the low noise floor of the TL07x. Designers requiring significantly faster ac response or ensured lower noise should consider the Excalibur TLE208x and TLE207x families of BiFET operational amplifiers.

AVAILABLE OPTIONS

				PACKAGE	DEVICES			CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	FORM‡ (Y)
	800 μV	TL051ACD TL052ACD	_	_	_	_	TL051ACP TL052ACP	
0°C to 70°C	1.5 mV	TL051CD TL052CD TL054ACD	_	_	_	TL054ACN	TL051CP TL052CP	TL051Y TL052Y TL054Y
	4 mV	TL054CD	_	_	_	TL054CN	_	
	800 μV	TL051AID TL052AID	_	_	_	_	TL051AIP TL052AIP	
-40°C to 85°C	1.5 mV	TL051ID TL052ID TL054AID			_	TL054AIN	TL051IP TL052IP	_
	4 mV	TL054ID				TL054IN		
	800 μV	800 μV TL051AMD TL051AMFK — TL051AMJG — TL051AMP TL052AMP						
-55°C to 125°C	1.5 mV	TL051MD TL052MD TL054AMD	TL051MFK TL052MFK TL054AMFK	TL054AMJ	TL051MJG TL052MJG	TL054AMN	TL051MP TL052MP	_
	4 mV	TL054MD	TL054MFK	TL054MJ		TL054MN	_	

† The D packages are available taped and reeled. Add R suffix to device type (e.g., TL054CDR).

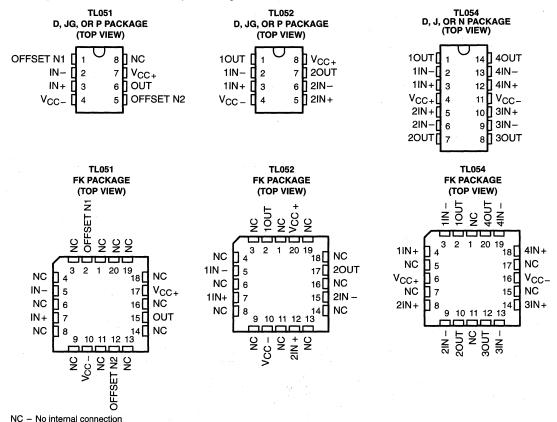
‡ Chip forms are tested at 25°C.



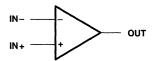
description (continued)

Because BiFET operational amplifiers are designed for use with dual power supplies, care must be taken to observe common-mode input voltage limits and output swing when operating from a single supply. DC biasing of the input signal is required and loads should be terminated to a virtual-ground node at midsupply. Texas Instruments TLE2426 integrated virtual ground generator is useful when operating BiFET amplifiers from single supplies.

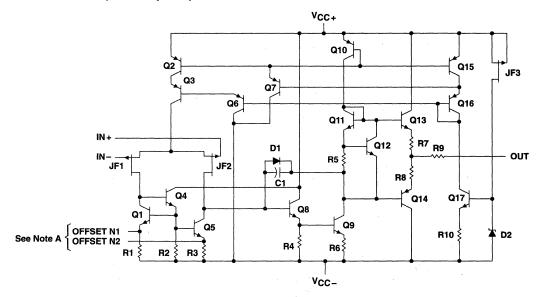
The TL05x are fully specified at \pm 15 V and \pm 5 V. For operation in low-voltage and/or single-supply systems, Texas Instruments LinCMOS families of operational amplifiers (TLC-prefix) are recommended. When moving from BiFET to CMOS amplifiers, particular attention should be paid to the slew rate and bandwidth requirements, and also the output loading.



symbol (each amplifier)



equivalent schematic (each amplifier)



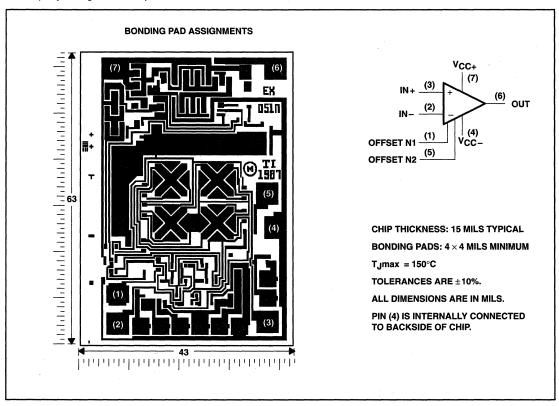
NOTE A: OFFSET N1 and OFFSET N2 are only available on the TL051x.

ACTUAL DEVICE COMPONENT COUNT										
COMPONENT	TL051	TL052	TL054							
Transistors	20	34	62							
Resistors	10	19	37							
Diodes	2	3	5							
Capacitors	1	2	4							

[†]These figures include all four amplifiers and all ESD, bias, and trim circuitry.

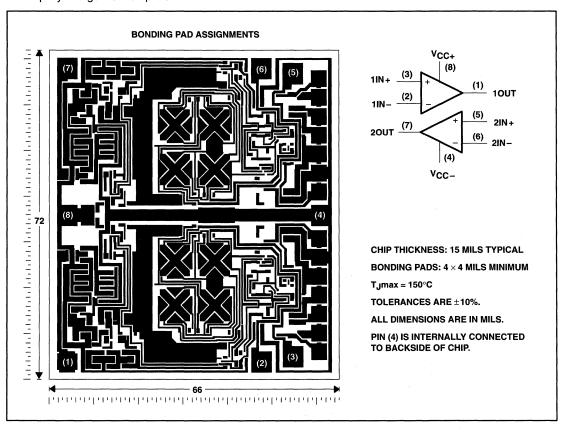
TL051Y chip information

This chip, when properly assembled, displays characteristics similar to the TL051. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



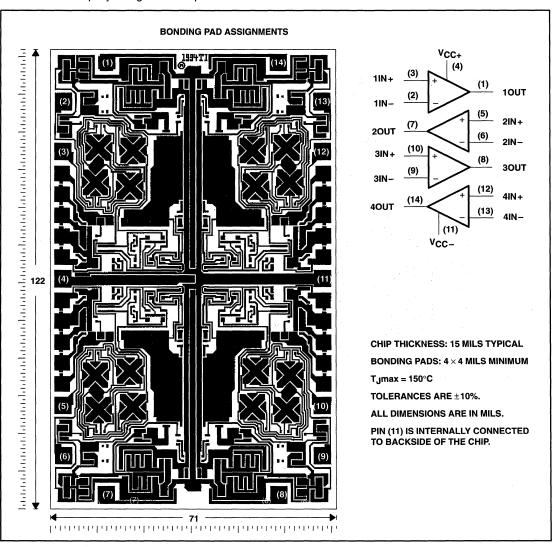
TL052Y chip information

This chip, when properly assembled, displays characteristics similar to the TL052. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TL054 chip information

This chip, when properly assembled, displays characteristics similar to the TL054C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. These chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)		18 V
Supply voltage, V _{CC} (see Note 1)		
Differential input voltage (see Note 2)		
Input voltage range, VI (any input, see Not		
Input current, I _I (each input)		
Output current, IO (each output)		
Total current into V _{CC+}		
Total current out of V _{CC}		
Duration of short-circuit current at (or below	w) 25°C (see Note 4)	unlimited
Continuous total power dissipation		See Dissipation Rating Table
Operating free-air temperature range, TA:	C suffix	0°C to 70°C
	I suffix	40°C to 85°C
	M suffix	55°C to 125°C
Storage temperature range		65°C to 150°C
Case temperature for 60 seconds: FK pacl		
Lead temperature 1,6 mm (1/16inch) from	case for 10 seconds: D, N, or P pag	ckage 260°C
Lead temperature 1,6 mm (1/16inch) from	case for 60 seconds: J or JG packa	ıge 300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- 4. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A ≈ 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
N	1575 mW	12.6 mW/°C	1008 mW	819 mW	315 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

		C SU	FFIX	I SUF	I SUFFIX M SUFFIX		FFIX	LINUT
		MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{CC±}		±5	±15	±5	±15	±5	±15	V
O	V _{CC±} = ±5 V	-1	4	-1	4	-1	4	V
Common-mode input voltage, V _{IC}	$V_{CC\pm} = \pm 15 V$	-11	,11	-11	11	-11	11	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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TL051C and TL051AC electrical characteristics at specified free-air temperature

						Т	L051C, 1	L051A0			
PARAMETER		TEST CO	NDITIONS	TAT	VC	C ± = ± 5	v	Vcc) ± = ± 18	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		0.75	3.5		0.59	1.5	
			TL051C	Full range			4.5		, .	2.5	
VIO	Input offset voltage	l l		25°C		0.55	2.8		0.35	0.8	mV
		l., ,	TL051AC	Full range			3.8			1.8	
	Temperature coefficient	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL051C	25°C to 70°C		8			8		
αVIO	of input offset voltage‡	1.13 = 55 12	TL051AC	25°C to 70°C		8			8	25	μV/°C
	Input offset voltage long-term drift§			25°C		0.04			0.04		μV/mo
		V _O = 0,	$V_{IC} = 0$,	25°C		4	100		5	100	pА
lο	Input offset current	See Figure		70°C		0.02	1		0.025	1	nA
	land black and	V _O = 0,	V _{IC} = 0,	25°C	T	20	200		30	200	pА
lΒ	Input bias current	See Figure	5	70°C		0.15	4		0.2	4	nA
			·		-1	-2.3		-11	-12.3		
				25°C	to	to		to	to		
VICR	Common-mode input voltage range				4	5.6		11	15.6		V
1011	voltage range			Full range	-1 to			–11 to			
ı		}		ruirange	4			11			
		1	R _L = 10 kΩ		3	4.2		13	13.9		
.,	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$			3			13			٠,,
VOM +		5 616			2.5	3.8		11.5	12.7		V
		R _L = 2 kΩ		Full range	2.5			11.5			
	/,	D 4010		25°C	-2.5	-3.5		-12	-13.2		
	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		Full range	-2.5			-12			1
VOM -	output voltage swing	D: 01:0		25°C	-2.3	-3.2		11	-12		٧
		$R_L = 2 k\Omega$		Full range	-2.3			-11			
	1!1 -!!#!!-!			25°C	25	59		50	105		
A_{VD}	Large-signal differential voltage amplification¶	$R_L = 2 k\Omega$		0°C	30	65		60	129		V/mV
	voltage amplification in	1		70°C	20	46		30	85		
rį	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		10			12		pF
		T., .,		25°C	65	85		75	93		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ $V_{O} = 0$,	min, $R_S = 50 \Omega$	0°C	65	84		75	92		dB
	rejection ratio	1 *0 = 0,	115 = 50 12	70°C	65	84		75	91		
	O			25°C	75	99		75	99		
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{O} = 0$,	$R_S = 50 \Omega$	0°C	75	98		75	98		dB
	(AVCC±/AVIC)			70°C	75	97		75	97		
				25°C		2.6	3.2		2.7	3.2	2 mA
Icc	Supply current	$V_O = 0$,	No load	0°C		2.7	3.2		2.8	3.2	
				70°C		2.6	3.2		2.7	3.2	

[†] Full range is 0°C to 70°C.



[‡]This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

^{\$} Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. ¶ For $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V, or for $V_{CC\pm}$ = ±15 V, V_O = ±10 V.

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TL051C and TL051AC operating characteristics at specified free-air temperature

						Ţ	L051C,	TL051AC	;			
	PARAMETER	TEST CO	NDITIONS	T _A †	VC	C±=±5	٧	Vcc)±=±1	5 V	UNIT	
					MIN	TYP	MAX	MIN	TYP	MAX		
	5			25°C		16		13	20			
SR+	Positive slew rate at unity gain‡	R _L = 2 kΩ,	C _l = 100 pF,	Full range		16.4		11	22.6) //	
		See Figure 1	_	25°C		15		13	18		V/μs	
SR-	Negative slew rate at unity gain‡			Full range		16		11	19.3			
				25°C		55			56			
tr	Rise time	l		0°C		54			55		1	
				70°C		63			63]	
		$V_{I(PP)} = \pm 10 \text{ r}$	nV,	25°C		55			57		ns	
tf	Fall time	R) = $2 k\Omega$, CL = 100 pF, See Figures 1 and 2		0°C		54			56			
				70°C		62			64		1	
				25°C		24%			19%			
	Overshoot factor			0°C		24%			19%		1	
					70°C		24%			19%		
V	Equivalent input noise		f = 10 Hz	25°C		75			75		- N// /TT	
٧n	voltage§	$R_S = 20 \Omega$,	f = 1 kHz	25°C		18			18	30	nV/√Hz	
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz	25°C		4			4		μV	
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz	
THD	Total harmonic distortion¶	$R_S = 1 k\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C		0.003%			0.003%			
				25°C		3			3.1			
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$ $C_{L} = 25 \text{ pF},$	$R_L = 2 k\Omega$, See Figure 4	0°C		3.2			3.3		MHz	
	·	OL - 20 pr.,	CCC i iguie 4	70°C		2.7			2.8			
				25°C	-	59°			62°			
Φm	Phase margin at unity gain	V _I = 10 mV, C _L = 25 pF,	R _L = 2 k Ω , See Figure 4	0°C		58°			62°]	
Vn Eq vol VN(PP) Pe inp In Eq noi THD Tot B1 Un	yum	OL - 20 pi,	COO I Iguile 4	70°C		59°			62°]	

[†] Full range is 0°C to 70°C.

For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V.

This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

 $[\]P$ For $V_{CC\pm} = \pm 5$ V, $V_{Orms} = 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{Orms} = 6$ V.

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TL051I and TL051AI electrical characteristics at specified free-air temperature

							TL0511, 7	TL051AI			
	PARAMETER	TEST CON	DITIONS	T _A †	٧c	C±=±5	٧	Vcc	C±=±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			TL0511	25°C		0.75	3.5		0.59	1.5	
V	Input offset voltage	I	11.0511	Full range			5.3			3.3	mV
ViO	Input offset voltage		TL051AI	25°C		0.55	2.8		0.35	0.8	l '''' l
		V _O = 0,	LOSIA	Full range			4.6			2.6	
	Temperature coefficient of	$V_{IC} = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL0511	25°C to 85°C		7			8		W00
αVIO	input offset voltage‡		TL051AI	25°C to 85°C		8			8	25	μV/°C
	Input offset voltage long-term drift§		-	25°C		0.04			0.04		μV/mo
,	to the first of the second	V _O = 0,	V _{IC} = 0,	25°C		4	100		5	100	pΑ
ΙΟ	Input offset current	See Figure 5	See Figure 5			0.06	10		0.07	10	nA
1	land bios summer	V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
lΒ	Input bias current	See Figure 5		85°C		0.6	20		0.7	20	nA
				25°C	-1	-2.3		-11	-12.3		
		1			to	to	1	to	to		
	Common-mode input				4	5.6		11	15.6		v
1011	voltage range	1		F!!	-1			-11			
				Full range	to 4			to 11			
		1	D 4010		3	4.2	-	13	13.9		V
	Maximum positive peak output voltage swing	R _L = 10 kΩ		Full range	3			13			
VOM +		D 010	B 240		2.5	3.8	4	11.5	12.7		
		$R_L = 2 k\Omega$		Full range	2.5			11.5			
		D 4010		25°C	-2.5	-3.5		-12	-13.2		
V	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		Full range	-2.5			-12			v
VOM -	output voltage swing	B 2 kO		25°C	-2.3	-3.2		-11	-12		
		$R_L = 2 k\Omega$		Full range	-2.3			-11			
	- - - - -		:	25°C	25	59		50	105		
A_{VD}	Large-signal differential voltage amplification¶	$R_L = 2 k\Omega$		−40°C	30	74		60	145		V/mV
	voltage amplification in			85°C	20	43		30	76		
rį	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		10			12		• pF
	0	V _{IC} = V _{ICB} n	nin,	25°C	65	85		75	93		
CMRR	Common-mode rejection ratio	$V_{\Omega} = 0$	•	-40°C	65	83		75	90		dB
	rojodion rado	$R_S = 50 \Omega$		85°C	65	84		75	93]
	C	Tv. 0		25°C	75	99		75	99		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$, $R_S = 50 \Omega$		-40°C	75	98		75	98		dB
	Iduo (AVCC±/AVIO)	115 - 50 12		85°C	75	99		75	99		
				25°C		2.6	3.2		2.7	3.2	3.2
Icc	Supply current	$V_O = 0$,	No load	-40°C		2.4	3.2		2.6	3.2	mA
			1		1	2.5	3.2		2.6	3.2	1

[†]Full range is -40°C to 85°C



[‡] This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. \P For $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V, or for $V_{CC\pm}$ = ±15 V, V_O = ±10 V.

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TL051I and TL051AI operating characteristics at specified free-air temperature

					TL051I, TL051AI						
	PARAMETER	TEST CONDITIONS		T _A †	ν _C	C±=±5	5 V	VC	C±=±1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
	D - W 1 1			25°C		16		13	20		
SR+	Positive slew rate at unity gain‡			Full				11			
	at anny gam	$R_L = 2 k\Omega$,	C _L = 100 pF,	range							V/μs
	Negative slew rate	See Figure 1		25°C	ļ	15		13	18		
SR-	at unity gain‡			Full				11			
				range 25°C	-	55			56		
	Dia a tima	1			 						
t _r	Rise time			-40°C	<u> </u>	52			53		
	Fall time	$V_{I(PP)} = \pm 10 \text{ mV},$ $R_{L} = 2 \text{ k}\Omega,$ $C_{L} = 100 \text{ pF},$		85°C	ļ	64			65 57		ns
				25°C	<u> </u>	55					1
t _f	raii time			-40°C		51			53		
		See Figures 1	85°C	ļ	64			65			
				25°C	ļ	24%			19%		
	Overshoot factor			-40°C		24%			19%		
			T	85°C		24%			19%		ļ
Vn	Equivalent input noise voltage§		f = 10 Hz	25°C		75			75		nV/√Hz
		$R_S \approx 20 \Omega$, See Figure 3	f = 1 kHz	25°C	ļ	18			18	30	ļ
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 5	f = 10 Hz to 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C	(0.003%		(0.003%		
				25°C		3			3.1		
B ₁	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	$R_L = 2 k\Omega$, See Figure 4	-40°C		3.5			3.6		MHz
		OL = 25 pr,	See Figure 4	85°C		2.6			2.7		1
				25°C		59°			62°		
φm	Phase margin at unity	V _I = 10 mV, C _L = 25 pF,	$R_L = 2 k\Omega$, See Figure 4	-40°C		58°			61°		1
	gain	OL = 25 pr,	See Figure 4	85°C		59°			62°		1

[†] Full range is -40°C to 85°C.

[‡] For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V. § This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[¶] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{Orms} = 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{Orms} = 6 \text{ V}$.

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TL051M and TL051AM electrical characteristics at specified free-air temperature

						TI	_051M, T	LO51AN	Λ .		
	PARAMETER	TEST CON	IDITIONS	T _A †	VC) ± = ± 5	٧	٧cc) ± = ± 15	5 V	UNIT
		<u> </u>			MIN	TYP	MAX	MIN	TYP	MAX	
			TLOGANA	25 C		0.75	3.5		0.59	1.5	
V	lament affect walters		TL051M	Full range			6.5			4.5	\/
V _{IO}	Input offset voltage	1	TLOETANA	25°C		0.55	2.8		0.35	0.8	mV
		\/- 0	TL051AM	Full range		-	5.8			3.8	
	Temperature coefficient of	$V_O = 0$, $V_{IC} = 0$, $R_S = 50 \Omega$	TL051M	25°C to 125°C		8			8		14/0.0
ανιο	input offset voltage	1.5	TL051AM	25°C to 125°C		8			8		μV/°C
	Input offset voltage long-term drift‡		<u> </u>	25°C		0.04			0.04		μV/mo
		VO = 0,	V _{IC} = 0,	25°C		4	100		5	100	pА
ΙΟ	Input offset current	See Figure 5		125°C		1	20		2	20	nA
		V _O = 0, V _{IC}	= 0,	25°C		20	200		30	200	pА
lΒ	Input bias current	See Figure 5		125°C		10	50		20	50	nA
	Common-mode input			25°C	-1 to 4	-2.3 to 5.6		-11 to 11	-12.3 to 15.6		
VICR	voltage range			Full range	-1 to 4			-11 to 11			V
		D: 1010		25°C	3	4.2		13	13.9		
V	Maximum positive peak	$R_L = 10 \text{ k}\Omega$		Full range	3			13 13.9 13	v		
V _{OM+}	output voltage swing	R _L = 2 kΩ		25°C	2.5	3.8		11.5	12.7		'
		11L - 2 KS2		Full range	2.5			11.5			
		R _L = 10 kΩ		25°C	-2.5	-3.5		-12	-13.2		
V _{OM} -	Maximum negative peak	H_ = 10 K22		Full range	-2.5			-12			v
VOM-	output voltage swing	R _L = 2 kΩ		25°C	-2.3	-3.2		-11	-12		'
		TIL - 2 K32		Full range	-2.3			-11			
	Large-signal differential			25°C	25	59		50	105		
AVD	voltage amplification§	$R_L = 2 k\Omega$		−55°C	30	76		60	149		V/mV
				125°C	10	32		15	49		
rj	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		10			12		pF
	Common-mode	VIC = VICR	nin,	25°C	65	85		75	93		
CMRR	rejection ratio	$V_0 = 0$,		−55°C	65	83		75	92		dB
	-	$R_S = 50 \Omega$		125°C	65	84		75	94		
	Supply-voltage rejection			25°C	75	99		75	99		
ksvr	ratio (ΔV _{CC±} /ΔV _{IO})	$V_O = 0$,	$R_S = 50 \Omega$	−55°C	75	98		75	98		dB
				125°C	75	100		75	100		
				25°C		2.6	3.2		2.7	3.2	
ICC	Supply current	$V_O = 0$,	No load	−55°C		2.3	3.2		2.4	3.2	mA
	Il vonce in 5500 to 10500	<u> </u>		125°C		2.4	3.2		2.5	3.2	

[†] Full range is -55°C to 125°C.

Truintage is 25 °C to 125 °C.

† Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ For V_{CC±} = ±5 V, V_O = ±2.3 V, or for V_{CC±} = ±15 V, V_O = ±10 V.

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TL051M and TL051AM operating characteristics at specified free-air temperature

						Т	L051M,	TL051A	/		
	PARAMETER	TEST CO	NDITIONS	TA	ν _C	C±=±5	i V	VC	C± = ±1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain [†]	$R_L = 2 k\Omega$	C _L = 100 pF,	25°C		16		13	20		V/μs
SR-	Negative slew rate at unity gain [†]	See Figure 1		25°C		15		13			ν /μs
				25°C		55			56		
t _r	Rise time	l		−55°C		51			52		
				125°C		68			68		ns
		V _{I(PP)} = ±10 r	mV,	25°C		55			57		115
tf	Fall time	$R_L = 2 k\Omega$, $C_L = 100 pF$,		−55°C		51			52		
		See Figures 1	and 2	125°C		68			69		
	*	1	g			24%			19%		
	Overshoot factor			−55°C	25°C 68 69 25°C 24% 19% 55°C 25% 19% 25°C 25% 19% 25°C 75 75						
				125°C		25%			19%		
v _n	Equivalent input noise		f = 10 Hz	25°C		75			75		nV/√Hz
٧n	voltage‡	$R_S = 20 \Omega$,	f = 1 kHz	25°C		18			19		IIV/VH2
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion§	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2k\Omega$,	25°C	О	0.003%		(0.003%		
				25°C		3	`		3.1		
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 2 k\Omega$, See Figure 4	-55°C		3.6			3.7		MHz
		OL = 25 pi-,	Gee i igule 4	125°C		2.3			2.4		
				25°C		59°			62°		
φm	Phase margin at unity	$ C = 25 \text{ pH}$. See Figure 4 \vdash		-55°C		57°		61°			
	gain		125°C		59°			62°			

[†] For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 V. † This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters. § For $V_{CC\pm} = \pm 5$ V, $V_{Orms} = 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{Orms} = 6$ V.

TL05x, TL05xA, TL05xY ENHANCED-JFET LOW-OFFSET OPERATIONAL AMPLIFIERS SLOS178 – FEBRUARY 1997

TL051Y electrical characteristics, $T_A = 25^{\circ}C$

						TLO	51Y			
	PARAMETER	TEST CONDITION	ıs [Vcc) ± = ± 8	5 V	Vcc	± = ± 1	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	$V_O = 0,$ $V_{IC} = 0$ $R_S = 50 \Omega$),		0.75			0.59		mV
110	Input offset current	$V_O = 0$, $V_{IC} = 0$ See Figure 5),		4			5		pА
IB	Input bias current	$V_O = 0$, $V_{IC} = 0$ See Figure 5),		20			30		pА
VICR	Common-mode input voltage range				-2.3 to 5.6			-12.3 to 15.6		٧
	Maximum positive peak output voltage	R _L = 10 kΩ			4.2			13.9		.,
V _{OM+}	swing	$R_L = 2 k\Omega$			3.8			12.7		V
V	Maximum negative peak output voltage	$R_L = 10 \text{ k}\Omega$			-3.5			-13.2		V
VOM -	swing	R _L = 2 kΩ			-3.2			-12		٧
AVD	Large-signal differential voltage amplification†	R _L = 2 kΩ			59			105		V/mV
rį	Input resistance				1012			1012		Ω
Cį	Input capacitance				10			12		pF
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min, V _O = 0, R _S = 5	0Ω		85			93		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	V _O = 0, R _S = 5	0Ω		99			99		dB
Icc	Supply current	V _O = 0, No load	b		2.6			2.7		mA

[†] For $V_{CC\pm} = \pm 5$ V, $V_{O} = \pm 2.3$ V, or for $V_{CC\pm} = \pm 15$ V, $V_{O} = \pm 10$ V.

TL05x, TL05xA, TL05xY **ENHANCED-JFET LOW-OFFSET** OPERATIONAL AMPLIFIERS SLOS178 - FEBRUARY 1997

TL051Y operating characteristics, $T_A = 25^{\circ}C$

						TL0	51Y			
	PARAMETER	TEST CO	NOITIONS	٧c	C± = ±5	5 V	٧cc)±=±1	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain†	$R_L = 2 k\Omega$	C _L = 100 pF,		16			20		V/μs
SR-	Negative slew rate at unity gain†	See Figure 1	_		15			18		V/μS
t _r	Rise time	$V_{I(PP)} = \pm 10 \text{ m}$	V,		55			56		
t _f	Fall time	$R_L = 2 k\Omega$, $C_L = 100 pF$,			55			57		ns
	Overshoot factor	See Figures 1 a	nd 2		24%			19%		
V	F		f = 10 Hz		75			75		nV/√Hz
V _n	Equivalent input noise voltage‡	$R_S = 20 \Omega$,	f = 1 kHz		18			18		ΠV/∀HZ
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz		4			4		μV
In	Equivalent input noise current	f = 1 kHz			0.01			0.01		pA/√Hz
THD	Total harmonic distortion§	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,		0.003%	6		0.003%)	
B ₁	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	$R_L = 2 k\Omega$, See Figure 4		3			3.1		MHz
φm	Phase margin at unity gain	V _i = 10 mV, C _L = 25 pF,	$R_L = 2 k\Omega$, See Figure 4		59°			62°		

For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V.

† This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

§ For V_{CC±} = ±5 V, V_{Orms} = 1 V; for V_{CC±} = ±15 V, V_{Orms} = 6 V.

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TL052C and TL052AC electrical characteristics at specified free-air temperature

						Т	L052C, 1	L052AC	;		
	PARAMETER	TEST CON	DITIONS	T _A †	٧c	C± = ±5	٧	VC	C± = ±15	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			T	25°C		0.73	3.5		0.65	1.5	
.,	P		TL052C	Full range			4.5			2.5	
VIO	Input offset voltage		71.0504.0	25°C		0.51	2.8		0.4	0.8	mV
		$V_{O} = 0$, $V_{IC} = 0$,	TL052AC	Full range			3.8			1.8	
00.00	Temperature coefficient	$R_S = 50 \Omega$	TL052C	25°C to 70°C		8			8		
αVIO	of input offset voltage‡		TL052AC	25°C to 70°C		8			6	25	μV/°C
	Input offset voltage long- term drift§	$V_O = 0$, $R_S = 50 \Omega$	V _{IC.} = 0,	25°C		0.04			0.04		μV/mo
l. a	Input offset surrent	V _O = 0,	V 0	25°C		4	100		5	100	pА
liO	Input offset current	See Figure 5	V _{IC} = 0,	70°C		0.02	1		0.025	1	nA
lin.	Input bias current	V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
lВ	input bias current	See Figure 5	AIC = 0,	70°C		0.15	4		0.2	4	nA
Vion	Common-mode input			25°C	–1 to 4	–2.3 to 5.6		-11 to 11	-12.3 to 15.6		٧
VICR	voltage range			Full range	-1 to 4			-11 to 11			V
		R _I = 10 kΩ		25°C	3	4.2		13	13.9		
V	Maximum positive peak			Full range	3			13			v
V _{OM+}	output voltage swing	$R_1 = 2 k\Omega$		25°C	2.5	3.8		11.5	12.7		. *
		TI_ = 2 K32		Full range	2.5			11.5			
		R _L = 10 kΩ		25°C	-2.5	-3.5		-12	-13.2		
V _{OM} _	Maximum negative peak	11 - 10 132		Full range	-2.5			-12			v
*ON-	output voltage swing	R _L = 2 kΩ		25°C	-2.3	-3.2		-11	-12		ľ
				Full range	-2.3			-11			
	Large-signal differential			25°C	25	59		50	105		
AVD	voltage amplification¶	$R_L = 2 k\Omega$		0°C	30	65		60	129		V/mV
				70°C	20	46		30	85		
ri	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		10			12		pF
	Common-mode	V _{IC} = V _{ICR} min,		25°C	65	85		. 75	93		
CMRR	rejection ratio	V _O = 0,	$R_S = 50 \Omega$	0°C	65	84		75	92		dB
t =		<u> </u>		70°C	65	84		75	91		

[†] Full range is 0°C to 70°C.

[‡] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. ¶ For V_{CC±} = ±5 V, V_O = ±2.3 V; at V_{CC±} = ±15 V, V_O = ±10 V.

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TL052C and TL052AC electrical characteristics at specified free-air temperature (continued)

						Т	L052C, 1	L052AC			
	PARAMETER	TEST CO	NDITIONS	TA	٧c	C± = ±5	V	Vcc)± = ±15	V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C	75	99		75	99		
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC} + /\Delta V_{IO}$)	$V_{O} = 0$,	$R_S = 50 \Omega$	0°C	75	98		75	98		dB
	1010 (AVCC ±/AVIO)			70°C	75	97		75	97		
				25°C		4.6	5.6		4.8	5.6	
Icc	Supply current (two amplifiers)	$V_{O} = 0$,	No load	0°C		4.7	6.4		4.8	6.4	mA
	(the ampinote)			70°C		4.4	6.4		4.6	6.4	
V _{O1} /V _C	2 Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

TL052C and TL052AC operating characteristics at specified free-air temperature

						Т	L052C,	TL052AC	;		
	PARAMETER	TEST CO	NDITIONS	T _A †	VC	C±=±5	V	Vcc) ± = ± 15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Slew rate at unity gain			25°C		17.8		9	20.7		
on+	Siew rate at unity gain	$R_L = 2 k\Omega$,	$C_L = 100 pF$,	Full range				8			V/μs
SR-	Negative slew rate	See Figure 1		25°C		15.4		9	17.8		ν/μ5
3n-	at unity gain‡			Full range				8			
				25°C		55			56		
t _r	Rise time			0°C		54			55		
	•			70°C		63			63		ns
		$V_{I(PP)} = \pm 10$	mV,	25°C		55			57		115
tf	Fall time	$R_L = 2 k\Omega$, $C_L = 100 pF$,		0°C		54			56		
		See Figures 1	and 2	70°C		62			64		
		1		25°C		24%			19%		
	Overshoot factor	1		0°C		24%			19%		İ
				70°C		24%		19%			
Vn	Equivalent input noise		f = 10 Hz	25°C		71			71		nV/√Hz
vn	voltage§	$R_S = 20 \Omega$,	f= 1 kHz	25°C		19			19	30	110/11/2
V _{N(PP)}	Peak-to-peak equivalent input noise current	See Figure 3	f = 10 Hz t 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C	0	.003%		C	0.003%		
				25°C		3			3		
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 2 k\Omega$, See Figure 4	0°C		3.2			3.2		MHz
		C_ = 20 pi,	Coc i iguie 4	70°C		2.6			2.7		
	Dhana manin at unit	10	D 01-0	25°C		60°			63°		
φm	Phase margin at unity gain	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 2 k\Omega$, See Figure 4	0°C		59°			63°]
Ī	5- ····]	222. iguio i	70°C		60°			63°		1

[†] Full range is 0°C to 70°C.

[¶] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O(RMS)} = 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O(RMS)} = 6 \text{ V}$.



 $[\]pm$ For V_{CC±} = \pm 5 V, V_I(PP) = \pm 1 V; for V_{CC±} = \pm 15 V, V_I(PP) = \pm 5 V. § This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL052I and TL052AI electrical characteristics at specified free-air temperature

PARAMETER	10.1	100				1	TL0521, 1	L052AI			
	PARAMETER	TEST CON	DITIONS	T _A †	٧c	C± = ±5	v	٧c	C± = ±15	V	UNIT
		i i			MIN	TYP	MAX	MIN	TYP	MAX	
			TI OFOI	25°C		0.73	3.5		0.65	1.5	
			TL052I	Full range			5.3	,		3.3	١,,
V _{IO}	Input offset voltage			25°C		0.51	2.8		0.4	0.8	mV
	•	V _O = 0, V _{IC} = 0,	TL052AI	Full range			4.6			2.6	
		$R_S = 50 \Omega$	TL052I	25°C to 85°C		7.			6		μV/°C
αVIO	Temperature coefficient‡		TL052AI	25°C to 85°C		6			6	25	μν/-С
	Input offset voltage long- term drift§	$V_O = 0$, $R_S = 50 \Omega$	V _{IC} = 0,	25°C		0.04			0.04	-	μV/mo
l. a	Input offset current	V _O = 0,	V _{IC} = 0,	25°C		4	100		5	100	pА
ΙO	input onset current	See Figure 5		85°C		0.06	. 10		0.07	10	nA
li-	Input bigg gurrent	V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
IB	Input bias current	See Figure 5		85°C		0.6	20		0.7	20	nA
	Common-mode input			25°C	-1 to 4	–2.3 to 5.6		–11 to 11	-12.3 to 15.6		v
VICR	voltage range			Full range	1 to 4			-11 to 11			V
		D 401-0		25°C	3	4.2		13	13.9		
V	Maximum positive peak	R _L = 10 kΩ		Full range	3			13			l _v
VOM+	output voltage swing	B 010		25°C	2.5	3.8		11.5	12.7		1 °
		$R_L = 2 k\Omega$		Full range	2.5			11.5			
		D 401-0		25°C	-2.5	-3.5		-12	-13.2		
V	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		Full range	-2.5			-12			V
V _{OM} -	output voltage swing	D. 040		25°C	-2.3	-3.2		-11	-12]
		$R_L = 2 k\Omega$		Full range	-2.3			-11			
				25°C	25	59		50	105		
A_{VD}	Large-signal differential voltage amplification	$R_L = 2 k\Omega$		-40°C	30	74		60	145		V/mV
	voitage amplification			85°C	20	43		30	76		<u> </u>
rį	Input resistance			25°C		1012			1012		Ω
cį	Input capacitance			25°C		10			12		pF
	Common mode			25°C	65	85		75	93		
CMRR		$V_{IC} = V_{ICRmin},$ $V_{O} = 0,$	$R_S = 50 \Omega$	-40°C	65	83		75	90		dΒ
	,			85°C	65	84		75	93		

[†] Full range is -40°C to 85°C.

[‡] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters

Stylical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

At V_{CC±} = ±5 V, V_O = ±2.3 V; at V_{CC±} = ±15 V, V_O = ±10 V.

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TL052I and TL052AI electrical characteristics at specified free-air temperature (continued)

		-			TL052I, T			L052AI			
	PARAMETER		ONDITIONS	TA	٧c	C± = ±5	V	٧cc)± = ±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C	75	99		75	99		
ksvr	Supply-voltage rejection	$V_{O} = 0$,	$R_S = 50 \Omega$	-40°C	75	98		75	98		dB
	ratio (ΔV _{CC±} /ΔV _{IO})			85°C	75	99		75	99		
				25°C		4.6	5.6		4.8	5.6	
Icc	Supply current (two amplifiers)	$V_{O} = 0$,	No load	-40°C		4.5	6.4		4.7	6.4	mA
	(two ampliners)			85°C		4.4	6.4		4.6	6.4	
V _{O1} /V _O	2 Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

TL052I and TL052AI operating characteristics at specified free-air temperature

							TL0521,	TL052AI			
	PARAMETER	TEST CO	NDITIONS	T _A †	Vcc)±=±5	v	Vcc) ± = ± 19	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Class make at somits maint			25°C		17.8		9	20.7		
3H +	Slew rate at unity gain‡	$R_L = 2 k\Omega$	C _L = 100 pF,	Full range				8			V/μs
SR –	Negative slew rate at	See Figure 1		25°C		15.4		9	17.8		ν/μ3
J11-	unity gain [‡]			Full range				8			
				25°C		55			56		
t _r	Rise time			-40°C		52			53]
]		85°C		64			65		ns
		$V_{I(PP)} = \pm 10$	mV.	25°C		55			57] "
tf	Fall time	$R_L = 2 k\Omega$,	$C_L = 100 pF$,	-40°C		51			53]
		See Figures 1	and 2	85°C		64			65		
		25°C 24% -40°C 24%		19%							
	Overshoot factor			-40°C		24%	55 57 51 53 64 65 24% 19% 24% 19%]			
				85°C		24%			19%		
V	Equivalent input noise		f = 10 Hz	25°C		71			71		
Vn	voltage§	$R_S = 20 \Omega$,	f = 1 kHz	25°C		19			19	30	
V _{N(PP)}	Peak-to-peak equivalent input noise current	See Figure 3	f = 10 Hz to 10 kHz	25°C		4		4			μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C	0	.003%		(0.003%		
				25°C		3			3		
B ₁	Unity-gain bandwidth	$V_1 = 10 \text{ mV},$ $C_1 = 25 \text{ pF},$	R _L = 2 k Ω , See Figure 4	-40°C		3.5			3.6		MHz
		OL - 20 pr.,	Oce i igule 4	85°C		2.5			2.6		
				25°C		60°			63°		
φm	Phase margin at unity gain	$V_I = 10 \text{ mV}, R_L = 2 \text{ k}\Omega,$ $C_L = 25 \text{ pF}, \text{See Figure 4}$	-40°C		58°		61°			1	
	gam	OL = 20 pr,	See Figure 4	85°C		60°			63°		1

[†] Full range is -40°C to 85°C.

[¶] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O(RMS)} = 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O(RMS)} = 6 \text{ V}$.



[‡] For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V. § This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TL052M and TL052AM electrical characteristics at specified free-air temperature

PARAMETER					Т	L052M,	TL052A	M		
PARAMETER	TEST CO	NDITIONS	T _A †	٧c	C±=±	5 V	Vcc)± = ± 1	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
		TLOSOM	25°C		0.73	3.5		0.65	1.5	
Input offeet voltage		TLU5ZIVI	Full range			6.5			4.5	mV
input onset voltage	\v- 0	TLOSOAM	25°C		0.51	2.8		0.4	0.8	1110
•		TEOSZAWI	Full range			5.8			3.8	
Temperature coefficient	$R_S = 50 \Omega$	TL052M	25°C to 125°C		10			9		
of input offset voltage		TL052AM	25°C to 125°C		9			8		μV/°C
Input offset voltage long- term drift‡	$V_O = 0$, $R_S = 50 \Omega$	V _{IC} = 0,	25°C		0.04			0.04		μV/mo
land 14 aff - 14 - 1 - 1	V _O = 0,	V _{IC} = 0,	25°C		4	100		5	100	pА
input oliset current	See Figure 5		125°C		1	20		2	20	nA
Input hise current	V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
input bias current	See Figure 5		125°C		10	50		20	50	nA
Common-mode input			25°C	-1 to 4	–2.3 to 5.6		-11 to 11	-12.3 to 15.6		٧
voltage range			Full range	to 4			to 11			
Maximum positive peak	$R_L = 10 \text{ k}\Omega$		25°C Full range	3	4.2	,	13 13	13.9		v
output voltage swing	$R_L = 2 k\Omega$		25°C Full range	2.5 2.5	3.8		11.5 11.5	12.7		v
Maximum pagativa pagl	R _L = 10 kΩ	***************************************	25°C	-2.5	-3.5		-12	-13.2		
output voltage swing	R _L = 2 kΩ	······································	25°C	-2.3	-3.2		-11	-12		٧
	-		<u> </u>					405		
Large-signal differential	B 2 kg									V/mV
voltage amplification§	UL = 2 K22									V/IIIV
Innut resistance	-			10			15			Ω
	- 			-			<u> </u>			pF
приг сараспапсе	 			65			75			PΓ
Common-mode		nin,								dB
rejection ratio										ا
Supply-voltage rejection	VO = 0.	Be = 50 O								dB
ratio (ΔV _{CC±} /ΔV _{IO})	1.0 = 3,	55 22								
			25°C	· ·	4.6	5.6	HŤ	4.8	5.6	
Supply current	$V_{O} = 0$	No load	-55°C	 	4.4	6.4		4.5	6.4	mA
(two amplifiers)	1		125°C		4.2	6.4		4.4	6.4	
Crosstalk attenuation	A _{VD} = 100		25°C		120		 	120		dB
	Input offset voltage Temperature coefficient of input offset voltage Input offset voltage long-term drift‡ Input offset current Input bias current Common-mode input voltage range Maximum positive peak output voltage swing Maximum negative peak output voltage swing Large-signal differential voltage amplification\$ Input resistance Input capacitance Common-mode rejection ratio Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO}) Supply current (two amplifiers)		Input offset voltage	$ \text{Input offset voltage} \\ \text{Input offset voltage} \\ \text{TL052M} \\ \text{TL052AM} \\ \text{Full range} \\ \text{25°C to} \\ \text{TL052AM} \\ \text{TL052AM} \\ \text{Sec to} \\ \text{125°C} \\ \text{Tlnput offset voltage} \\ \text{Input offset voltage long-term drift‡} \\ \text{Input offset voltage long-term drift‡} \\ \text{Input offset current} \\ \text{Input offset current} \\ \text{VO} = 0, \\ \text{See Figure 5} \\ \text{VO} = 0, \\ \text{See Figure 5} \\ \text{VIC} = 0, \\ \text{See Figure 5} \\ \text{Input bias current} \\ \text{Input bias current} \\ \text{VO} = 0, \\ \text{See Figure 5} \\ \text{VO} = 0, \\ \text{See Figure 5} \\ \text{VIC} = 0, \\ \text{25°C} \\ \text{125°C} \\ \text{Full range} \\ \text{25°C} \\ \text{Full range} \\ \text{Maximum positive peak output voltage swing} \\ \text{RL} = 10 \text{ k}\Omega \\ \text{RL} = 2 \text{ k}\Omega \\ \text{Maximum negative peak output voltage swing} \\ \text{RL} = 2 \text{ k}\Omega \\ \text{RL} = 2 \text{ k}\Omega \\ \text{Full range} \\ \text{25°C} \\ \text{75°C} \\ \text{125°C} \\ \text{25°C} \\ \text{125°C} \\ 125$	$ \text{Input offset voltage } \\ \text{Input offset voltage } \\ \text{TLO52M} \\ \text{Temperature coefficient of input offset voltage } \\ \text{TLO52AM} \\$	PARAMETER TEST CONDITIONS TA ↑ WC = ±± Input offset voltage TL052M 25°C 3.73 7.052M 25°C to 125°C 0.51 7.052M 25°C to 125°C 0.51 7.052M 7.052M 25°C to 125°C 0.51 7.052M 7.052M 25°C to 125°C 0.04 <t< td=""><td> PARAMETER PAR</td><td> PARAMETER PAR</td><td> Input offset voltage Input offset voltage Input offset voltage Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Rs = 50 Ω IL052AM IL05</td><td>PARAMETER TEST C N ITONS Table N ITONS VCC±±±5 V N ITONS N ITONS M ITONS VCC±±±15 V N ITONS N ITONS M ITONS N ITONS M ITONS 25°C N ITONS 0.05 N ITONS 1.5 N ITONS</td></t<>	PARAMETER PAR	PARAMETER PAR	Input offset voltage Input offset voltage Input offset voltage Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Vo = 0, Rs = 50 Ω IL052AM IL05	PARAMETER TEST C N ITONS Table N ITONS VCC±±±5 V N ITONS N ITONS M ITONS VCC±±±15 V N ITONS N ITONS M ITONS N ITONS M ITONS 25°C N ITONS 0.05 N ITONS 1.5 N ITONS

[†] Full range is - 55°C to 125°C.



The transfers = 35 C to 12 C. The tr

TL05x, TL05xA, TL05xY **ENHANCED-JFET LOW-OFFSET** OPERATIONAL AMPLIFIERS SLOS178 – FEBRUARY 1997

TL052M and TL052AM operating characteristics at specified free-air temperature

						. Т	L052M,	TL052AN	1			
	PARAMETER	TEST CO	NDITIO	ONS	TAT	VC	C±=±5	5 V	Vcc)±=±1	5 V	UNIT
						MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate				25°C		17.8		9	20.7		
0111	at unity gain‡	$R_L = 2 k\Omega$, $C_L = 100 pF$,			Full range				8			V/μs
SR-	Negative slew rate	See Figure 1			25°C		15.4		9	17.8		ν /μs
J.,	at unity gain‡	<u> </u>			Full range				8			
					25°C		55			56]
t _r	Rise time				−55°C		51			52		j
			$V_{I(PP)} = \pm 10 \text{ mV},$ $R_{L} = 2 \text{ k}\Omega,$ $C_{L} = 100 \text{ pF},$ See Figures 1 and 2				68			68		ns
							55			57		""
tf	Fall time						51			52		
			and 2		125°C		68			69		
					25°C		24%			19%		
	Overshoot factor		<u> </u>				25%		19%			
					125°C		25%			19%		
v _n	Equivalent input noise		f =	10 Hz	25°C		71			71		nV/√Hz
٧n	voltage§	$R_S = 20 \Omega$	f =	1 kHz	25°C		19			19		110/1112
V _{N(PP)}	Peak-to-peak equivalent input noise current	See Figure 3	f=	10 Hz to 10 kHz	25°C		4			4		μV
I _n	Equivalent input noise current	f = 1 kHz			25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 kΩ$, f = 1 kHz	R _L = 2	2 kΩ,	25°C	0	.003%		C	0.003%		
			_		25°C		3			3		
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	R _L = 2	2 kΩ, igure 4	−55°C		3.6			3.7		MHz
		- 20 pi,		.9410 -	125°C		2.3			2.4		
	51				25°C		60°			63°		
Φm	Phase margin at unity gain	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	RL = 2 See F	2 kΩ, igure 4	−55°C		57°			61°		
	a	- Lo pi,	5001	.9410 4	125°C		60°			63°		

[†] Full range is - 55°C to 125°C.

[‡] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{I(PP)} = \pm 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{I(PP)} = \pm 5 \text{ V}$. § This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters. If For $V_{CC\pm}=\pm 5$ V, $V_{O(RMS)}=1$ V; for $V_{CC\pm}=\pm 15$ V, $V_{O(RMS)}=6$ V.

TL05x, TL05xA, TL05xY ENHANCED-JFET LOW-OFFSET OPERATIONAL AMPLIFIERS SLOS178 - FEBRUARY 1997

TL052Y electrical characteristics, $T_A = 25^{\circ}C$

				TL052Y						
	PARAMETER	TEST CON	DITIONS	VC	C±=±5	v	Vcc)± = ± 19	5 V	UNIT
	•			MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V- 0			0.73			0.65		mV
	Input offset voltage long-term drift	$V_O = 0$, $R_S = 50 \Omega$	$V_{IC} = 0$,		0.04			0.04		μV/mo
lio	Input offset current	V _O = 0, See Figure 5	V _{IC} = 0,		4			5		рA
I _{IB}	Input bias current	V _O = 0, See Figure 5	V _{IC} = 0,		20			30		pА
	Common-mode input voltage				-2.3			-12.3		
VICR	range				to			to		V
				<u> </u>	5.6			15.6		ļ
V _{OM+}	Maximum positive peak	$R_L = 10 \text{ k}\Omega$		<u> </u>	4.2			13.9		
*OM+	output voltage swing	$R_L = 2 k\Omega$		ŀ	3.8			12.7		l v
	Maximum negative peak output	$R_L = 10 \text{ k}\Omega$			-3.5			-13.2		\
VOM-	voltage swing	$R_L = 2 k\Omega$			-3.2			-12		
AVD	Large-signal differential voltage amplification	R _L = 2 kΩ			59			105		V/mV
ri	Input resistance		•		1012			1012		Ω
ci	Input capacitance				10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $V_{O} = 0$,	$R_S = 50 \Omega$		85			93		dB
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	V _O = 0,	R _S = 50 Ω		99			99		dB
lcc	Supply current (two amplifiers)	V _O = 0,	No load		4.6			4.8		mA
V _{O1} /V _{O2}	Crosstalk attenuation	AVD = 100		1	120			120		dB

 $[\]dagger$ For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{O} = \pm 2.3 \text{ V}$; at $V_{CC\pm} = \pm 15 \text{ V}$, $V_{O} = \pm 10 \text{ V}$.

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TL052Y operating characteristics, $T_A = 25^{\circ}C$

						TL0	52Y			
	PARAMETER	TEST	CONDITIONS	ν _C	C± = ±5	٧	Vcc)± = ±15	V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain [†]	R _L = 2 kΩ,	C _L = 100 pF,		17.8			20.7		Mus
SR-	Negative slew rate at unity gain†	See Figure 1	- ·		15.4		17			V/μs
t _r	Rise time	V _{I(PP)} = ±10 n	nV.	. 55		56				
tf	Fall time	$R_L = 2 k\Omega$, $C_L = 100 pF$, See Figures 1 and 2			55			ns		
	Overshoot factor				24%		19%			
V	Equivalent input noise		f = 10 Hz		71			71		\.//TT
V _n	voltage‡	$R_S = 20 \Omega$, $f = 1 \text{ kHz}$			19		19			nV/√Hz
V _{N(PP)}	Peak-to-peak equivalent input noise current	See Figure 3	f = 10 Hz to 10 kHz		4			4		μV
In	Equivalent input noise current	f = 1 kHz			0.01			0.01		pA/√Hz
THD	Total harmonic distortion§	$R_S = 1 \text{ k}\Omega, \qquad R_L = 2 \text{ k}\Omega,$ $f = 1 \text{ kHz}$		0	.003%		0	.003%		
В1	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	R _L = 2 kΩ, See Figure 4		3			3		MHz
φm	Phase margin at unity gain	V _I = 10 mV, C _L = 25 pF,	R _L = 2 kΩ, See Figure 4		60°			63°		

[†] This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters. ‡ For $V_{CC\pm} = \pm 5$ V, $V_{I(PP)} = \pm 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{I(PP)} = \pm 5$ V. § For $V_{CC\pm} = \pm 5$ V, $V_{I(PP)} = \pm 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{I(PP)} = \pm 5$ V.

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TL054C and TL054AC electrical characteristics at specified free-air temperature

					TI	L054C, 1	L054A	С			
	PARAMETER	TEST CO	NDITIONS	T _A †	٧c	C ± = ± 5	v	٧c	C ± = ± 1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
			71.0540	25°C		0.64	5.5		0.56	4	
	land affect of the second		TL054C	Full range			7.7			6.2	
V _{IO}	Input offset voltage		TI 05 440	25°C		0.57	3.5		0.5	1.5	mV
		V _O = 0,	TL054AC	Full range			5.7			3.7	
	Temperature coefficient	$V_{IC} = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL054C	25°C to 70°C		. 25			23	,	
αNIO	of input offset voltage		TL054AC	25°C to 70°C		24			23		μV/°C
	Input offset voltage long-term drift [‡]	1		25°C		0.04			0.04		μV/mo
1	lancet affact account	V _O = 0,	V _{IC} = 0,	25°C		4	100		5	100	pА
lo	Input offset current	See Figure !		70°C		0.02	1		0.025	1	nA
1	Innut bing growt	V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
lВ	Input bias current	See Figure !		70°C		0.15	4		0.2	4	nA
	Common mode input			25°C	-1 to 4	-2.3 to 5.6		-11 to 11	-12.3 to 15.6		
VICR	Common-mode input voltage range				-1			-11	10.0		V
	voltage range				to			to			
				Full range	4			11			
				25°C	3	4.2		13	13.9		
	Maximum positive peak	$R_L = 10 \text{ k}\Omega$		Full range	3			13			١.,
VOM +	output voltage swing	D 01-0		25°C	2.5	3.8		11.5	12.7		٧
		$R_L = 2 k\Omega$		Full range	2.5			11.5			
		D 4010		25°C	-2.5	-3.5		-12	-13.2		
V	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		Full range	-2.5			-12			l _v
VOM –	output voltage swing	D. O.I.O.		25°C	-2.3	-3.2		-11	-12		1 °
		$R_L = 2 k\Omega$		Full range	-2.3			-11			1
	L			25°C	25	72		50	133		
AVD	Large-signal differential voltage amplification§	$R_L = 2 k\Omega$		0°C	30	88		60	173		V/mV
				70°C	20	57		30	85		
rį	Input resistance			25°C		1012			1012		Ω
ci	Input capacitance			25°C		10			12		pF
	Common media	J	!	25°C	65	84		75	92		
CMRR	Common-mode rejection ratio	VIC = VICR	min, $R_S = 50 \Omega$	0°C	65	84		75	92		dB
		10-0,	1.5 - 50 12	70°C	65	84		75	93		<u></u>
	Complements of the state of the	1,4	25°C 75	99		75	99				
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC\pm} = \pm 5 \text{ V to } \pm 15 \text{ V}$ $V_{O} = 0$, $R_{S} = 50 \text{ s}$		0°C	75	99		75	99		dB
	(4 V C C ± /4 V (C)	10-0,	. 15 - 50 22	70°C	75	99		75	99		
	0		25°C		8.1	11.2		8.4	11.2		
lcc	Supply current (four amplifiers)	V _O = 0, No load	0°C		8.2	12.8		8.5	12.8	mA	
	(.ca. ampilioro)			70°C		7.9	11.2		8.2	11.2	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

[†]Full range is 0°C to 70°C.



[‡] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. § For $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V, at $V_{CC\pm}$ = ±15 V, V_O = ±10 V.B

TL054C and TL054AC operating characteristics at specified free-air temperature

						-	ΓL054C,	TL054C			
	PARAMETER	TEST CO	NDITIONS	T _A †	VC	C±=±5	V	VCC)± = ±15	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
00	Positive slew rate			25°C		15.4		10	17.8		
SR+	at unity gain			0°C.		15.7		8	17.9		
		$R_L = 2 k\Omega$,	$C_L \approx 100 \text{ pF},$	70°C		14.4		8	17.5		.,,
00	Negative slew rate at	See Figure 1	and Note 7	25°C		13.9		10	15.9		V/µs
SR-	unity gain [‡]			0°C		14.3		8	16.1		
				70°C		13.3		8	15.5		
						55			56		
t _r	Rise time					54			55		1
						63			63		
			$V_{I(PP)} = \pm 10 \text{ mV},$			55			57		ns
tf	Fall time	$R_L = 2 k\Omega$, $C_1 = 100 pF$,		0°C		54			56		
		See Figures 1 and 2		70°C		62			64		
]		25°C		24%			19%		
	Overshoot factor			0°C		24%			19%		1
				70°C		24%			19%		
.,	Equivalent input noise		f = 10 Hz	25°C		75			75		nV/√Hz
٧n	voltage§	$R_S = 20 \Omega$,	f = 1 kHz	25°C		21			21	45	IIV/VH2
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		p A /√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C	0	0.003%		. 0	.003%		
				25°C		2.7			2.7		<u> </u>
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$R_L = 2 k\Omega$,	0°C		3			3		MHz
		$C_L = 25 pF$,	See Figure 4	70°C		2.4			2.4		1
	D		5	25°C		61°			64°		
φm		$V_{I} = 10 \text{ mV}, \qquad R_{L} = 2 \text{ k}\Omega$ $C_{L} = 25 \text{ pF}, \qquad \text{See Figure}$	$R_L = 2 k\Omega$,	0°C		60°			64°		
			See Figure 4	70°C		61°			63°		1

[†] Full range is 0°C to 70°C.

For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V.

§ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[¶] For $V_{CC\pm} = \pm 5$ V, $V_{o(rms)} = 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{o(rms)} = 6$ V.

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TL054I and TL054AI electrical characteristics at specified free-air temperature

1						•	ΓL0541, 1	ΓL054AI			
	PARAMETER	TEST CON	DITIONS	T _A †	ν _C	C±=±5	V	VC	C± = ±15	5 V	UNIT
				''	MIN	TYP	MAX	MIN	TYP	MAX	
			TI 05 41	25°C		0.64	5.5		0.56	4	
\/	land affect walks as		TL054I	Full range			8.8			7.3	
VIO	Input offset voltage		TI 05 (A)	25°C		0.57	3.5		0.5	1.5	mV
		\v- 0	TL054AI	Full range			6.8			4.8	
	Temperature coefficient of	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL054I	25°C to 85°C		25			24		
αVIO	input offset voltage	1.3 00	TL054AI	25°C to 85°C		25			23		μV/°C
	Input offset voltage long-term drift‡			25°C		0.04			0.04		μV/mo
lio	Input offeet ourrent		V _{IC} = 0,	25°C		4	100		5	100	pA
lio	Input offset current	See Figure 5		85°C		0.06	. 10		0.07	10	nA
l. n	Input bigg gurrent	$V_{O} = 0,$	V _{IC} = 0,	25°C		20	200		30	200	рA
lВ	Input bias current	See Figure 5		85°C		0.6	20		0.7	20	nA
Vion	Common-mode input			25°C	-1 to 4	-2.3 to 5.6		-11 to 11	-12.3 to 15.6		V
VICR	voltage range			Full range	-1 to 4			-11 to 11			
		D. 1010		25°C	3	4.2		13	13.9		,
V _{OM+}	Maximum positive peak	$R_L = 10 \text{ k}\Omega$		Full range	3			13			٧
VOM +	output voltage swing	$R_1 = 2 k\Omega$		25°C	2.5	3.8		11.5	12.7		. •
		TL = 2 KS2	-	Full range	2.5			11.5			
		R _L = 10 kΩ		25°C	2.5	-3.5		-12	-13.2		
V _{OM} –	Maximum negative peak	11 - 10 162		Full range	-2.5			-12			v
VOIVI –	output voltage swing	R _L = 2 kΩ		25°C	-2.3	-3.2		-11	-12		•
		11 - 2 132		Full range	-2.3			-11			
	Large-signal differential			25°C	25	72		50	133		
AVD	voltage amplification§	$R_L = 2 k\Omega$		-40°C	30	101		60	212		V/mV
				85°C	20	50		30	70		
rį	Input resistance	<u> </u>		25°C		1012			1012		Ω
ci	Input capacitance			25°C		10			12		pF
	Common-mode	V _{IC} = V _{ICR} m	nin	25°C	65	84		75	92		
CMRR	rejection ratio		$R_S = 50 \Omega$	-40°C	65	83		75	92		dB
	•	J = 7	J	85°C	65	84		75	93		
	Supply-voltage rejection	V _{CC±} = ±5 \	/ to + 15 \/	25°C	75	99		75	99		
ksvr	ratio (ΔV _{CC±} /ΔV _{IO})		$R_S = 50 \Omega$	-40°C	75	98		75	99		dB
	. 001 107	ļ .		85°C	75	99		75	99		
	Supply current	l., .		25°C		8.1	11.2		8.4	11.2	
Icc	(four amplifiers)	$V_O = 0$,	No load	-40°C		7.9	12.8		8.2	12.8	mA
		<u> </u>		85°C		7.6	11.2		7.9	11.2	<u> </u>
V _{O1} /V _{O2}	Crosstalk attenuation is -40°C to 85°C.	A _{VD} = 100		25°C	L	120			120		dB

[†] Full range is -40°C to 85°C.

[§] For $V_{CC\pm} = \pm 5$ V, $V_{O} = \pm 2.3$ V, at $V_{CC\pm} = \pm 15$ V, $V_{O} = \pm 10$ V.



[‡] Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$ °C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TL054I and TL054AI operating characteristics at specified free-air temperature

							TL054I, 1	ΓL054AI			_
	PARAMETER	TEST CO	NDITIONS	T _A †	VC	C±=±5	V	Vcc)± = ±1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
00.	Positive slew rate			25°C		15.4		10	17.8		
SR+	at unity gain			-40°C		16.4		8	18		
		R _L ≈ 2 kΩ,	$C_L = 100 pF$,	85°C		14		8	17.3		1//
SR-	Negative slew rate at	See Figure 1		25°C		13.9		10	15.9		V/μs
SH-	unity gain‡			-40°C		14.7		8	16.1		
				85°C		13		8	15.3		
				25°C		55			56		
t _r	Rise time	l				52			53		
				85°C		64			65		
		V _I (PP) = ±10 i	mV, $R_L = 2 k\Omega$,	25°C		55			57		ns
tf	Fall time	C _L ≈ 100 pF,		-40°C		51			53		
		See Figures 1 and 2		85°C		64			65		
				25°C		24%			19%		
	Overshoot factor			−40°C		24%			19%		
				85°C		24%			19%		
· · ·	Equivalent input noise		f = 10 Hz	25°C		75			75		nV/√Hz
v _n	voltage§	$R_S \approx 20 \Omega$,	f = 1 kHz	25°C		21			21	45	110/17
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L \approx 2 k\Omega$,	25°C	0	.003%		C	0.003%		
				25°C		2.7			2.7		
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 25 \text{ pF},$	$R_L = 2 k\Omega$, See Figure 4	-40°C		3.3			3.3		MHz
		OL = 25 pF,	See Figure 4	85°C		2.3			2.4		
	Dhara marin at	10	D 01:0	25°C		61°			64°		
φm			$R_L = 2 kΩ$, See Figure 4	-40°C		59°			62°		
		CL = 20 pl,		85°C		61°			64°		

[†] Full range is -40°C to 85°C.

For V_{CC±} = ±5 V, V_I(PP) = ±1 V; for V_{CC±} = ±15 V, V_I(PP) = ±5 V.

This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[¶] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{o(rms)} = 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{o(rms)} = 6 \text{ V}$.

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TL054M and TL054AM electrical characteristics at specified free-air temperature

							L054M, 1				
	PARAMETER	TEST CON	IDITIONS	T _A †	٧c	C±=±5	٧	٧c	C±=±15	٧	UNIT
				:	MIN	TYP	MAX	MIN	TYP	MAX	
			TL054M	25°C		0.64	5.5		0.56	4	
V	Innut offeet veltere	1	1 LU54IVI	Full range			10.5			9	mV
VIO	Input offset voltage		TL054AM	25°C		0.57	3.5		0.5	1.5	mv
		V _O = 0,	I LU54AW	Full range		-	8.5			6.5	
	Temperature coefficient of	$V_{IC} = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	TL054M	25°C to 85°C		21			20		1400
αΛΙΟ	input offset voltage	1.3	TL054AM	25°C to 85°C		21	·	-	20		μV/°C
	Input offset voltage long-term drift‡			25°C		0.04			0.04		μV/mo
1 .	1	V _O = 0,	V _{IC} = 0,	25°C		4	100		. 5	100	pА
lio	Input offset current	See Figure 5		125°C		1	20		2	20	nA
		V _O = 0,	V _{IC} = 0,	25°C		20	200		30	200	pА
IB	Input bias current	See Figure 5		125°C		10	50		20	50	nA
	Common mode input			25°C	-1 to 4	-2.3 to 5.6		-11 to	-12.3 to 15.6		
VICR	Common-mode input voltage range				-1 to	0.0		-11 to	10.0		V
	Maximum positive peak	R _L = 10 kΩ		25°C Full range	3	4.2		13 13	13.9		
V _{OM} +	output voltage swing			25°C	2.5	3.8		11.5	12.7		٧
		$R_L = 2 k\Omega$		Full range	2.5			11.5			1
				25°C	-2.5	-3.5		-12	-13.2		
.,	Maximum negative peak	$R_L = 10 \text{ k}\Omega$		Full range	-2.5			-12			١.,
VOM -	output voltage swing	5 010		25°C	-2.3	-3.2		-11	-12		٧
		$R_L = 2 k\Omega$		Full range	-2.3			-11			
				25°C	25	72		50	133		
AVD	Large-signal differential voltage amplification§	$R_L = 2 k\Omega$		−55°C	30	99		60	209		V/mV
	voitage ampinications			125°C	10	35		15	35		
rį	Input resistance			25°C		1012			1012		Ω
Cį	Input capacitance			25°C		10			12		pF
		V _{IC} = V _{ICR} n	nin,	25°C	65	84		75	92		
CMRR	Common-mode rejection ratio	$V_O = 0$,	•	−55°C	65	83		75	92		dB
	rejection ratio	$R_S = 50 \Omega$		125°C	65	84		75	93		
	0 1 1 1	V _{CC±=±5}	V to ±15 V,	25°C	75	99		75	99		
ksvr	Supply-voltage rejection	$V_O = 0$,	,	-40°C	75	98		75	98		dB
	ratio (ΔV _{CC±} /ΔV _{IO})	$R_S = 50 \Omega$		85°C	75	100		75	100		
	^ ·	T		25°C		8.1	11.2		8.4	11.2	
lcc	Supply current (four emplifiers)	$V_{O} = 0$,	No load	−55°C		7.8	12.8		8.1	12.8	mA
	(lour amplifiers)		125°C		7.1	11.2		7.5	11.2		
V ₀₁ /V ₀₂	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

[†] Full range is -55°C to 125°C.



Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV. § For V_{CC±} = ±5 V, V_O = ±2.3 V, at V_{CC±} = ±15 V, V_O = ±10 V.

TL05x, TL05xA, TL05xY **ENHANCED-JFET LOW-OFFSET** OPERATIONAL AMPLIFIERS SLOS178 – FEBRUARY 1997

TL054M and TL054AM operating characteristics at specified free-air temperature

		-				Т	L054M, 1	TL054AN	1		
	PARAMETER	TEST CON	NDITIONS	T _A †	VC	C±=±5	V	VCC)±=±1	5 V	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
00	Positive slew rate			25°C		15.4		10	17.8		
SR+	at unity gain			-55°C		16.7			18.3		
		$R_L = 2 k\Omega$,	C _L = 100 pF,	125°C		12.9			16.7		\//
CD.	Negative slew rate at unity gain‡	See Figure 1		25°C		13.9		10	15.9		V/μs
SR-	unity gain+			-55°C		14.7			16.3		
				125°C		12.2			14.5		
						55			56		
t _r	Rise time	1	_			51			52		
		V _{I(PP)} = ±10 mV,		125°C		68			68		
				25°C		55			57		ns
t _f	Fall time	$R_L = 2 k\Omega$, $C_1 = 100 pF$,		-55°C		51			52		
		See Figures 1 a	and 2	125°C		68			69		
]	<u>-</u>	25°C		24%			19%		
	Overshoot factor			-55°C		25%			19%		
				125°C		25%			19%		
.,	Equivalent input noise		f = 10 Hz	25°C		75			75		nV/√Hz
v_n	voltage§	$R_S = 20 \Omega$,	f = 1 kHz	25°C		21			21	45	nv/√Hz
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz	25°C		4			4		μV
In	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1 \text{ k}\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	25°C	0	.003%		C	0.003%		
				25°C		2.7			2.7		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$R_L = 2 k\Omega$,	-55°C		3.4			3.4		MHz
		C _L = 25 pF, See Figure 4		125°C		2.1			2.1		
	D	se margin at $V_1 = 10 \text{ mV}, R_L = 2 \text{ k}\Omega,$ $V_1 = 10 \text{ mV},$ $V_1 = 10 mV$	25°C	<u> </u>	61°			64°			
φm	Phase margin at unity gain			−55°C		58°			62°		
	unity gain		Joe i igule 4	125°C		60°			64°		1

[†] Full range is -55°C to 125°C.

[‡] For $V_{CC\pm} = \pm 5$ V, $V_{I(PP)} = \pm 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{I(PP)} = \pm 5$ V. § This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

 $[\]P$ For $V_{CC\pm} = \pm 5$ V, $V_{orms} = 1$ V; for $V_{CC\pm} = \pm 15$ V, $V_{orms} = 6$ V.

TL05x, TL05xA, TL05xY ENHANCED-JFET LOW-OFFSET OPERATIONAL AMPLIFIERS SLOS178 – FEBRUARY 1997

TL054Y electrical characteristics, $T_A = 25^{\circ}C$

			TL	054Y	
	PARAMETER	TEST CONDITIONS	V _{CC ±} = ± 5 V	V _{CC ±} = ± 15 V	UNIT
	*		MIN TYP MAX	MIN TYP MAX	
V _{IO}	Input offset voltage	$V_O = 0,$ $V_{IC} = 0,$ $R_S = 50 \Omega$	0.64	0.56	mV
lio	Input offset current	$V_O = 0$, $V_{IC} = 0$, See Figure 5	4	5	pA
lΒ	Input bias current	$V_O = 0$, $V_{IC} = 0$, See Figure 5	20	30	pА
			-2.3	-12.3	
VICR	Common-mode input voltage range		to	to	V
			5.6	15.6	
V	Maximum positive peak	$R_L = 10 \text{ k}\Omega$	4.2	13.9	V
VOM +	output voltage swing	$R_L = 2 k\Omega$	3.8	12.7	v
.,	Maximum negative peak	$R_L = 10 \text{ k}\Omega$	-3.5	-13.2	V
VOM -	output voltage swing	$R_L = 2 k\Omega$	-3.2	-12	٧
AVD	Large-signal differential voltage amplification†	$R_L = 2 k\Omega$,	72	133	V/mV
ri	Input resistance		1012	1012	Ω
Cį	Input capacitance		10	12	pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $V_{O} = 0$, $R_{S} = 50 \Omega$	84	92	dB
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm} = \pm 5 \text{ V to } \pm 15 \text{ V},$ $V_{O} = 0,$ $R_{S} = 50 \Omega$	99	99	dB
lcc	Supply current (four amplifiers)	V _O = 0, No load	8.1	8.4	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100	120	120	dB

[†] For $V_{CC\pm} = \pm 5$ V, $V_{O} = \pm 2.3$ V, at $V_{CC\pm} = \pm 15$ V, $V_{O} = \pm 10$ V.

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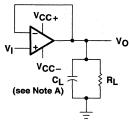
TL054Y operating characteristics, T_A = 25°C

				TL054Y						
	PARAMETER	TEST	CONDITIONS	VC	C±=±5	٧	VCC)±=±18	5 V	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain†	R _L = 2 kΩ,	C _L = 100 pF,		15.4			17.8		V/a
SR-	Negative slew rate at unity gain	See Figure 1	_	13.9		15.9			V/μs	
t _r	Rise time	V _{I(PP)} = ±10	mV,		55			56		
tf	Fall time	$R_L = 2 k\Omega$,			55			57		ns
	Overshoot factor		C _L = 100 pF, See Figures 1 and 2		24%			19%		
V	Equivalent input noise		f = 10 Hz		75			75		nV/√Hz
v _n	voltage‡	$R_S = 20 \Omega$,	f = 1 kHz		21			21		IIV/VIIZ
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	See Figure 3	f = 10 Hz to 10 kHz		4			4		μV
I _n	Equivalent input noise current	f = 1 kHz			0.01			0.01		pA/√Hz
THD	Total harmonic distortion§	$R_S = 1 k\Omega$, f = 1 kHz	$R_L = 2 k\Omega$,	C	.003%		C	.003%		
В1	Unity-gain bandwidth	V _I = 10 mV, C _L = 25 pF,	$R_L = 2 kΩ$, See Figure 4		2.7			2.7		MHz
φm	Phase margin at unity gain	V _I = 10 mV, C _L = 25 pF,	$R_L = 2 kΩ$, See Figure 4		61°			64°		

[†] For V_{CC±} = ±5 V, V_{I(PP)} = ±1 V; for V_{CC±} = ±15 V, V_{I(PP)} = ±5 V. † This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[§] For $V_{CC\pm} = \pm 5 \text{ V}$, $V_{o(rms)} = 1 \text{ V}$; for $V_{CC\pm} = \pm 15 \text{ V}$, $V_{o(rms)} = 6 \text{ V}$.

PARAMETER MEASUREMENT INFORMATION



NOTE A: CL includes fixture capacitance.

Figure 1 . Slew Rate, Rise/Fall Time, and Overshoot Test Circuit

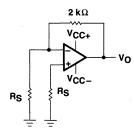


Figure 3. Noise-Voltage Test Circuit

typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

input bias and offset current

At the picoamp-bias-current level typical of the TL05x and TL05xA, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test

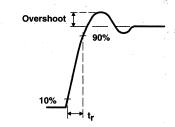
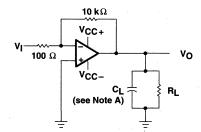


Figure 2 . Rise Time and Overshoot Waveform



NOTE A: CL includes fixture capacitance.

Figure 4. Unity-Gain Bandwidth and Phase-Margin Test Circuit

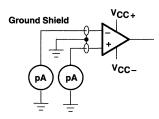


Figure 5. Input-Bias and Offset-Current Test Circuit

socket leakages can easily exceed the actualdevice bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted in the socket, and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

noise

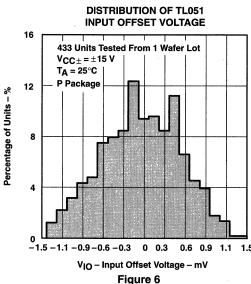
Because of the increasing emphasis on low noise levels in many of today's applications, the input noise voltage density is sample tested at f = 1 kHz. Texas Instruments also has additional noise testing capability to meet specific application requirements. Please contact the factory for details.



Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	6 – 11
αVIO	Temperature coefficient of input offset voltage	Distribution	12, 13, 14
lв	Input bias current	vs Common-mode input voltage vs Free-air temperature	15 16
10	Input offset current	vs Free-air temperature	16
VIC	Common-mode input voltage range limits	vs Supply voltage vs Free-air temperature	17 18
Vo	Output voltage	vs Differential input voltage	19, 20
Vом	Maximum peak output voltage	vs Supply voltage vs Output current vs Free-air temperature	21 25, 26 27, 28
VO(PP)	Maximum peak-to-peak output voltage	vs Frequency	22, 23, 24
A _{VD}	Large-signal differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	29 30 31, 32, 33
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	34, 35 36
z _o	Output impedance	vs Frequency	37
ksvr	Supply-voltage rejection ratio	vs Free-air temperature	38
los	Short-circuit output current	vs Supply voltage vs Time vs Free-air temperature	39 40 41
lcc	Supply current	vs Supply voltage vs Free-air temperature	42, 43, 44 45, 46, 47
SR	Slew rate	vs Load resistance vs Free-air temperature	48 – 53 54 –59
	Overshoot factor	vs Load capacitance	60
٧n	Equivalent input noise voltage	vs Frequency	61, 62
THD	Total harmonic distortion	vs Frequency	63
B ₁	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	64, 65, 66 67, 68, 69
φm	Phase margin	vs Supply voltage vs Load capacitance vs Free-air temperature	70, 71, 72 73, 74, 75 76, 77, 78
	Phase shift	vs Frequency	30
	Voltage-follower small-signal pulse response	vs Time	79
	Voltage-follower large-signal pulse response	vs Time	80

TYPICAL CHARACTERISTICS



DISTRIBUTION OF TL052 INPUT OFFSET VOLTAGE

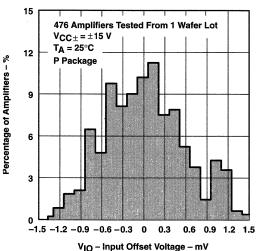


Figure 8

DISTRIBUTION OF TL051A INPUT OFFSET VOLTAGE

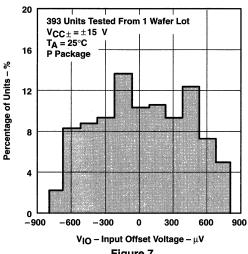


Figure 7

DISTRIBUTION OF TL052A INPUT OFFSET VOLTAGE

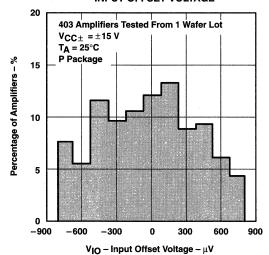
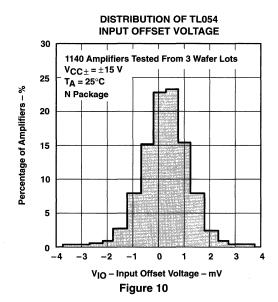
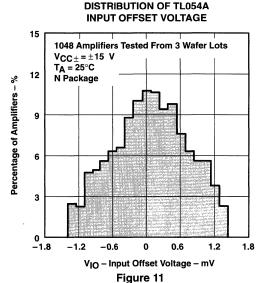


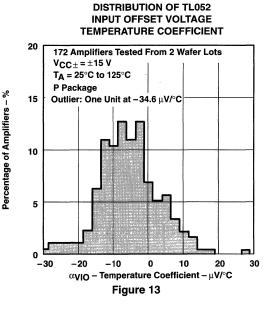
Figure 9

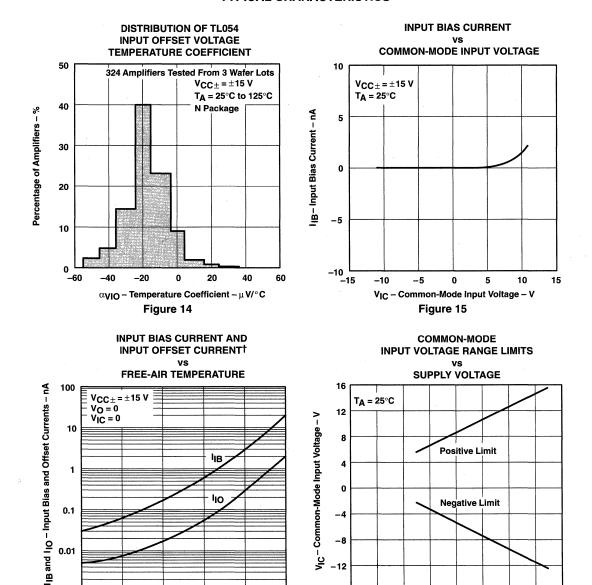
TYPICAL CHARACTERISTICS





DISTRIBUTION OF TL051 INPUT OFFSET VOLTAGE **TEMPERATURE COEFFICIENT** 20 120 Units Tested From 2 Wafer Lots $V_{CC\pm} = \pm 15 \text{ V}$ T_A = 25°C to 125°C 16 P Package Percentage of Units - % 12 8 4 -25 -20 -15 -10 -5 0 10 15 20 α_{VIO} – Temperature Coefficient – μ V/°C Figure 12





125

105

T_A - Free-Air Temperature - °C

Figure 16



-12

-16

0 2 14 16

8 10

IVCC±I - Supply Voltage - V

Figure 17

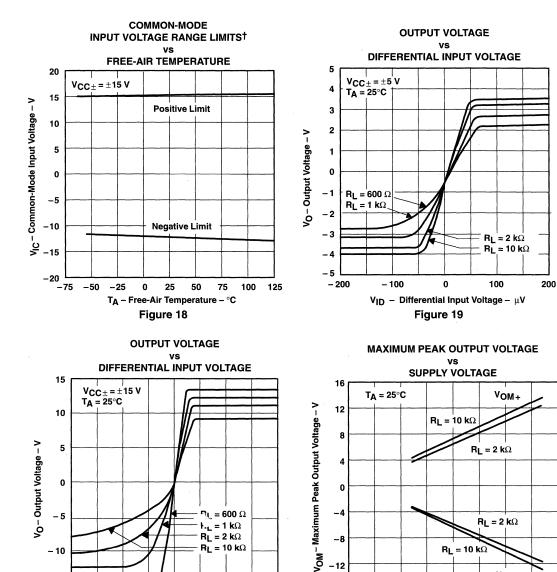
0.01

0.001

25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



400

ł._ = 1 kΩ $R_L = 2 k\Omega$

 $R_L = 10 \text{ k}\Omega$

200

- 5

- 10

- 15

- 400

- 200

0

V_{ID} - Differential Input Voltage - μV

Figure 20



16

 $R_L = 2 k\Omega$

VOM-

12

10

IV_{CC±}I – Supply Voltage – V

Figure 21

-4

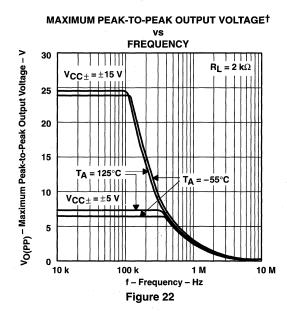
-8

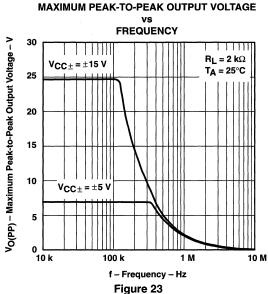
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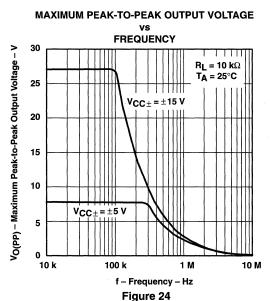
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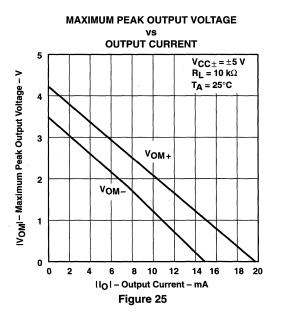
2

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





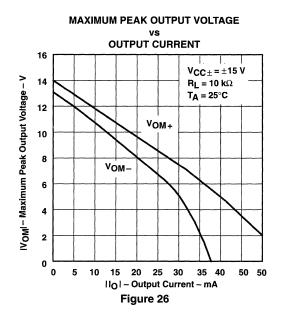




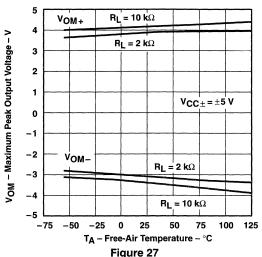
[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



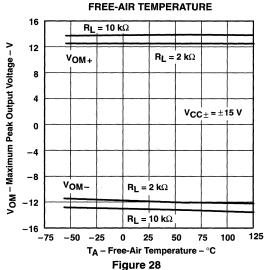
TYPICAL CHARACTERISTICS



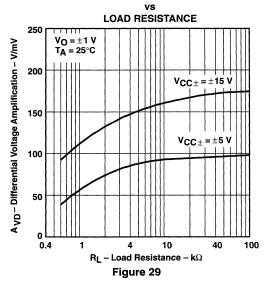
MAXIMUM PEAK OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE



MAXIMUM PEAK OUTPUT VOLTAGET



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

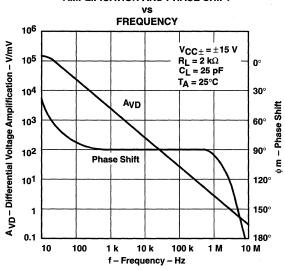
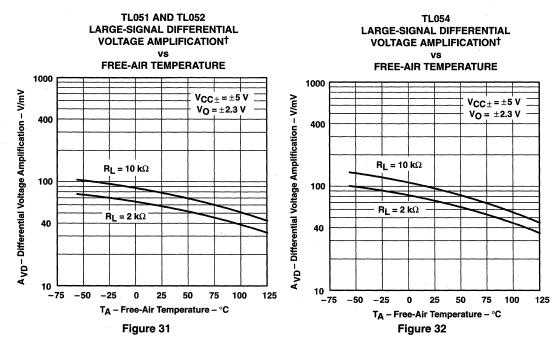
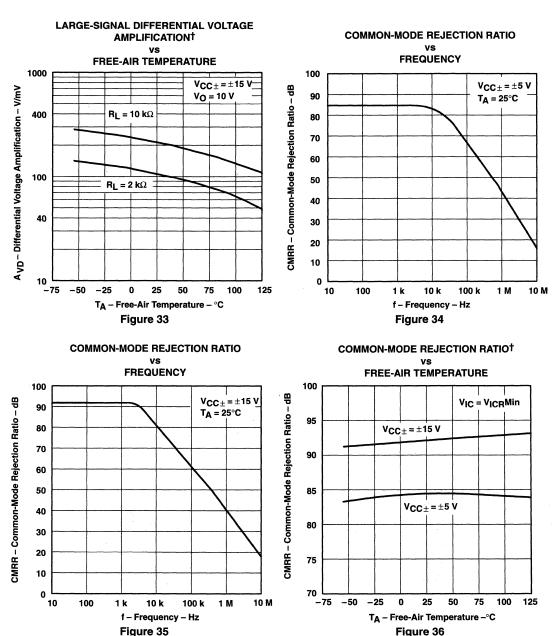


Figure 30

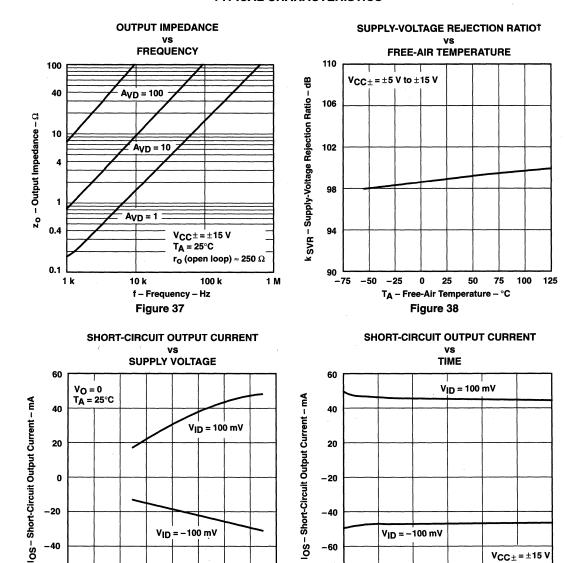


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





-60

0

 $V_{ID} = -100 \text{ mV}$

20

30

t - Time - s

Figure 40

40

10

V_{CC±} = ±15 V $T_A = 25^{\circ}C$

50

60

 $V_{ID} = -100 \text{ mV}$

IV_{CC±}I - Supply Voltage - V

Figure 39

10 12 14 16

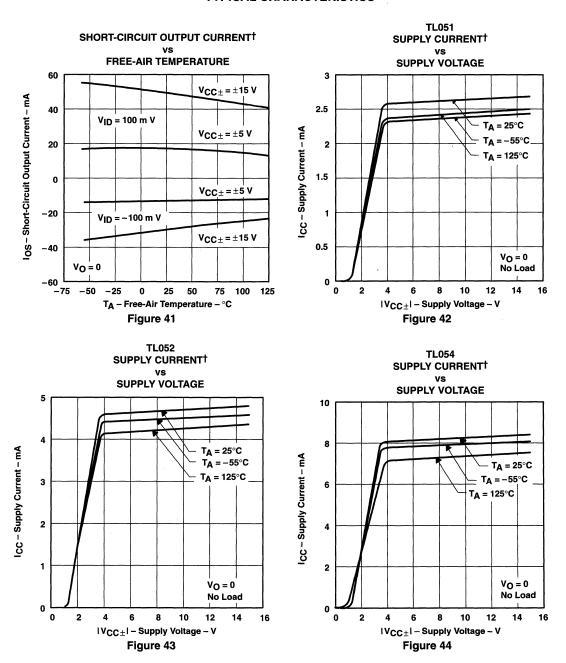


-40

-60

0 2

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

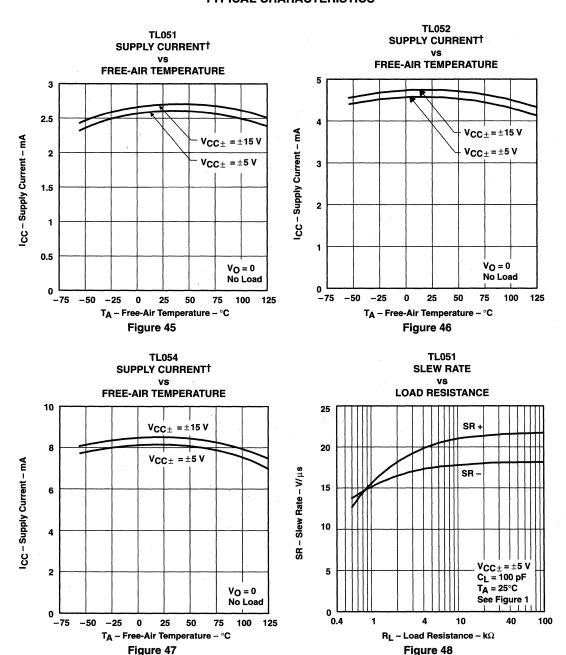


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



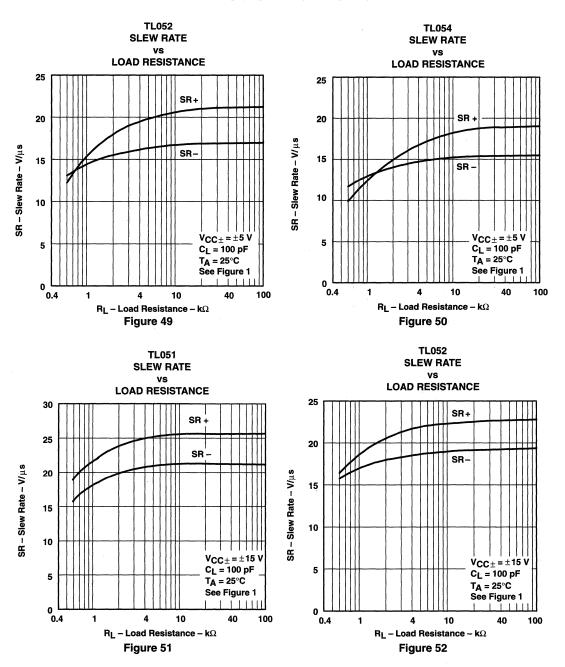
TYPICAL CHARACTERISTICS

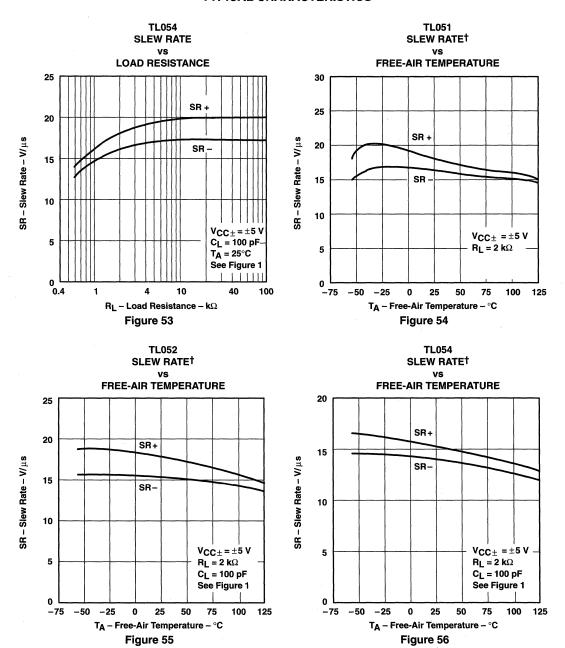
. . .



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

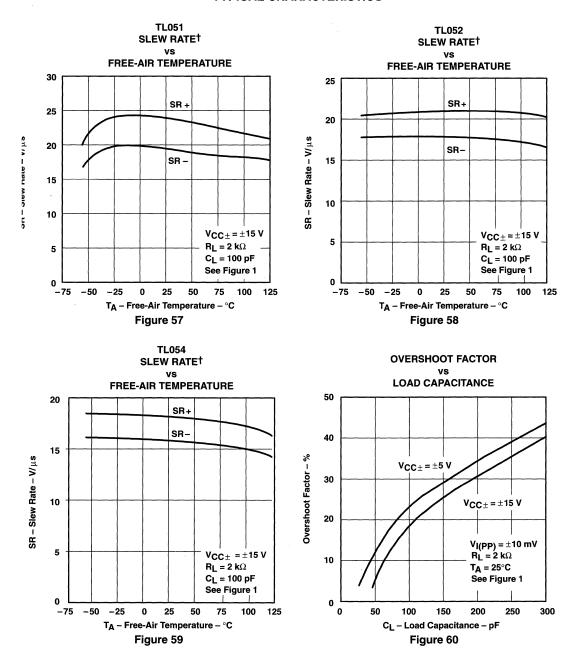






[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

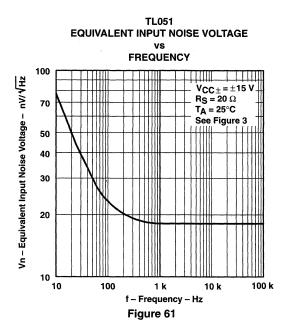




[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



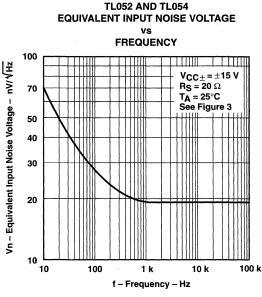
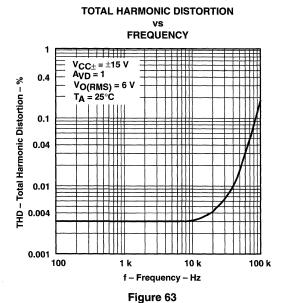
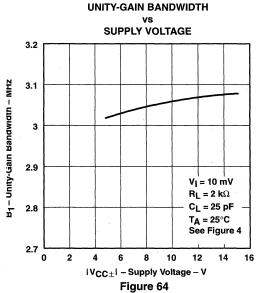


Figure 62

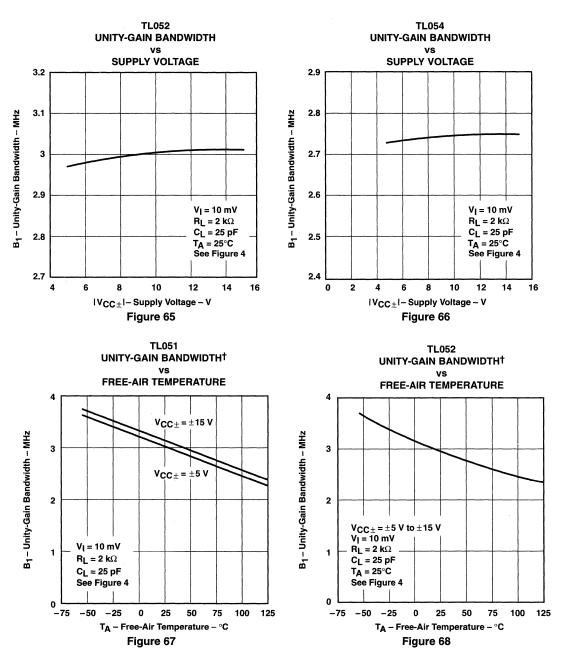
TL051





TEXAS INSTRUMENTS

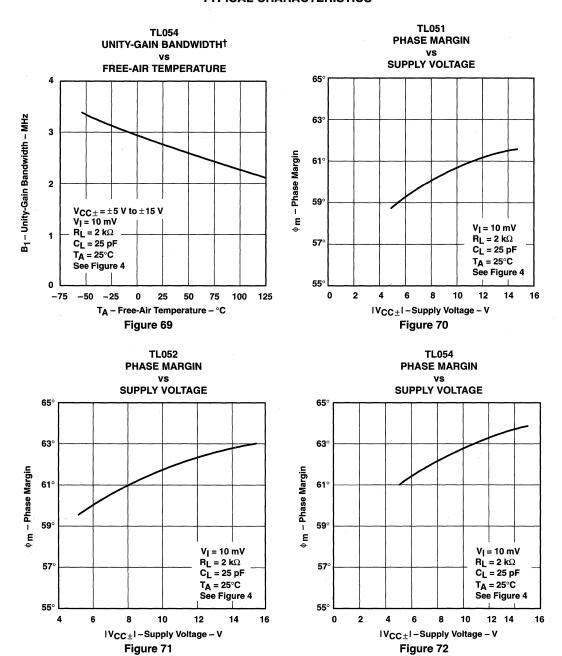
TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



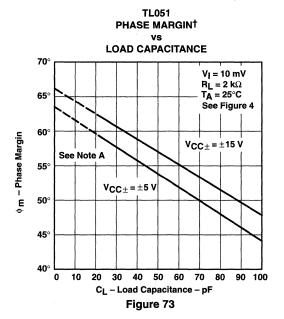
TYPICAL CHARACTERISTICS

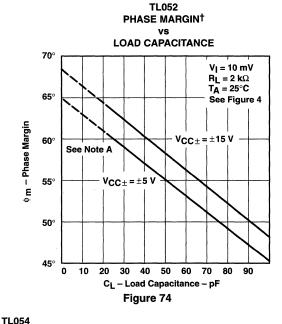


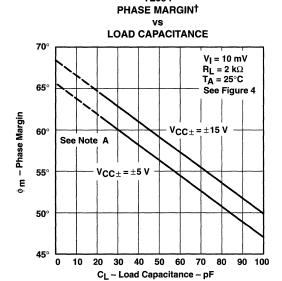
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS





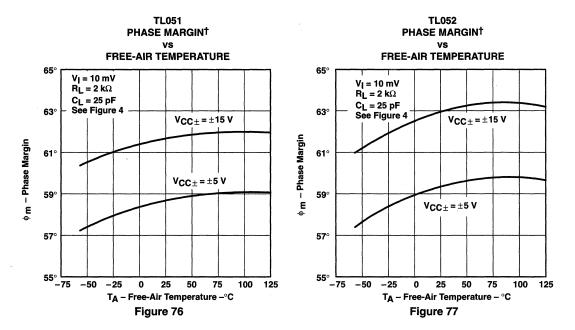


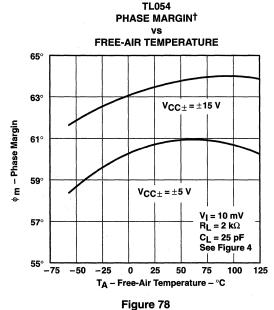
[†] Values of phase margin below a load capacitance of 25 pF were estimated.



Figure 75

TYPICAL CHARACTERISTICS

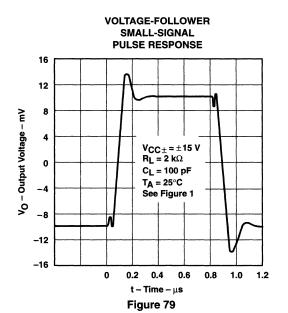


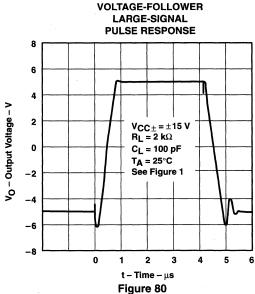


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS





APPLICATION INFORMATION

output characteristics

All operating characteristics (except bandwidth and phase margin) are specified with 100-pF load capacitance. The TL05x and TL05xA drive higher capacitive loads; however, as the load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation. The value of the load capacitance at which oscillation occurs varies with production lots. If an application appears to be sensitive to oscillation due to load capacitance, adding a small resistance in series with the load should alleviate the problem. Capacitive loads of 1000 pF and larger may be driven if enough resistance is added in series with the output (see Figure 81 and Figure 82).

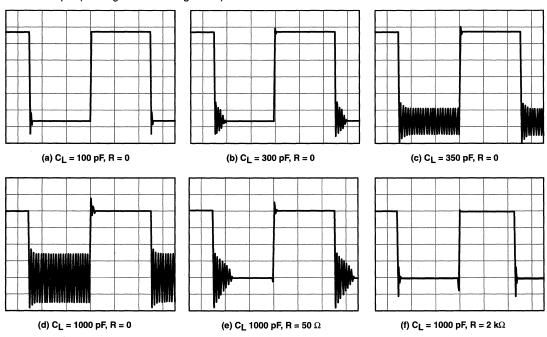


Figure 81. Effect of Capacitive Loads

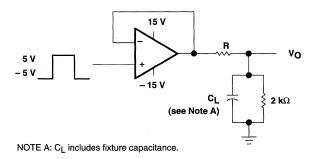


Figure 82. Test Circuit for Output Characteristics



APPLICATION INFORMATION

input characteristics

The TL05x and TL05xA are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias current requirements, the TL05x and TL05xA are well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias current requirements and cause degradation in system performance. It is good practice to include guard rings around inputs (see Figure 83). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

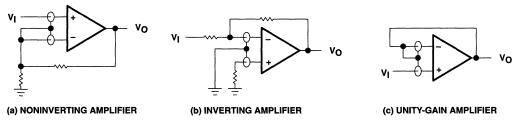


Figure 83. Use of Guard Rings

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TL05x and TL05xA result in a very low current noise. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω .

APPLICATION INFORMATION

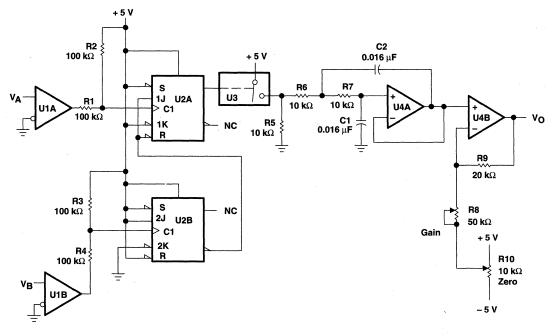
phase meter

The phase meter in Figure 84 produces an output voltage of 10 mV per degree of phase delay between the two input signals V_A and V_B . The reference signal V_A must be the same frequency as V_B . The TLC3702 comparators (U1) convert these two input sine waves into ± 5 -V square waves. Then R1 and R4 provide level shifting prior to the SN74HC109 dual J-K flip flops.

Flip-flop U2B is connected as a toggle flip-flop and generates a square wave at half the frequency of V_B . Flip-flop U2A also produces a square wave at half the input frequency. The pulse duration of U2A varies from zero to half the period, where zero corresponds to zero phase delay between V_A and V_B and half the period corresponds to V_B lagging V_A by 360 degrees.

The output pulse from U2A causes the TLC4066 (U3) switch to charge the TL05x (U4) integrator capacitors C1 and C2. As the phase delay approaches 360 degrees, the output of U4A approximates a square wave and U2A has an output of almost 2.5 V. U4B acts as a noninverting amplifier with a gain of 1.44 in order to scale the 0- to 2.5-V integrator output to a 0- to 3.6-V output range.

R8 and R10 provide output gain and zero-level calibration. This circuit operates over a 100-Hz to 10-kHz frequency range.



NOTE A: U1 = TLC3702; $V_{CC\pm} = \pm 5 \text{ V}$ U2 = SN74HC109 U3 = TLC4066 U4, U5 = TL05x; $V_{CC\pm} = \pm 5 \text{ V}$

Figure 84. Phase Meter

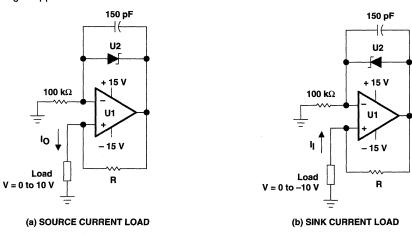


APPLICATION INFORMATION

precision constant-current source over temperature

A precision current source (see Figure 85) benefits from the high input impedance and stability of Texas Instruments enhanced-JFET process. A low-current shunt regulator maintains 2.5 V between the inverting input and the output of the TL05x. The negative feedback then forces 2.5 V across the current setting resistor R; therefore, the current to the load is simply 2.5 V divided by R.

Possible choices for the shunt regulator include the LT1004, LT1009, and LM385. If the regulator's cathode connects to the operational amplifier output, this circuit sources load current. Similarly, if the cathode connects to the inverting input, the circuit sinks current from the load. To minimize output current change with temperature, R should be a metal film resistor with a low temperature coefficient. Also, this circuit must be operated with split-voltage supplies.



NOTE B: U1 = 1/2 TL05x U2 = LM385, LT1004, or LT1009 voltage reference I = $\frac{2.5 \text{ V}}{\text{R}}$, R = Low temperature coefficient metal film resistor

Figure 85. Precision Constant-Current Source

APPLICATION INFORMATION

instrumentation amplifier with adjustable gain/null

The instrumentation amplifier in Figure 86 benefits greatly from the high input impedance and stable input offset voltage of the TL05xA. Amplifiers U1A, U1B, and U2A form the actual instrumentation amplifier, while U2B provides offset null. Potentiometer R1 provides gain adjust. With R1 = $2 k\Omega$, the circuit gain equals 100, while with R1 = 200 k Ω , the circuit gain equals two. The following equation shows the instrumentation amplifier gain as a function of R1:

$$A_V = 1 + \left(\frac{R2 + R3}{R1}\right)$$

Readjusting the offset null is necessary whenever the circuit gain is changed. If U2B is needed for another application, R7 can be terminated at ground. The low input offset voltage of the TL05xA minimizes the dc error of the circuit. For best matching, all resistors should be one percent tolerance. The matching between R4, R5, R6, and R7 controls the CMRR of this application.

The following equation shows the output voltages when the input voltage equals zero. This dc error can be nulled by adjusting the offset null potentiometer; however, any change in offset voltage over time or temperature also creates an error. To calculate the error from changes in offset, consider the three offset components in the equation as delta offsets rather than initial offsets. The improved stability of Texas Instruments enhanced JFETs minimizes the error resulting from change in input offset voltage with time. Assuming V_I equals zero, V_O can be shown as a function of the offset voltage:

$$V_{O} = V_{IO2} \left[\left(1 + \frac{R3}{R1} \right) \left(\frac{R7}{R5 + R7} \right) \left(1 + \frac{R6}{R4} \right) + \frac{R2}{R1} \left(\frac{R6}{R4} \right) \right]$$

$$-V_{IO1} \left[\frac{R3}{R1} \left(\frac{R7}{R5 + R7} \right) \left(1 + \frac{R6}{R4} \right) + \frac{R6}{R4} \left(1 + \frac{R2}{R1} \right) \right] + V_{IO3} \left(1 + \frac{R6}{R4} \right)$$

$$V_{I} - \frac{V_{IO1} \left[\frac{R3}{R1} \left(\frac{R7}{R5 + R7} \right) \left(1 + \frac{R6}{R4} \right) + \frac{R6}{R4} \left(1 + \frac{R2}{R1} \right) \right] + V_{IO3} \left(1 + \frac{R6}{R4} \right)$$

$$V_{I} - \frac{V_{IO1} \left[\frac{R3}{R1} \left(\frac{R7}{R5 + R7} \right) \left(1 + \frac{R6}{R4} \right) + \frac{R6}{R4} \left(1 + \frac{R2}{R1} \right) \right] + V_{IO3} \left(1 + \frac{R6}{R4} \right)$$

$$V_{I} - \frac{R4}{R1} \frac{R6}{R1} \frac$$

Figure 86. Instrumentation Amplifier



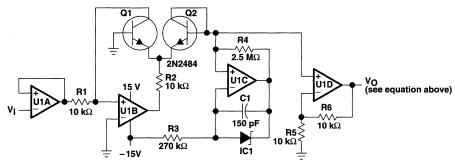
APPLICATION INFORMATION

high input impedance log amplifier

The low input offset voltage and high input impedance of the TL05xA creates a precision log amplifier (see Figure 87). IC1 is a 2.5-V, low-current precision, shunt regulator. Transistors Q1 and Q2 must be a closely matched NPN pair. For best performance over temperature, R4 should be a metal film resistor with a low temperature coefficient.

In this circuit, U1A serves as a high-impedance unity-gain buffer. Amplifier U1B converts the input voltage to a current through R1 and Q1. Amplifier U1C, IC1, and R4 form a 1-µA temperature-stable current source that sets the base-emitter voltage of Q2. U1D amplifies the difference between the base-emitter voltage of Q1 and Q2 (see Figure 88). The output voltage is given by the following equation:

$$V_O = -\left[1 + \frac{R6}{R5}\right] \frac{kT}{q} \left[ln \frac{V_I}{\left(R1 \times 1 \times 10^{-6}\right)} \right] \text{ where } k = 1.38 \times 10^{-23}, \ q = 1.602 \times 10^{-19}, \\ and T is in degrees kelvin.$$



NOTE A: U1A through U1D = TL05xA. IC1 = LM385, LT1004, or LT1009 voltage reference.

Figure 87. Log Amplifier

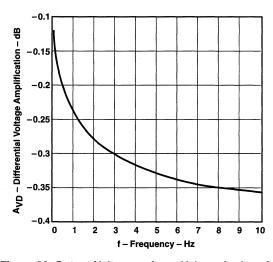


Figure 88. Output Voltage vs Input Voltage for Log Amplifier



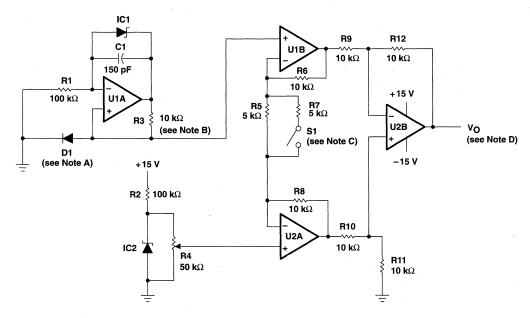
APPLICATION INFORMATION

analog thermometer

By combining a current source that does not vary over temperature with an instrumentation amplifier, a precise analog thermometer can be built (see Figure 89). Amplifier U1A and IC1 establish a constant current through the temperature-sensing diode D1. For this section of the circuit to operate correctly, the TL05x must use split supplies and R3 must be a metal-film resistor with a low temperature coefficient.

The temperature-sensitive voltage from the diode is compared to a temperature-stable voltage reference set by IC2. R4 should be adjusted to provide the correct output voltage when the diode is at a known temperature. Although this potentiometer resistance varies with temperature, the divider ratio of the potentiometer remains constant.

Amplifiers U1B, U2A, and U2B form the instrumentation amplifier that converts the difference between the diode and reference voltage to a voltage proportional to the temperature. With switch S1 closed, the amplifier gain equals 5 and the output voltage is proportional to temperature in degrees Celsius. With S1 open, the amplifier gain is 9 and the output is proportional to temperature in degrees Fahrenheit. Every time that S1 is changed, R4 must be recalibrated. By setting S1 correctly, the output voltage equals 10 mV per degree (C or F).



- NOTES: A. Temperature-sensing diode ≈ (-2 mV/°C)
 - B. Metal-film resistor (low temperature coefficient)
 - C. Switch open for °F and closed for °C
 - D. $V_O \alpha$ temperature; 10 mV/°C or 10 mV/°F
 - E. U1, U2 = TL05x. IC1, IC2 = LM385, LT1004, or LT1009 voltage reference

Figure 89. Analog Thermometer

APPLICATION INFORMATION

voltage-ratio-to-dB converter

The application in Figure 90 measures the amplitude ratio of two signals and then converts the ratio to decibels (see Figure 91). The output voltage provides a resolution of 100 mV/dB. The two inputs can be either dc or sinusoidal ac signals. When using ac signals, both signals should be the same frequency or output glitches will occur. For measuring two input signals of different frequencies, extra filtering should be added after the rectifiers.

The circuit contains three low-offset TL05xA devices. Two of these devices provide the rectification and logarithmic conversion of the inputs. The third TL05xA forms an instrumentation amplifier. The stage performing the logarithmic conversion also requires two well-matched npn transistors.

The input signal first passes through a high impedance unity-gain buffer U1A (U2A). Then U1B (U2B) rectifies the input signal at a gain of 0.5, and U1C (U2C) provides a noninverting gain of 2 so that the system gain is still one. U1D (U2D), R6 (R13), and Q1 (Q2) perform the logarithmic conversion of the rectified input signal. The instrumentation amplifier formed by U3A, U3B, U3D scales the difference of the two logarithmic voltages by a gain of 33.6. As a result, the output voltage equals 100 mV/dB. The 1-k Ω potentiometer on the input of U3C calibrates the zero dB reference level. The following equations are used to derive the relationship between the input voltage ratio expressed in decibels and the output voltage.

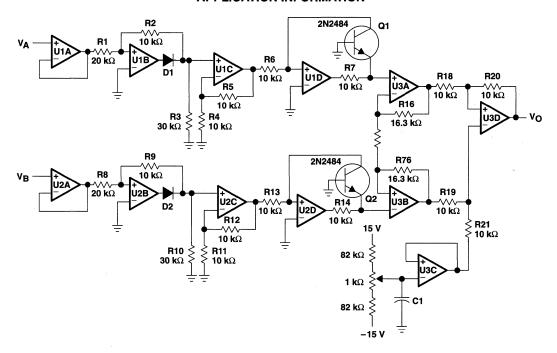
$$\begin{array}{l} \text{X dB} = 20 \, \log \biggl[\frac{\text{V}_{\text{A}}}{\text{V}_{\text{B}}} \biggr] = 20 \, \biggl[\frac{\text{In} \, \left(\text{V}_{\text{A}} \right) - \left(\text{V}_{\text{B}} \right)}{\text{In} \, \left(10 \right)} \biggr] \\ \\ \text{X dB} = 8.686 \, \biggl[\text{In} \, \left(\text{V}_{\text{A}} \right) - \text{In} \, \left(\text{V}_{\text{B}} \right) \biggr] \\ \\ \text{V}_{\text{BE}(\text{Q1})} = \frac{\text{kT}}{\text{q}} \, \text{In} \, \biggl[\frac{\text{V}_{\text{A}}}{\text{R} \times \text{I}_{\text{S}}} \biggr] \\ \\ \text{V}_{\text{BE}} = \text{V}_{\text{BE}(\text{Q1})} - \text{V}_{\text{BE}(\text{Q2})} = \frac{\text{kT}}{\text{q}} \, \left[\text{In} \, \left(\text{V}_{\text{A}} \right) - \text{In} \, \left(\text{V}_{\text{B}} \right) \right] \\ \\ \text{X dB} = \frac{8.686}{\text{kT/q}} \, \biggl[\text{V}_{\text{BE}(\text{Q1})} - \text{V}_{\text{BE}(\text{Q2})} \biggr] = 336 \, \biggl[\text{V}_{\text{BE}(\text{Q1})} - \text{V}_{\text{BE}(\text{Q2})} \biggr] \, \text{at } 25^{\circ}\text{C} \end{array}$$

where

$$k = 1.38 \times 10^{-23}$$
, $q = 1.602 \times 10^{-19}$, and T is in kelvins.

This would give a resolution of 1 V/dB. Therefore, the gain of the instrumentation amplifier is set at 33.6 to obtain 100 mV/dB.

APPLICATION INFORMATION



NOTE A: U1A through U3D = TL05xA, $V_{CC\pm}$ = \pm 15 V. D1 and D2 = 1N914.

Figure 90. Voltage-Ratio-to-dB Converter

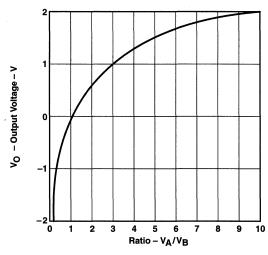


Figure 91. Output Voltage vs the Ratio of the Input Voltages for Voltage-to-dB Converter

APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim Parts™, the model generation software used with Microsim PSpice™. The Boyle macromodel (see Note 5) and subcircuit Figure 92 are generated using the TL05x typical electrical and operating characteristics at $T_A = 25$ °C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Intergrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

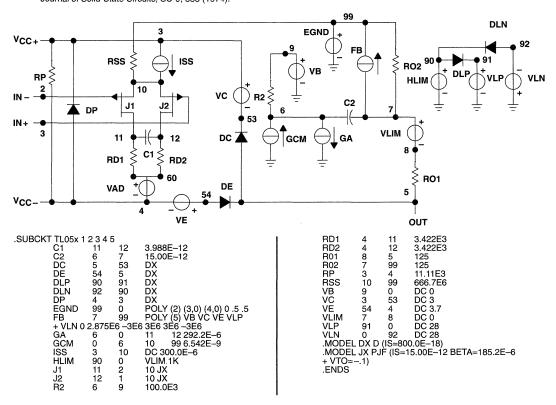


Figure 92. Boyle Macromodel and Subcircuit

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TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS078C - NOVEMBER 1978 - REVISED AUGUST 1996

- Very Low Power Consumption
- Typical Supply Current . . . 200 μA (per Amplifier)
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Common-Mode Input Voltage Range Includes V_{CC+}

- Output Short-Circuit Protection
- High Input impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 3.5 V/μs Typ

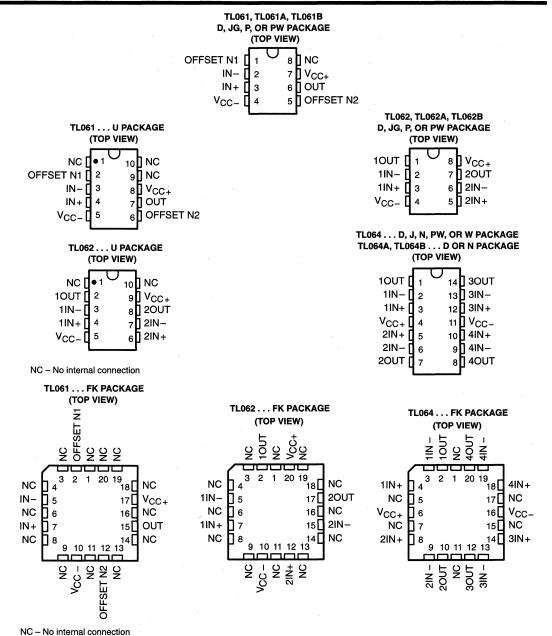
description

The JFET-input operational amplifiers of the TL06_ series are designed as low-power versions of the TL08_ series amplifiers. They feature high input impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The TL06_ series feature the same terminal assignments as the TL07_ and TL08_ series. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

The C-suffix devices are characterized for operation from 0° C to 70° C. The I-suffix devices are characterized for operation from -40° C to 85° C, and the M-suffix devices are characterized for operation over the full military temperature range of -55° C to 125° C.

TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JEET-INPUT OPERATIONAL AMPLIFIERS

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TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS SLOS078C - NOVEMBER 1978 - REVISED AUGUST 1996

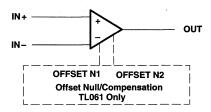
AVAILABLE OPTIONS

			PACKAGED DEVICES							
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D008)†	SMALL OUTLINE (D014)†	PLASTIC DIP (N)	PLASTIC DIP (P)	TSSOP (PW)	CHIP FORM (Y)			
	15 mV 6 mV 3 mV	TL061CD TL061ACD TL061BCD			TL061CP TL061ACP TL061BCP	TL061CPW	TL061Y			
0°C to 70°C	15 mV 6 mV 3 mV	TL062CD TL062ACD TL062BCD			TL062CP TL062ACP TL062BCP	TL062CPW	TL062Y			
	15 mV 6 mV 3 mV		TL064CD TL064ACD TL064BCD	TL064CN TL064ACN TL064BCN		TL064CPW	TL064Y			

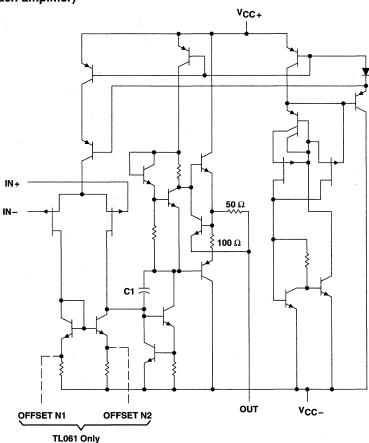
P)							PACKAGE						
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D008) [†]	SMALL OUTLINE (D014)†	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	FLAT PACK (U)	FLAT PACK (W)			
-40°C to 85°C	6mV	TL061ID TL062ID	TL064ID				TL064IN	TL061IP TL062IP					
-55°C to 125°C	6mV 6mV 9mV			TL061MFK TL062MFK TL064MFK	TL064MJ	TL061MJG TL062MJG			TL061MU TL062MU	TL064MW			

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL061CDR).

symbol (each amplifier)



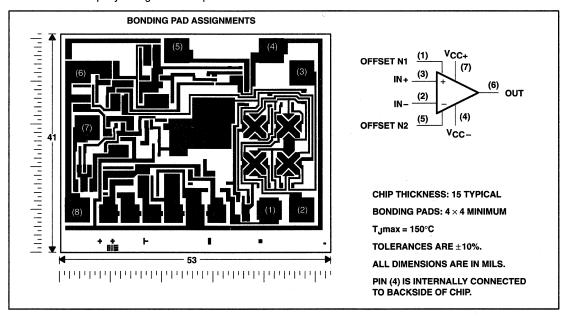
schematic (each amplifier)



C1 = 10 pF on TL061, TL062, and TL064 Component values shown are nominal.

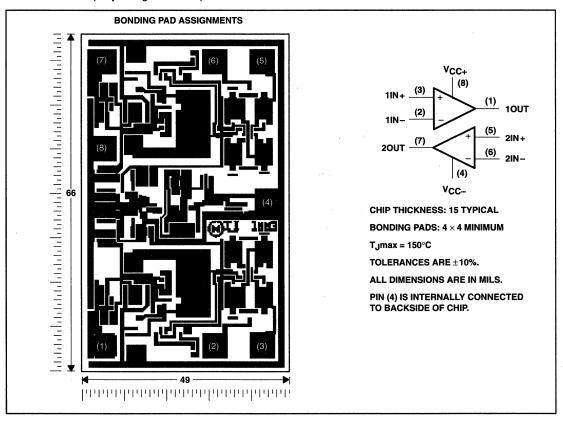
TL061Y chip information

This chip, when properly assembled, displays characteristics similar to the TL061. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. The chips may be mounted with conductive epoxy or a gold-silicon preform.



TL062Y chip information

This chip, when properly assembled, displays characteristics similar to the TL062. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. The chips may be mounted with conductive epoxy or a gold-silicon preform.

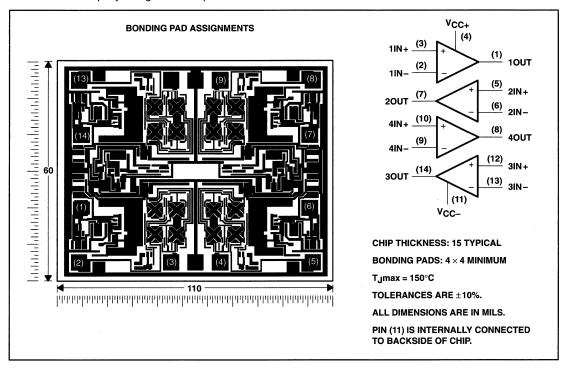


TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

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TL064Y chip information

This chip, when properly assembled, displays characteristics similar to the TL064. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. The chips may be mounted with conductive epoxy or a gold-silicon preform.



TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

		_	•		•		
		TL06_C TL06_AC TL06_BC	TL06_I	TL06_M	UNIT		
Supply voltage, V _{CC+} (see Note 1)		18	18	18	٧		
Supply voltage, V _{CC} (see Note 1)	-18	-18	-18	V			
Differential input voltage, V _{ID} (see Note 2)	±30	±30	± 30	V			
Input voltage, V _I (see Notes 1 and 3)			±15	±15	V		
Duration of output short circuit (see Note 4)		unlimited	unlimited	unlimited			
Continuous total dissipation	-	See Dissipation Rating Table					
Operating free-air temperature range	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	0 to 70	-40 to 85	-55 to 125	°C		
Storage temperature range		-65 to 150	-65 to 150	65 to 150	°C		
Case temperature for 60 seconds	FK package			260	°C		
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, U, or W package			300	°C		
Lead temperature 1,6 mm (1/6 inch) from case for 10 seconds	D, N, P, or PW package	260	260		°C		

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values except differential voltages are with respect to the midpoint between V_{CC+} and V_{CC-}.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25^{\circ}C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D (8 pin)	680 mW	5.8 mW/°C	33°C	465 mW	378 mW	N/A
D (14 pin)	680 mW	7.6 mW/°C	60°C	604 mW	490 mW	N/A
FK	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
J	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
JG	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
N	680 mW	9.2 mW/°C	76°C	680 mW	597 mW	N/A
Р	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A
PW (8 pin)	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
PW (14 pin)	700 mW	5.6 mW/°C	25°C	448 mW	N/A	N/A
U	675 mW	5.4 mW/°C	25°C	432 mW	351 m/W	135 mW
w	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW

electrical characteristics, $V_{CC\pm} = \pm 15 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CO	ONDITIONS†		TL061C TL062C TL064C		Т	L061AC L062AC L064AC		1	L061BC L062BC L064BC	;		TL0611 TL0621 TL0641		UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Via	Input offset voltage	V _O = 0,	T _A = 25°C		3	15		3	6		2	3		3	6	mV
VIO	input onset voltage	$R_S = 50 \Omega$	T _A = Full range			20	-		7.5			5			9	1110
ανιο	Temperature coefficient of input offset voltage	V _O = 0, T _A = Full rang	$R_S = 50 \Omega$, je		10			10			10			10		μV/°C
lio	Input offset current	V _O = 0	T _A = 25°C		5	200		5	100		5	100		5	100	pА
lio	input onset current	AQ = 0	T _A = Full range			5			3			3			10	nA
lin		V _O = 0	T _A = 25°C		30	400		30	200		30	200		30	200	pА
IB	Input bias current‡	AQ = 0	T _A = Full range			10			7			. 7			20	nA
VICR	Common-mode input voltage range	T _A = 25°C		±11	-12 to 15		±11	-12 to 15		±11	-12 to 15		±11	-12 to 15		Ÿ
V	, Maximum peak output	$R_L = 10 \text{ k}\Omega$,	T _A = 25°C	±10	±13.5		±10	±13.5		±10	±13.5		±10	±13.5		V
Vом	voltage swing	R _L ≥ 10 kΩ,	T _A = Full range	±10			±10			±10			±10			v
Δ	Large-signal differential	$V_0 = \pm 10 \text{ V},$	T _A = 25°C	3	6		4	6		4	6		4	6		V/mV
AVD	voltage amplification	R _L ≥ 10 kΩ	T _A = Full range	3			4			4			4			V/111V
B ₁	Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega$,	T _A = 25°C		1			1			1			1		MHz
rj	Input resistance	T _A = 25°C			1012			1012			1012			1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}m$ $R_S = 50 \Omega$,	in, $V_O = 0$, $T_A = 25^{\circ}C$	70	86		80	86		80	86		80	86		dB
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 9 V t$ $V_{O} = 0$, $T_{A} = 25^{\circ}C$	o \pm 15 V, R _S = 50 Ω ,	70	95		80	95		80	95		80	95		dB
PD	Total power dissipation (each amplifier)	V _O = 0, No load	T _A = 25°C,		6	7.5		6	7.5		6	7.5		6	7.5	mW
ICC	Supply current (each amplifier)	V _O = 0, No load	T _A = 25°C,		200	250		200	250		200	250		200	250	μА
V _{O1} /V _{O2}	Crosstalk attenuation	$A_{VD} = 100,$	T _A = 25°C		120			120			120			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for TA is 0°C to 70°C for TL06_C, TL06_AC, and TL06_BC and -40°C to 85°C for TL06_I.

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 15. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

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electrical characteristics, $V_{CC\pm} = \pm 15 \text{ V}$ (unless otherwise noted)

	PARAMETER TE		TEST CONDITIONS†		TL061M TL062M			TL064M		UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
Vio	Input offset voltage	$V_{O} = 0$,	T _A = 25°C		3	6		3	9	mV
2	input onset voltage	$R_S = 50 \Omega$	$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$			9			15	ij.
α_{VIO}	Temperature coefficient of input offset voltage	$V_{O} = 0,$ $T_{A} = -55 ^{\circ}C t$	R _S = 50 Ω, o 125°C		10			10		μV/°C
			T _A = 25°C		5	100		5	100	pА
ΙΟ	Input offset current	VO = 0	T _A = -55°C to 125°C			20			20	nA
1		V - 0	T _A = 25°C		30	200		30	200	рA
lВ	Input bias current‡	VO = 0	T _A = -55°C to 125°C			50			50	nA
VICR	Common-mode input voltage range	T _A = 25°C		±11.5	-12 to 15		±11.5	-12 to 15		٧
.,	Maximum peak output	$R_L = 10 \text{ k}\Omega$	T _A = 25°C	±10	±13.5		±10	±13.5		
VOM	voltage swing	R _L ≥ 10 kΩ,	T _A = -55°C to 125°C	±10			±10			V
	Large-signal differential	$V_0 = \pm 10 \text{ V},$	T _A = 25°C	4	6		4	6		V/mV
AVD	voltage amplification		$T_A = -55^{\circ}C$ to 125°C	4			4			. V/IIIV
B ₁	Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega$,	T _A = 25°C							MHz
rį	Input resistance	T _A = 25°C			10 ¹²			1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC}=V_{ICR}mi$ $R_S = 50 \Omega$,		80	86	v	80	86		dB
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC}=\pm 9 \text{ V to}$ $R_S=50 \Omega$,		80	95		80	95		dB
PD	Total power dissipation (each amplifier)	V _O = 0, No load	T _A = 25°C,		6	7.5		6	7.5	mW
lcc	Supply current (each amplifier)	V _O = 0, No load	T _A = 25°C,		200	250		200	250	μΑ
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100,	T _A = 25°C		120			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

	PARAMETER	TEST CO	MIN	TYP	MAX	UNIT		
SR	Slew rate at unity gain (see Note 5)	V _I = 10 V, C _L = 100 pF,	R _L = 10 kΩ, See Figure 1	1.5	3.5		V/μs	
t _r	Rise time	V _I = 20 V,	$R_{I} = 10 \text{ k}\Omega$		0.2			
	Overshoot factor	C _L = 100 pF,	See Figure 1		10%		μs	
٧n	Equivalent input noise voltage	$R_S = 20 \Omega$,	f = 1 kHz		42		nV/√Hz	

NOTE 5: Slew rate at -55°C to 125°C is 0.7 V/μs min.

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 15. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

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electrical characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CONDITION	onst		TL061Y TL062Y TL064Y		UNIT
				MIN	TYP	MAX	
V _{IO}	Input offset voltage	$V_{O} = 0,$	$R_S = 50 \Omega$		3	15	mV
ανιο	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$		10		μV/°C
lio	Input offset current	V _O = 0			5	200	pА
lв	Input bias current‡	V _O = 0			30	400	pА
VICR	Common-mode input voltage range			±11	-12 to 15		٧
V _{OM}	Maximum peak output voltage swing	R _L = 10 kΩ		±10	±13.5		٧
AVD	Large-signal differential voltage amplification	$V_0 = \pm 10 \text{ V},$	R _L ≥2kΩ	3	6		V/mV
B ₁	Unity-gain bandwidth	R _L = 10 kΩ			1		MHz
rį	Input resistance				1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}^{min}$, RS = 50 Ω	V _O = 0,	70	86		dB
ksvr	Supply voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ R _S = 50 Ω	V _O ≈ 0,	70	95		dB
PD	Total power dissipation (each amplifier)	V _O = 0,	No load		6	7.5	mW
Icc	Supply current (per amplifier)	V _O = 0,	No load		200	250	μΑ
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100			120		dB

TAll characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CO	TEST CONDITIONS			TL061Y TL062Y TL064Y		
				MIN	TYP	MAX		
SR	Slew rate at unity gain	V _I = 10 mV, C _L = 100 pF,	R _L = 10 kΩ, See Figure 1	1.5	3.5		V/µs	
t _r	Rise time	V _I = 20 V,	$R_{\parallel} = 10 \text{ k}\Omega$		0.2		μs	
	Overshoot factor	C _L = 100 pF,	See Figure 1		10%			
Vn	Equivalent input noise voltage	$R_S = 20 \Omega$,	f = 1 kHz		42		nV/√Hz	

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 15. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

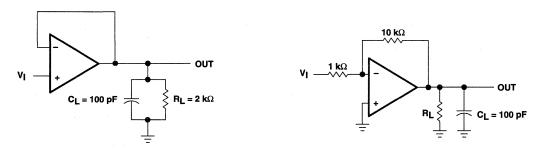


Figure 1. Unity-Gain Amplifier

Figure 2. Gain-of-10 Inverting Amplifier

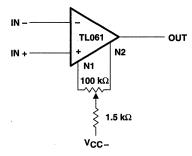


Figure 3. Input Offset Voltage Null Circuit

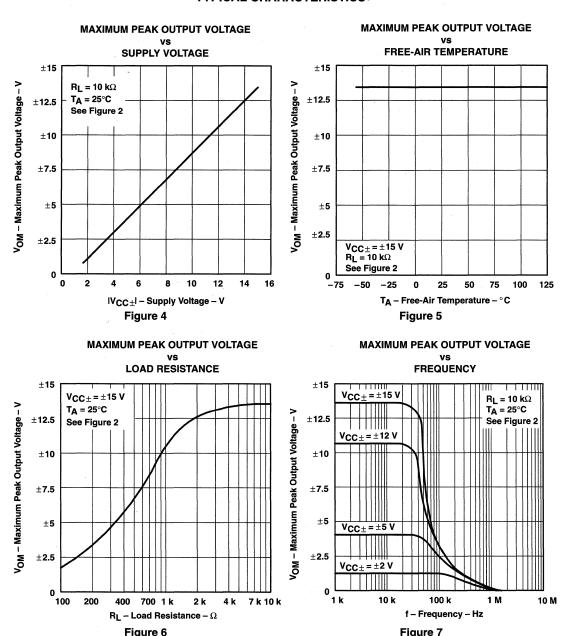
TL061, TL061A, TL061B, TL061Y, TL062, TL062A TL062B, TL062Y, TL064, TL064A, TL064B, TL064Y LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS SLOS078C - NOVEMBER 1978 - REVISED AUGUST 1996

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{ОМ}	Maximum output voltage	vs Supply voltage vs Free-air temperature vs Load resistance vs Frequency	4 5 6 7
AVD	Differential voltage amplification	vs Free-air temperature	8
A _{VD}	Large-signal differential voltage amplification	vs Frequency	9
	Phase shift	vs Frequency	9
ICC	Supply current	vs Supply voltage vs Free-air temperature	10 11
PD	Total power dissipation	vs Free-air temperature	12
CMRR	Common-mode rejection ratio	vs Free-air temperature	13
	Normalized unity-gain bandwidth	vs Free-air temperature	14
	Normalized slew rate	vs Free-air temperature	14
	Normalized phase shift	vs Free-air temperature	14
lв	Input bias current	vs Free-air temperature	15
	Large-signal pulse response	vs Time	16
VO	Output voltage	vs Elapsed time	17
٧ _n	Equivalent input noise voltage	vs Frequency	18

TYPICAL CHARACTERISTICS†



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS† DIFFERENTIAL VOLTAGE AMPLIFICATION

FREE-AIR TEMPERATURE

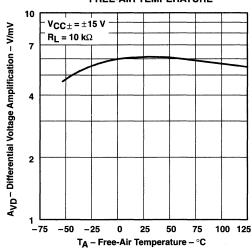
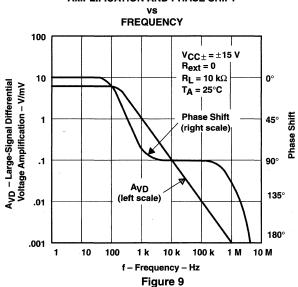


Figure 8

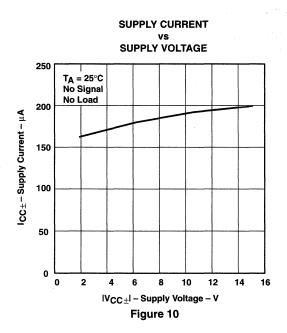
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

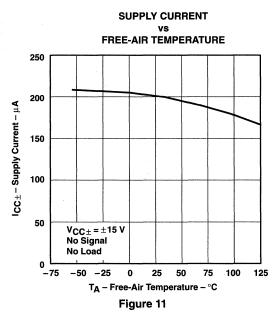


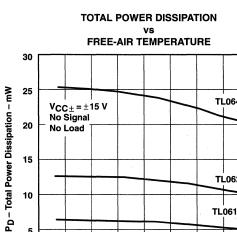
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]







25 50

TA - Free-Air Temperature - °C Figure 12

75

V_{CC±} = ±15 V No Signal

No Load

20

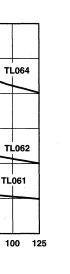
15

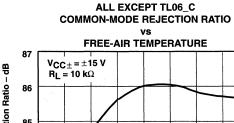
10

5

0

-75 -50 -25





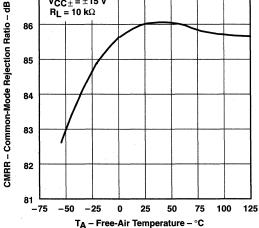


Figure 13

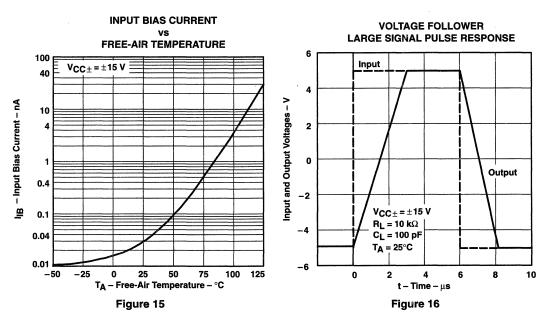
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS

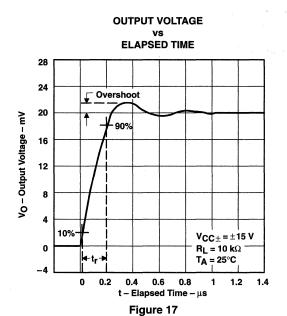
NORMALIZED UNITY GAIN BANDWIDTH SLEW RATE, AND PHASE SHIFT

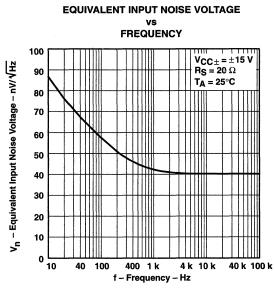
FREE-AIR TEMPERATURE 1.03 1.3 Normalized Unity-Gain Bandwidth and Slew Rate Unity-Gain Bandwidth 1.2 1.02 (left scale) **Phase Shift** (right scale) 1.01 Normalized Phase Shift 1.1 **Slew Rate** (left scale) 0.9 0.99 V_{CC±} = ±15 V 8.0 0.98 $R_L = 10 \text{ k}\Omega$ f = B1 for Phase Shift _____{0.97} 0.7 -25 25 -75 -50 75 T_A - Free-Air Temperature - °C Figure 14





TYPICAL CHARACTERISTICS





APPLICATION INFORMATION

Table of Application Diagrams

APPLICATION DIAGRAM	PART NUMBER	FIGURE
Instrumentation filter	TL064	19
0.5-Hz square-wave oscillator	TL061	20
High-Q notch filter	TL061	21
Audio-distribution amplifier	TL064	22
Low-level light detector preamplifier	TL061	23
AC amplifier	TL061	24
Microphone preamplifier with tone control	TL061	25
Instrumentation amplifier	TL062	26
IC preamplifier	TL062	27

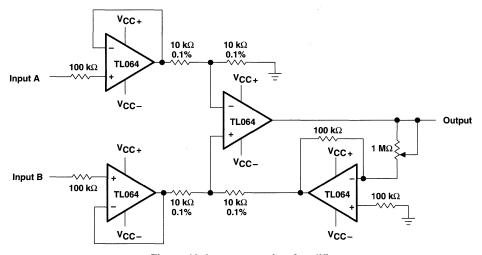


Figure 19. Instrumentation Amplifier

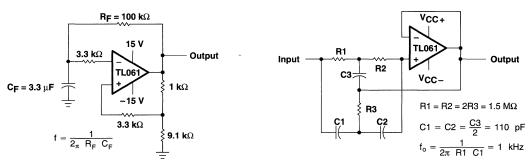


Figure 20. A 0.5-Hz Square-Wave Oscillator

Figure 21. High-Q Nothc Filter



APPLICATION INFORMATION

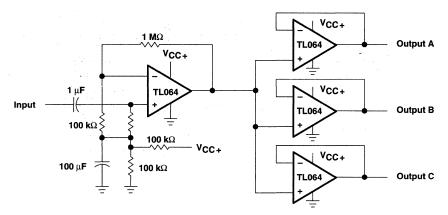


Figure 22. Audio-Distribution Amplifier

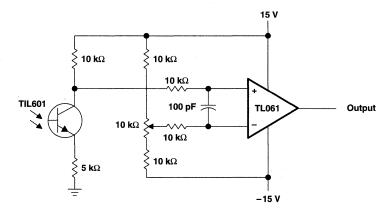


Figure 23. Low-Level Light-Detector Preamplifier

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APPLICATION INFORMATION

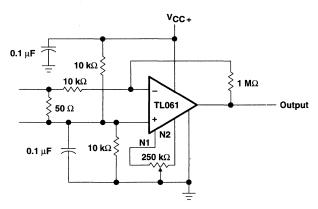


Figure 24. AC Amplifier

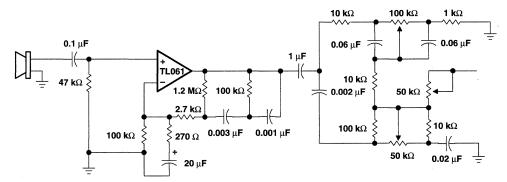


Figure 25. Microphone Preamplifier With Tone Control

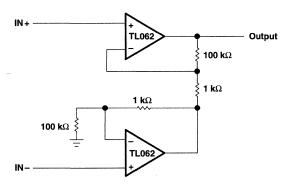
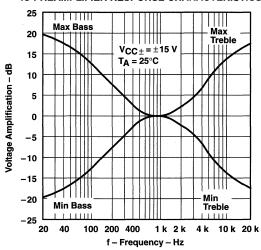


Figure 26. Instrumentation Amplifier

APPLICATION INFORMATION

IC PREAMPLIFIER RESPONSE CHARACTERISTICS



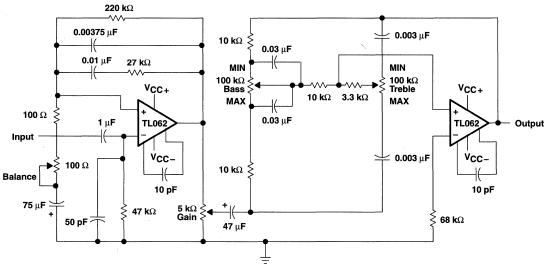


Figure 27. IC Preamplifier

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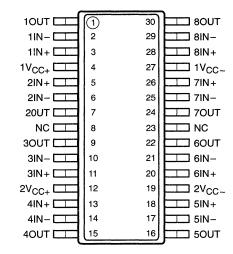
- Very Low Power Consumption
- Typical Supply Current . . . 200 μA (Per Amplifier)
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Common-Mode Input Voltage Range Includes V_{CC+}
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 3.5 V/μs Typ

description

The TL064x2 JFET-input operational amplifier is designed as a low-power version of the TL084x2 amplifier. It features high input impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The TL064x2 features the same terminal assignments as the TL074x2 and TL084x2. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

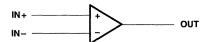
The TL064x2 is characterized for operation from 0° C to 70° C.

DB PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)

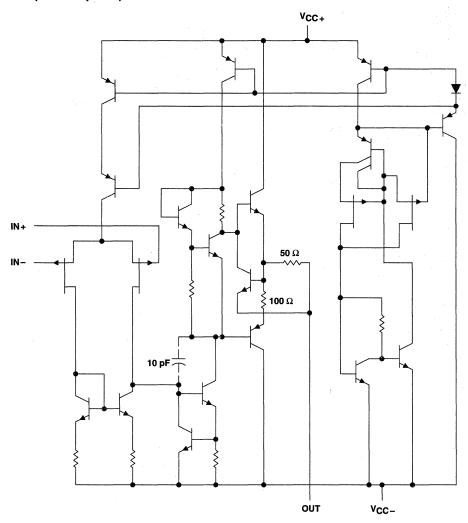


AVAILABLE OPTION

		PACKAGE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (DB) [†]
0°C to 70°C	7 mV	TL064x2DBLE

[†] The DB package is only available left-end taped and reeled.

schematic (each amplifier)



All component values shown are nominal.

ACTUAL DEVICE COMPONENT COUNT				
Transistors	116			
Resistors	60			
JFET	24			
Capacitors	8			
Diodes	4			



TL064x2 LOW-POWER JFET-INPUT OCTAL OPERATIONAL AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	18 V
Supply voltage, V _{CC} – (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage, V _I (any input) (see Notes 1 and 3)	
Duration of output short circuit to ground (see Note 4)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages and V_{CC} specified for the measurement of I_{OS}, are with respect to the midpoint between V_{CC+} and V_{CC-}.
 - 2. Differential voltages are at IN + with respect to IN -.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - 4. The output can be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25^{\circ}C$ POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING
DB	1024 mW	8.2 mW/° C	655 mW

TL064x2 **LOW-POWER JFET-INPUT OCTAL OPERATIONAL AMPLIFIER**

electrical characteristics, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		T _A ‡	MIN	TYP	MAX	UNIT
Vio	Input offset voltage	V _O = 0,	R _S = 50 Ω	25°C		3	15	mV
۷IO	input onset voltage	ν _O = 0,	ng = 50 12	Full range			20	1117
αΛΙΟ	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		10		μV/°C
lio	land the state of	Va = 0		25°C		5	200	PΑ
lo	Input offset current	V _O = 0		Full range			5	nA
lin	land him and 8	V _O = 0		25°C		30	400	PΑ
^I IB	Input bias current§	vO = 0		Full range			10	nA
VICR	Common-mode input voltage range			25°C	±11	-12 to 15		V
V	OM Maximum peak output voltage swing	R _L = 10 kΩ		25°C	±10	±13.5		V
VOM	Maximum peak output voltage swing	R _L ≥ 10 kΩ		Full range	±10			V
AVD	Large-signal differential voltage	V _O = ± 10 V,	R _I ≥ 10 kΩ	25°C	3	6		V/mV
~\U	amplification	VO = ± 10 V,	11[= 10 K32	Full range	3			V/111V
B ₁	Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega$,		25°C		1		MHz
r ₁	Input resistance			25°C		1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,	25°C	70	86		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,	25°C	70	95		dB
PD	Total power dissipation (each amplifier)	V _O = 0,	No load	25°C		6	7.5	mW
lcc	Supply current (each amplifier)	V _O = 0,	No load	25°C		200	250	μΑ
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

T All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CO	TEST CONDITIONS		TYP	MAX	UNIT
SR	Slew rate at unity gain	V _I = 10 mV, C _L = 100 pF,	R _L = 10 kΩ, See Figure 1	1.5	3.5		V/μs
t _r	Rise time	V _I = 20 V,	$P_L = 10 \text{ k}\Omega$		0.2		μs
	Overshoot factor	C _L = 100 pF,	See Figure 1		10%		
٧n	Equivalent input noise voltage	$R_S = 20 \Omega$,	f = 1 kHz		42		nV/√Hz

[‡] Full range is 0°C to 70°C.

[§] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 13. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

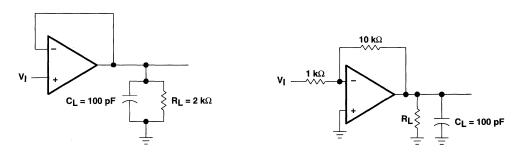


Figure 1. Unity-Gain Amplifier

Figure 2. Gain-of-10 Inverting Amplifier

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{ОМ}	Maximum peak output voltage	vs Supply voltage vs Free-air temperature vs Load resistance vs Frequency	3 4 5 6
A _{VD}	Differential voltage amplification	vs Free-air temperature	7
AVD	Large-signal differential voltage amplification	vs Frequency	8
Icc	Supply current	vs Supply voltage vs Free-air temperature	9 10
PD	Total power dissipation	vs Free-air temperature	11
	Normalized unity-gain bandwidth	vs Free-air temperature	12
	Normalized slew rate	vs Free-air temperature	12
lв	Input bias current	vs Free-air temperature	13
	Pulse response	Large signal	14
Vo	Output voltage	vs Time	15
٧n	Equivalent input noise voltage	vs Frequency	16
	Normalized phase shift	vs Free-air temperature	12



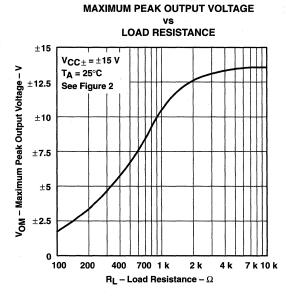
MAXIMUM PEAK OUTPUT VOLTAGE vs SUPPLY VOLTAGE ±15 $R_L = 10 \text{ k}\Omega$ VoM - Maximum Peak Output Voltage - V T_A = 25°C ±12.5 See Figure 2 ±10 ±7.5 ±5 ±2.5 0 6 8 10 12 14 16 IVCC±I - Supply Voltage - V

MAXIMUM PEAK OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE ±15 VOM - Maximum Peak Output Voltage - V ±12.5 ±10 ±7.5 ± 5 ±2.5 $V_{CC\pm} = \pm 15 \text{ V}$ $R_L = 10 \text{ k}\Omega$ See Figure 2 10 60 70

Figure 3



TA - Free-Air Temperature - °C



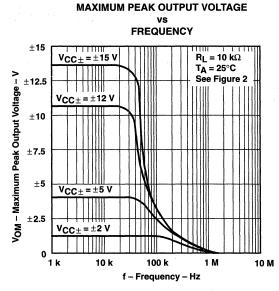


Figure 5

Figure 6

DIFFERENTIAL VOLTAGE AMPLIFICATION FREE-AIR TEMPERATURE 10 V_{CC±} = ± 15 V A_{VD} – Differential Voltage Amplification – V/mV $R_L = 10 \text{ k}\Omega$ 7 0 10 20 30 40 50 60 70 TA - Free-Air Temperature - °C

Figure 7

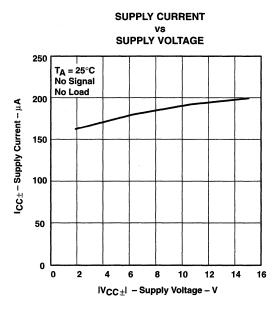


Figure 9

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

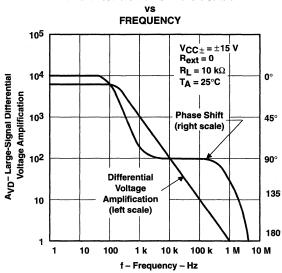


Figure 8

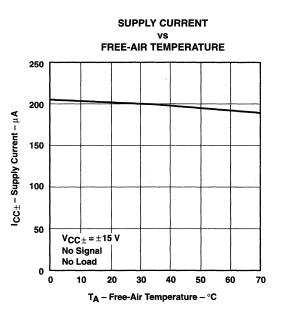
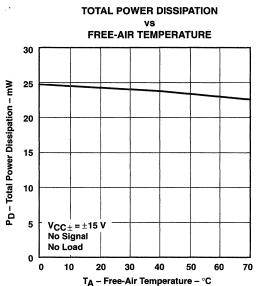


Figure 10





NORMALIZED UNITY-GAIN BANDWIDTH, NORMALIZED SLEW RATE, AND NORMALIZED PHASE SHIFT vs

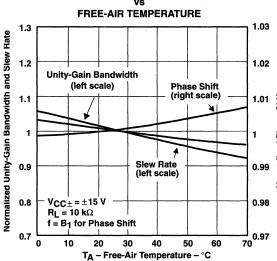
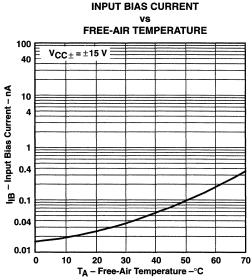


Figure 11

Figure 12

VOLTAGE FOLLOWER LARGE SIGNAL PULSE RESPONSE



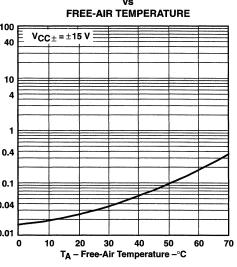


Figure 13

6 Input 4 Input and Output Voltages - V 2 0 Output -2 V_{CC±} = ±15 V $R_L = 10 \text{ k}\Omega$ -4 C_L = 100 pF T_A = 25°C -6 0 8 10 t - Time - μs

Figure 14



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TYPICAL CHARACTERISTICS

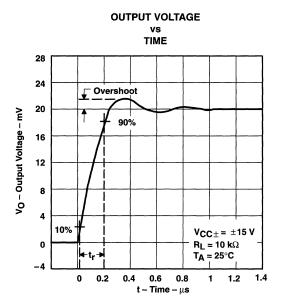


Figure 15

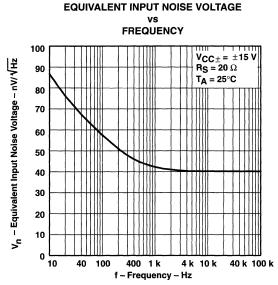


Figure 16

TL070 JFET-INPUT OPERATIONAL AMPLIFIER

8 COMP

Ovcc+

5 NOFFSET N2

6 DOUT

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D, P, OR PW PACKAGE

(TOP VIEW)

N1/COMP

OFFSET N2

IN- [

3

IN+

V_{CC} -

- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion 0.003% Typ
- Low Noise $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ at f = 1 kHz
- High Input Impedance . . . JFET Input Stage
- Common-Mode Input Voltage Range Includes V_{CC+}
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ

description

The JFET-input TL070 operational amplifier is designed as the lower-noise version of the TL080

amplifier with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL070 ideally suited for high-fidelity and audio preamplifier applications. This amplifier features JFET inputs (for high input impedance) coupled with bipolar output stages integrated on a single monolithic chip.

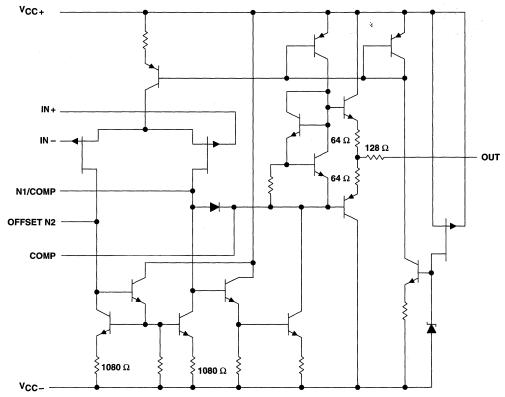
symbol

The TL070C device is characterized for operation from 0°C to 70°C. The TL070I device is characterized for operation from –40°C to 85°C. The TL070M device is characterized for operation from –55°C to 125°C.

AVAILABLE OPTIONS

	V		PACKAGE	
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)	TSSOP (PW)
0°C to 70°C	10 mV	TL070CD	TL070CP	TL070CPW
-40°C to 85°C	10 mV	TL070ID	TL070IP	_
-55°C to 125°C	10 mV	TL070MD	TL070MP	_

schematic



All component values shown are nominal.

COMPONENT COUNT†				
Transistors	13			
Diodes	2			
Resistors	10			
epi-FET	1			
JFET	2			

† Includes all bias and trim circuitry

TL070 JFET-INPUT OPERATIONAL AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)		18 V
Supply voltage, V _{CC}		–18 V
Differential input voltage, V _{ID} (see Note 2)		±30 V
Input voltage, V _I (see Notes 1 and 3)		
Duration of short-circuit current (see Note 4)	4)	unlimited
Continuous total dissipation		
Operating free-air temperature range, T _A :	C suffix	0°C to 70°C
	I suffix	
1	M suffix	55°C to 125°C
Storage temperature range		65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from (case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC} + and V_{CC} -.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	680 mW	5.8 mW/°C	33°C	464 mW	377 mW	145 mW
Р	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW
PW	525 mW	4.2 mW/°C	70°C	336 mW	N/A	N/A

electrical characteristics, $V_{\mbox{CC}\pm}$ = ± 15 V (unless otherwise noted)

	DADAMETER				TL070C			UNIT
	PARAMETER	TEST CONDIT	IONS	T _A †	MIN	TYP	MAX	UNII
VIO	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$	25°C		3	10	mV
۷۱۵	input onset voltage	VO = 0,	ng = 50 12	Full range			13	1110
ανιο	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18		μV/°C
l _{IO}	Input offset current	V _O = 0		25°C		5	100	рA
טוי	input onset current	VO=0		Full range			10	nA
Iв	Input bias current‡	V _O = 0	-0			65	200	pΑ
אוי	Input bias current+	10-0		Full range			7	nA
VICR	Common-mode input voltage range			25°C	±11	-12 to 15		٧
	Maimum peak output voltage swing	R _L = 10 kΩ		25°C	±12	±13.5		v
Vом		R _L ≥ 10 kΩ		Full raises	±12			
		R _L ≥ 2 kΩ		Full range	±10			
Λ	Large-signal differential voltage	V _O = ±10 V,		25°C	25	200		V/mV
AVD	amplification	R _L ≥2 kΩ		Full range	15			V/IIIV
B ₁	Unity-gain bandwidth			25°C		3		MHz
rį	Input resistance	, and the second		25°C		1012		Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min, R _S = 50 Ω	V _O = 0,	25°C	70	100		dB
ksvr	Supply voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,	25°C	70	100		dB
lcc	Supply current	V _O = 0,	No load	25°C		1.4	2.5	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for T_A is 0°C to 70°C.

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 5. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

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electrical characteristics, $V_{\mbox{CC}\pm}$ = ± 15 V (unless otherwise noted)

	DADAMETED					TL0701		UNIT
	PARAMETER	TEST CONDITI	ONS	T _A †	MIN	TYP	MAX	UNII
۷iO	Input offset voltage	V _O = 0,	R _S = 50 Ω	25°C		3	10	mV
۷۱٥	input onset voltage	VO = 0,	ng = 50 12	Full range			13	1110
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18		μV/°C
lio	lament offerst account	V _O = 0		25°C		5	100	рA
IIO	Input offset current	VO = 0		Full range			10	nA
lin	Input bias current‡	V _O = 0		25°C		65	200	pА
lΒ	input bias current+	AQ = 0		Full range			20	nA
VICR	Common-mode input voltage range			25°C	±11	–12 to 15		٧
		$R_L = 10 \text{ k}\Omega$		25°C	±12	±13.5		
Vом	Maximum peak output voltage swing	R _L ≥ 10 kΩ		Full range	±12			V.
		R _L ≥ 2 kΩ		ruii range	±10			
A. m	Large-signal differential voltage	V _O = ±10 V,		25°C	25	200		V/mV
AVD	amplification	R _L ≥ 2 kΩ		Full range	15			V/IIIV
B ₁	Unity-gain bandwidth			25°C		3		MHz
rį	Input resistance			25°C		1012		Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min, R _S = 50 Ω	V _O = 0,	25°C	70	100		dB
ksvr	Supply voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ R _S = 50 Ω	V _O = 0	25°C	70	100		dB
Icc	Supply current	V _O = 0,	No load	25°C		1.4	2.5	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for T_A is -40°C to 85°C

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 5. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

electrical characteristics, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

	PARAMETER			_ +		TL070M		UNIT
	PARAMETER	TEST CONDIT	IONS	T _A †	MIN	TYP	MAX	UNII
۷ _{IO}	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$	25°C		3	10	mV
۷۱٥	input onset voltage	VO = 0,	ng = 50 12	Full range			13	1110
ανιο	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18		μV/°C
lio	land affect of many	V _O = 0		25°C		5	100	pА
lio .	Input offset current	VO = 0		Full range			20	nA
i.	Input bias current‡	V _O = 0		25°C		65	200	pА
^I IB	input bias current+	VO = 0		Full range			50	nA
VICR	Common-mode input voltage range			25°C	±11	–12 to 15		٧
		$R_L = 10 \text{ k}\Omega$		25°C	±12	±13.5		
V _{OM}	Maximum peak output voltage swing	$R_L \ge 10 \text{ k}\Omega$		Full range	±12			٧
		R _L ≥ 2 kΩ		ruii tarige	±10			
AVD	Large-signal differential voltage	V _O = ±10 V,	R _I ≥2kΩ	25°C	25	200		V/mV
AVD	amplification	VO = ±10 V,	nL < 2 k32	Full range	15			V/IIIV
B ₁	Unity-gain bandwidth			25°C		3		MHz
rį	Input resistance			25°C		1012		Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min, R _S = 50 Ω	V _O = 0,	25°C	70	100		dB
ksvr	Supply voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,	25°C	70	100		dB
lcc	Supply current	V _O = 0,	No load	25°C		1.4	2.5	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for TA is -55°C to 125°C.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST C	ONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _I = 10 V, C _L = 100 pF,	$R_L = 2 k\Omega$, See Figure 1	8	13		V/μs
	Disa time everaheet factor	overshoot factor $ \begin{array}{cccc} V_{I} = 20 \text{ mV}, & R_{L} = 2 \text{ k}\Omega, \\ C_{L} = 100 \text{ pF}, & \text{See Figure 1} \end{array} $			0.1		μs
tr	nise time overshoot factor				20		%
V	Equivalent input noise voltage	R _S = 20 Ω	f = 1 kHz		18		nV/√Hz
Vn	Equivalent input noise voltage	NS = 20 12	f = 10 Hz to 10 kHz		4		μV
In	Equivalent input noise current	$R_S = 20 \Omega$,	f = 1 kHz		0.01		pA/√Hz
THD	Total harmonic distortion	$V_{O(rms)} = 10 \text{ V},$ $R_L \ge 2 \text{ k}\Omega,$	R _S ≤ 1 kΩ, f = 1 kHz		0.003		%

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 5. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

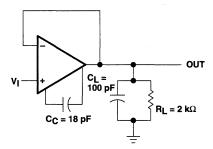


Figure 1. Unity-Gain Amplifier

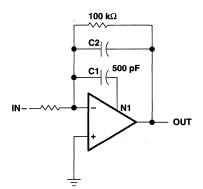


Figure 3. Feed-Forward Compensation

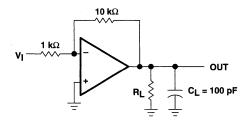


Figure 2. Gain-of-10 Inverting Amplifier

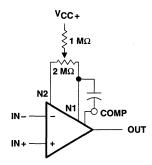


Figure 4. Input Offset Voltage Null Circuit

Table of Graphs

			FIGURE
l _{IB}	Input bias current	vs Free-air temperature	5
V _{ОМ}	Maximum output voltage	vs Frequency vs Free-air temperature vs Load resistance vs Supply voltage	6, 7, 8 9 10 11
AVD	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	12 14
AVD	Differential voltage amplification	vs Frequency	13
	Phase shift	vs Frequency	14
	Normalized unity-gain bandwidth	vs Free-air temperature	15
	Normalized phase shift	vs Free-air temperature	15
CMRR	Common-mode rejection ratio	vs Free-air temperature	16
lcc	Supply current	vs Supply voltage vs Free-air temperature	17 18
PD	Total power dissipation	vs Free-air temperature	19
	Normalized slew rate	vs Free-air temperature	20
V _n	Equivalent input noise voltage	vs Frequency	21
THD	Total harmonic distortion	vs Frequency	22
	Large-signal pulse response	vs Time	23
V _O	Output voltage	vs Elapsed time	24



MAXIMUM PEAK OUTPUT VOLTAGE

TYPICAL CHARACTERISTICS[†]

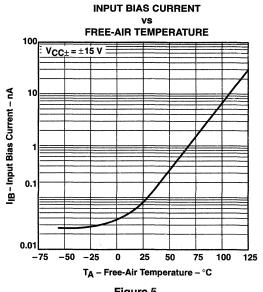
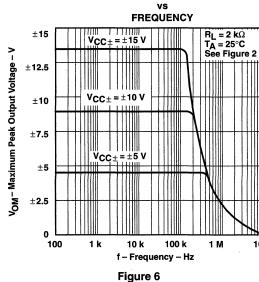
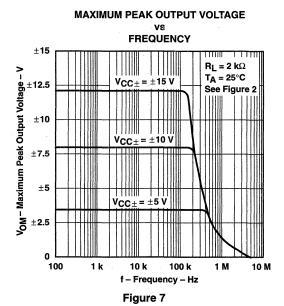
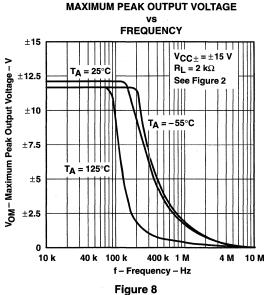


Figure 5







[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used.



10 M

MAXIMUM PEAK OUTPUT VOLTAGE FREE-AIR TEMPERATURE ±15 $R_L = 10 \text{ k}\Omega$ V_{OM} - Maximum Peak Output Voltage - V ±12.5 $R_L = 2 k\Omega$ ±10 ±7.5 ±5 ±2.5 V_{CC±} = ±15 V See Figure 2 0 75 -50 -25 0 25 50 75 100 125 TA - Free-Air Temperature - °C

Figure 9

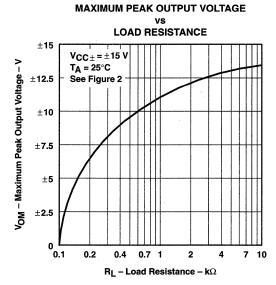
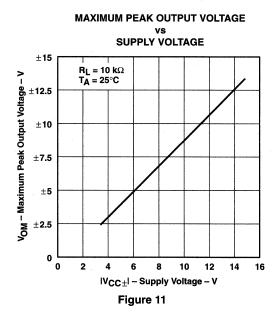
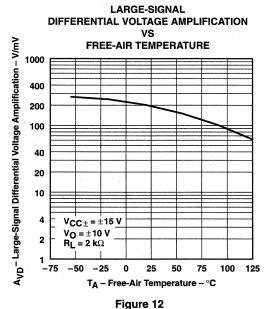


Figure 10





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used.



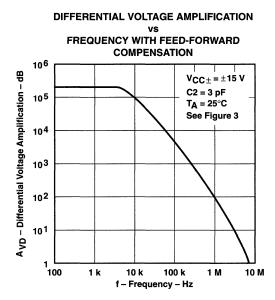


Figure 13

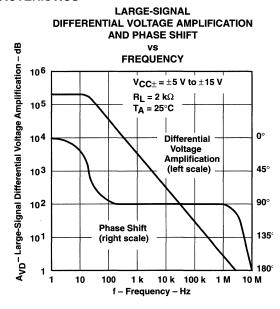
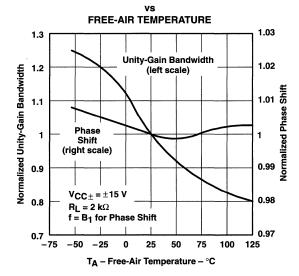


Figure 14

NORMALIZED UNITY-GAIN BANDWIDTH AND PHASE SHIFT



COMMON-MODE REJECTION RATIO

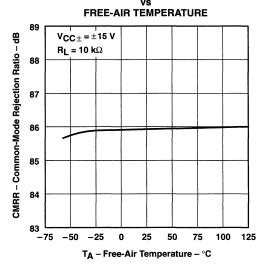
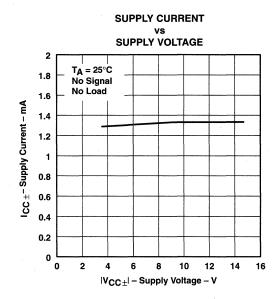


Figure 15 Figure 16

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used.



TYPICAL CHARACTERISTICS[†]

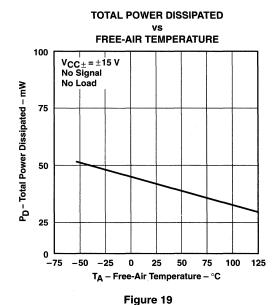


SUPPLY CURRENT FREE-AIR TEMPERATURE 2 $V_{CC\pm} = \pm 15 V$ No Signal 1.8 No Load 1.6 ICC ±- Supply Current - mA 1.4 1.2 1 0.8 0.6 0.4 0.2 -50 -25 0 25 50 75 100 125 -75 T_A - Free-Air Temperature - °C

Figure 17

Figure 18

NORMALIZED SLEW RATE



VS FREE-AIR TEMPERATURE 1.15 V_{CC±} = ±15 V R_L = 2 kΩ 1.10 CL = 100 pF 1.05 0.95 0.95 T_A - Free-Air Temperature - °C

9 Figure 20

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. An 18-pF compensation capacitor is used.



EQUIVALENT INPUT NOISE VOLTAGE vs **FREQUENCY** V_n – Equivalent Input Noise Voltage – nV/√Hz 50 $V_{CC\pm} = \pm 15 \text{ V}$ AVD = 10 $R_S = 20 \Omega$ TA = 25°C 40 30 20 10 0 4 k 10 k 40 k 100 k 10 40 100 400 1 k f - Frequency - Hz

Figure 21

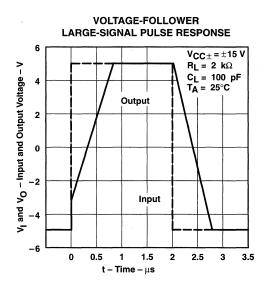


Figure 23

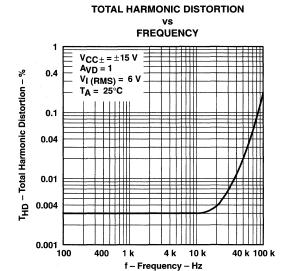


Figure 22

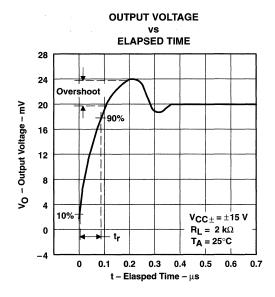


Figure 24



APPLICATION INFORMATION

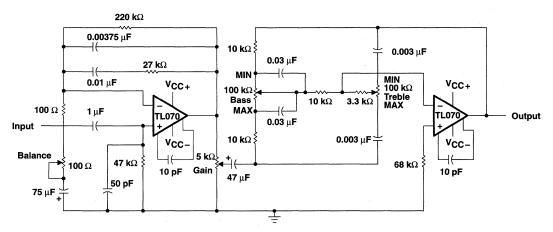


Figure 25. IC Preamplifier

IC PREAMPLIFIER RESPONSE CHARACTERISTICS

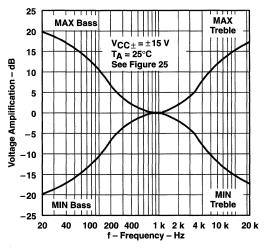


Figure 26

TL071, TL071A, TL071B, TL072 TL072A, TL072B, TL074, TL074A, TL074B LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion 0.003% Typ

Low Noise

 $V_n = 18 \text{ nV}/\sqrt{\text{Hz}}$ Typ at f = 1 kHz

- High Input Impedance . . . JFET Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ
- Common-Mode Input Voltage Range Includes V_{CC+}

description

The JFET-input operational amplifiers in the TL07_ series are designed as low-noise versions of the TL08_ series amplifiers with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL07_ series ideally suited for high-fidelity and audio preamplifier applications. Each amplifier features JFET inputs (for high input impedance) coupled with bipolar output stages integrated on a single monolithic chip.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

AVAILABLE OPTIONS

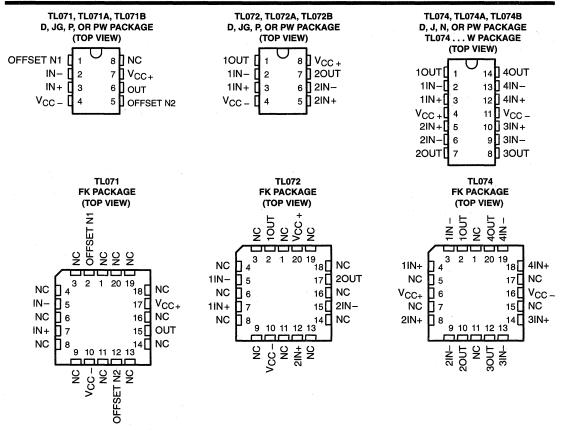
					PA	CKAGE			
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D) [†]	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	TSSOP PACKAGE (PW)	FLAT PACKAGE (W)
	10 mV 6 mV 3 mV	TL071CD TL071ACD TL071BCD	_	_			TL071CP TL071ACP TL071BCP	TL071CPWLE — —	
0°C to 70°C	10 mV 6 mV 3 mV	TL072CD TL072ACD TL072BCD	_	_	_	_	TL072CP TL072ACP TL072BCP	TL072CPWLE — —	_
	10 mV 6 mV 3 mV	TL074CD TL074ACD TL074BCD		_		TL074CN TL074ACN TL074BCN		TL074CPWLE — —	-
-40°C to 85°C	6 mV	TL071ID TL072ID TL074ID	_	_	_	— — TL074IN	TL071IP TL072IP	_	_
−55°C to 125°C	6 mV 6 mV 9 mV		TL071MFK TL072MFK TL074MFK	— — TL074MJ	TL071MJG TL072MJG —	 TL074MN	TL072MP		 TL074MW

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL071CDR). The PW package is only available left-ended taped and reeled (e.g., TL072CPWLE).



TL071, TL071A, TL071B, TL072 TL072A, TL072B, TL074, TL074A, TL074B LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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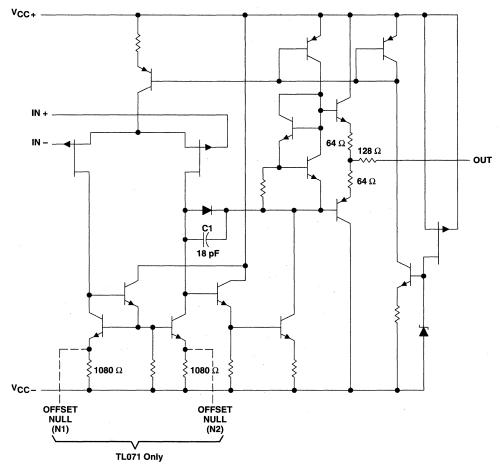


NC - No internal connection

symbols



schematic (each amplifier)



All component values shown are nominal.

COMPONENT COUNT									
COMPONENT TL071 TL072 TL074									
Resistors	11	22	44						
Transistors	14	28	56						
JFET	2	4	6						
Diodes	1	2	4						
Capacitors	1	2	4						
epi-FET	1	2	4						

[†] Includes bias and trim circuitry

TL071, TL071A, TL071B, TL072 TL072A, TL072B, TL074, TL074A, TL074B LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)
Supply voltage, V _{CC} (see Note 1)
Differential input voltage, V _{ID} (see Note 2)
Input voltage, V _I (see Notes 1 and 3)
Duration of output short circuit (see Note 4) unlimited
Continuous total power dissipation
Operating free-air temperature range, T _A : C suffix
suffix40°C to 85°C
M suffix
Storage temperature range
Case temperature for 60 seconds: FK package
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J, JG, or W package 300°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds: D. N. P. or PW package 260°C.

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VCC+ and VCC-.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25^{\circ}C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D (8 pin)	680 mW	5.8 mW/°C	33°C	465 mW	378 mW	N/A
D (14 pin)	680 mW	7.6 mW/°C	60°C	604 mW	490 mW	N/A
FK	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
J	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
JG	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
N	680 mW	9.2 mW/°C	76°C	680 mW	597 mW	N/A
Р	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A
PW (8 pin)	525 mW	4.2 mW/°C	70°C	525 mW	N/A	N/A
PW (14 pin)	700 mW	5.6 mW/°C	70°C	700 mW	N/A	N/A
w	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW

electrical characteristics, $V_{CC\pm} = \pm 15 \text{ V}$ (unless otherwise noted)

P/	ARAMETER	TEST CON	IDITIONS†	T _A ‡		TL071C TL072C TL074C		1	ΓL071Α(ΓL072Α(ΓL074Α(;	1	L071B0 L072B0 L074B0	;		TL071I TL072I TL074I		UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$	25°C		3	10		3	6		2	3		3	6	mV
·10	input onset voltage	VO = 0,	115 - 50 32	Full range			13			7.5			5			8	, III V
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18			18			18			18		μV/°C
lo	Input offset current	V _O = 0		25°C		5	100		5	100		5	100		5	100	рA
·10	input onset current	VO = 0		Full range			10			2			2			2	nΑ
lв	Input bias current§	V _O = 0		25°C		65	200		65	200		65	200		65	200	pА
'ID	imput bias currento	.0-0		Full range			7			7			7			20	nA
VICR	Common-mode input voltage range			25°C	±11	-12 to 15		±11	–12 to 15		±11	-12 to 15		±11	-12 to 15		٧
	Maximum peak	R _L = 10 kΩ		25°C	±12	±13.5		±12	±13.5		±12	±13.5		±12	±13.5		
Vом	output voltage	$R_L \ge 10 \text{ k}\Omega$		Full range	±12			±12			±12			±12			٧
	swing	R _L ≥ 2 kΩ		rull range	±10			±10			±10			±10			
AVD	Large-signal differential voltage	V _O = ±10 V,	$R_1 \ge 2 k\Omega$	25°C	25	200		50	200		50	200		50	200		V/mV
	amplification		_	Full range	15			25			25			25			
B ₁	Unity-gain bandwidth			25°C		3			3			3			3		MHz
ri	Input resistance			25°C		1012			1012			1012			1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}n$ $V_{O} = 0$,	nin, R _S = 50 Ω	25°C	70	100		75	100		75	100		75	100		dB
ksvr	Supply-voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC} = \pm 9 V$ $V_{O} = 0,$	to $\pm 15 \text{ V}$, R _S = 50Ω	25°C	70	100		80	100		80	100		80	100		dB
lcc	Supply current (each amplifier)	V _O = 0,	No load	25°C		1.4	2.5		1.4	2.5		1.4	2.5		1.4	2.5	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120			120			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.
‡ Full range is T_A = 0°C to 70°C for TL07_C, TL07_BC and is T_A = -40°C to 85°C for TL07_I.
§ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 4. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

TL071, TL071A, TL071B, TL072 TL072A, TL072B, TL074, TL074A, TL074B LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics, $V_{CC\pm} = \pm 15 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS†	T _A ‡		TL071M TL072M			TL074M		UNIT
		ŀ			MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$	25°C		3	6		3	9	mV
VIO	Input onset voltage	VO = 0,	118 = 30 22	Full range			9			15	1110
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18			18		μV/°C
lio	Input offset current	V _O = 0		25°C		5	100		5	100	pА
·ΙΟ	input onset current	VO = 0		Full range			20			20	nA
Iв	Input bias current‡	V _O = 0		25°C		65	200		65	200	рA
чВ	Input bias current+	VO = 0					50			50	nA
VICR	Common-mode input voltage range			25°C	±11	-12 to 15		±11	–12 to 15		V
		R _L = 10 kΩ		25°C	±12	±13.5		±12	±13.5		
Vом	Maximum peak output voltage swing	$R_L \ge 10 \text{ k}\Omega$	ı	Full range	±12			±12			V
		R _L ≥2 kΩ		ruii rarige	±10			±10			
AVD	Large-signal differential	$V_{O} = \pm 10 \text{ V},$	Bi >2k0	25°C	35	200		35	200		V/mV
~VD	voltage amplification	VO = ±10 V,	11 5 5 V75		15			15			V/111V
B ₁	Unity-gain bandwidth	T _A = 25°C				3			3		MHz
rį	Input resistance	T _A = 25°C				1012			1012		Ω
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} n V _O = 0,	nin, $R_S = 50 \Omega$	25°C	80	86		80	86		dB
ksvr	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 9 V$ $V_{O} = 0$,		25°C	80	86		80	86		dB
lcc	Supply current (each amplifier)	V _O = 0,	No load	25°C		1.4	2.5		1.4	2.5	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB

T Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 4. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

[‡] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range is $T_A = -55$ °C to 125°C.

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operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST /	TL07xM			ALL	UNIT			
	PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	V _I = 10 V, C _L = 100 pF,	$R_L = 2 k\Omega$, See Figure 1	5	13		8	13		V/µs
	Rise time overshoot	V _I = 20 mV,	$R_L = 2 k\Omega$,		0.1			0.1		μs
tr	factor	C _L = 100 pF,	See Figure 1		20%			20%		
V	Equivalent input noise	R _S = 20 Ω	f = 1 kHz		18			18		nV/√Hz
٧n	voltage	ng = 20 12	f = 10 Hz to 10 kHz		4			4		μV
In	Equivalent input noise current	$R_S = 20 \Omega$,	f = 1 kHz		0.01			0.01		pA/√Hz
THD	Total harmonic distortion	V_{l} rms = 6 V, $R_{L} \ge 2 k\Omega$, f = 1 kHz	$A_{VD} = 1$, $R_S \le 1 \text{ k}\Omega$,		0.003%			0.003%		

PARAMETER MEASUREMENT INFORMATION

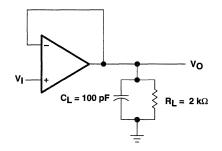


Figure 1. Unity-Gain Amplifier

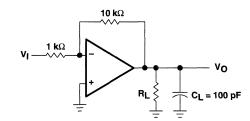


Figure 2. Gain-of-10 Inverting Amplifier

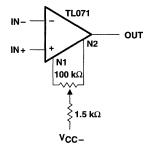


Figure 3. Input Offset Voltage Null Circuit

TL071, TL071A, TL071B, TL072 TL072A, TL072B, TL074, TL074A, TL074B LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS SLOS080D - SEPTEMBER 1978 - REVISED AUGUST 1996

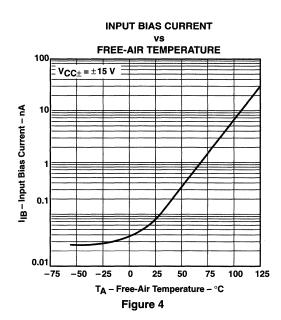
TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
I _{IB}	Input bias current	vs Free-air temperature	4
Vом	Maximum output voltage	vs Frequency vs Free-air temperature vs Load resistance vs Supply voltage	5, 6, 7 8 9 10
A _{VD}	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	11 12
	Phase shift	vs Frequency	12
	Normalized unity-gain bandwidth	vs Free-air temperature	13
	Normalized phase shift	vs Free-air temperature	13
CMRR	Common-mode rejection ratio	vs Free-air temperature	14
Icc	Supply current	vs Supply voltage vs Free-air temperature	15 16
PD	Total power dissipation	vs Free-air temperature	17
	Normalized slew rate	vs Free-air temperature	18
٧n	Equivalent input noise voltage	vs Frequency	19
THD	Total harmonic distortion	vs Frequency	20
	Large-signal pulse response	vs Time	21
٧o	Output voltage	vs Elapsed time	22

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TYPICAL CHARACTERISTICS†



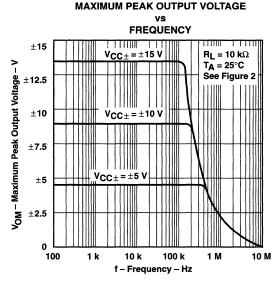
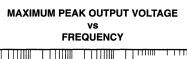


Figure 5



V_{CC±} = ±15 V

 $V_{CC\pm} = \pm 10 V$

V_{CC±} = ±5 V

10 k

Figure 6

f - Frequency - Hz

100 k

1 M

±15

±12.5

±10

±7.5

±5

±2.5

0

100

1 k

V_{OM} - Maximum Peak Output Voltage - V



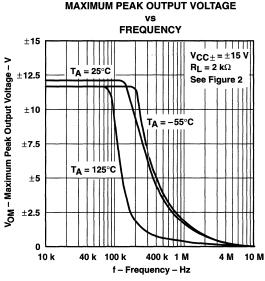
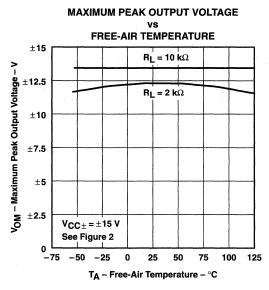


Figure 7

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

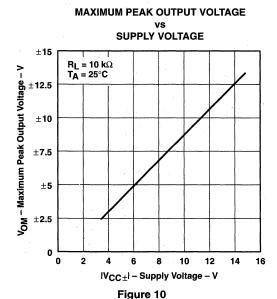


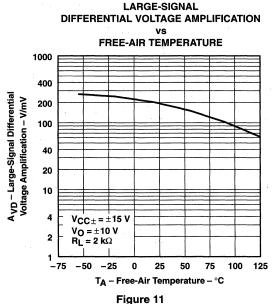
LOAD RESISTANCE ±15 V_{CC±} = ±15 V V_{OM} ~ Maximum Peak Output Voltage ~ V T_A = 25°C ±12.5 See Figure 2 ±10 ±7.5 ±5 ± 2.5 0 0.2 2 4 7 10 0.1 0.4 0.7 1 R_L - Load Resistance - kΩ

MAXIMUM PEAK OUTPUT VOLTAGE

Figure 8







† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

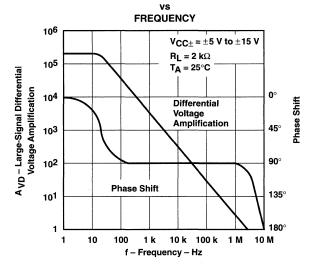


Figure 12

NORMALIZED UNITY-GAIN BANDWIDTH AND PHASE SHIFT

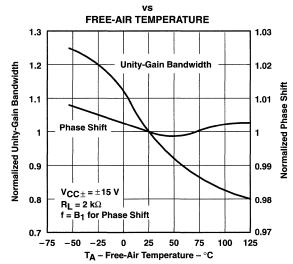


Figure 13

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†

COMMON-MODE REJECTION RATIO FREE-AIR TEMPERATURE 89 $V_{CC\pm} = \pm 15 \text{ V}$ CMRR - Common-Mode Rejection Ratio - dB $R_L = 10 \text{ k}\Omega$ 88 87 86 85 84 -75 -50 -25 25 50 75 100 125 TA - Free-Air Temperature - °C

Figure 14

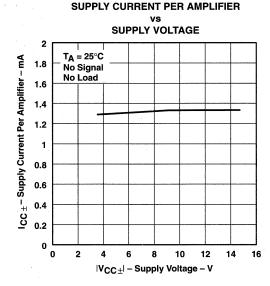


Figure 15

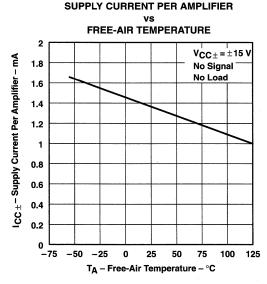


Figure 16

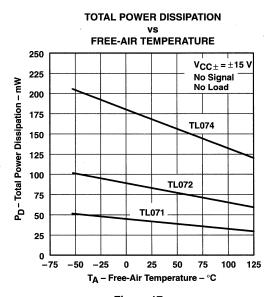


Figure 17

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS

NORMALIZED SLEW RATE FREE-AIR TEMPERATURE 1.15 V_{CC±} = ±15 V $R_L = 2 k\Omega$ 1.10 CL = 100 pF Normalized Slew Rate - V/µ s 1.05 1 0.95 0.90 0.85 -75 -50 -25 0 25 50 75 100 125

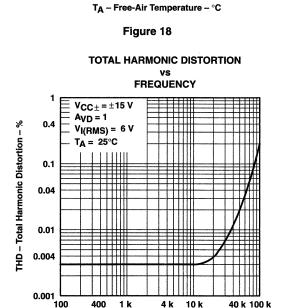


Figure 20

f - Frequency - Hz

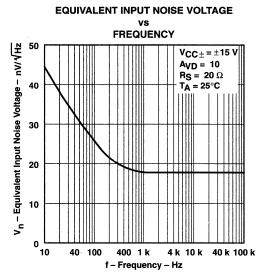


Figure 19

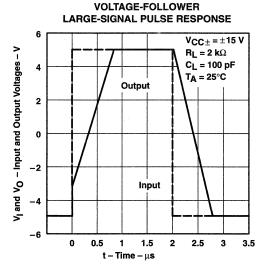


Figure 21

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE vs **ELAPSED TIME** 28 24 Overshoot V_O - Output Voltage - mV 20 90% 16 12 8 4 10% V_{CC±} = ±15 V $R_L = 2 k\Omega$ 0 T_A = 25°C 0.1 0.2 0.3 0.4 0.5 0.6 t - Elapsed Time - μs

Figure 22

APPLICATION INFORMATION

Table of Application Diagrams

APPLICATION DIAGRAM	PART NUMBER	FIGURE
0.5-Hz square-wave oscillator	TL071	23
High-Q notch filter	TL071	24
Audio-distribution amplifier	TL074	25
100-kHz quadrature oscillator	TL072	26
AC amplifier	TL071	27

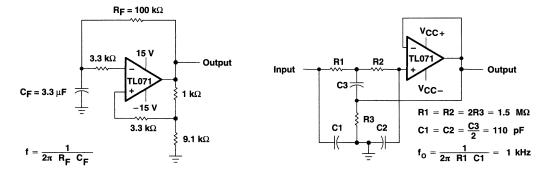


Figure 23. 0.5-Hz Square-Wave Oscillator

Figure 24. High-Q Notch Filter

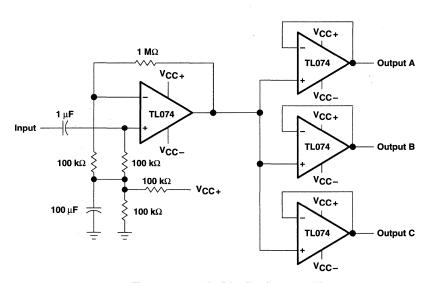
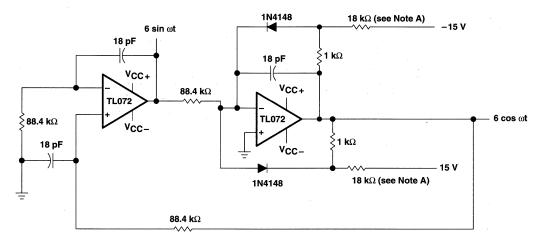


Figure 25. Audio-Distribution Amplifier

APPLICATION INFORMATION



NOTE A: These resistor values may be adjusted for a symmetrical output.

Figure 26. 100-kHz Quadrature Oscillator

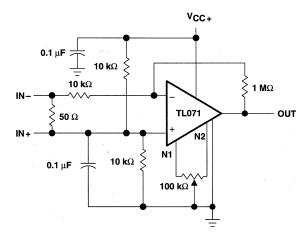


Figure 27. AC Amplifier

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Low Power Consumption

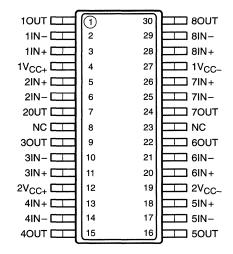
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion 0.003% Typ
- Low Noise
 V_n = 18 nV/√Hz Typ at f = 1 kHz
- High Input Impedance . . . JFET Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ
- Common-Mode Input Voltage Range Includes V_{CC+}

description

The TL074x2 JFET-input operational amplifier is designed as a lower-noise version of the TL084x2 amplifier with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL074x2 ideally suited for high-fidelity and audio-preamplifier applications. Each amplifier features JFET inputs (for high input impedance) coupled with bipolar output stages integrated on a single monolithic chip.

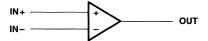
The TL074x2 is characterized for operation from 0° C to 70° C.

DB PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)

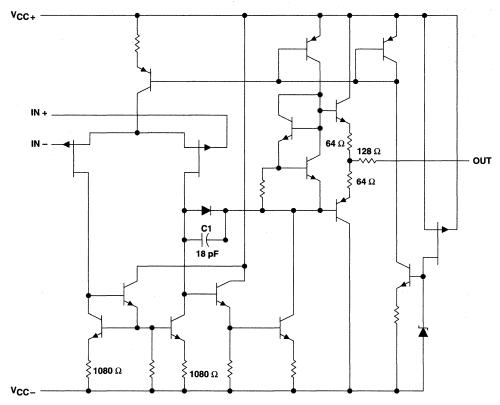


AVAILABLE OPTION

ſ			PACKAGE
	TA		SMALL OUTLINE (DB) [†]
Ī	0°C to 70°C	10 mV	TL074x2DBLE

[†] The DB package is only available left-end taped and reeled.

schematic (each amplifier)



All component values shown are nominal.

COMPONENT COUNT†								
Resistors	88							
Transistors	112							
JFET	20							
Diodes	12							
Capacitors	8							

[†] Includes bias and trim circuitry

TL074x2 JFET-INPUT OCTAL OPERATIONAL AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	
Supply voltage, V _{CC} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (see Notes 1 and 3)	±15 V
Duration of output short circuit (see Note 4)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	65°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC+}.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- The output can be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING
DB	1024 mW	8.2 mW/° C	655 mW

TL074x2 JFET-INPUT **OCTAL OPERATIONAL AMPLIFIER**

electrical characteristics, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

PARAMETER		TEST CONDITIO	TEST CONDITIONS†			TYP	MAX	UNIT
VIO	Input offset voltage	Va = 0	Rs = 50 Ω	25°C		3	10	mV
VIO		$V_O = \Omega$,	115 - 30 32	Full range			13	1110
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		18		μV/°C
lio	Input offeet europt	V _O = 0		25°C		5	100	pА
100	Input offset current	ΛO = 0		Full range			10	nA
I _{IB}	Input bias current§	V _O = 0		25°C		65	200	pΑ
чВ	input bias currents	VO = 0		Full range			7	nA
VICR	Common-mode input voltage range			25°C	±11	–12 to 15		٧
		R _L = 10 kΩ	25°C	±12	±13.5			
V _{OM}	Maximum peak output voltage swing	R _L ≥ 10 kΩ	Full range	±12			V	
		R _L ≥2 kΩ	Full lalige	±10				
Λ	Large-signal differential voltage	V _O = ±10 V,	R _I ≥2kΩ	25°C	25	200		V/mV
AVD	amplification	VO = ±10 V,	L	Full range	15			V/IIIV
B ₁	Unity-gain bandwidth			25°C		3		MHz
rį	Input resistance			25°C		1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,	25°C	70	100		dB
k _{SVR}	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC} = \pm 9 \text{ V to } \pm 15 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,	25°C	70	100		dB
lcc	Supply current (each amplifier)	V _O = 0,	No load	25°C		1.4	2.5	mA
V _{Q1} /V _{Q2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

operating characteristics, $V_{CC\pm} = \pm 15$ V, $T_{A} = 25^{\circ}C$

	PARAMETER	TEST C	CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _I = 10 V, C _L = 100 pF,	R _L = 2 kΩ, See Figure 1	8	13		V/μs
		V _I = 20 mV,	$R_L = 2 k\Omega$,		0.1		μs
t _r		$C_L = 100 pF$,	See Figure 1	20%			
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	En instanting to the I	R _S = 20 Ω	f = 1 kHz		18		nV/√Hz
Vn	Equivalent input noise voltage		f = 10 Hz to 10 kHz		4		μV
l _n	Equivalent input noise current	$R_S = 20 \Omega$,	f = 1 kHz		0.01		pA/√Hz
THD	Total harmonic distortion	V_{O} rms = 10 V, $R_{L} \ge 2 \text{ k}\Omega$,	$R_S \le 1 \text{ k}\Omega$, f = 1 kHz	(0.003%		

 [‡] Full range is T_A = 0°C to 70°C.
 § Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 2. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

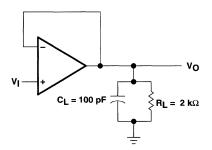


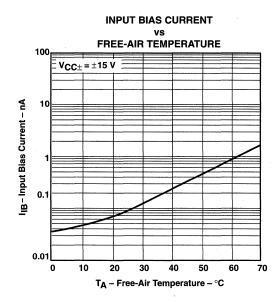
Figure 1. Unity-Gain Amplifier

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
lв	Input bias current	vs Free-air temperature	2
V _{ОМ}	Maximum peak output voltage	vs Frequency vs Free-air temperature vs Load resistance vs Supply voltage	3, 4, 5 6 7 8
A _{VD}	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	9 10
	Normalized unity-gain bandwidth	vs Free-air temperature	11
CMRR	Common-mode rejection ratio	vs Free-air temperature	12
Icc	Supply current	vs Supply voltage vs Free-air temperature	13 14
PD	Total power dissipation	vs Free-air temperature	15
	Normalized slew rate	vs Free-air temperature	16
Vn	Equivalent input noise voltage	vs Frequency	17
THD	Total harmonic distortion	vs Frequency	18
	Pulse response	Large signal	19
٧o	Output voltage	vs Time	20
	Normalized phase shift	vs Free-air temperature	11

TYPICAL CHARACTERISTICS



MAXIMUM PEAK OUTPUT VOLTAGE FREQUENCY ±15 $V_{CC\pm} = \pm 15 \text{ V}$ $R_L = 2 k\Omega$ TA = 25°C V_{OM} - Maximum Peak Output Voltage - V See Figure 2 ±12.5 ±10 V_{CC±} = ±10 V ±7.5 ±5 ± 2.5 0 100 1 k 10 k 100 k 1 M 10 M f - Frequency - Hz

Figure 2

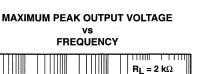
V_{CC±} = ±15 V

 $V_{CC\pm} = \pm 10 \text{ V}$

V_{CC±} = ±5 V

10 k

100 k



T_A = 25°C

See Figure 2

FREQUENCY ±15 $V_{CC\pm} = \pm 15 \text{ V}$ $R_L = 2 k\Omega$ \pm 12.5 See Figure 2 T_A = 25°C ±10 ±7.5 ±5 ±2.5 0

Figure 3

MAXIMUM PEAK OUTPUT VOLTAGE

vs

Figure 4

f - Frequency - Hz

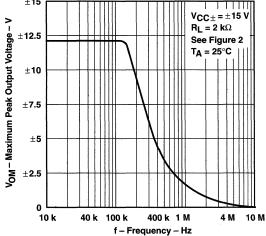


Figure 5



10 M

±15

±12.5

±10

±7.5

±5

±2.5

0

100

VOM - Maximum Peak Output Voltage - V

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE FREE-AIR TEMPERATURE ±15 $R_L = 10 \text{ k}\Omega$ VOM - Maximum Peak Output Voltage - V ±12.5 $R_L = 2 k\Omega$ ±10 ±7.5 ±5 ± 2.5 $V_{CC\pm} = \pm 15 \text{ V}$ See Figure 2 0 0 30 10 40 50 60 70 TA - Free-Air Temperature - °C

Figure 6

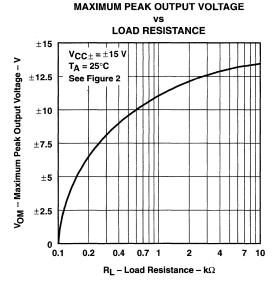


Figure 7

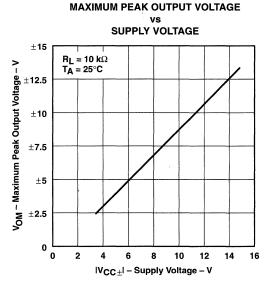


Figure 8

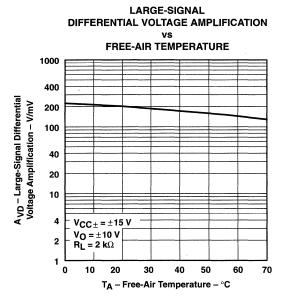


Figure 9

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TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

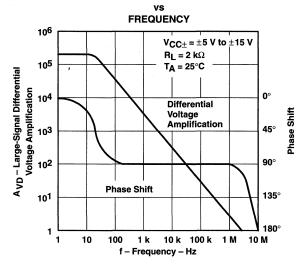


Figure 10

NORMALIZED UNITY-GAIN BANDWIDTH AND PHASE SHIFT

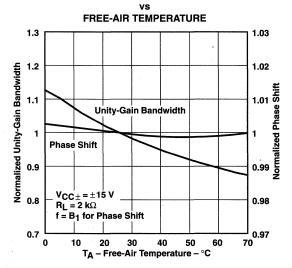


Figure 11

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TYPICAL CHARACTERISTICS

COMMON-MODE REJECTION RATIO FREE-AIR TEMPERATURE 89 CMRR - Common-Mode Rejection Ratio - dB $V_{CC\pm} = \pm 15 V$ $R_L = 10 \text{ k}\Omega$ 88 87 86 85 84 83 10 20 30 40 50 60 70 TA - Free-Air Temperature - °C

Figure 12

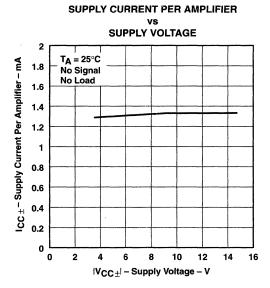


Figure 13

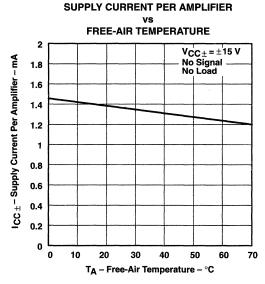


Figure 14

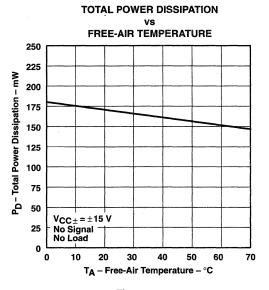


Figure 15

TYPICAL CHARACTERISTICS

NORMALIZED SLEW RATE FREE-AIR TEMPERATURE 1.15 V_{CC±} = ±15 V $R_L = 2 k\Omega$ 1.1 C_L = 100 pF Normalized Slew Rate 1.05 1 0.95 0.9 0.85 10 20 30 40 50 60 70 TA - Free-Air Temperature - °C

Figure 16

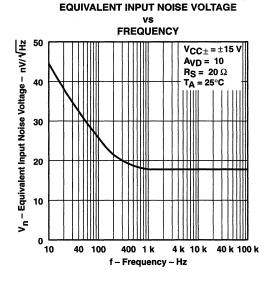


Figure 17

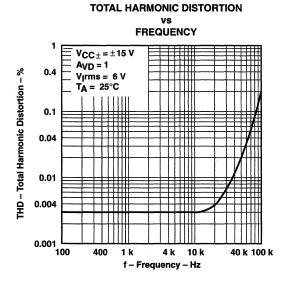


Figure 18

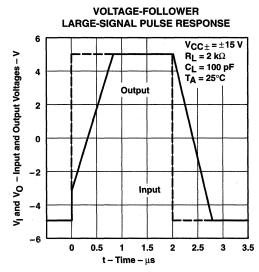


Figure 19

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE vs TIME 28 24 Overshoot V_O - Output Voltage - mV 20 90% 16 12 8 4 10% $V_{CC\pm} = \pm 15 V$ $R_L = 2 k\Omega$ - $T_A = 25^{\circ}C$ 0 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 t - Time - μs

Figure 20

TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS081D - FEBRUARY 1977 - REVISED FEBRUARY 1997

- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic
 Distortion . . . 0.003% Typ

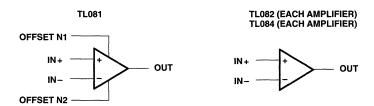
- High Input Impedance . . . JFET-Input Stage
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ
- Common-Mode Input Voltage Range Includes V_{CC+}

description

The TL08x JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient. Offset adjustment and external compensation options are available within the TL08x family.

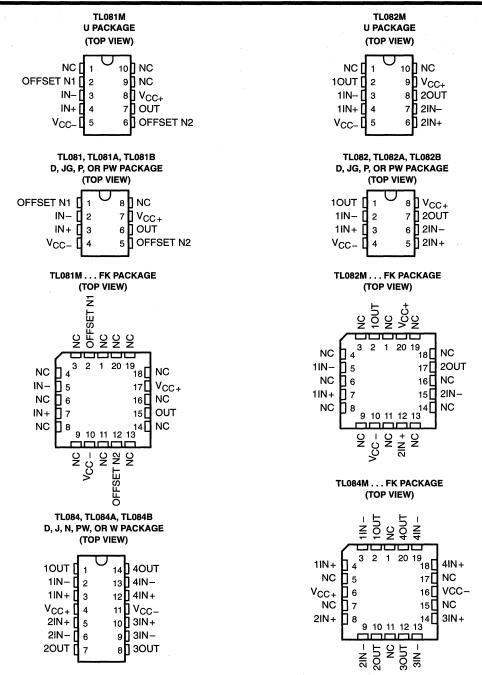
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

symbols



TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS081D - FEBRUARY 1977 - REVISED FEBRUARY 1997



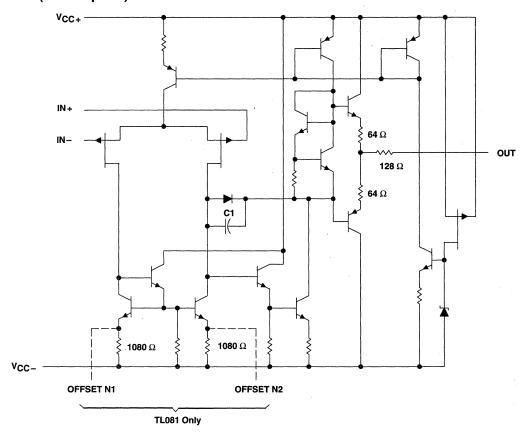
NC - No internal connection

AVAILABLE OPTIONS

						PACKAGE	DEVICES					CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D008)	SMALL OUTLINE (D014)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	TSSOP (PW)	FLAT PACK (U)	FLAT PACK (W)	FORM (Y)
	15 mV 6 mV 3 mV	TL081CD TL081ACD TL081BCD	_		-		_	TL081CP TL081ACP TL081BCP	TL081CPW	_	_	_
0°C to 70°C	15 mV 6 mV 3 mV	TL082CD TL082ACD TL082BCD	_		_		_	TL082CP TL082ACP TL082BCP	TL082CPW	-	_	TL082Y
	15 mV 6 mV 3 mV	_	TL084CD TL084ACD TL084BCD			_	TL084CN TL084ACN TL084BCN	_	TL084CPW	_		TL084Y
-40°C to 85°C	6 mV 6 mV 6 mV	TL081ID TL082ID TL084ID	TL084ID		_		TL084IN	TL081IP TL082IP		_	_	-
-55°C to 125°C	6 mV 6 mV 9 mV	_	_	TL081MFK TL082MFK TL084MFK	TL084MJ	TL081MJG TL082MJG		_		TL081MU TL082MU	TL084MW	_

The D package is available taped and reeled. Add R suffix to the device type (e.g., TL081CDR).

schematic (each amplifier)



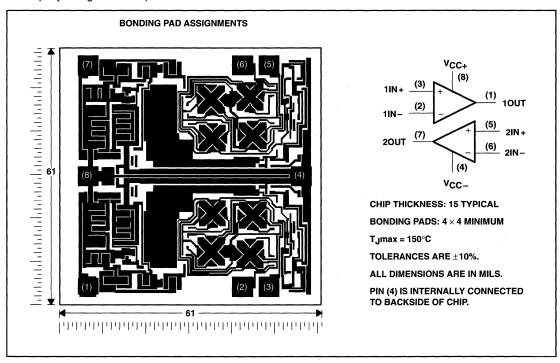
Component values shown are nominal.

TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS081D - FEBRUARY 1977 - REVISED FEBRUARY 1997

TL082Y chip information

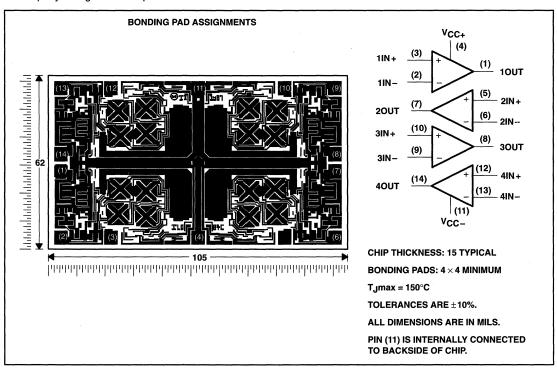
These chips, when properly assembled, display characteristics similar to the TL082. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



SLOS081D - FEBRUARY 1977 - REVISED FEBRUARY 1997

TL084Y chip information

These chips, when properly assembled, display characteristics similar to the TL084. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

SLOS081D - FEBBUARY 1977 - REVISED FEBBUARY 1997

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

	- ,	•				
		TL08_C TL08_AC TL08_BC	TL08_I	TL08_M	UNIT	
Supply voltage, V _{CC+} (see Note 1)		18	18	18	٧	
Supply voltage V _{CC} - (see Note 1)	-18	-18	-18	٧		
Differential input voltage, V _{ID} (see Note 2)	± 30	± 30	± 30	V		
Input voltage, V _I (see Notes 1 and 3)	±15	±15	±15	V		
Duration of output short circuit (see Note 4)		unlimited	unlimited	unlimited		
Continuous total power dissipation		See Dissipation Rating Table				
Operating free-air temperature range, TA		0 to 70	- 40 to 85	- 55 to 125	°C	
Storage temperature range, T _{Stg}		- 65 to 150	- 65 to 150	- 65 to 150	°C	
Case temperature for 60 seconds, T _C	FK package			260	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J or JG package			300	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N, P, or PW package	260	260		°C	

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC-} and V_{CC-}
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
 - The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T _A	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D (8 pin)	680 mW	5.8 mW/°C	32°C	460 mW	373 mW	N/A
D (14 pin)	680 mW	7.6 mW/°C	60°C	604 mW	490 mW	N/A
FK	680 mW	11.0 mW/°C	88°C	680 mW	680 mW	273 mW
J	680 mW	11.0 mW/° C	88°C	680 mW	680 mW	273 mW
JG	680 mW	8.4 mW/°C	69°C	672 mW	546 mW	210 mW
N	680 mW	9.2 mW/°C	76°C	680 mW	597 mW	N/A
Р	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	N/A
PW (8 pin)	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
PW (14 pin)	700 mW	5.6 mW/°C	25°C	448 mW	N/A	N/A
U	675 mW	5.4 mW/°C	25°C	432 mW	351 mW	135 mW
W	680 mW	8.0 mW/°C	65°C	640 mW	520 mW	200 mW

electrical characteristics, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TEST CONDITIONS TAT			TL081C TL082C TL084C	:	TL081AC TL082AC TL084AC		TLO81BC TL082BC TL084BC		TL081I TL082I TL084I		UNIT	
·/			<u> </u>	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input offset voltage	Vo = 0	Re = 50 Ω	25°C		3	15		3	6		2	3		3	6	mV
	1.0		Full range	Ĺ		20	<u> </u>		7.5			5	<u> </u>		9	
Temperature coefficient of input offset voltage	V _O = 0	R _S = 50 Ω	Full range		18			18			18			18		μV/°C
Input offset current ‡	Vo = 0		25°C		5	200		5	100		5	100		5	100	pА
Input onset ourrent.	VO-V		Full range			2			2			2	<u> </u>		10	nA
Input bias current‡	VO = 0	- 1	25°C	<u> </u>	30	400	L	30	200		30	200	<u> </u>	30	200	pΑ
input bido darront :			Full range			10			7			7			20	nA
Common-mode input		ļ	2500	1	-12 to		±11	-12 to		±44	-12			-12 to		_v
voltage range		ļ	25.0	I I I I	15		Ξ11	15		±11	15		± 11	15	1	
	$R_L = 10 \text{ k}\Omega$		25°C	±12	±13.5		±12	±13.5		±12	±13.5		±12	±13.5		
	$R_L \ge 10 \text{ k}\Omega$		Full range	±12			±12			±12			±12] v
output voltage ong	R _L ≥2kΩ		Full range	±10	±12		±10	±12		±10	±12		±10	±12		
Large-signal	$V_0 = \pm 10 \text{ V},$	$R_L \ge 2 k\Omega$	25°C	25	200		50	200		50	200		50	200		\ \(\sigma_{\sigma}\)
amplification	$V_0 = \pm 10 \text{ V},$	R _L ≥2 kΩ	Full range	15			25			25			25			V/mV
Unity-gain bandwidth			25°C		3			3			3			. 3		MHz
Input resistance			25°C		1012	٠.		1012			1012			1012		Ω
Common-mode rejection ratio	$V_{IC} = V_{ICR}mi$ $V_{O} = 0$,	nin, RS = 50 Ω	25°C	70	86		75	86		75	86		75	86		dB
Supply voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC} = \pm 15 \text{ V}$ $V_{O} = 0$,	$'$ to ± 9 V, R _S = 50 Ω	25°C	70	86		80	86		80	86		80	86		dB
Supply current (per amplifier)	V _O = 0,	No load	25°C		1.4	2.8		1.4	2.8		1.4	2.8	-	1.4	2.8	mA
Crosstalk attenuation	A _{VD} = 100		25°C		120			120			120			120		dB
	Input offset voltage Temperature coefficient of input offset voltage Input offset current‡ Input bias current‡ Common-mode input voltage range Maximum peak output voltage swing Large-signal differential voltage amplification Unity-gain bandwidth Input resistance Common-mode rejection ratio Supply voltage rejection ratio (ΔVCC±/ΔVIO) Supply current (per amplifier)		$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	ARAMETER TEST CONDITIONS TA† TLO82 TLO82 TLO84	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Part Part	Part Part

TL081, TL081A, TL081B, TL082, TL082A, TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for TA is 0°C to 70°C for TL08_C, TL08_AC, TL08_BC and -40°C to 85°C for TL08_I.

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

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electrical characteristics, $V_{CC\,\pm}$ = ± 15 V (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS		_	TL081M, TL082M			TL084M				
PARAMETER		TEST CONDITIONS†		TA	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
	Innut offertualteen	V- 0	D- 500	25°C		3	6		3	9	mV	
VIO	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$	-55°C to 125°C			9			15	mv	
αVIO	Temperature coefficient of input offset voltage	V _O = 0	R _S = 50 Ω	-55°C to 125°C		18			18		μV/°C	
li o	Input offset current‡	VO = 0		25°C		5	100		5	100	pΑ	
lio	input offset current+	VO = 0		125°C			20			20	nA	
Iв	Input bias current‡	V _O = 0		25°C		30	200		30	200	pА	
מוי	Input bias current+	10-0		125°C			50			50	nA	
VICR	Common-mode input voltage range			25°C	±11	±12 to 15		±11	± 12 to 15		٧	
	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$		25°C	±12	±13.5		±12	±13.5		V	
Vом		$R_L \ge 10 \text{ k}\Omega$		-55°C to 125°C	±12			±12				
		R _L ≥2 kΩ		-55 C to 125 C	±10	±12		±10	±12			
AVD	Large-signal differential voltage	$V_0 = \pm 10 V$,	$R_L \ge 2 k\Omega$	25°C	25	200		25	200		V/mV	
~\D	amplification	$V_0 = \pm 10 \text{ V},$	$R_L \ge 2 \; k\Omega$	-55°C to 125°C	15			15		v	V/111V	
B ₁	Unity-gain bandwidth			25°C		3			3		MHz	
rį	Input resistance			25°C		1012			1012		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}m$ $V_{O} = 0$,	$R_S = 50 \Omega$	25°C	80	86		80	86		dB	
ksvr	Supply voltage rejection ratio (ΔV _{CC±} /ΔV _{IO})	$V_{CC} = \pm 15 \text{ V}$ $V_{O} = 0$,	to $\pm 9 \text{ V}$, R _S = 50 Ω	25°C	80	86		80	- 86		dB	
lcc	Supply current (per amplifier)	V _O = 0,	No load	25°C		1.4	2.8		1.4	2.8	mA	
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120			120		dB	

T All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics, $V_{CC\pm} = \pm 15 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	PARAMETER		TEST CONDIT	TIONS		MIN	TYP	MAX	UNIT
		V _i = 10 V,	$R_L = 2 k\Omega$,	C _L = 100 pF,	See Figure 1	8*	13		
SR	Slew rate at unity gain	$V_{I} = 10 \text{ V},$ $T_{A} = -55^{\circ}\text{C to } 125^{\circ}\text{C},$	$R_L = 2 kΩ$, See Figure 1	C _L = 100 pF,		5*			V/μs
t _r	Rise time	V _I = 20 mV,	D. 010	C. 100 = F	Con Figure 1		0.05		μs
	Overshoot factor	$V_1 = 20 \text{ mV},$	$R_L = 2 k\Omega$,	C _L = 100 pF,	See Figure 1		20%		
v	Equivalent input noise	R _S = 20 Ω	f = 1 kHz				18		nV/√Hz
Vn	voltage	ns = 20 12	f = 10 Hz to 10 kHz				4		μV
In	Equivalent input noise current	R _S = 20 Ω,	f = 1 kHz				0.01		pA/√Hz
THD	Total harmonic distortion	V _I rms = 6 V, f = 1 kHz	A _{VD} = 1,	R _S ≤ 1 kΩ,	R _L ≥ 2 kΩ,		0.003%		

^{*}On products compliant to MIL-PRF-38535, this parameter is not production tested.

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperatures as close to the ambient temperature as is possible.

TL081, TL081A, TL081B, TL082, TL082A, TL082B TL082Y, TL084, TL084A, TL084B, TL084Y JFET-INPUT OPERATIONAL AMPLIFIERS

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electrical characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST SOME	TL082Y, TL084Y			UNIT	
	PARAMETER	TEST CONDITIONS†			TYP	MAX	UNII
V _{IO}	Input offset voltage	V _O = 0,	$R_S = 50 \Omega$		3	15	mV
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	R _S = 50 Ω		18		μV/°C
lio	Input offset current‡	V _O = 0,			5	200	pА
lв	Input bias current‡	V _O = 0,			30	400	рA
VICR	Common-mode input voltage range			±11	-12 to 15		٧
Vом	Maximum peak output voltage swing	$R_L = 10 \text{ k}\Omega$,		±12	±13.5		٧
AVD	Large-signal differential voltage amplification	$V_0 = \pm 10 \text{ V},$	R _L ≥ 2 kΩ	25	200		V/mV
B ₁	Unity-gain bandwidth				3		MHz
rį	Input resistance				1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$, RS = 50 Ω	V _O = 0,	70 70	86 86		dB
ksvr	Supply voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC} = \pm 15 \text{ V to :} $ $V_{O} = 0,$		70 70	86 86		dB
lcc	Supply current (per amplifier)	V _O = 0,	No load		1.4	2.8	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100			120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$

	PARAMETER		TEST CO	NDITIONS		MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _I = 10 V,	$R_L = 2 k\Omega$,	C _L = 100 pF,	See Figure 1	8	13		V/µs
t _r	Rise time	V _I = 20 mV,	Di = 2 kO	C _L = 100 pF,	See Figure 1		0.05		μs
	Overshoot factor	7 VI = 20 mV,	nL = 2 K12,				20%		
V	Equivalent input noise voltage	R _S = 20 Ω	f = 1 kHz				18		nV/√Hz
٧n	Vn Equivalent input noise voltage	f = 10 Hz to 10 kHz					4		μV
In	Equivalent input noise current	$R_S = 20 \Omega$,	f = 1 kHz				0.01		pA/√Hz
THD	Total harmonic distortion	V _I rms = 6 V, f = 1 kHz	A _{VD} = 1,	R _S ≤ 1 kΩ,	R _L ≥ 2 kΩ,		0.003%		

[‡] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

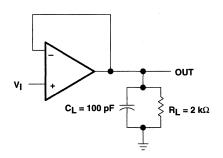


Figure 1

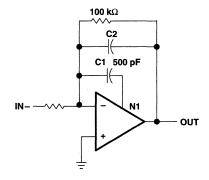


Figure 3

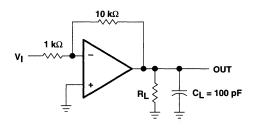


Figure 2

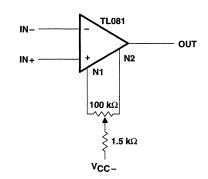


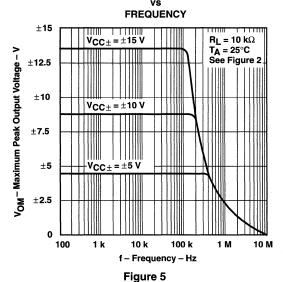
Figure 4

TYPICAL CHARACTERISTICS

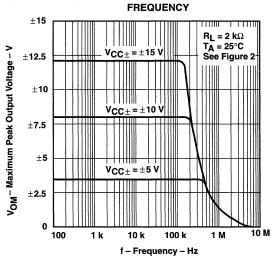
Table of Graphs

Vом	Maximum peak output voltage	vs Frequency vs Free-air temperature vs Load resistance vs Supply voltage	5, 6, 7 8 9 10			
AVD	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	11 12			
	Differential voltage amplification	vs Frequency with feed-forward compensation	13			
PD	Total power dissipation	vs Free-air temperature	14			
Icc	Supply current	vs Free-air temperature vs Supply voltage	15 16			
lв	Input bias current	vs Free-air temperature	17			
	Large-signal pulse response	vs Time	18			
٧o	Output voltage	vs Elapsed time	19			
CMRR	Common-mode rejection ratio	vs Free-air temperature	20			
V _n	Equivalent input noise voltage	vs Frequency	21			
THD	Total harmonic distortion	vs Frequency	22			

MAXIMUM PEAK OUTPUT VOLTAGE



MAXIMUM PEAK OUTPUT VOLTAGE VS



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TYPICAL CHARACTERISTICS†

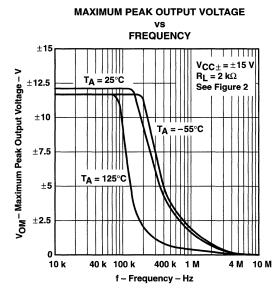


Figure 7

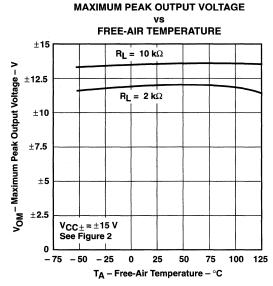
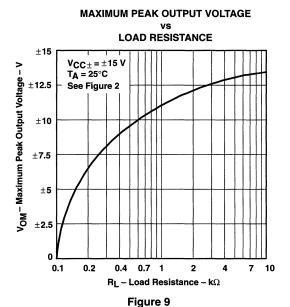


Figure 8



MAXIMUM PEAK OUTPUT VOLTAGE

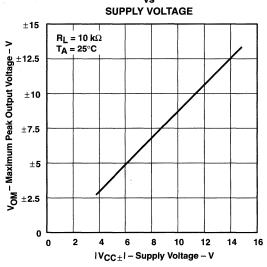


Figure 10

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION**

vs FREE-AIR TEMPERATURE 1000 700 400 A_{VD} - Large-Signal Differential Voltage Amplification – V/mV 200 100 70 40 20 10 7 4 V_{CC±} = ±15 V V_O = ±10 V 2 $R_L = 2 k\Omega$ -50 -25 25 50 75 100 -75 TA - Free-Air Temperature - °C

Figure 11

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION**

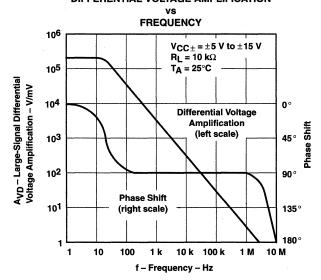


Figure 12

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS†

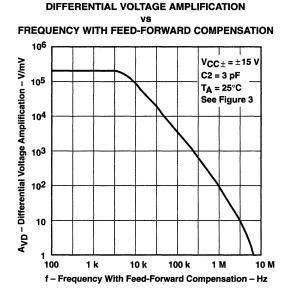


Figure 13

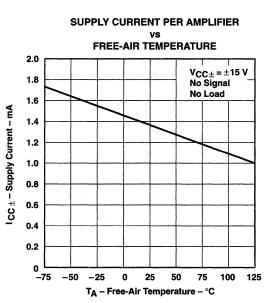


Figure 15

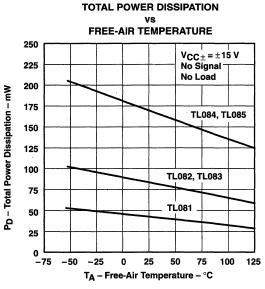
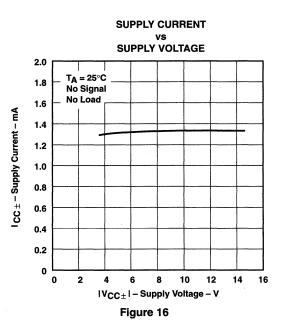


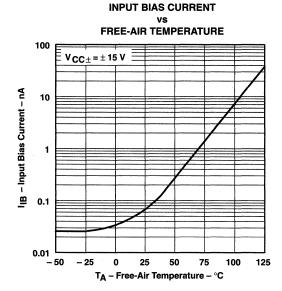
Figure 14



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†



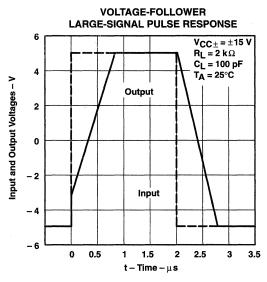
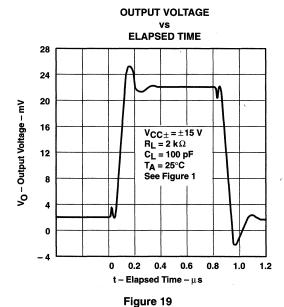


Figure 17





COMMON-MODE REJECTION RATIO FREE-AIR TEMPERATURE 89

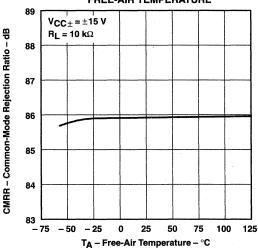


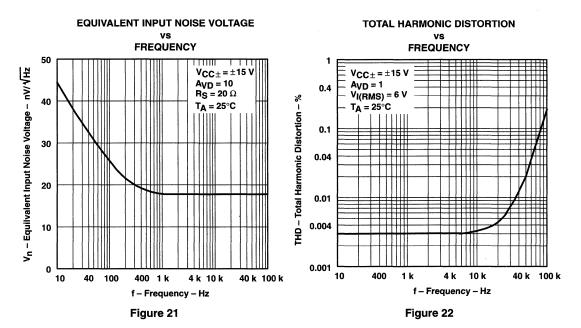
Figure 20

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS†



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION

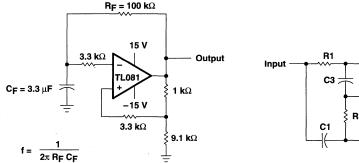


Figure 23

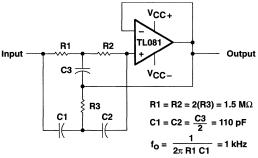


Figure 24

APPLICATION INFORMATION

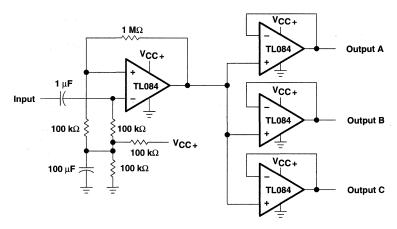
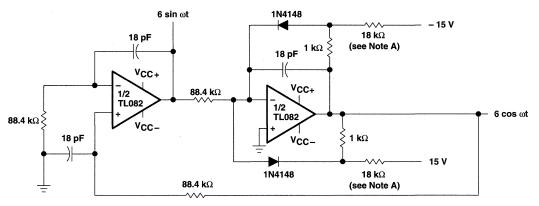


Figure 25. Audio-Distribution Amplifier



NOTE A: These resistor values may be adjusted for a symmetrical output.

Figure 26. 100-KHz Quadrature Oscillator

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APPLICATION INFORMATION

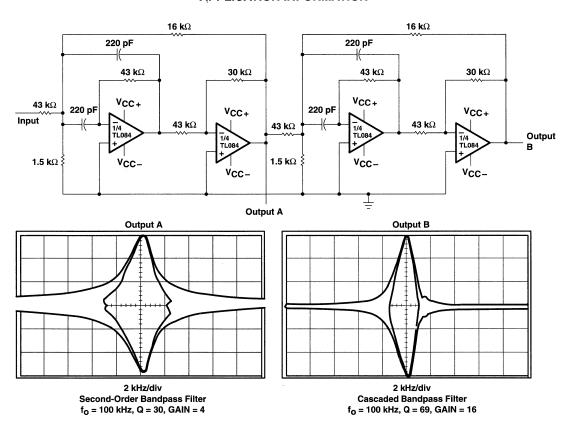


Figure 27. Positive-Feedback Bandpass Filter

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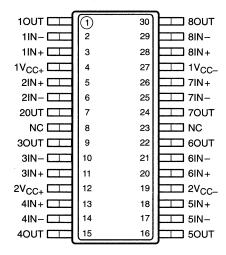
- **Low Power Consumption**
- **Wide Common-Mode and Differential** Voltage Ranges
- **Low Input Bias and Offset Currents**
- **Output Short-Circuit Protection**
- **Low Total Harmonic** Distortion . . . 0.003% Typ
- High Input Impedance . . . JFET-Input Stage
- **Latch-Up-Free Operation**
- High Slew Rate . . . 13 V/us Typ
- **Common-Mode Input Voltage Range** Includes V_{CC+}

description

The TL084x2 JFET-input operational amplifier incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The device features high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

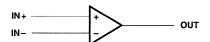
The TL084x2 is characterized for operation from 0°C to 70°C.

DB PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



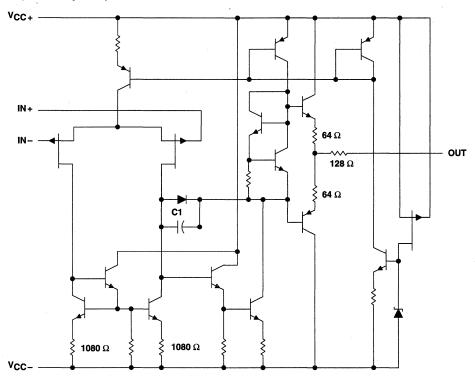
AVAILABLE OPTION

		PACKAGE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (DB) [†]
0°C to 70°C	15 mV	TL084x2DBLE

† The DB package is only available left-end taped and reeled.

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schematic (each amplifier)



All component values shown are nominal.

COMPONENT COUNT				
Resistors	76			
Transistors	120			
JFET	20			
Diodes	12			
Capacitors	8			

TL084x2 JFET-INPUT OCTAL OPERATIONAL AMPLIFIER

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	18 V
Supply voltage, V _{CC} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage, V _I (any input) (see Notes 1 and 3)	±15 V
Duration of output short circuit to ground (see Note 4)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages and V_{CC} specified for the measurement of I_{OS}, are with respect to the midpoint between V_{CC+} and V_{CC-}.

- 2. Differential voltages are at IN + with respect to IN -.
- 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
- The output can be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING
DB	1024 mW	8.2 mW/° C	655 mW

TL084x2 JFET-INPUT OCTAL OPERATIONAL AMPLIFIER

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electrical characteristics, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

	PARAMETER	TEST CONDITION	onst	T _A ‡	MIN	TYP	MAX	UNIT
Via	Input offset voltage	V 0	R _S = 50 Ω	25°C		5	15	mV
VIO	input onset voitage	$V_O = 0$,	ng = 50 12	Full range			20	IIIV
αVIO	Temperature coefficient of input offset voltage	V _O = 0,	R _S = 50 Ω	Full range		10		μV/°C
li o	land affect or mont	V2 = 0		25°C		5	200	рA
lio	Input offset current	VO = 0		Full range			5	nA
lin	14 bi	Va = 0		25°C		30	400	pА
lВ	Input bias current§	VO = 0		Full range			10	nA
VICR	Common-mode input voltage range			25°C	±10	±11		٧
		$R_L = 10 \text{ k}\Omega$		25°C	±12	±13.5		
Vом	Maximum peak output voltage swing	$R_L \ge 10 \text{ k}\Omega$		Full range	±12] v
		R _L ≥ 2 kΩ		Full range	±10	±12		
Δ	Large-signal differential voltage	$V_0 = \pm 10 \text{ V},$	R _L ≥ 2 kΩ	25°C	25	200		
AVD	amplification	$V_0 = \pm 10 \text{ V},$	R _L ≥ 2 kΩ	Full range	15		200 5 400	V/mV
B ₁	Unity-gain bandwidth			25°C		3		MHz
rį	Input resistance			25°C		1012		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,	25°C	70	76		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{CC\pm}/\Delta V_{IO})$	$V_{CC} = \pm 15 \text{ V to } \pm 9 \text{ V},$ R _S = 50 \(\Omega\)	V _O = 0,	25°C	70	76		dB
Icc	Supply current (per amplifier)	V _O = 0,	No load	25°C		1.4	2.8	mA
V _{O1} /V _{O2}	Crosstalk attenuation	A _{VD} = 100		25°C		120		dB

[†] All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

operating characteristics, $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$ (unless otherwise noted)

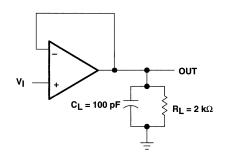
	PARAMETER		TEST C	ONDITIONS		MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _I = 10 V,	$R_L = 2 k\Omega$,	C _L = 100 pF,	See Figure 1		13		V/μs
t _r	Rise time	V. 00 mV	D 010	C _L = 100 pF,	See Figure 1		0.05		μs
	Overshoot factor	\ \(\(\) = 20 \(\) \(\)	HL = 2 K22,				20%		
٧n	Equivalent input noise voltage	$R_S = 20 \Omega$,	f = 1 kHz				18		nV/√Hz

[‡] Full range is 0°C to 70°C.

[§] Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 14. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

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PARAMETER MEASUREMENT INFORMATION



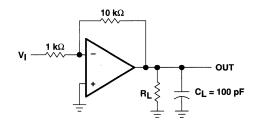


Figure 1. Unity-Gain Amplifier

Figure 2. Gain-of-10 Inverting Amplifier

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
Vом	Maximum peak output voltage	vs Frequency vs Free-air temperature vs Load resistance vs Supply voltage	3, 4, 5 6 7 8
AVD	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	9 10
PD	Total power dissipation	vs Free-air temperature	11
Icc	Supply current	vs Free-air temperature vs Supply voltage	12 13
I _{IB}	Input bias current	vs Free-air temperature	14
	Pulse response	Large signal	15
Vo	Output voltage	vs Elasped time	16
CMRR	Common-mode rejection ratio	vs Free-air temperature	17
v _n	Equivalent input noise voltage	vs Frequency	18
THD	Total harmonic distortion	vs Frequency	19
	Phase shift	vs Free-air temperature	10

VOM - Maximum Peak Output Voltage - V

0

100

1 k

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE FREQUENCY ±15 $R_L = 10 \text{ k}\Omega$ V_{CC±} = ±15 V TA = 25°C See Figure 2 ±12.5 ±10 V_{CC±} = ±10 V ±7.5 V_{CC±} = ±5 V ±5 ±2.5

f - Frequency - Hz Figure 3

10 k

100 k

1 M

10 M

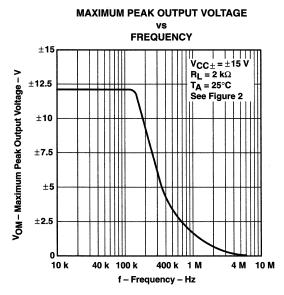


Figure 5

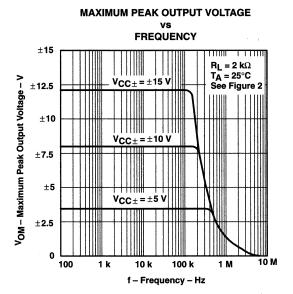


Figure 4

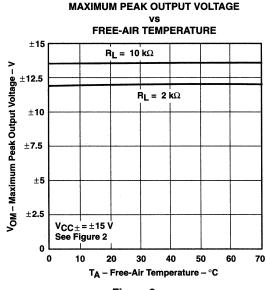


Figure 6

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TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE

LOAD RESISTANCE

±15 V_{CC±} = ±15 V VoM - Maximum Peak Output Voltage - V TA = 25°C ±12.5 See Figure 2 ±10 ±7.5

±5

±2.5

0.1

0.2

MAXIMUM PEAK OUTPUT VOLTAGE



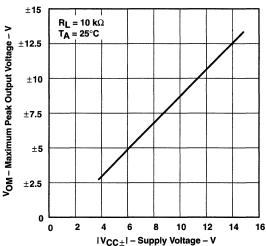


Figure 7

0.7 1

R_L – Load Resistance – $k\Omega$

4 7

2

Figure 8

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION**

10

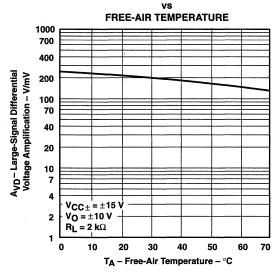


Figure 9

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION

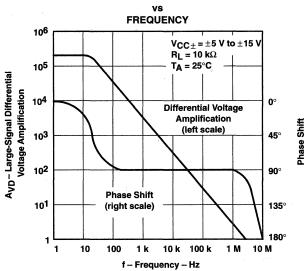


Figure 10

TOTAL POWER DISSIPATION

vs FREE-AIR TEMPERATURE 250 V_{CC±} = ±15 V No Signal ⊢ 225 No Load P_D - Total Power Dissipation - mW 200 175 150 125 100 75 50 25 0 10 30 40 50 70 20 60

Figure 11

T_A - Free-Air Temperature - °C

SUPPLY CURRENT (PER AMPLIFIER)

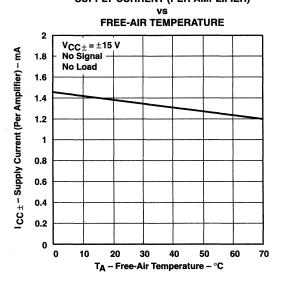


Figure 12



INPUT BIAS CURRENT

FREE-AIR TEMPERATURE

TYPICAL CHARACTERISTICS

0.01

10

20

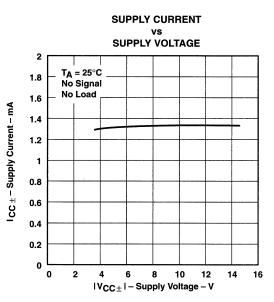


Figure 13



30

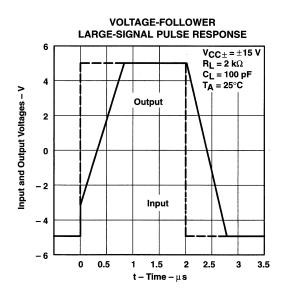
T_A - Free-Air Temperature - °C

40

50

60

70



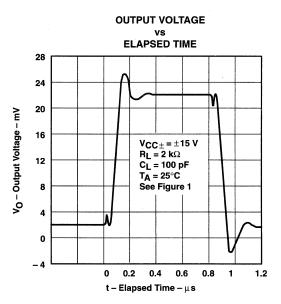
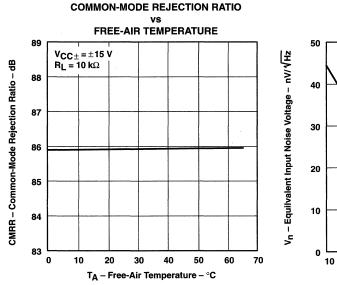


Figure 15

Figure 16





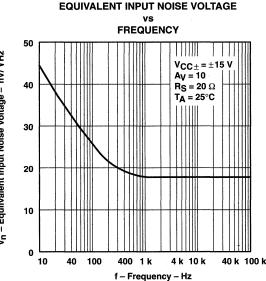


Figure 17

Figure 18



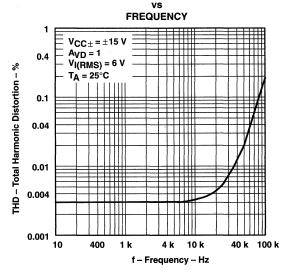


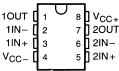
Figure 19

TL2828Z, TL2828Y HIGH-TEMPERATURE DUAL OPERATIONAL AMPLIFIERS

SLOS104 - DECEMBER 1991

- Operating Free-Air Temperature Range -40°C to 150°C
- Wide Range of Supply Voltages: Single Supply or Dual Supply . . . 4 V to 30 V
- Low Supply Current Drain Independent of Supply Voltage . . . 0.7 mA Typ
- Internal Frequency Compensation
- Low Input Bias and Offset Parameters Input Offset Voltage . . . 3 mV Typ Input Offset Current . . . 2 nA Typ Input Bias Current . . . 15 nA Typ
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 30 V
- Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ

TL2828Z...D OR P PACKAGE (TOP VIEW)



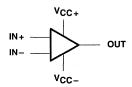
description

The TL2828Z and TL2828Y devices consist of two independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate over a wide range of voltages from a single supply. Operation from split supplies is also possible as long as the difference between the two supplies is 4 V to 30 V, and V_{CC} is at least 1.5 V more positive than the common-mode input voltage. The low supply current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply voltage systems. For example, the TL2828Z can be operated on automotive engine blocks directly off the standard 12-V supply with minimal electrical protection.

The TL2828Z is characterized for operation over the extended temperature range of -40°C to 150°C.

symbol (each amplifier)



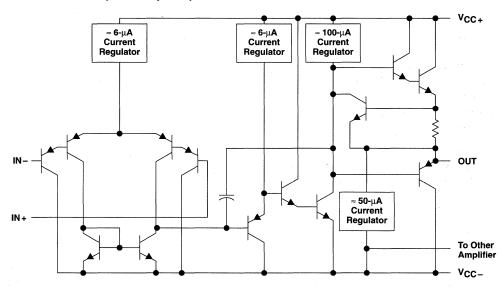
AVAILABLE OPTIONS

TA	Viemer	PACKAGED	DEVICES	CHIP FORM
	V _{IO} max at 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)	(Y)
-40°C to 150°C	7 mV	TL2828ZD	TL2828ZP	TL2828Y

The D packages are available taped and reeled. Add R suffix to device type (i.e., TL2828ZDR). The chip form is tested at $T_A = 25^{\circ}C$.

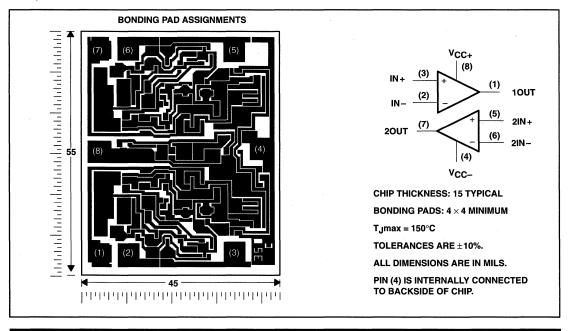


equivalent schematic (each amplifier)



TL2828Y chip information

This chip, when properly assembled, displays characteristics similar to the TL2828Z. Thermal compression bonding may be used on the gold bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TL2828Z, TL2828Y HIGH-TEMPERATURE DUAL OPERATIONAL AMPLIFIERS

SLOS104 - DECEMBER 1991

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	16 V
Supply voltage, V _{CC}	
Differential input voltage, V _{ID} (see Note 2)	±32 V
Input voltage range, V _I (any input)	
Input current, I _I (each input)	±1 mA
Output current, I _O	±40 mA
Total current into V _{CC+}	60 mA
Total current out of V _{CC}	60 mA
Duration of short-circuit at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	40°C to 150°C
Storage temperature range	65°C to 165°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-} when dual supplies are specified (e.g., V_{CC±} = ±15 V) and with respect to V_{CC-} when a single supply is specified (e.g., V_{CC} = 5 V).
 - 2. Differential voltages are at the noninverting input with respect to the noninverting input. Excessive current will flow if the input is below VCC-
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 105°C POWER RATING	T _A = 125°C POWER RATING	T _A = 150°C POWER RATING
D	812 mV	5.8 mW/°C	551 mW	348 mW	232 mW	87 mW
Р	1120 mV	8.0 mW/°C	760 mW	480 mW	320 mW	120 mW

recommended operating conditions

		MIN	MAX	UNIT	
Supply voltage, V _{CC±}		±2	±15	V	
mmon-mode input voltage, V _{IC}	V _{CC±} = ±2.5 V	-2.5	0.5	V	
	$V_{CC\pm} = \pm 15 \text{ V}$	-15	13	V	
Innut veltage venge M.	V _{CC±} = ±2.5 V	-2.5	0.5	v	
it voltage range, V _I	V _{CC±} = ±15 V	-15	13		
Operating free-air temperature, TA					

TL2828Z, TL2828Y HIGH-TEMPERATURE DUAL OPERATIONAL AMPLIFIERS

SLOS104 - DECEMBER 1991

electrical characteristics at specified free-air temperature, $V_{CC} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONF	TEST CONDITIONS TAT TL2828Z		TEST CONDITIONS T. T		TL2828Z		UNIT
	PANAMETEN	TEST CONL	// IONS	'A'	MIN	TYP	MAX	UNII	
VIO	Input offset voltage			25°C		3	7	mV	
VIO	input onset voltage			Full range			10	1110	
αVIO	Temperature coefficient of input offset voltage	V _{IC} = 0,	V _O = 1.4 V,	Full range		15		μV/°C	
lio	Input offset current	$V_{IC} = 0,$ $R_{S} = 50 \Omega$ $I_{OH} = 0.1 \text{ mA}$ $I_{OH} = 1 \text{ mA}$ $I_{OL} = 0.1 \text{ mA}$ $V_{O} = 1 \text{ V to } 3.5 \text{ V}, \qquad R_{L}$		25°C		2	30	nA	
10	input onset durient			Full range			200	11/4	
lв	Input bias current	1		25°C		-15	-100	nA	
-ID	mpar blas carrent			Full range			-500	101	
V	Common mode input valtage vange	B- 50.0		25°C	0 to 3.5	0 to 3.5		v	
VICR	Common-mode input voltage range	Full range	0 to 3						
		0.4		25°C	3.3	3.7			
VOH High-level output voltage	High level output veltage	IOH = 0.1 IIIA		Full range	3.2			v	
vOH	nigii-level output voltage	lou - 1 mA		25°C	3.3	3.6			
		IOH = 1 IIIA		Full range	3.2				
		1 0.1		25°C	0.8	0.6		v	
VOL	Low-level output voltage	IOL = 0.1 IIIA)L = 0.1 mA		1				
VOL	Low-level output voltage	lo: - 1 mA		25°C	ange]			
		TOL = TIMA		Full range	1.1				
A _{VD}	Large-signal differential voltage	Vo = 1 V to 3.5 V	$R_1 = 2 k\Omega$	25°C	25	100		V/mV	
~VD	amplification	VO = 1 V 10 3.3 V,	11[- 2 132	Full range	0.7			V/111V	
CMRR	Common-mode rejection ratio		$V_0 = 1.4 V$,	25°C	65	80		dB	
O.V	- Common mode rejection ratio	$R_S = 50 \Omega$		Full range	45			u _D	
ksvr	Supply-voltage rejection ratio	$V_{CC} = 5 V \text{ to } 30 V$	$V_0 = 1.4 V$,	25°C	65	100		dB	
ovn		$R_L = 10 \text{ k}\Omega$		Full range	65		·	45	
Icc	Supply current (total package)			25°C		0.7		mA	
		V _{IC} = 0,	$V_0 = 2.5 V$,	Full range			1.2	****	
ΔICC	Supply current change over operating temperature range	No load		Full range		140		μА	

[†] Full range is -40°C to 150°C.

TL2828Z, TL2828Y HIGH-TEMPERATURE DUAL OPERATIONAL AMPLIFIERS SLOS104 - DECEMBER 1991

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

	DADAMETED	TEST OO	IDITIONS	T - +	-	TL2828Z	TL2828Z		
	PARAMETER	TEST COM	NUTTIONS	T _A †	MIN	TYP	MAX	UNIT	
V _{IO}	Input offset voltage			25°C		3	7	mV	
VIO	input onset voltage			Full range			10	IIIV	
αVIO	Temperature coefficient of input offset voltage	V _{IC} = 0,	V _O = 0,	Full range		15		μV/°C	
lio	Input offset current	$R_S = 50 \Omega$		25°C		2	30	nA	
ΙΟ	input onset current			Full range			200	ш	
lв	Input bias current			25°C		-15	-100	n:A	
שוי	input bias current			Full range			-500	11/5	
VICR	Common-mode input voltage range	R _S = 50 Ω		25°C	-15 to 13.5			٧	
1011			2	Full range	-15 to 13				
		IO = -0.1 mA		25°C	13.2	14.1			
		10 - 0.11114		Full range	13.1				
V _{OM+}	Maximum positive peak output voltage	I _O = -1 mA		25°C	13.1	14		v	
- OWI+	swing	10 - 11111		Full range	13			·	
		IO = -10 mA		25°C	12.8	-13.6			
		10 - 10 11.21		Full range	12.7				
		IO = 0.1 mA		25°C	-13.7	-14.4			
		.0 411 /121		Full range	-13.1				
V _{OM} _	Maximum negative peak output	IO = 1 mA		25°C	-13.6	-14.3		V	
OWI-	voltage swing			Full range	-13				
		IO = 7 mA		25°C	-12.9	-13.8			
		0		Full range	-12.5				
AVD	Large-signal differential voltage	$R_1 = 2 k\Omega$	$V_{\Omega} = -5 \text{ V to 5 V}$	25°C	25	100		V/mV	
	amplification			Full range	0.8			.,	
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min,	$V_0 = 1.4 V$,	25°C	65	75		dB	
		$R_S = 50 \Omega$		Full range	50				
ksvr	Supply-voltage rejection ratio	V _{CC} = 5 V to 30 V,	$R_1 = 50 \text{ k}\Omega$	25°C	65	100		dB	
371		100 0 1 10 30 4,		Full range	65				
lcc	Supply current (total package)			25°C		0.7	2	⊢ mA i	
		V _{IC} = 0,	$V_O = 0$,	Full range			2		
ΔICC	Supply current change over operating temperature range	No load		Full range		140		μΑ	

[†]Full range is -40°C to 150°C.

TL2828Z, TL2828Y HIGH-TEMPERATURE DUAL OPERATIONAL AMPLIFIERS SLOS104 – DECEMBER 1991

operating characteristics at specified free-air temperature, $V_{CC\pm}$ = $\pm 15~V$

	PARAMETER	TEST CO	ONDITIONS	- +	Т	L2828Z			
	PARAMETER	IESI CC	SNOTTIONS	T _A †	MIN	TYP	MAX	UNIT	
SR+	Positive slew rate			25°C	0.15				
on+	FOSITIVE SIEW Tate	V _O = 1 V to 4.5	V, A _{VD} = 1,	Full range	0.1			V/µs	
SR-	Nogotive eleverate	$R_L = 2 k \Omega^{\ddagger}$,	C _L = 100 pF	25°C	0.15			V/μS	
3N-	Negative slew rate			Full range	0.1		,		
.,	Equivalent input noise voltage	f = 10 Hz		25°C		39		nV/√Hz	
Vn	Equivalent input noise voltage	f = 10 kHz		25.0		23		nv/√Hz	
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10	-lz	25°C		0.9		μV	
В1	Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF	25°C		400		kHz	
φm	Phase margin	$R_L = 10 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF	25°C		60°			

[†] Full range is -40°C to 150°C. ‡ R_L terminates at 0 V.

electrical characteristics at $V_{CC\pm}$ = ± 15 V, T_A = $25^{\circ}C$ (unless otherwise noted)

	PARAMETER	TEST (CONDITIONS					UNIT
	TANAMETER	1251	JOHDITIONS			TYP	MAX	Olui
V _{IO}	Input offset voltage					3	7	mV
lio	Input offset current	$V_{IC} = 0,$	$V_O = 0$,	$R_S = 50 \Omega$		2	30	nA
Iв	Input bias current					-15	-100	IIA
VICR	Common-mode input voltage range	R _S = 50 Ω			-15 to 13.5			٧
		$I_0 = -0.1 \text{ mA}$			13.2	14.1		
∨ом+	Maximum positive peak output voltage swing	I _O = -1 mA			13.1	14		٧
		I _O = – 10 mA			12.8	13.6		
		I _O = 0.1 mA			-13.7	-14.4		
VOM-	Maximum negative peak output voltage swing	I _O = 1 mA			-13.6	-14.3		٧ .
		I _O = 10 mA			-12.9	-13.8		
AVD	Large-signal differential voltage amplification	$V_O = 1 \text{ V to } -1.5 \text{ V},$	$R_L = 2 k\Omega$		25	100		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 28 V,	V _O = 1.4 V,	$R_S = 50 \Omega$	65	75		dB
ksvr	Supply-voltage rejection ratio	$V_{CC} = 5 \text{ V to } 30 \text{ V},$	V _O = 1.4 V,	$R_L = 10 \text{ k}\Omega$	65	100		dB
Icc	Supply-current (total package)	V _{IC} = 0,	V _O = 0,	No load		0.7	2	mA

TL2829Z, TL2829Y HIGH-TEMPERATURE QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS067A - APRIL 1991 - REVISED MARCH 1993

- Free-Air Operating Temperature Range -40°C to 150°C
- Wide Range of Supply Voltages: Single Supply . . . 4 V to 30 V or Dual Supplies
- Low Supply Current Drain independent of Supply Voltage . . . 0.8 mA

SUPPLY CURRENT

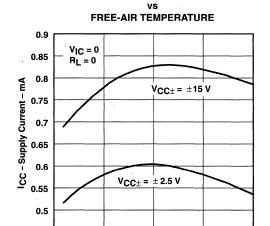
Internal Frequency Compensation

Low Input Bias and Offset Parameters at 25°C

> Input Offset Voltage . . . 3 mV Typ Input Offset Current . . . 2 nA Typ Input Bias Current . . . 15 nA Typ

- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 30 V
- **Open-Loop Differential Voltage** Amplification . . . 100 V/mV Typ at 25°C

description



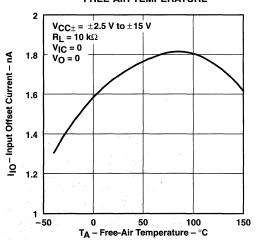
50

TA - Free-Air Temperature - °C

100

150

INPUT OFFSET CURRENT FREE-AIR TEMPERATURE



description

0.45 -50

> These devices consist of four independent, high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible as long as the difference between the two supplies is 4 V to 30 V, and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

> Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, the TL2829 can be operated on automotive engine blocks directly off the standard 12-V supply with minimal electrical protection.

The TL2829 is characterized for operation over the extended temperature range of -40°C to 150°C.

AVAILABLE OPTIONS

	Viemov	PACKAGED	DEVICES	CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (N)	FORM (Y)
-40°C to 150°C	7 mV	TL2829ZD	TL2829ZN	TL2829Y

The D packages are available taped and reeled. Add R suffix to device type (i.e., TL2829ZDR).

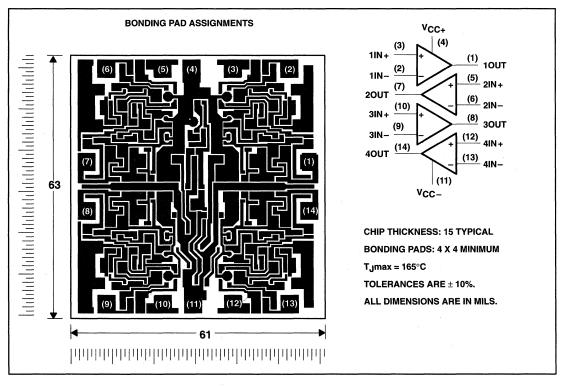


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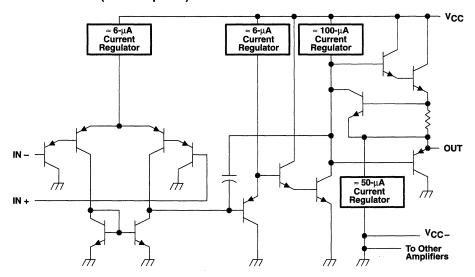
TL2829Z...D OR N PACKAGE symbol (each amplifier) (TOP VIEW) VCC+ 14] 40UT 10UT[1IN-[13 4IN-1IN+[] 3 12 4IN+ OUT 11 VCC-V_{CC+}[] 4 2IN+[] 5 10 3IN+ VCC-2IN-[9 3IN-**20UT** 8 1 30UT

TL2829Y chip information

This chip, properly assembled, displays characteristics similar to the TL2829. Thermal compression bonding may be used on the gold bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic (each amplifier)



COMPONENT COUNT (total device)					
Epi-FET	1				
Diodes	4				
Resistors	11				
Transistors	95				
Capacitors	4				

TL2829Z, TL2829Y HIGH-TEMPERATURE QUADRUPLE OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{CC+} (see Note 1)	16 V
Supply voltage, V _{CC} (see Note 1)	16 V
Differential input voltage, V _{ID} (see Note 2)	±32 V
Input voltage range, V _I (any input)	–16 to 16 V
Input current, I _I (each input)	±1 mA
Output current, IO	±40 mA
Total current into V _{CC+}	60 mA
Total current out of V _{CC}	
Duration of short-circuit current at (or below) 25°C (see Note 3)	
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, TA	–40°C to 150°C
Storage temperature range	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC} + and V_{CC} when dual supplies are specified (e.g., V_{CC} + = ±15 V) and with respect to V_{CC} when a single supply is specified (e.g., V_{CC} = 5 V).
 - Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if input is brought below VCC.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25^{\circ}C$ POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 100°C POWER RATING	T _A = 125°C POWER RATING	T _A = 150°C POWER RATING
D	1064 mW	7.6 mW/°C	722 mW	494 mW	304 mW	114 mW
N	1764 mW	12.6 mW/°C	1197 mW	819 mW	504 mW	189 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{CC±}		±2	±15	V
Common mode input veltage V.	$V_{CC\pm}=\pm 2.5 V$	-2.5	-2.5 0.5	
Common-mode input voltage, V _{IC}	$V_{CC\pm} = \pm 15 V$	-15	13	V
Input valtage range Vi	V _{CC±} = ±2.5 V	-2.5	0.5	V
Input voltage range, V _I	$V_{CC\pm}=\pm 15 V$	-15	13	V
Operating free-air temperature, T _A			150	°C

TL2829Z, TL2829Y HIGH-TEMPERATURE QUADRUPLE OPERATIONAL AMPLIFIERS SLOS067A – APRIL 1991 – REVISED MARCH 1993

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

	DADAMETED	TEST OF	NDITIONS	_ +	TL2829Z			UNIT
	PARAMETER	1EST CO	NDITIONS	T _A †	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		3	7	mV
۷Ю	input onset voltage			Full range			10	1110
α_{VIO}	Temperature coefficient of input offset voltage	V _O = 1.4 V,	V _{IC} = 0,	Full range		15		μV/°C
l. a	Input offset current	R _S = 50 Ω	10 /	25°C		2.0	30	nA
lio	input onset current			Full range			200	IIA
l.=	Input bias current			25°C		-12	-100	nA
lВ	input bias current			Full range			-500	IIA
VICR	Common-mode input voltage range	R _S = 50 Ω		25°C	0 to 3.5	0 to 3.5		٧
TICH	Common-mode input voltage range	ng = 50 sz		Full range	0 to 3			V
		. 04		25°C	3.3	3.7		- v
Vон	High-level output voltage	I _{OH} = 0.1 mA		Full range	3.2			v
vон	nigri-level output voltage			25°C	3.3	3.6		V
		I _{OH} = 1 mA		Full range	3.2			
		I _{OI} = 0.1 mA		25°C	0.8	0.6		
VOL	Low-level output voltage	IOL = 0.1 IIIA		Full range	1			v
VOL	Low-level output voltage	IOI = 1 mA		25°C	0.9	0.7		\ \ \
		IOL = 1 IIIA		Full range	1.1			
AVD	Large-signal differential voltage	V _O = 1 V to 3.5 V,	D 2 kO	25°C	25	60		V/mV
~VD	amplification	VO = 1 V 10 3.5 V,	nL = 2 ks2	Full range	0.8			V/IIIV
CMRR	Common-mode rejection ratio	V _O = 1.4 V,	V _{IC} = V _{ICR} min,	25°C	65	81		dB
CIVITA	Common-mode rejection ratio	$R_S = 50 \Omega$		Full range	50			uБ
ksvr	Supply-voltage rejection ratio	$V_{CC} = 5 \text{ V to } 30 \text{ V},$	$V_0 = 1.4 V$,	25°C	65	65 103		dB
∿SVH	Suppry-voltage rejection ratio	$R_L = 10 \text{ k}\Omega$		Full range	65			цÞ
lcc	Supply current (total package)			25°C		0.6	1.2	mA
100		V _O = 2.5 V,	$V_{IC} = 0$,	Full range			1.2	111/5
ΔICC	Supply current change over operating temperature range	No load		Full range		140		μΑ

[†] Full range is -40°C to 150°C.

TL2829Z, TL2829Y HIGH-TEMPERATURE QUADRUPLE OPERATIONAL AMPLIFIERS SLOS067A – APRIL 1991 – REVISED MARCH 1993

electrical characteristics at specified free-air temperature, $V_{\text{CC}\pm}$ = ± 15 V (unless otherwise noted)

PARAMETER		TEST COI	UDITIONS	- +		TL2829Z		
	PANAWEIEN	TEST COI	ADITIONS	T _A †	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		3	7	mV
VIO	mput onset voltage			Full range			10	1110
ανιο	Temperature coefficient of input offset voltage	V _O = 0,	$R_S = 50 \Omega$	Full range		15		μV/°C
lio	Input offset current	V _{IC} = 0	,	25°C		2	30	nA
10	input onset current			Full range			200	114
lin.	Input bias current			25°C		-15	-100	nA
İΒ	input bias current			Full range			-500	11/4
VICR	Common-mode input voltage range	R _S = 50 Ω		25°C	-15 to 13.5			٧
				Full range	-15 to 13			
		IO = -0.1 mA		25°C	13.2	14.1		
		10 = -0.1 IIIA		Full range	13.1			
Vou	Maximum positive peak output voltage	IO = -1 mA		25°C	13.1	14		v
V _{OM+}	range	10 1 111A		Full range	13			·
		lo = -10 mA		25°C	12.8	13.6		
		$I_{O} = -10 \text{ mA}$		Full range	12.7			
		I _O = 0.1 mA		25°C	-13.7	-14.4		
•	•	10 = 0.1 IIIA		Full range	-13.1			
VOM-	Maximum negative peak output voltage	I _O = 1 mA		25°C	-13	-14.3		V
VOM-	range	IO = TIIIA		Full range	-13			v
		IO = 10 mA		25°C	-12.9	-13.8		
		10 = 10 IIIA		Full range	-12.9			
AVD	Large-signal differential voltage	$R_1 = 2 k\Omega$	$V_{O} = -5 \text{ V to 5 V}$	25°C	25	210		V/mV
AVD	amplification	HL = 2 KS2,	vO = −3 v to 3 v	Full range	5			V/IIIV
CMRR	Common-mode rejection ratio	V _O = 1.4 V,	$R_S = 50 \Omega$	25°C	65	75		dB
Civinn	Common-mode rejection ratio	V _{IC} = V _{ICR} min		Full range	50			uВ
kayım	Supply-voltage rejection ratio	$V_{CC} = 5 \text{ V to } 30 \text{ V},$	V _O = 1.4 V	25°C 65 103	103		dB	
ksvr	Supply-vollage rejection ratio	$R_L = 10 \text{ k}\Omega$,		Full range	65			uв
loo	Supply current (total package)			25°C		0.8	3	mA
Icc	Supply current (total package)	V _O = 0,	$V_{IC} = 0$,	Full range			3	IIIA
ΔICC	Supply current change over operating temperature range	No load		Full range		140		μА

[†] Full range is -40°C to 150°C.

TL2829Z, TL2829Y HIGH-TEMPERATURE QUADRUPLE OPERATIONAL AMPLIFIERS SLOS067A – APRIL 1991 – REVISED MARCH 1993

operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS	-+	TL2829Z			UNIT
	PANAMETER	TEST CON	IDITIONS	'A'	TA [†] MIN TYP MAX		MAX]
SR+	Positive slew rate			25°C	0.2			
Sn+	Positive siew rate	$V_O = 1 \text{ V to } 4.5 \text{ V},$	$A_{VD} = 1$,	Full range	0.1			V/110
SR-	Negative slew rate	$V_O = 1 \text{ V to } 4.5 \text{ V},$ $R_L = 2 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF	25°C	0.25			V/μs
	Negative siew rate			Full range	0.2			
V	f = 10 H	f = 10 Hz		25°C		39		
Vn	Equivalent input noise voltage	f = 10 kHz		25°C		23		nV/√Hz
V _{n(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		0.9		μV
Bn	Unity-gain bandwidth	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF	25°C		400		kHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF	25°C		60°		

[†] Full range is -40°C to 150°C.

electrical characteristics at $V_{CC\pm}$ = ± 15 V, T_{A} = $25^{\circ}C$

	PARAMETER	TEST CO	ONDITIONS		TL2829Y		
	PARAMETER	TEST CC	DINDITIONS	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	.,			3	7	mV
lio	Input offset current	$V_O = 0$, $R_S = 50 \Omega$	$V_{IC} = 0$,		2	30	nA
l _{IB}	Input bias current	115-00 22			-15	-100	ii.
VICR	Common-mode input voltage range	R _S = 50 Ω		-15 to 13.5			٧
		$I_{O} = -0.1 \text{ mA}$		13.2	14.1		
V _{OM+}	Maximum positive peak output voltage range	I _O = -1 mA		13.1	14		V
		$I_{O} = -10 \text{ mA}$		12.8	13.6		
		I _O = 0.1 mA		-13.7	-14.4		V V
V _{OM} -	Maximum negative peak output voltage range	I _O = 1 mA		-13.6	-14.3		٧
		I _O = 10 mA		-12.9	-13.8		
AVD	Large-signal differential voltage amplification	$V_O = 1 \text{ V to } -1.5 \text{ V},$	R _L = 2 kΩ	25	210		V/mV
CMRR	Common-mode rejection ratio	V _O = 1.4 V, R _S = 50 Ω	V _{IC} = 0 V to 28 V,	65	75		dB
ksvr	Supply-voltage rejection ratio	$V_{CC} = 5 \text{ V to } 30 \text{ V},$ $R_L = 10 \text{ k}\Omega$	V _O = 1.4 V,	65	103		dB
lcc	Supply current (total package)	V _O = 0, No load	V _{IC} = 0,		0.8	3	mA

[‡]R_L terminates at 0 V.

Table of Graphs

			FIGURE
lio	Input offset current	vs Free-air temperature	1
lΒ	Input bias current	vs Free-air temperature ($V_{CC} = \pm 2.5 \text{ V}$)	2
		vs Free-air temperature ($V_{CC} = \pm 15 \text{ V}$)	3
V _{OM+}	Maximum positive peak output voltage swing	vs Free-air temperature ($V_{CC} = \pm 2.5 \text{ V}$)	4
		vs Free-air temperature ($V_{CC} = \pm 15 \text{ V}$)	5
V _{OM} -	Maximum negative peak output voltage swing	vs Free-air temperature ($V_{CC} = \pm 2.5 \text{ V}$)	6
		vs Free-air temperature ($V_{CC} = \pm 15 \text{ V}$)	7
los	Short-circuit output current	vs Free-air temperature (V _{ID} = 1 V)	8
		vs Free-air temperature ($V_{ID} = -1 V$)	9
AVD	Differential voltage amplification	vs Free-air temperature	10
CMRR	Common-mode rejection ratio	vs Free-air temperature	11
ksvr	Supply-voltage rejection ratio	vs Free-air temperature	12
lcc	Supply current	vs Free-air temperature	13
SR+	Positive slew rate	vs Free-air temperature	14
SR-	Negative slew rate	vs Free-air temperature	15
	Equivalent input noise voltage	Over a 10-second period	16

INPUT OFFSET CURRENT FREE-AIR TEMPERATURE

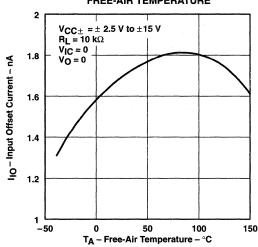


Figure 1

INPUT BIAS CURRENT vs

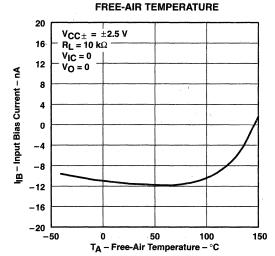


Figure 2

INPUT BIAS CURRENT

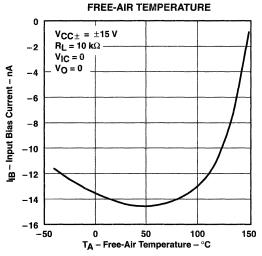


Figure 3

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE

FREE-AIR TEMPERATURE VOM+ - Maximum Positive Peak Output Voltage - V 1.8 V_{CC±} = ± 2.5 V 1.6 1.4 $I_0 = -1 \text{ mA}$ $I_0 = -0.1 \text{ mA}$ 1.2 1 8.0 lo = -10 mA 0.6 0.4 -50 50 100 150

Figure 4

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE

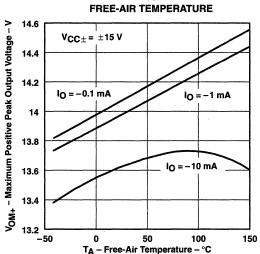


Figure 5

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE

TA - Free-Air Temperature - °C

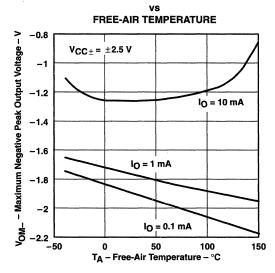


Figure 6

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE

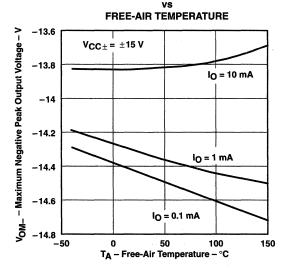


Figure 7



SHORT-CIRCUIT OUTPUT CURRENT **FREE-AIR TEMPERATURE** -14 V_{ID} = 1 V $V_{O} = 0$ -16 - Short-Circuit Output Current - mA -18 V_{CC±} = ±2.5 V -20 -22 -24 -26 V_{CC±} = ±15 V -28 -30 -32SO -34 -36 -50 50 100 150 TA - Free-Air Temperature - °C

Figure 8

LARGE-SIGNAL VOLTAGE AMPLIFICATION

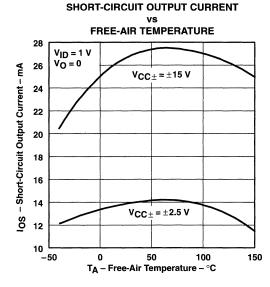


Figure 9

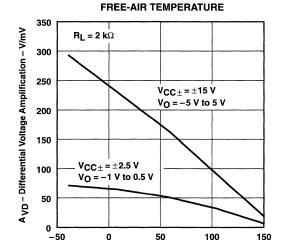


Figure 10

TA - Free-Air Temperature - °C

LARGE-SIGNAL VOLTAGE AMPLIFICATION

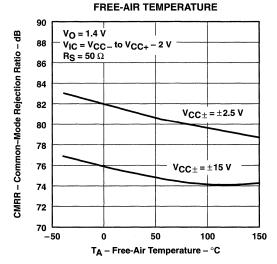


Figure 11



SUPPLY-VOLTAGE REJECTION RATIO FREE-AIR TEMPERATURE 110 $V_{CC\pm} = 5 \text{ V to } 30 \text{ V}$ 108 V_O = 1.4 V kSVR - Supply-Voltage Rejection - db $R_L = 10 \text{ k}\Omega$ 106 104 102 100 98 96 94 92 90 88 86 -50 50 100 150

SUPPLY CURRENT FREE-AIR TEMPERATURE 0.9 $V_{IC} = 0$ No Load 0.85 0.8 I_{CC} - Supply Current - mA $V_{CC\pm} = \pm 15 \text{ V}$ 0.75 0.7 0.65 0.6 V_{CC±} = ±2.5 V 0.55 0.5 0.45 -50 150 0 50 100

Figure 12

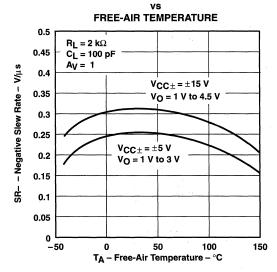
TA - Free-Air Temperature - °C

Figure 13

TA - Free-Air Temperature - °C

NEGATIVE SLEW RATE





SR+ - Positive Slew Rate - V/µs $V_{CC\pm} = \pm 15 \text{ V}$ 0.3 V_O = 1 V to 4.5 V 0.25 0.2 0.15 $V_{CC\pm} = \pm 5 V$ Vo = 1 V to 3 V 0.1 0.05 0 -50 150 TA - Free-Air Temperature - °C

Figure 15

Figure 14



0.5

0.45

0.4

0.35

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TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD

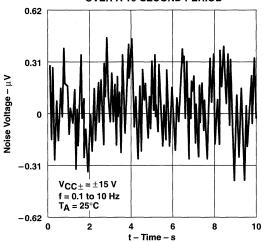


Figure 16

TLC251, TLC251A, TLC251B, TLC251Y LINCMOSTM PROGRAMMABLE LOW-POWER OPERATIONAL AMPLIFIERS

D OR P PACKAGE

(TOP VIEW)

7 ∇_{DD}

ΠΟυτ 6

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BIAS SELECT

OFFSET N2

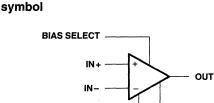
- Wide Range of Supply Voltages 1.4 V to 16 V
- True Single-Supply Operation
- Common-Mode Input Voltage Range Includes the Negative Rail
- Low Noise . . . 30 nV/√Hz Typ at 1 kHz (High Bias)
- **ESD Protection Exceeds 2000 V Per** MIL-STD-833C, Method 3015.1

OFFSET N1

V_{DD}_/GND

IN-

IN+ **∏** 3



OFFSET N1 **OFFSET N2**

description

The TLC251C, TLC251AC, and TLC251BC are low-cost, low-power programmable operational amplifiers designed to operate with single or dual supplies. Unlike traditional metal-gate CMOS operational amplifiers, these devices utilize Texas Instruments silicon-gate LinCMOS™ process, giving them stable input offset voltages without sacrificing the advantages of metal-gate CMOS.

This series of parts is available in selected grades of input offset voltage and can be nulled with one external potentiometer. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this family is ideally suited for battery-powered or energy-conserving applications. A bias-select pin can be used to program one of three ac performance and power-dissipation levels to suit the application. The series features operation down to a 1.4-V supply and is stable at unity gain.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC251C series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS™ operational amplifiers without the power penalties of traditional bipolar devices. Remote and inaccessible equipment applications are possible using the low-voltage and low-power capabilities of the TLC251C series.

In addition, by driving the bias-select input with a logic signal from a microprocessor, these operational amplifiers can have software-controlled performance and power consumption. The TLC251C series is well suited to solve the difficult problems associated with single battery and solar cell-powered applications.

The TLC251C series is characterized for operation from 0°C to 70°C.

AVAILABLE OPTIONS

	V _{IO} max AT 25°C	PACKAGED DEVICES		CHIP FORM
TA		SMALL OUTLINE (D)	PLASTIC DIP (P)	(Y)
	10 mV	TLC251CD	TLC251CP	TLC251Y
0°C to 70°C	5 mV	TLC251ACD	TLC251ACP	_
	2 mV	TLC251BCD	TLC251BCP	_

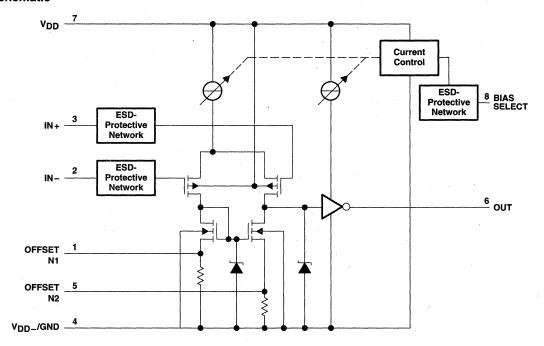
The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC251CDR). Chips are tested at 25°C.

LinCMOS is a trademark of Texas Instruments Incorporated



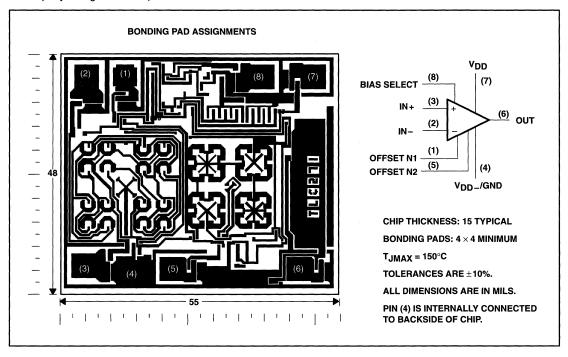
TLC251, TLC251A, TLC251B, TLC251Y LinCMOS™ PROGRAMMABLE LOW-POWER OPERATIONAL AMPLIFIERS SLOS001E – JULY 1983 – REVISED AUGUST 1994

schematic



TLC251Y chip information

These chips, properly assembled, display characteristics similar to the TLC251C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TLC251, TLC251A, TLC251B, TLC251Y LinCMOS™ PROGRAMMABLE LOW-POWER OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	±18 V
Input voltage range, V _I (any input)	
Duration of short circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD}_/GND.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{DD}		1.4	16	V
	V _{DD} = 1.4 V	0	0.2	
Common mode innut valtage Vi-	V _{DD} = 5 V	-0.2	4	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	9	V
	V _{DD} = 16 V	-0.2	14	
Operating free-air temperature, TA		0	70	°C
Bias-select voltage			Applica	

HIGH-BIAS MODE

electrical characteristics at specified free-air temperature

					Т	LC251C	, TLC25	1AC, TL	C251BC		
	PARAMETER		TEST CONDITIONS	TAT	V	DD = 5 \	,	٧ _t	OD = 10	v	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		1.1	10		1.1	10	
		TLC251C		Full range			12			12	
			V _O = 1.4 V, V _{IC} = 0 V,	25°C		0.9	5		0.9	5	
VIO	Input offset voltage	TLC251AC	$R_S = 50 \Omega$,	Full range			6.5			6.5	mV
		TI 0054D0	$R_L = 10 \text{ k}\Omega$	25°C		0.34	2		0.39	2	
		TLC251BC		Full range			3			3	
αΝΙΟ	Average temperature input offset voltage	coefficient of		25°C to 70°C		1.8			2		μV/°C
			$V_O = V_{DD}/2$,	25°C		0.1			0.1		
ΙΟ	Input offset current (s	see Note 4)	V _{IC} = V _{DD} /2	70°C		7	300		7	300	рA
		- M-4- A	$V_O = V_{DD}/2$,	25°C		0.6			0.7		^
IB	Input bias current (se	e Note 4)	V _{IC} = V _{DD} /2	70°C		40	600		50	600	pΑ
	Common-mode input	voltage		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		٧
VICR	range (see Note 5)	voltage		Full range	-0.2 to 3.5			-0.2 to 8.5			٧
				25°C	3.2	3.8		8	8.5		
Vон	High-level output volt	age	V _{ID} = 100 mV,	0°C	3	3.8		7.8	8.5		٧
			$R_L = 10 \text{ k}\Omega$	70°C	3	3.8		7.8	8.4		
				25°C		0	50		0	50	
VOL	Low-level output volta	age	$V_{\text{ID}} = -100 \text{ mV},$ $I_{\text{OL}} = 0$	0°C		0	50		0	50	mV
			IOL = 0	70°C		0	50		0	50	
				25°C	5	23		10	36		
A_{VD}	Large-signal different amplification	ial voltage	R _L = 10 kΩ, See Note 6	0°C	4	27		7.5	42		V/mV
	amplification		Gee Note o	70°C	4	20		7.5	32		
				25°C	65	80		65	85		
CMRR	Common-mode rejec	tion ratio	V _{IC} = V _{ICR} min	0°C	60	84		60	88		dB
				70°C	60	85		60	88		
		,		25°C	65	95		65	95		
ksvr	Supply-voltage reject (ΔVDD/ΔVIO)	ion ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$ $V_{O} = 1.4 \text{ V}$	0°C	60	94		60	94		dB
	(U) * C(U) - 4 (U)		· U = 1.7 V	70°C	60	96		60	96		
I(SEL)	Input current (BIAS S	SELECT)	V _{I(SEL)} = 0	25°C		-1.4			-1.9		μΑ
			$V_O = V_{DD}/2$,	25°C		675	1600		950	2000	
lDD	Supply current		$V_{IC} = V_{DD}/2$,	0°C		775	1800		1125	2200	μА
			No load	70°C		575	1300		750	1700	

[†] Full range is 0°C to 70°C.

^{6.} At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

HIGH-BIAS MODE

operating characteristics, $V_{DD} = 5 \text{ V}$

	PARAMETER	1	EST CONDITION	ONS	TA	TLC2510	UNIT					
						MIN	TYP	MAX				
					25°C		3.6					
ļ				V _{I(PP)} = 1 V	0°C		4					
SR	Slew rate at unity gain	R _L = 10 kΩ,	C. 20 pE		70°C		3		V/vo			
Jon .	Siew rate at unity gain	n[= 10 k22,	CL = 20 pr		25°C		2.9		V/μs			
1		$V_{i(PP)} = 2.$				*	$V_{I(PP)} = 2.5 V$	0°C		3.1		
				70°C		2.5						
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		25		nV/√Hz			
	-				25°C		320					
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	$C_{L} = 20 pF$,	$R_L = 10 \text{ k}\Omega$	0°C		340		kHz			
ł					70°C		260					
					25°C		1.7					
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$		0°C		2		MHz			
					70°C		1.3					
					25°C		46°					
φm	Phase margin	V _I = 10 mV,	f = B ₁ ,	C _L = 20 pF	0°C		47°					
					70°C		44°					

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER	1	EST CONDITION	ONS	TA	TLC251	UNIT		
						MIN	TYP	MAX	
,					25°C		5.3		
		Ì		V _{I(PP)} = 1 V	0°C		5.9		
SR	Slew rate at unity gain	B 10 kg	C _I = 20 pF		70°C		4.3		V/us
Jon .	Siew rate at unity gain	TL = 10 K32,	CL = 20 pr		25°C		4.6		V/μs
		1		$V_{I(PP)} = 5.5 V$	0°C		5.1		
					70°C		3.8		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		25		nV/√Hz
					25°C		200		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	$C_L = 20 pF$,	$R_L = 10 \text{ k}\Omega$	0°C		220		kHz
					70°C		140		
					25°C		2.2		
B ₁	Unity-gain bandwidth	$V_{i} = 10 \text{ mV},$	$C_L = 20 pF$		0°C		2.5		MHz
					70°C		1.8		1
		1			25°C		49°		
φm	Phase margin	$V_{j} = 10 \text{ mV},$	$f = B_1$	$C_L = 20 pF$	0°C		50°		
					70°C		46°		

MEDIUM-BIAS MODE

electrical characteristics at specified free-air temperature

					Т	LC251C	, TLC25	1AC, TL	C251BC		
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5 \	,	٧	D = 10	V	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		1.1	10		1.1	10	
		TLC251C	V- 14V	Full range			12			12	
l.,	land offert college	TI 005440	V _O = 1.4 V, V _{IC} = 0 V,	25°C		0.9	5		0.9	5	
VIO	Input offset voltage	TLC251AC	$R_S = 50 \Omega$,	Full range			6.5			6.5	mV
1		TI 0054D0	$R_L = 10 \text{ k}\Omega$	25°C		0.34	2		0.39	2	
		TLC251BC		Full range			3			3	
ανιο	Average temperature input offset voltage	coefficient of		25°C to 70°C		1.7			2.1		μV/°C
1	land offers and the	Note 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		- ^
110	Input offset current (s	ee Note 4)	$V_{IC} = V_{DD}/2$	70°C		7	300		7	300	pΑ
1	Input bigs gurrent (as	o Noto 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		π Λ
ΙΒ	Input bias current (se	e Note 4)	$V_{IC} = V_{DD}/2$	70°C		40	600		50	600	рA
					-0.2	-0.3		-0.2	-0.3		
				25°C	to 4	to 4.2		to 9	to 9.2		V
VICR	Common-mode input range (see Note 5)	voltage			-0.2	4.2		-0.2	5.2		
	range (coo rivile o)			Full range	-0.2 to			to			v
					3.5			8.5			
			1001/	25°C	3.2	3.9		8	8.7		
Vон	High-level output volta	age	$V_{ID} = 100 \text{ mV},$ $R_{I} = 10 \text{ k}\Omega$	0°C	3	3.9		7.8	8.7		٧
				70°C	3	4		7.8	8.7		
			V 400 V	25°C		0	50		0	50	
VOL	Low-level output volta	ige	V _{ID} = -100 mV, I _{OL} = 0	0°C		0	50		0	50	mV
			-OL -	70°C		0	50		0	50	
	1	-1	D 401-0	25°C	25	170		25	275		
AVD	Large-signal different amplification	iai voitage	$R_L = 10 \text{ k}\Omega$, See Note 6	0°C	15	200		15	320		V/mV
				70°C	15	140		15	230		
				25°C	65	91		65	94		
CMRR	Common-mode reject	tion ratio	V _{IC} = V _{ICR} min	0°C	60	91		60	94		dB
				70°C	60	92		60	94		
				25°C	70	93		70	93		
ksvr	Supply-voltage rejecti (ΔVDD/ΔVIO)	on ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$ $V_{O} = 1.4 \text{ V}$	0°C	60	92		60	92		dB
	(~*DD/~*IO)			70°C	60	94		60	94		
li(SEL)	Input current (BIAS S	ELECT)	$V_{I(SEL)} = V_{DD}/2$	25°C		-130			-160		nA
		,	$V_O = V_{DD}/2$,	25°C		105	280		143	300	
IDD	Supply current		$V_{IC} = V_{DD}/2$,	0°C		125	320		173	400	μΑ
			No load	70°C		85	220		110	280	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



MEDIUM-BIAS MODE

operating characteristics, V_{DD} = 5 V

	PARAMETER	т	EST CONDITIO	DNS	TA	TLC251C, TLC251AC, TLC251BC			UNIT
						MIN	TYP	MAX	
					25°C		0.43		
				V _{I(PP)} = 1 V	0°C		0.46		
SR	Slew rate at unity gain	R _L = 100 kΩ,	C: 20 pE		70°C		0.36		Mus
on	Siew rate at unity gain	H[= 100 k32,	C[= 20 pr		25°C		0.40		V/μs
				$V_{I(PP)} = 2.5 V$	0°C		0.43		
					70°C		0.34		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		32		nV/√Hz
					25°C		55		
ВОМ	Maximum output-swing bandwidth	Vo = VoH,	C _L = 20 pF,	$R_L = 100 \text{ k}\Omega$	0°C		60		kHz
					70°C		50		
					25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$		0°C		600		kHz
					70°C		400		
					25°C		40°		
φm	Phase margin	V _I = 10 mV,	$f = B_1$,	C _L = 20 pF	0°C		41°		
					70°C		39°		

operating characteristics, V_{DD} = 10 V

	PARAMETER	т	EST CONDITIO	TA	TLC251C, TLC251AC, TLC251BC			UNIT	
					-	MIN	TYP	MAX	
					25°C		0.62		
				V _{I(PP)} = 1 V	0°C		0.67		
SR	Class rate at units agin	B: 100 kg	C: 00 mE		70°C		0.51		V///
J Sh	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$	CL = 20 pr		25°C		0.56		V/μs
				$V_{I(PP)} = 5.5 V$	0°C		0.61		
					70°C		0.46		1
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		32		nV/√Hz
	,				25°C		35		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	$C_{L} = 20 pF$,	$R_L = 100 \text{ k}\Omega$	0°C		40		kHz
1			•		70°C	,	30		
					25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF		0°C		710		kHz
Ì					70°C		510]
					25°C		43°		
φm	Phase margin	V _I = 10 mV,	f = B ₁ ,	C _L = 20 pF	0°C		44°		
					70°C		42°		

LOW-BIAS MODE

electrical characteristics at specified free-air temperature

					Т	LC251C	, TLC25	1AC, TL	C251BC		
	PARAMETER		TEST CONDITIONS	T _A †	٧	DD = 5 \	,	٧ _t	D = 10	V	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	·
		TI 00510		25°C		1.1	10		1.1	10	
		TLC251C	V- 14V	Full range			12			12	
.,	l	TI 005440	$V_O = 1.4 \text{ V},$ $V_{IC} = 0 \text{ V},$	25°C		0.9	5		0.9	5	
VIO	Input offset voltage	TLC251AC	$R_S = 50 \Omega$,	Full range			6.5			6.5	mV
ĺ		TI 0054B0	$R_L = 10 M\Omega$	25°C		0.24	2		0.26	2	
		TLC251BC		Full range			3			3	
ανιο	Average temperature input offset voltage	coefficient of		25°C to 70°C		1.1			1		μV/°C
1	Innut offeet coment (e	as Nota 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		- 4
lo	Input offset current (s	ee Note 4)	$V_{IC} = V_{DD}/2$	70°C		7	300		7	300	рA
1	Innut bigg gurrant /gg	a Nieta 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		- 4
IB	Input bias current (se	e Note 4)	$V_{IC} = V_{DD}/2$	70°C		40	600		50	600	рA
	Common-mode input	voltage		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		٧
VICR	range (see Note 5)	rollago		Full range	-0.2 to 3.5			-0.2 to 8.5			V
				25°C	3.2	4.1		8	8.9		
Vон	High-level output volt	age	$V_{ID} = 100 \text{ mV},$ $R_{I} = 1 \text{ M}\Omega$	0°C	3	4.1		7.8	8.9		v
			LL = 1 IVIS2	70°C	3	4.2		7.8	8.9		
				25°C		0	50		0	50	
VOL	Low-level output volta	ige	V _{ID} = -100 mV, I _{OL} = 0	0°C		0	50		0	50	mV
			IOL	70°C		0	50		0	50	
				25°C	50	520		50	870		
AVD	Large-signal different amplification	ial voltage	$R_L = 1 M\Omega$, See Note 6	0°C	50	700		50	1030		V/mV
	атриновног		000 14010 0	70°C	50	380		50	660		
				25°C	65	94		65	97		
CMRR	Common-mode reject	tion ratio	V _{IC} = V _{ICR} min	0°C	60	95		60	97		dB
				70°C	60	95		60	97		
	_			25°C	70	97		70	97		
ksvr	Supply-voltage rejecti (ΔVDD/ΔVIO)	ion ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$ $V_{O} = 1.4 \text{ V}$	0°C	60	97	***	60	97		dB
	(2400/2410)		VO = 1.4 V	70°C	60	98		60	98		
I _(SEL)	Input current (BIAS S	ELECT)	V _{I(SEL)} = V _{DD}	25°C		65			95		nA
			$V_O = V_{DD}/2$,	25°C		10	17		14	23	
lDD	Supply current		$V_{IC} = V_{DD}/2$,	0°C		12	21		18	33	μΑ
			No load	70°C		8	14		11	20	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



LOW-BIAS MODE

operating characteristics, V_{DD} = 5 V

	PARAMETER	1	EST CONDITIO	DNS	TA	TLC2510	C, TLC2 .C251B0		UNIT
						MIN	TYP	MAX	
					25°C		0.03		
				V _{I(PP)} = 1 V	0°C		0.04		
SR	Claus mate at smiths agin	D. 1 MO	C. 20 pF		70°C		0.03		Muo
on	Slew rate at unity gain	$R_L = 1 M\Omega$,			25°C		0.03		V/μs
				$V_{I(PP)} = 2.5 V$	0°C		0.03		
				` '	70°C		0.02		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		68		nV/√Hz
					25°C		5		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	$C_L = 20 pF$,	$R_L = 1 M\Omega$	0°C		6		kHz
					70°C		4.5		
					25°C		85		
B ₁	Unity-gain bandwidth	$V_I = 10 \text{ mV},$	C _L = 20 pF		0°C		100		kHz
					70°C		65		
					25°C		34°		
φm	Phase margin	V _I = 10 mV,	$f = B_1$	C _L = 20 pF	0°C		36°		
					70°C	1	30°		

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER	Т	TEST CONDITIONS				TLC251C, TLC251AC, TLC251BC			
					TA	MIN	TYP	MAX		
					25°C		0.05			
				V _{I(PP)} = 1 V	0°C		0.05			
SR	Slow rate at unity gain	D. 1MO	C: - 20 pE		70°C		0.04		Who	
J SH	Slew rate at unity gain	$R_L = 1 M\Omega$,	C _L = 20 pF	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	25°C		0.04		V/μs	
				$V_{I(PP)} = 5.5 \text{ V}$	0°C		0.05			
					70°C		0.04			
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		25°C		68		nV/√Hz	
					25°C		1			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$	$C_L = 20 pF$	$R_L = 1 M\Omega$	0°C		1.3		kHz	
					70°C		0.9			
					25°C		110			
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$		0°C		125		kHz	
					70°C		90]	
					25°C		38°			
φm	Phase margin	V _I = 10 mV,	$f = B_1$	$C_L = 20 pF$	0°C		40°			
					70°C		34°		1	

TLC251, TLC251A, TLC251B, TLC251Y LinCMOS™ PROGRAMMABLE LOW-POWER OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, $V_{DD} = 1.4 \text{ V}$

	PARAMETE	R	TEST COND	ITIONST	TA‡	BIAS	TLC251	C, TLC2 .C251B0		UNIT
							MIN	TYP	MAX	
		TLC251C	1		25°C	Any			10	
		1202310			Full range	Ally			12	
VIO	Input offset	TLC251AC	V _O = 0.2 V,	$R_S = 50 \Omega$	25°C	Any			5	mV
V10	voltage	TEOZSTAO	VO = 0.2 V,	115 - 30 22	Full range	Ally			6.5	1110
		TLC251BC			25°C	Any			2	
		12023100			Full range	Ally			3	
αVIO	Average temp coefficient of i voltage				25°C to 70°C	Any		1		μV/°C
lio	Input offset cu	urront	V _O = 0.2 V		25°C	Any		1		pА
lo	input onset ct		VO = 0.2 V		Full range	Any			300	PΑ
I _{IB}	Input bias cur	ront	V _O = 0.2 V		25°C	Any		1		рA
אוי	Input blas cui		VO = 0.2 V		Full range	Ally			600	PΛ
VICR	Common-moo voltage range				25°C	Any	0 to 0.2			V
V _{ОМ}	Peak output v swing§	oltage	V _{ID} = 100 mV		25°C	Any	450	700		mV
AVD	Large-signal	differential	V _O = 100 to 300 mV,	Po = 50 O	25°C	Low		20		
~\D	voltage amplit	fication	VO = 100 to 300 mv,	HS = 30 22	23 0	High		10		
CMRR	Common-mod ratio	de rejection	$R_S = 50 \Omega$, $V_{IC} = V_{ICR}$ min	$V_{O} = 0.2 \text{ V},$	25°C	Any	60	77		dB
I _{DD}	Supply curren	+	V _O = 0.2 V,	No load	25°C	Low		5	17	μА
טטי	Cappiy curren		1 VO = 0.2 V,	140 1044		High		150	190	μΛ

 $[\]overline{t}$ All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following values: for low bias, $R_L=1~M\Omega$, for medium bias, $R_L=10~k\Omega$, and for high bias, $R_L=10~k\Omega$.

operating characteristics, V_{DD} = 1.4 V, T_A = 25°C

	PARAMETER	TEST CONDITIONS	BIAS	TLC251C, TLC251AC, TLC251BC			UNIT
				MIN	TYP	MAX	
<u>.</u>	Unity-gain bandwidth	C _L = 100 pF	Low	12			kHz
B ₁	Onity-gain bandwidth	C[= 100 pr	High		12		КПZ
SR	Slew rate at unity gain	See Figure 1	Low	0.001			V/μs
on .	Siew rate at unity gain	See Figure 1	High		0.1		V /μS
	Overshoot factor	Can Figure 1	Low		35%		
	Oversnoot factor	See Figure 1	High		30%		

[‡] Full range is 0°C to 70°C.

[§] The output swings to the potential of VDD_/GND.

TLC251, TLC251A, TLC251B, TLC251Y LinCMOS™ PROGRAMMABLE **LOW-POWER OPERATIONAL AMPLIFIERS**

SLOS001E - JULY 1983 - REVISED AUGUST 1994

electrical characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

						7	LC251	7				
	PARAMETER	TEST CONDITIONS	Н	GH-BIA MODE	s	ME	DIUM-B MODE	IAS	L	OW-BIA MODE	S	UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $V_{IC} = 0 \text{ V},$ $R_{S} = 50 \Omega,$ R_{L}^{\dagger}		1.1	10		1.1	10		1.1	10	mV
αVIO	Average temperature coefficient of input offset voltage			1.8			1.7			1.1		μV/°C
lio	Input offset current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.1			0.1			0.1		pА
lв	Input bias current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.6			0.6			0.6		рA
VICR	Common-mode input voltage range (see Note 5)		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		٧
Vон	High-level output voltage	V _{ID} = 100 mV, R _L †	3.2	3.8		3.2	3.9		3.2	4.1		V
VOL	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0		0	50		0	50		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 0.25 V, R _L †	5	23		25	170		50	480		V/mV
CMRR	Common-mode rejection ratio	VIC = VICRmin	65	80		65	91		65	94		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _{DD} = 5 V to 10 V, V _O = 1.4 V	65	95		70	93		70	97		dB
l(SEL)	Input current (BIAS SELECT)	V _{I(SEL)} = V _{DD} /2		-1.4			-0.13			0.065		μΑ
lDD	Supply current	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2,$ No load		675	1600		105	280		10	17	μА

 $[\]overline{T}$ For high-bias mode, R_L = 10 k Ω ; for medium-bias mode, R_L = 100 k Ω ; and for low-bias mode, R_L = 1 M Ω :

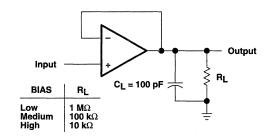
NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.

operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

							T	LC251	1				
	PARAMETER	TEST CONDITIONS			HIGH-BIAS MODE			MEDIUM-BIAS MODE			LOW-BIAS MODE		
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
SR	Slew rate at	RL [†] ,	V _{I(PP)} = 1 V		3.6			0.43			0.03		V/μs
Jon L	unity gain	C _L = 20 pF	$V_{I(PP)} = 2.5 V$		2.9			0.40			0.03		ν /μδ
٧n	Equivalent input noise voltage	f = 1 kHz,	R _S = 20 Ω		25			32			68		nV/√Hz
ВОМ	Maximum output swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$	C _L = 20 pF,		320			55			4.5		kHz
B ₁	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF		1700			525			65		kHz
φm	Phase margin	f = B ₁ , C _L = 20 pF	V _I = 10 mV,		46°			40°			34°		

[†] For high-bias mode, $R_L = 10 \text{ k}\Omega$; for medium-bias mode, $R_L = 100 \text{ k}\Omega$; and for low-bias mode, $R_L = 1 \text{ M}\Omega$.

PARAMETER MEASUREMENT INFORMATION



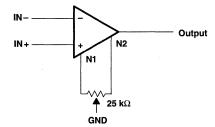


Figure 1. Unity-Gain Amplifier

Figure 2. Input Offset Voltage Null Circuit

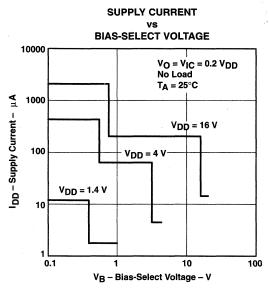
TYPICAL CHARACTERISTICS

Table of Graphs

				FIGURE
lDD	Supply current		vs Bias-select voltage vs Supply voltage vs Free-air temperature	3 4 5
			vs Frequency	6
AVD			vs Frequency	7
		High bias	vs Frequency	8
		Low bias	vs Frequency	6
	Phase shift	Medium bias	vs Frequency	7
	,	vs Frequency	8	



TYPICAL CHARACTERISTICS



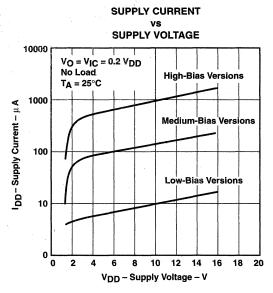


Figure 3

Figure 4

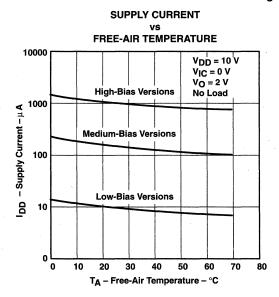


Figure 5

TYPICAL CHARACTERISTICS

LOW-BIAS LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT**

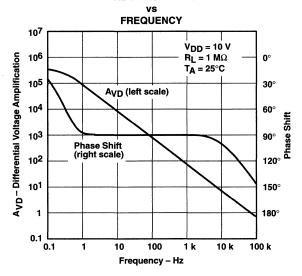


Figure 6

MEDIUM-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

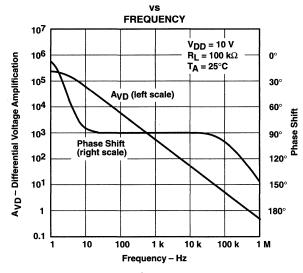
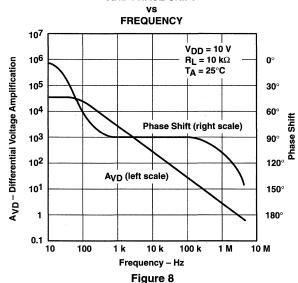


Figure 7



TYPICAL CHARACTERISTICS

HIGH-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



APPLICATION INFORMATION

latch-up avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNPN structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the operational amplifier supplies should be applied simultaneously with, or before, application of any input signals.

APPLICATION INFORMATION

using BIAS SELECT

The TLC251 has a terminal called BIAS SELECT that allows the selection of one of three I_{DD} conditions (10, 150, and 1000 μ A typical). This allows the user to trade-off power and ac performance. As shown in the typical supply current (I_{DD}) versus supply voltage (V_{DD}) curves (Figure 4), the I_{DD} varies only slightly from 4 V to 16 V. Below 4 V, the I_{DD} varies more significantly. Note that the I_{DD} values in the medium- and low-bias modes at $V_{DD}=1.4$ V are typically 2 μ A, and in the high mode are typically 12 μ A. The following table shows the recommended BIAS SELECT connections at $V_{DD}=10$ V.

BIAS MODE	AC PERFORMANCE	BIAS SELECT CONNECTION [†]	TYPICAL I _{DD} ‡
Low	Low	V_{DD}	10 μΑ
Medium	Medium	0.8 V to 9.2 V	150 μΑ
High	High	Ground pin	1000 μΑ

[†] Bias selection may also be controlled by external circuitry to conserve power, etc. For information regarding BIAS SELECT, see Figure 3 in the typical characteristics curves.

output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage (V_{OH}) is virtually independent of the I_{DD} selection and increases with higher values of V_{DD} and reduced output loading. The low-level output voltage (V_{OL}) decreases with reduced output current and higher input common-mode voltage. With no load, V_{OL} is essentially equal to the potential of V_{DD} _/GND.

input offset nulling

The TLC251C series offers external offset null control. Nulling may be achieved by adjusting a 25-k Ω potentiometer connected between the offset null terminals with the wiper connected to the device V_{DD}_/GND pin as shown in Figure 2. The amount of nulling range varies with the bias selection. At an I_{DD} setting of 1000 μ A (high bias), the nulling range allows the maximum offset specified to be trimmed to zero. In low or medium bias or when the amplifier is used below 4 V, total nulling may not be possible for all units.

supply configurations

Even though the TLC251C series is characterized for single-supply operation, it can be used effectively in a split-supply configuration when the input common-mode voltage (V_{ICR}), output swing (V_{OL} and V_{OH}), and supply voltage limits are not exceeded.

circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive dc leakages.



[‡] For I_{DD} characteristics at voltages other than 10 V, see Figure 4 in the typical characteristics curves.

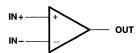
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- A-Suffix Versions Offer 5-mV V_{IO}
- B-Suffix Versions Offer 2-mV V_{IO}
- Wide Range of Supply Voltages
 1.4 V to 16 V
- True Single-Supply Operation
- Common-Mode Input Voltage Includes the Negative Rail
- Low Noise . . . 30 nV/√Hz Typ at f = 1 kHz (High-Bias Versions)

symbol (each amplifier)

description

The TLC252, TLC25L2, and TLC25M2 are low-cost, low-power dual operational amplifiers designed to operate with single or dual supplies. These devices utilize the Texas Instruments



silicon gate LinCMOS™ process, giving them stable input offset voltages that are available in selected grades of 2, 5, or 10 mV maximum, very high input impedances, and extremely low input offset and bias currents. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this series is ideally suited for battery-powered or energy-conserving applications. The series offers operation down to a 1.4-V supply, is stable at unity gain, and has excellent noise characteristics.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

AVAILABLE OPTIONS

	Viemay	PACKAGED	DEVICES	CHIP FORM
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)	(Y)
	10 mV	TLC252CD	TLC252CP	TLC252Y
	5 mV	TLC252ACD	TLC252ACP	
	2 mV	TLC252BCD	TLC252BCP	
	10 mV	TLC25L2CD	TLC25L2CP	TLC25L2Y
0°C to 70°C	5 mV	TLC25L2ACD	TLC25L2ACP	all characters and a second and
	2 mV	TLC25L2BCD	TLC25L2BCP	
	10 mV	TLC25M2CD	TLC25M2CP	TLC25M2Y
	5 mV	TLC25M2ACD	TLC25M2ACP	
	2 mV	TLC25M2BCD	TLC25M2BCP	

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC252CDR). Chips are tested at 25°C.

LinCMOS is a trademark of Texas Instruments Incorporated.



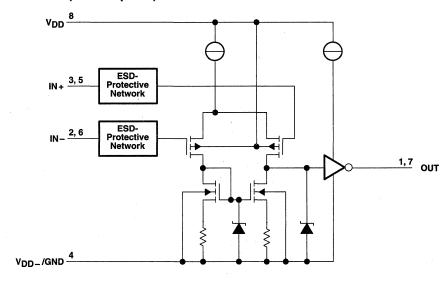
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description (continued)

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC252/25_2 series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS™ operational amplifiers without the power penalties of traditional bipolar devices. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC252/25_2 series devices. Remote and inaccessible equipment applications are possible using their low-voltage and low-power capabilities. The TLC252/25_2 series is well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications. This series includes devices that are characterized for the commercial temperature range and are available in 8-pin plastic dip and the small-outline package. The device is also available in chip form.

The TLC252/25_2 series is characterized for operation from 0°C to 70°C.

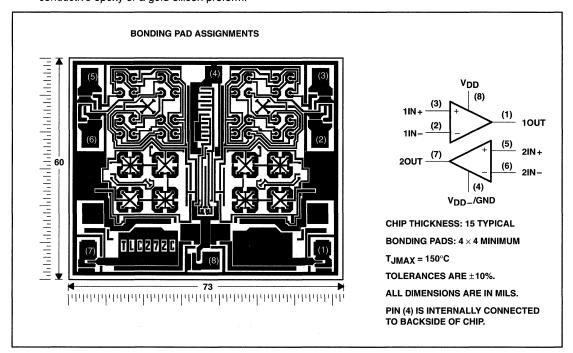
equivalent schematic (each amplifier)



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TLC252Y, TLC25L2Y, and TLC25M2Y chip information

These chips, properly assembled, display characteristics similar to the TLC252/25_2. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input)	
Duration of short circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation	. See Dissipation Rating Table
Operating free-air temperature range, T _A	0°C to 70°C
Storage temperature range	65°C to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD}_/GND.

2. Differential voltages are at IN+, with respect to IN-.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_{\mbox{\scriptsize A}} \le 25^{\circ}\mbox{\scriptsize C}$ POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{DD}		1.4	16	V
	V _{DD} = 1.4 V	0	0.2	
Common mode inmut veltare V	V _{DD} = 5 V	-0.2	4	V.
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	9	v
	V _{DD} = 16 V	-0.2	14	
Operating free-air temperature, TA	-	0	70	°C

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electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V (unless otherwise noted)

	DADAM	TED		.o+	TL	.C252_	С	TL	C25L2	_C	TL	C25M2	_C	UNIT
	PARAME	IEK	TEST CONDITION	151	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
				25°C			10			10			10	
		TLC25_2C		0°C to 70°C			12			12			12	
	Input		V _O = 0.2 V,	25°C			5			5			5	
V _{IO}	offset voltage	TLC25_2AC	$R_S = 50 \Omega$	0°C to 70°C			6.5			6.5			6.5	mV
				25°C			2			2			2	
		TLC25_2BC		0°C to 70°C			3			3			3	
ανιο		temperature nt of input tage		25°C to 70°C		1			1			1		μV/°C
				25°C		1			1			1		
ΙO	Input offs	set current	V _O = 0.2 V	0°C to 70°C			300			300			300	рA
				25°C		1			1			1		
lΒ	Input bia	s current	V _O = 0.2 V	0°C to 70°C			600	ı		600			600	рA
VICR	Common voltage r	n-mode input ange		25°C	0 to 0.2			0 to 0.2			0 to 0.2			V
VOM	Peak out swing‡	put voltage	V _{ID} = 100 mV	25°C	450	700		450	700		450	700		mV
AVD	Large-sig differenti amplifica	al voltage	$V_O = 100 \text{ to } 300 \text{ mV},$ $R_S = 50 \Omega$	25°C		10			20			20		V/mV
CMRR	Commor rejection		V _O = 0.2 V, V _{IC} = V _{ICR} min	25°C	60	77		60	- 77		60	77		dB
IDD	Supply c	urrent	V _O = 0.2 V, No load	25°C		300	375		25	34		200	250	μА

TAll characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following value: for low bias $R_L = 1~M\Omega_c$ for medium bias $R_L = 100 \text{ k}\Omega$, and for high bias $R_L = 10 \text{ k}\Omega$.

operating characteristics, V_{DD} = 1.4 V, T_A = 25°C

	PARAMETER	TEGT COMPLETIONS	TLC252_C			TL	C25L2_	С	TLC25M2_C			UNIT
	PARAMETER	TEST CONDITIONS	MIN TYP MAX		MIN TYP MAX		MAX MIN TYP MAX			JONII		
B ₁	Unity-gain bandwidth	$AV = 40 \text{ dB},$ $C_L = 10 \text{ pF},$ $R_S = 50 \Omega$		12			12			12	,	kHz
SR	Slew rate at unity gain	See Figure 1		0.1			0.001			0.01		V/μs
	Overshoot factor	See Figure 1		30%			35%			35%	,	

[‡] The output swings to the potential of V_{DD}_/GND.

TLC252A, TLC252B, TLC252Y, TLC25L2A, TLC25L2B, TLC25L2Y, TLC25M2A, TLC25M2B, TLC25M2Y LINCMOSTM DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST COND	ITIONS	TAT	TLC252	C, TLC2 .C252B		UNIT
				:		MIN	TYP	MAX	
		TLC252C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		11.02520	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	
V	Innut offert valters	TICOFOAC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	\/
ViO	Input offset voltage	TLC252AC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	mV
		TLC252BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.23	2	
		TLUZSZBU	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3	
αVIO	Average temperature coeff input offset voltage	ficient of			25°C to 70°C		1.8		μV/°C
I	logest offerst assument (a.e. N	-1- 4\	V- 05V	V - 0.5.V	25°C		0.1		1
lio	Input offset current (see No	ote 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	рA
li-	Input bigg gurrent (a.e. Not	·	V- 05V	V : 0.E.V	25°C		0.6		A
IB	Input bias current (see Not	(e 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		40	600	рA
	Common-mode input volta	ae			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	range (see Note 5)				Full range	-0.2 to 3.5			٧
			***************************************		25°C	3.2	3.8		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	3	3.8		V
					70°C	3	3.8		
		,			25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
					25°C	5	23		
AVD	Large-signal differential vo amplification	Itage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	0°C	4	27		V/mV
	ampinioation				70°C	4	20		
i					25°C	65	80		
CMRR	Common-mode rejection ra	atio	V _{IC} = V _{ICR} min		0°C	60	84		dB
					70°C	60	85		
	Cumply voltage rais -+1	41.0			25°C	65	95		
ksvr	Supply-voltage rejection ra (ΔV _{DD} /ΔV _{DD})	IIIO	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
l					70°C	60	96		
			V _O = 2.5 V,	V _{IC} = 2.5 V,	25°C		1.4	3.2	
IDD	Supply current (two amplif	iers)	VO = 2.5 V, No load	VIC = 2.5 V,	0°C		1.6	3.6	mA
					70°C		1.2	2.6	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	TAT	TLC252	C, TLC2 .C252B0		UNIT
_					'^	MIN	TYP	MAX	
		TI 00500	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC252C	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			12	
V	lament affact contains	TLC252AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	Input offset voltage	TLUZSZAU	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	mv
		TLC252BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.29	2	
		TLUZSZBU	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3	
αVIO	Average temperature coeff offset voltage	ficient of input			25°C to 70°C		2		μV/°C
1	Innut offert assument (e.g. N	-4- 4\	V- 05V	V 05V	25°C		0.1		1
liO	Input offset current (see No	ote 4)	V _O = 2.5 V,	$V_{IC} = 2.5 V$	70°C		7	300	рA
l	Input bigg surrent (see Not	to 4)	V- 05V	V:= 05V	25°C		0.6		
IB	Input bias current (see Not	le 4)	$V_{O} = 2.5 \text{ V},$	V _{IC} = 2.5 V	70°C		50	600	рA
	Common-mode input volta	ae			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	range (see Note 5)	90			Full range	-0.2 to 8.5			٧
				Control of the Contro	25°C	8	8.5		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	8	8.5		٧
					70°C	7.8	8.4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
					25°C	10	36		
AVD	Large-signal differential vo amplification	Itage	$V_O = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	0°C	7.5	42		V/mV
	ampimoation				70°C	7.5	32		
					25°C	65	85		
CMRR	Common-mode rejection ra	atio	V _{IC} = V _{ICR} min		0°C	60	88		dB
					70°C	60	88		
	0 1 "				25°C	65	95		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVDD)	IIIO	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
					70°C	60	96		
			Vo - 5 V	V _{IC} = 5 V,	25°C		1.9	4	
IDD	Supply current (two amplifi	iers)	V _O = 5 V, No load	AIC = 2 A'	0°C		2.3	4.4	mA
					70°C		1.6	3.4	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LINCMOS™ DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, V_{DD} = 5 V

	PARAMETER		TEST CONDITI	ONS	TA	TLC252 TL	C, TLC2 .C252B0		UNIT
						MIN	TYP	MAX	
					25°C		3.6		
				V _{I(PP)} = 1 V	0°C		4		i i
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$	C _L = 20 pF,		70°C		3		V/μs
J Sn	Siew rate at unity gain	See Figure 1			25°C		2.9		V/μS
				$V_{I(PP)} = 2.5 V$	0°C		3.1		
					70°C		2.5		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		25		nV/√Hz
					25°C		320		
ВОМ	Maximum output-swing bandwidth	VO = VOH, See Figure	$C_L = 20 pF$,	$R_L = 100 \text{ k}\Omega$,	0°C		340		kHz
		Jee rigure			70°C		260		
					25°C		1.7		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		2		MHz
					70°C		1.3		
			. 5	0 00 5	25°C		46°		
φm	n Phase margin	V _I = 10 mV, See Figure 3		$C_L = 20 pF$,	0°C		47°		
		See . iguie o			70°C		43°		

operating characteristics, V_{DD} = 10 V

	PARAMETER		TEST CONDITI	ONS	TA	TLC252 TL	C, TLC2 .C252B0		UNIT
					"	MIN	TYP	MAX	
	•				25°C		5.3		
				V _{I(PP)} = 1 V	0°C		5.9		
SR	Slow rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 20 pF,		70°C		4.3		V/uo
on	Slew rate at unity gain	See Figure 1	_		25°C		4.6		V/μs
				$V_{I(PP)} = 5.5 V$	0°C		5.1		
	·]			70°C		3.8		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		25		nV/√Hz
					25°C		200		
ВОМ	Maximum output-swing bandwidth	VO = VOH, See Figure 1	$C_L = 20 pF$,	$R_L = 100 \text{ k}\Omega$,	0°C		220		kHz
	<u> </u>	Coo'r igaic i			70°C		140		
	,				25°C		2.2		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		2.5		MHz
					70°C		1.8		
		·	, D	0 00 - 5	25°C		49°		
φm	Phase margin	V _I = 10 mV, See Figure 3		$C_L = 20 pF$,	0°C		50°		
		garo o			70°C		46°		

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	TA [†]	TL	LC25L20 C25L2A C25L2B	С	UNIT
						MIN	TYP	MAX	
		TLC252C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLUZSZU	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	
VIO	Input offset voltage	TLC252AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	input onset voltage	TEO232AC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			6.5	1117
		TLC252BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.204	2	
		TEGESEBC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3	
αΝΙΟ	Average temperature co input offset voltage	efficient of			25°C to 70°C		1.1		μV/°C
li a	Input offeet ourrent (con	Note 4)	V- 05V	V:- 2 F V	25°C		0.1		ν Δ
ΙΟ	Input offset current (see	Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	pΑ
1	Innut bion ourset (one N	lata 4)	V- 05V	V:- 05V	25°C		0.6		^
lВ	Input bias current (see N	iole 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		50	600	pΑ
	Common-mode input vo	Itage			25°C	-0.2 to 4	-0.3 to 4.2		V
VICR	range (see Note 5)	ilage			Full range	-0.2 to 3.5			V
					25°C	3.2	4.1		
۷он	High-level output voltage	e	V _{ID} = 100 mV,	$R_L = 1 M\Omega$	0°C	3	4.1		٧
					70°C	3	4.2		
					25°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
	1				25°C	50	700		
A_{VD}	Large-signal differential amplification	voitage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	0°C	50	700		V/mV
	ampimoation .				70°C	50	380		
					25°C	65	94		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		0°C	. 60	95		dB
					70°C	60	95		
	0				25°C	70	97		
ksvr	Supply-voltage rejection (ΔVDD/ΔVDD)	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
	(_ · DD, _ • DD)				70°C	60	98		
			V- 05V	V:- 0.5.V	25°C		20	34	
lDD	Supply current (two amp	lifiers)	V _O = 2.5 V, No load	vIC = 2.5 V,	0°C		24	42	μΑ
					70°C		16	28	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC252, TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LinCMOS™ DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT	TL	-C25L20 C25L2A C25L2B	С	UNIT
						MIN	TYP	MAX	
		TLC252C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		11.02320	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	
V _{IO}	Input offset voltage	TLC252AC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.9	5	mV
VIO	input onset voltage	TEGESEAG	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			6.5	1111
		TLC252BC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.235	2	
		TEOZSZBO	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3	
αVIO	Average temperature coinput offset voltage	oefficient of			25°C to 70°C		1		μV/°C
l	Input offeet comput (e.e.	Note 4)	V- 5V	V 5.V	25°C		0.1		A
lo	Input offset current (see	Note 4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	70°C		8	300	pA
t	Input bigg gurrent (see	Note 4)	V _O = 5 V,	V 5.V	25°C		0.7		1
lВ	Input bias current (see	Note 4)	VO = 5 V	$V_{IC} = 5 V$	70°C		50	600	рA
	Common-mode input vo	oltage			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	range (see Note 5)	gc			Full range	-0.2 to 8.5		-	V
		7			25°C	8	8.9		
VOH	High-level output voltag	je	$V_{ID} = 100 \text{ mV},$	$R_L = 1 M\Omega$	0°C	7.8	8.9		V
					70°C	7.8	8.9		
					25°C		0	50	
VOL	Low-level output voltage	e	$V_{1D} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
	Large-signal differential	l voltogo			25°C	50	860		
AVD	amplification	voltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	0°C	50	1025		V/mV
					70°C	50	660		
			1		25°C	65	97		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min		0°C	60	97		dB
			<u> </u>		70°C	60	97		
	Cumply voltage vs!!:	a watia			25°C	70	97		
ksvr	Supply-voltage rejection (ΔV _{DD} /ΔV _{DD})	ıı ıaılu	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
			L		70°C	60	98		
			V _O = 5 V _s	V _{IC} = 5 V,	25°C		29	46	
IDD	Supply current (two am	plifiers)	VO = 5 V, No load	AIC = a A'	0°C		36	66	μΑ
					70°C		22	40	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LINCMOSTM DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, $V_{DD} = 5 \text{ V}$

	PARAMETER		TEST CONDITIO	DNS	[™] A	TLO	C25L2C C25L2A C25L2B	С	UNIT
						MIN	TYP	MAX	
					25°C		0.03		
				V _{I(PP)} = 1 V	0°C		0.04		
SR	Slow rate at unity gain	$R_L = 1 M\Omega$,	C _L = 20 pF,		70°C		0.03		V/uo
on .	Slew rate at unity gain	See Figure 1			25°C		0.03		V/μs
				$V_{I(PP)} = 2.5 V$	0°C		0.03		
]			70°C		0.02		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		68		nV/√Hz
					25°C		5		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure	$C_L = 20 pF$,	$R_L = 1 M\Omega$,	0°C		6		kHz
	barrawian	occ i iguic			70°C		4.5		
					25°C		85		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		100		MHz
					70°C		65		
		V 40 V		0 00 - 5	25°C		34°		
φm	Phase margin	V _I = 10 mV, See Figure 3		$C_L = 20 pF$,	0°C		36°		
] SSSgu, o o			70°C		30°		

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER		TEST CONDITI	ons	TA	TLO	TLC25L2C TLC25L2AC TLC25L2BC		
						MIN	TYP	MAX	
					25°C		0.05		
				V _{I(PP)} = 1 V	0°C		0.05		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	C _L = 20 pF,		70°C		0.04		V/μs
Jon .	Siew rate at unity gain	See Figure 1			25°C		0.04		V/μS
				$V_{I(PP)} = 5.5 V$	0°C		0.05		
					70°C		0.04		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		68		nV/√Hz
					25°C		1		
ВОМ	Maximum output-swing bandwidth	VO = VOH, See Figure 1	$C_L = 20 pF$,	$R_L = 1 M\Omega$,	0°C		1.3		kHz
	baridwidth	Oce rigare r			70°C		0.9		
					25°C		110		
B ₁	Unity-gain bandwidth	V _i = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		125		MHz
					70°C		90		
		V 40 V	, 5	0 00 5	25°C		38°		
φm	m Phase margin	V _I = 10 mV, See Figure 3	$f = B_1$,	$C_L = 20 pF$,	0°C		40°		
		550 , 194,50			70°C		34°		

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	T _A †	TL	.C25M20 C25M2A C25M2B	C	UNIT
						MIN	TYP	MAX	
		TLC252C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		11.02520	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	
V _{IO}	Input offset voltage	TLC252AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	input onset voltage	TEO252AC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	1111
		TLC252BC	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		0.22	2	
		11023250	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3	
ανιο	Average temperature co input offset voltage	efficient of			25°C to 70°C		1.7		μV/°C
1	Innut offeet surrent (e.e.	Note 4)	V- 05V	V 0.5.V	25°C		0.1		pA
ΙΟ	Input offset current (see	Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V	70°C		7	300	PΑ
1	Innut bigg growent (age !	ulata 4\	V _O = 2.5 V,	V _{IC} = 2.5 V	25°C		0.6		pА
IB	Input bias current (see I	Note 4)	VO = 2.5 V,	AIC = 5.2 A	70°C		40	600	PΑ
	Common-mode input vo	ultane			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	range (see Note 5)	mago			Full range	-0.2 to 3.5			٧
					25°C	3.2	3.9		
Vон	High-level output voltag	е	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	0°C	3	3.9		V
					70°C	3	4		
					25°C		0	50	
V_{OL}	Low-level output voltage	e	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
					25°C	25	170		
AVD	Large-signal differential amplification	voltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	0°C	15	200		V/mV
	ampillioation	-			70°C	15	140		
					25°C	65	91		
CMRR	Common-mode rejectio	n ratio	V _{IC} = V _{ICR} min		0°C	60	91		dB
					70°C	60	92		
	O				25°C	70	93		
ksvr	Supply-voltage rejection (ΔVDD/ΔVDD)	і гатіо	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	92		dB
	(70°C	60	94		<u></u>
			V _O = 2.5 V,	V _{IC} = 2.5 V,	25°C		210	560	
IDD	Supply current (two amp	olifiers)	VO = 2.5 V, No load	VIC = 2.5 V,	0°C		250	640	μА
					70°C		170	440	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	τ _A †	TL	.C25M20 C25M2A C25M2B	C	UNIT
						MIN	TYP	MAX	
		TLC252C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLUZSZU	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	
VIO	Input offset voltage	TLC252AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
100	input onset voltage	TLUZSZAC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	1110
		TLC252BC	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		0.224	2	
		TLOZDZBO	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3	
ανιο	Average temperature coe input offset voltage	fficient of			25°C to 70°C		2.1		μV/°C
li o	Input offset surrent (see N	loto 4)	V= - 5 V	V _{IC} = 5 V	25°C		0.1		n^
10	Input offset current (see N	NOIE 4)	V _O = 5 V,	AIC = 2 A	70°C		7	300	рA
lun.	Input bias current (see No	sto 4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		рA
lВ	input bias current (see No	же 4)	vO = 5 v,	AIC ≈ 2 A	70°C		50	600	рA
	Common-mode input volt	age			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	range (see Note 5)	9-			Full range	-0.2 to 8.5			٧
					25°C	8	8.7		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	0°C	7.8	8.7		٧
					70°C	7.8	8.7		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
	1				25°C	25	275		
AVD	Large-signal differential ve amplification	oitage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	0°C	15	320		V/mV
	amp.mod.tom				70°C	15	230		
					25°C	65	94		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		0°C	60	94		dB
					70°C	60	94		
	0	_4!_			25°C	70	93		
ksvr	Supply-voltage rejection r (ΔV _{DD} /ΔV _{DD})	auO	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	92		dB
	,— , DD,— , DD,				70°C	60	94		
			V _O = 5 V,	V:= = E V	25°C		285	600	
lDD	Supply current (two ampli	fiers)	VO = 5 V, No load	$V_{IC} = 5 V$	0°C		345	800	μΑ
					70°C		220	560	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC252A, TLC252B, TLC252Y, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LINCMOS™ DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

operating characteristics, $V_{DD} = 5 \text{ V}$

	PARAMETER		TEST CONDITI	ons	TA	TL TL(C	UNIT	
						MIN	TYP	MAX	
	:				25°C		0.43		
				V _{I(PP)} = 1 V	0°C		0.46		
SR	Slow rate at unity gain	$R_L = 100 \text{ k}\Omega$	C _L = 20 pF,		70°C		0.36		V/μs
Jon	Slew rate at unity gain	See Figure 1			25°C		0.40		ν /μS
				$V_{I(PP)} = 2.5 V$	0°C		0.43		
					70°C		0.34		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		32		nV/√Hz
					25°C		55		
ВОМ	Maximum output-swing bandwidth	VO = VOH, See Figure	$C_L = 20 pF$,	$R_L = 100 \text{ k}\Omega$,	0∘C		60		kHz
		Goo'r igaio			70°C		50		
					25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		600		MHz
					70°C		400		
		10	. D	0 00 -5	25°C		40°		
φm	Phase margin	V _I = 10 mV, See Figure 3	f = B ₁ ,	$C_L = 20 pF$,	0°C		41°		
		see a see			70°C		39°		

operating characteristics, V_{DD} = 10 V

	PARAMETER		TEST CONDITI	TA	TL TL(UNIT			
						MIN	TYP	MAX	
					25°C		0.62		
				V _{I(PP)} = 1 V	0°C		0.67		
SR	Class rate at units rain	$R_L = 100 \text{ k}\Omega$	C _L = 20 pF,		70°C		0.51		1////
on	Slew rate at unity gain	See Figure 1			25°C		0.56		V/μs
				$V_{I(PP)} = 5.5 V$	0°C		0.61		
					70°C		0.46		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	See Figure 2	25°C		32		nV/√Hz
					25°C		35		
Вом	Maximum output-swing bandwidth	VO = VOH, See Figure 1	$C_L = 20 pF$,	$R_L = 100 \text{ k}\Omega$,	0°C		40		kHz
		Oce i igale i			70°C		30		
			ı		25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 3	0°C		710		MHz
					70°C		510		1
					25°C		43°		·
φm	Phase margin	V _I = 10 mV, See Figure 3		C _L = 20 pF,	0°C		44°		
		occ i igule o			70°C		42°		1

TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LinCMOSTM DUAL OPERATIONAL AMPLIFIERS SLOS002G – JUNE 1983 – REVISED AUGUST 1996

electrical characteristics, V_{DD} = 5 V, T_A = 25°C

			TLC252Y		Т	LC25L2	Υ	TI	.C25M2	Υ		
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	TINU
VIO	Input offset voltage	$V_O = 1.4 \text{ V}, V_{IC} = 0 \text{ V}, \\ R_S = 50 \Omega, \text{See Note 6}$		1.1	10		1.1	10		1.1	10	mV
αVIO	Average temperature coefficient of input offset voltage			1.8			1.1			1.7		μV/°C
lio	Input offset current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.1			0.1			0.1		р А
I _{IB}	Input bias current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.6			0.6			0.6		pА
VICR	Common-mode input voltage range (see Note 5)		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		٧
Vон	High-level output voltage	V _{ID} = 100 mV, See Note 6	3.2	3.8		3.2	4.1		3.2	3.9		٧
V _{OL}	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0		0	50		0	50		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 0.25 V, See Note 6	5	23		50	700		25	170		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	65	80		65	94		65	91		dB
^k SVR	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V, V _O = 1.4 V	65	95		70	97		70	93		dB
lDD	Supply current	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load		1.4	3.2		0.02	0.034		0.21	0.56	mA

operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CONDITIONS		TLC252Y		TLC25L2Y			TLC25M2Y		UNIT			
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	OINI	
	Slew rate at	C _L = 20 pF, V _{I(PP)} = 1 V		3.6		0.03			0.43		V/µs			
	unity gain	See Note 6	$V_{I(PP)} = 2.5 \text{ V}$		2.9			0.03			0.40		V/μS	
Vn	Equivalent input noise voltage	f = 1 kHz,	R _S = 20 Ω		2.5			68			32		nV√/Hz	
ВОМ	Maximum output- swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$	C _L = 20 pF,		320			5			55		kHz	
B ₁	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF		1.7			0.085			0.525		MHz	
φm	Phase margin	f = B ₁ , C _L = 20 pF	V _I = 10 mV,		46°			34°			40°			

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. For low-bias mode, $R_L = 1~M\Omega$; for medium-bias mode, $R_L = 100~k\Omega$, and for high-bias mode, $R_L = 10~k\Omega$.

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PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC252, TLC25L2, and TLC25M2 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

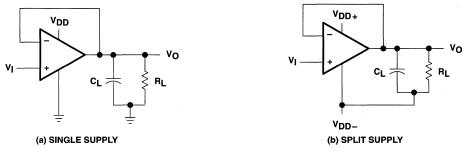


Figure 1. Unity-Gain Amplifier

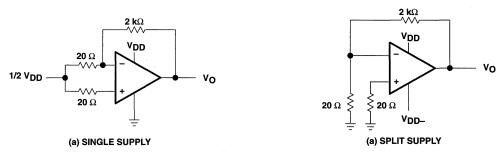


Figure 2. Noise-Test Circuit

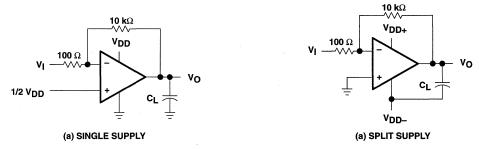


Figure 3. Gain-of-100 Inverting Amplifier

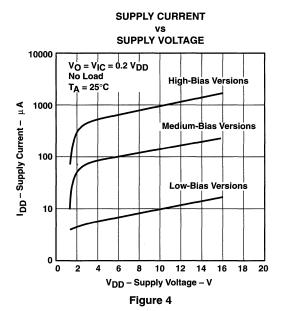


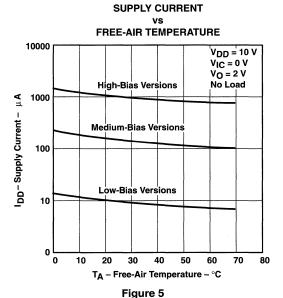
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TYPICAL CHARACTERISTICS

Table of Graphs

				FIGURE
I _{DD}	Supply current	vs Supply voltage vs Free-air temperature	4 5	
AVD	Large-signal differential voltage amplification	Low bias	vs Frequency	6
		Medium bias	vs Frequency	7
		High bias	vs Frequency	8
		Low bias	vs Frequency	6
	Phase shift	Medium bias	vs Frequency	7
		High bias	vs Frequency	8





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TYPICAL CHARACTERISTICS

LOW-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

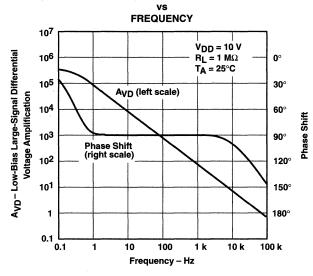


Figure 6

MEDIUM-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

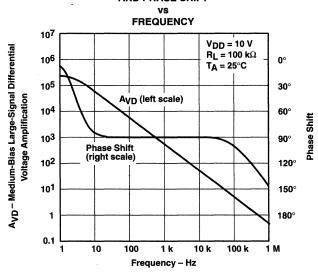


Figure 7

TLC252A, TLC252B, TLC252Y, TLC25L2, TLC25L2A, TLC25L2B TLC25L2Y, TLC25M2, TLC25M2A, TLC25M2B, TLC25M2Y LINCMOSTM DUAL OPERATIONAL AMPLIFIERS SLOS002G - JUNE 1983 - REVISED AUGUST 1996

TYPICAL CHARACTERISTICS

HIGH-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

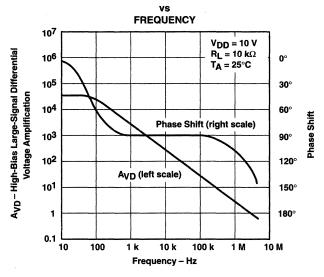


Figure 8

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APPLICATION INFORMATION

latch-up avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNPN structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the operational amplifier supplies should be applied simultaneously with, or before, application of any input signals.

output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage (V_{OH}) is virtually independent of the I_{DD} selection and increases with higher values of V_{DD} and reduced output loading. The low-level output voltage (V_{OL}) decreases with reduced output current and higher input common-mode voltage. With no load, V_{OL} is essentially equal to the potential of V_{DD} _/GND.

supply configurations

Even though the TLC252/25_2C series is characterized for single-supply operation, it can be used effectively in a split-supply configuration if the input common-mode voltage (V_{ICR}), output swing (V_{OL} and V_{OH}), and supply voltage limits are not exceeded.

circuit layout precautions

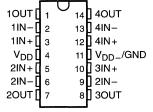
The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive dc leakages.



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- A-Suffix Versions Offer 5-mV V_{IO}
- B-Suffix Versions Offer 2-mV V_{IO}
- Wide Range of Supply Voltages
 1.4 V to 16 V
- True Single-Supply Operation
- Common-Mode Input Voltage Includes the Negative Rail
- Low Noise . . . 25 nV/√Hz Typ at f = 1 kHz (High-Bias Version)

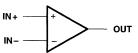
D, N, OR PW PACKAGE (TOP VIEW)



description

The TLC254, TLC254A, TLC254B, TLC25L4, TLC254L4A, TLC254L4B, TLC25M4, TLC25M4A and TL25M4B are low-cost, low-power quad operational amplifiers designed to operate with single or dual supplies. These devices utilize the Texas Instruments silicon gate LinCMOS™

symbol (each amplifier)



process, giving them stable input-offset voltages that are available in selected grades of 2, 5, or 10 mV maximum, very high input impedances, and extremely low input offset and bias currents. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this series is ideally suited for battery-powered or energy-conserving applications. The series offers operation down to a 1.4-V supply, is stable at unity gain, and has excellent noise characteristics.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for these devices include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS operational amplifiers without the power penalties of traditional bipolar devices.

Available options

Available options										
	V	PAC	CHIP FORM							
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (N)	TSSOP (PW)	(Y)					
	10 mV	TLC254CD	TLC254CN	TLC254CPW	TLC254Y					
	5 mV	TLC254ACD	TLC254ACN		_					
	2 mV	TLC254BCD	TLC254BCN		_					
	10 mV	TLC25L4CD	TLC25L4CN	TLC25L4CPW	TLC25L4Y					
0°C to 70°C	5 mV	TLC25L4ACD	TLC25L4ACN	_	_					
	2 mV	TLC25L2BCD	TLC25L4BCN		_					
	10 mV	TLC25M4CD	TLC25M4CN	TLC25M4CPW	TLC25M4Y					
	5 mV	TLC25M4ACD	TLC25M4ACN	_	-					
	2 mV	TLC25M4BCD	TLC25M4BCN		_					

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC254CDR). Chips are tested at 25°C.

LinCMOS is a trademark of Texas Instruments Incorporated.



TLC254A, TLC254B, TLC254Y, TLC25L4A, TLC25L4B, TLC25L4Y, TLC25M4A, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

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description (continued)

General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with these devices. Remote and inaccessible equipment applications are possible using their low-voltage and low-power capabilities. These devices are well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications. This series includes devices that are characterized for the commercial temperature range and are available in 14-pin plastic dip and the small-outline packages. The device is also available in chip form.

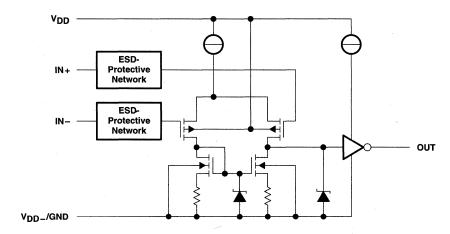
These devices are characterized for operation from 0°C to 70°C.

DEVICE FEATURES

PARAMETER	TLC25L4_C (LOW BIAS)	TLC25M4_C (MEDIUM BIAS)	TLC254_C (HIGH BIAS)
Supply current (Typ)	40 μΑ	600 μΑ	4000 μΑ
Slew rate (Typ)	0.04 V/μA	0.6 V/μA	4.5 V/μA
Input offset voltage (Max) TLC254C, TLC25L4C, TLC25M4C TLC254AC, TLC25L4AC, TLC25M4AC TLC254BC, TLC25L4BC, TLC25M4BC	10 mV 5 mV 2 mV	10 mV 5 mV 2 mV	10 mV 5 mV 2 mV
Offset voltage drift (Typ)	0.1 μV/month [†]	0.1 μV/month [†]	0.1 μV/month [†]
Offset voltage temperature coefficient (Typ)	0.7 μV/°C	2 μV/°C	5 μV/°C
Input bias current (Typ)	1 pA	1 pA	1 pA
Input offset current (Typ)	1 pA	1 pA	1 pA

[†] The long-term drift value applies after the first month.

equivalent schematic (each amplifier)

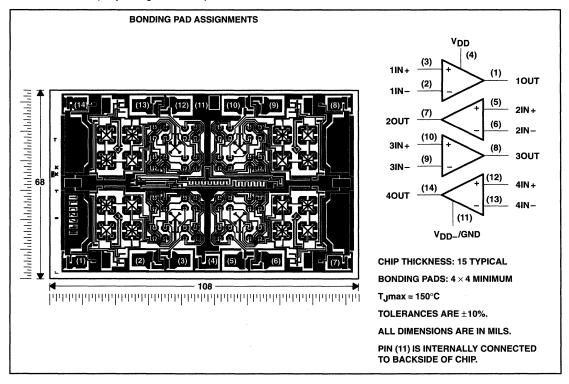


TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

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chip information

These chips, when properly assembled, display characteristics similar to the TLC25_4C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TLC254, TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	18 V
Differential input voltage (see Note 2)	
Input voltage range (any input)	
Duration of short-circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation	. See Dissipation Rating Table
Operating free-air temperature range	0°C to 70°C
Storage temperature range	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD}_/GND.

2. Differential voltages are at IN+, with respect to IN-.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW
N	1050 mW	9.2 mW/°C	736 mW
PW	700 mW	5.6 mW/°C	448 mW

recommended operating conditions

		MIN	MAX	UNIT	
Supply voltage, V _{DD}	$V_{DD} = 1.4 \text{ V}$ $V_{DD} = 5 \text{ V}$				
	V _{DD} = 1.4 V	0	0.2		
Common-mode input voltage. Vice	V _{DD} = 5 V	-0.2	4	V	
Common-mode input voltage, VIC	V _{DD} = 10 V	-0.2	9	'	
	V _{DD} = 16 V	-0.2	14		
Operating free-air temperature, TA		. 0	70	°C	

electrical characteristics at specified free-air temperature, $V_{DD} = 1.4 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CONDITIONST	-	TL	.C254_C	;	TL	C25L4_	С	TLO	C25M4_	С	UNIT
L	PARAWETER		TEST CONDITIONS	TA	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
		TLC25_4C		25°C			10			10			10	
		12023_40		0°C to 70°C			12			12			12	
VIO	Input offset voltage	TLC25_4AC	$V_{\Omega} = 0.2 \text{ V}, R_{S} = 50 \Omega$	25°C			5			5			5	mV
110	input onset voltage	12025_4A0	VO = 0.2 V, 115 = 30 32	0°C to 70°C			6.5			6.5			6.5	""
		TLC25_4BC	*	25°C			2			2			2	
		112020_400		0°C to 70°C			3			3			3	
avio	Average temperature input offset voltage	coefficient of		25°C to 70°C		1			1			1		μV/°C
lio	Input offset current		V _O = 0.2 V	25°C		1			1			1		pА
10	input onset current		V() = 0.2 V	0°C to 70°C			300			300			300	PA
IB	Input bias current		V _O = 0.2 V	25°C		1			1			1		pА
I'IB	Input bias current		VO = 0.2 V	0°C to 70°C			600			600			600	PA
VICR	Common-mode input	voltage range		25°C	0 to 0.2			0 to 0.2			0 to 0.2			V
VOM	Peak output voltage s	wing‡	V _{ID} = 100 mV	25°C	450	700		450	700		450	700		mV
AVD	Large-signal differenti amplification	al voltage	$V_O = 100 \text{ to } 300 \text{ mV},$ $R_S = 50 \Omega$	25°C		10			20			20		V/mV
CMRR	Common-mode reject	ion ratio	$V_O = 0.2 \text{ V},$ $V_{IC} = V_{ICR}$ min	25°C	60	77		60	77		60	77		dB
IDD	Supply current		V _O = 0.2 V, No load	25°C		600	750		50	68		400	500	μА

[†] All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following value: for low bias, R_L = 1 MΩ, for medium bias R_L = 100 kΩ, and for high bias R_L = 10 kΩ.
‡ The output swings to the potential of V_{DD}_/GND.

operating characteristics, $V_{DD} = 1.4 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CONDITIONS		TLC254_C		TLC25L4_C			TLC25M4_C			UNIT	
	FARAMETER	TEST CO	ADITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	ONII
SR	Slew rate at unity gain	See Figure 1			0.1			0.001			0.01		V/μs
B ₁	Unity-gain bandwidth	$A_V = 40 \text{ dB},$ $R_S = 50 \Omega,$	C _L = 10 pF, See Figure 1		12			12			12		kHz
	Overshoot factor	See Figure 1			30%			35%			35%		

TLC254, TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LINCMOSTM QUAD OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	T _A †				UNIT
						MIN	1.1 10 12 0.9 5 6.5 0.34 2 3 1.8 0.1 7 300 0.6 40 600 0.2 -0.3 to to 4 4.2 0.2 to 3.5 3 3.8		
		TLC254C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		1202040	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	
V _{IO}	Input offset voltage	TLC254AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	input offset voltage	TEOZOGAC	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			6.5	1110
	, i	TLC254BC	$V_0 = 1.4 V$,	V _{IC} = 0,	25°C		0.34	2	
		1023400	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3	
ανιο	Average temperature coefficie offset voltage	nt of input			25°C to 70°C		1.8		μV/°C
1		4)	V- 05V	V - 05V	25°C		0.1		1
lio	Input offset current (see Note	4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	70°C		7	300	pΑ
lin	Input bias current (see Note 4	\	V _O = 2.5 V,	V _{IC} = 2.5 V	25°C		0.6		pA
lB	input bias current (see Note 4) 	VO = 2.5 V,	AIC = 5.5 A	70°C		40	600	pΑ
.,	Common-mode input voltage	range		,	25°C		to		.,
VICR	(see Note 5)	v			Full range	-0.2 to 3.5			V
					0°C	3	3.8		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	25°C	3.2	3.8		٧
					70°C	. 3	3.8		
					0°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	I _{OL} = 0	25°C		0	50	mV
					70°C		0	50	
					0°C	4	27		
A_{VD}	Large-signal differential voltage amplification	e	$V_0 = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	25°C	5	23		V/mV
	атриовного				70°C	4	- 20		
					0°C	60	84		200
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		25°C	65	80		dB
				:	70°C	60	85		
			1		0°C	60	94		
ksvr	Supply-voltage rejection ratio (Δν _{DD} /Δνιο)	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	25°C	65	95		dB
					70°C	60	96		
			V- 05V	V 0 = V	0°C		3.1	7.2	
IDD	Supply current (four amplifiers		$V_O = 2.5 \text{ V},$ V_{IC}	$V_{IC} = 2.5 \text{ V},$	25°C		2.7	6.4	mA
					70°C		2.3	5.2	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F – JUNE 1983 – REVISED AUGUST 1994

electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †		C, TLC2 C254B0		UNIT
						MIN	TYP		
		TLC254C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
	•	1202540	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	
V	land the office to the second	TLC254AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	Input offset voltage	TLC254AC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	1117
		TLC254BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.39	2	
		TLC254BC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3	
∝VIO	Average temperature coeff offset voltage	ficient of input			25°C to 70°C		2		μV/°C
1		-4- 4)	1, 5,,		25°C		0.1		
10	Input offset current (see N	ole 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	70°C		7	300	рA
1	land bina sumant (see No.	h- 4\	V- 5V	V - 5 V	25°C		0.7		4
IB	Input bias current (see No	te 4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	70°C		50	600	рA
	0				25°C	-0.2 to	-0.3 to 9.2		
IVICD	Common-mode input voltage range (see Note 5)				Full range	-0.2 to 8.5			V
					0°C	7.8	8.5		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	25°C	8	8.5		V
			ĺ		70°C	7.8	8.4		
					0°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	25°C		0	50	mV
					70°C		0	50	
					0°C	7.5	42		
AVD	Large-signal differential vo amplification	Itage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	25°C	10	36		V/mV
	ampinication				70°C	7.5	32		
					0°C	60	88		
CMRR	Common-mode rejection r	atio	V _{IC} = V _{ICR} min		25°C	65	85		dB
					70°C	60	88		
	0				0°C	60	94		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVIO)	เแบ	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	25°C	65	95		dB
					70°C	60	96		
			Vo = 5 V	V10 - 5 V	0°C		4.5	8.8	
IDD	Supply current (four amplit	iers)	$V_O = 5 V$, V_{IC} No load	$V_{IC} = 5 V$,	25°C		3.8	8	mA
					70°C		3.2	6.8	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LINCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F – JUNE 1983 – REVISED AUGUST 1994

operating characteristics, V_{DD} = 5 V

	PARAMETER	Т	EST CONDITIO	NS	TA	<u> </u>	C254B0	·	UNIT
						MIN	TYP	MAX	
l				V _{I(PP)} = 1 V	0∘C	<u> </u>	4		
				VI(PP) - 1 V	25°C		3.6]
SR	Class rate at units anim	$R_L = 10 \text{ k}\Omega$,	$C_{L} = 20 pF$,	V _{I(PP)} = 1 V	70°C		3		1////
Sh.	Slew rate at unity gain	See Figure 1			0°C		3.1		V/μs
				$V_{I(PP)} = 2.5 V$	25°C		2.9		
					70°C		2.5		1
Vn	Equivalent input noise voltage	f = 1 kHz,	R _S = 20 Ω,	See Figure 2	25°C		25		nV/√Hz
,					0°C		340		
ВОМ	Maximum output-swing bandwidth	VO = VOH, See Figure 1	$C_L = 20 pF$,	$R_L = 10 \text{ k}\Omega$,	25°C		320		kHz
ļ		See Figure 1			70°C		260		1
					0°C		2		
B ₁	Unity-gain bandwidth	$V_{I} = 10 \text{ mV},$	$C_L = 20 pF$,	See Figure 1	25°C		1.7		MHz
					70°C		1.3		1
					0°C		47°		
φm	Phase margin	V _I = 10 mV, See Figure 3	$f = B_1$,	$C_L = 20 pF$,	25°C		46°		
	Thase margin	See Figure 3			70°C		43°		1

operating characteristics, V_{DD} = 10 V

	PARAMETER	т	EST CONDITIO	NS	TA	TLC254	C, TLC2 .C254B0		UNIT	
						MIN	TYP	MAX		
					0°C		5.9			
1				V _{I(PP)} = 1 V	25°C		5.3			
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	$C_L = 20 pF$,		70°C		4.3		V/μs	
l on	Siew rate at unity gain	See Figure 1			0°C		5.1		V/μ5	
				$V_{I(PP)} = 5.5 V$	25°C		4.6	,		
				·	70°C		3.8			
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		25		nV/√Hz	
					0°C		220			
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	$C_L = 20 pF$,	$R_L = 10 \text{ k}\Omega$,	25°C		200		kHz	
		Occ riguie r		<u> </u>	70°C		140			
					0°C		2.5			
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 1	25°C		2.2		MHz	
					70°C		1.8			
		10	, D	0 00 5	0°C		50°			
φm		V _I = 10 mV, See Figure 3		$C_L = 20 pF$,	25°C		49°		}	
		guic o			70°C		46°]	

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F - JUNE 1983 - REVISED AUGUST 1994

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		· TEST CONI	DITIONS	T _A †	TL TLC TLC	UNIT		
						MIN	TYP	3	
		TLC25L4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLO25L40	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			12	
VIO	Input offset voltage	TLC25L4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	input onset voltage	TEOZGLAAO	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			6.5	
		TLC25L4BC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.24	2	i
		TLO25L4BO	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3	
∝VIO	Average temperature coeff offset voltage	icient of input			25°C to 70°C		1.1		μV/°C
	1	-t 4\	V 05.V		25°C		0.1		
lio	Input offset current (see No	ne 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	рA
1	Innut him aumant (asa Nat	- 4)	V- 05V	V 0.5.V	25°C		0.6		1
IB	Input bias current (see Not	e 4)	V _O = 2.5 V,	$V_{IC} = 2.5 V$	70°C		40	600	рA
	Common-mode input volta	ge range			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICD	(see Note 5)				Full range	-0.2 to 3.5			V
					0°C	3	4.1		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 1 M\Omega$	25°C	3.2	4.1		V
			•		70°C	3	4.2		
			•		0°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	25°C		0	50	mV
					70°C		0	50	
					0°C	50	680		
AVD	Large-signal differential vol amplification	tage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	25°C	50	520		V/mV
	amplification				70°C	50	380		
					0°C	60	95		
CMRR	Common-mode rejection ra	atio	V _{IC} = V _{ICR} min		25°C	65	94		dB
					70°C	60	95		
					0°C	60	97		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVIO)	tio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	25°C	70	98		dB
	(A • DD/A • IO/				70°C	60	97		
			0.5.4	V 0511	0°C		48	84	
lDD	Supply current (four amplif	iers)	V _O = 2.5 V, No load	VIC = 2.5 V	25°C		40	68	μΑ
					70°C		31	56	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

TLC254, TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LINCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F-JUNE 1983 - REVISED AUGUST 1994

electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	τ _A †	TL	TLC25L4C TLC25L4AC TLC25L4BC		UNIT
						MIN	TYP	MAX	
		TLC25L4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		12025240	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			12	
Vio	Input offset voltage	TLC25L4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV -
VIO	input offset voltage	TEO23E4AC	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			6.5	1110
		TLC25L4BC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.26	2	
		TEOZSE4BO	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3	
αVIO	Average temperature coef input offset voltage	ficient of			25°C to 70°C		1		μV/°C
1		-1- 4)	V 5V		25°C		0.1		
lio	Input offset current (see N	ote 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	70°C		7	300	рA
1	Innut bios sument (see No	to 4)	V- 5V	V- 5V	25°C		0.7		- ^
lВ	Input bias current (see No	te 4)	$V_0 = 5 V$,	$V_{IC} = .5 V$	70°C		50	600	pΑ
	Common-mode input volta	ige range (see			25°C	-0.2 to 9	-0.3 to 9.2		V,
VICR	Note 5)	ge lange (eee			Full range	-0.2 to 8.5			V
					0°C	7.8	8.9		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 1 M\Omega$	25°C	8	8.9		٧
					70°C	7.8	8.9		
					0°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	25°C		0	50	mV
					70°C		0	50	
					0°C	50	1025		
AVD	Large-signal differential vo amplification	oltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	25°C	50	870		V/mV
	ampinioanon				70°C	50	660		
					0°C	60	97		
CMRR	Common-mode rejection r	atio	V _{IC} = V _{ICR} min		25°C	65	97		dB
					70°C	60	97		
	0				0°C	60	97		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVIO)	OITE	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	25°C	70	97		dB
	(2 · DD/2 · IO)				70°C	60	98		
			W 5.V		0°C		72	132	
lDD	Supply current (four ampli	fiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	25°C		57	92	μΑ
			1		70°C		44	80	

[†] Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F - JUNE 1983 - REVISED AUGUST 1994

operating characteristics, V_{DD} = 5 V

	PARAMETER	TE	EST CONDITION	NS	TA	TLC25L4C TLC25L4AC TLC25L4BC		UNIT	
						MIN	TYP	MAX	
					0°C		0.04		
				V _{I(PP)} = 1 V	25°C		0.03		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	$C_{L} = 20 pF$,		70°C		0.03		V/μs
J Sn	Siew rate at unity gain	See Figure 1			0°C		0.03		V /μS
				V _{I(PP)} =2.5V	25°C		0.03		
					70°C		0.02		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		70		nV/√Hz
					0°C		6		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	$C_L = 20 pF$	$H_L = 1 M\Omega$,	25°C		5		kHz
		See rigare r			70°C		4.5		
					0°C		100		
B ₁	Unity-gain bandwidth	$V_{ } = 10 \text{ mV},$	$C_L = 20 pF$,	See Figure 1	25°C		85		kHz
		,			70°C		65		
		V 40V	4 0	0. 005	0°C		36°		
φm	Phase margin	$V_I = 10 \text{ mV}, \qquad f = B_1, \qquad C_L$ See Figure 3		$C_L = 20 pF$,	25°C		34°		
		J cccgui o o			70°C		30°		

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER	TE	EST CONDITION	NS	TLC25L4C TLC25L4AC TLC25L4BC		C	UNIT	
						MIN	TYP	MAX	
					0°C		0.05		
				V _{I(PP)} = 1 V	25°C		0.05		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	$C_L = 20 pF$,		70°C		0.04		V/μs
Sh	Siew rate at unity gain	See Figure 1			0°C		0.05		V/μS
				$V_{I(PP)} = 5.5 V$	25°C		0.04]
					70°C		0.04		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		70		nV/√Hz
					0°C		1.3		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	$C_L = 20 pF$,	$H_L = 1 M\Omega$,	25°C		1		kHz
		See rigule r			70°C		0.9		}
					0°C		125		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 1	25°C		110		kHz
					70°C		90		1
		V 40V	, D	0 00 5	0°C		40°		
φm	m Phase margin	V _I = 10 mV, See Figure 3	$f = B_1$	C _L = 20 pF,	25°C		38°		}
		Coo , iguire o			70°C		34°		1

TLC254, TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4A, TLC25M4A, TLC25M4B, TLC25M4Y LINCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F - JUNE 1983 - REVISED AUGUST 1994

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TL	.C25M40 C25M4A C25M4B	C	UNIT
						MIN	TYP	MAX	
		TLC25M4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TEO25WI40	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	
VIO	Input offset voltage	TLC25M4AC	$V_0 = 1.4 \text{ V},$	$V_{IC} = 0$,	25°C		0.9	5	mV
10	input onset voltage	TEOZSIVIAAO	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	111.0
		TLC25M4BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.25	2	
		TEO25W4BC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3	
∝VIO	Average temperature of input offset voltage	coefficient of			25°C to 70°C		1.7		μV/°C
					25°C		0.1		
lio	Input offset current (se	e Note 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	70°C		7	300	pΑ
					25°C		0.6		
ΙΒ	Input bias current (see	Note 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		40	600	pΑ
	Common-mode input v	oltage range			25°C	-0.2 t0 4	-0.3 to 4.2		٧
VICR	(see Note 5)	onage range			Full range	-0.2 to 3.5			٧
					0°C	3	3.9		
Vон	High-level output voltage	ge	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	25°C	3.2	3.9		V
					70°C	3	4		
					0°C		0	50	
VOL	Low-level output voltage	je	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	25°C		0	50	mV
					70°C		0	50	
					0°C	15	200		
AVD	Large-signal differentia amplification	ıl voltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	25°C	25	170		V/mV
	amplification				70°C	15	140		
	`				0°C	60	91		
CMRR	Common-mode rejection	on ratio	V _{IC} = V _{ICR} min		25°C	65	91		dB
					70°C	60	92		
	_				0°C	60	. 92		
ksvr	Supply-voltage rejection	n ratio	V _{DD} = 5 V to 10 V,	V _O = 1.4 V	25°C	70	93		dB
	(ΔΛ ^{DD} / ₇ ΛΙΟ)			-	70°C	60	94		
					0°C		500	1280	
IDD	Supply current (four ar	nplifiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	25°C		420	1120	μΑ
			INO IDAU		70°C		340	880	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LINCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F – JUNE 1983 – REVISED AUGUST 1994

electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST COND	ITIONS	T _A †	TL	.C25M4C C25M4A C25M4B	С	UNIT
						MIN	TYP	MAX	
		TLC25M4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC25W4C	$R_S = 50 \Omega$	$R_L = 100 \text{ k}\Omega$	Full range			12	
V _{IO}	Input offset voltage	TLC25M4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	input onset voltage	TECZSWIAAC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	1110
,		TLC25M4BC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.26	2	
		TEO25WI4DO	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3	
αVIO	Average temperature coeffi offset voltage	cient of input			25°C to 70°C		2.1		μV/°C
li o	Input offset surrent (see No	to 4)	V- 5V	V:- EV	25°C		0.1		n 1
10	Input offset current (see No	le 4)	V _O = 5 V,	V _{IC} = 5 V	70°C		7	300	pA
li-	Input bigg ourrent (age Note	. 4\	V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		nΛ
IВ	Input bias current (see Note	; 4)	VO = 5 V,	AIC = 2 A	70°C		50	600	рA
	Common-mode input voltace	je range (see			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	ICR Common-mode input voltage range (see Note 5)				Full range	-0.2 to 8.5			٧
					0°C	7.8	8.7		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	25°C	8	8.7		V
					70°C	7.8	8.7		
					0°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	25°C		0	50	mV
					70°C		0	50	
	1		/		0°C	15	320		
AVD	Large-signal differential volt amplification	age	$V_0 = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	25°C	25	275		V/mV
					70°C	15	230		
					0°C	60	94		
CMRR	Common-mode rejection ra	tio	V _{IC} = V _{ICR} min		25°C	65	94		dB
			L		70°C	60	94		
					0°C	60	92		
ksvr	Supply-voltage rejection rati	ο (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	25°C	70	93		dB
					70°C	60	94		
			V _O = 5 V,	V _{IC} = 5 V,	0°C		690	1600	
αα ^l	Supply current (four amplific	ers)	VO = 5 V, No load	v IC = 2 v,	25°C		570	1200	μΑ
					70°C		440	1120	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

TLC254, TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

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operating characteristics, V_{DD} = 5 V

	PARAMETER	т	EST CONDITIO	NS	TA	TLC25M4C TLC25M4AC TLC25M4BC		UNIT		
						MIN	TYP	MAX		
					0°C		0.46		V/µs	
1				V _{I(PP)} = 1 V	25°C		0.43		V/µs	
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$	C _L = 20 pF,		70°C		0.36			
on .	Siew rate at unity gain	See Figure 1	- T		0°C	:	0.43		V/μs	
				$V_{I(PP)} = 2.5 V$	25°C		0.40		ν/μ5	
					70°C		0.34			
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		32		nV/√Hz	
,					0°C		60			
Вом	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	$C_L = 20 \text{ pF},$	$R_L = 100 \text{ k}\Omega$,	25°C		55		kHz	
		Occ i iguic i			70°C		50			
					0°C		610			
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 1	25°C		525		kHz	
					70°C		400			
		V. 10 mV	4 D.	C. 20 = E	0°C		41°			
φm	m Phase margin	V _I = 10 mV, See Figure 3	$f = B_{1}$	$C_L = 20 pF$,	25°C		40°			
					70°C		39°			

operating characteristics, V_{DD} = 10 V

	PARAMETER	т	EST CONDITION	NS	TA	TLC25M4C TLC25M4AC TLC25M4BC		C	UNIT
				•		MIN	TYP	MAX	
					0°C		0.67		
				$V_{I(PP)} = 1 V$	25°C		0.62		
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$,	$C_L = 20 pF$,		70°C		0.51		V/μs
1011	Siew rate at unity gain	See Figure 1			0°C		0.61		V/μ3
		ĺ		$V_{I(PP)} = 5.5 V$	25°C		0.56		
					70°C		0.46		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2	25°C		32		nV/√Hz
		., .,			0°C		40		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	$C_L = 20 \text{ pF},$	$R_L = 100 \text{ k}\Omega$,	25°C		35		kHz
		Oce rigule i			70°C		30		
					0°C		710		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	See Figure 1	25°C		635		kHz
					70°C		510		
		V 40 mV	4 D	C: 00.=E	0°C		44°		
φm	Phase margin	$V_1 = 10 \text{ mV}, \qquad f = B_1, \qquad 0$ See Figure 3		CL = 20 pr,	25°C	,	43°		
L		232 : .gui 0 0			70°C		42°		

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F - JUNE 1983 - REVISED AUGUST 1994

electrical characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	PARAMETER	TEST	T	LC254\	′	T	LC25L4	Υ	TI	_C25M4	Υ	UNIT
	PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
VIO	Input offset voltage	$V_O = 1.4 \text{ V},$ $V_{IC} = 0 \text{ V},$ $R_S = 50 \Omega,$ See Note 6		1.1	10		1.1	10		1.1	10	mV
αVIO	Average temperature coefficient of input offset voltage			1.8			1.1			1.7		μV/°C
lio	Input offset current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.1			0.1			0.1		pА
^I IB	Input bias current (see Note 4)	$V_O = V_{DD}/2,$ $V_{IC} = V_{DD}/2$		0.6			0.6			0.6		pА
VICR	Common-mode input voltage range (see Note 5)		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		-0.2 to 4	-0.3 to 4.2		٧
VOH	High-level output voltage	V_{ID} = 100 mV, R _L = 100 k Ω	3.2	3.8		3.2	4.1		3.2	3.9		٧
V _{OL}	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0		0	50		0	50		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 0.25 V, See Note 6	5	23		50	520		25	170		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	65	80		65	94		65	91		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V, V _O = 1.4 V	65	95		70	97		70	93		dB
DO	Supply current	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load		2.7	6.4		0.04	0.068		0.42	1.12	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. For low-bias mode, R_L = 1 M Ω , for medium-bias mode, R_L = 100 k Ω , and for high-bias mode, R_L = 10 k Ω .

operating characteristics, V_{DD} = 5 V, T_A = 25°C

-	•	•	· .										
D	ARAMETER	TEST CO	ONDITIONS	TLC254Y TLC25L4Y TLC25M4Y		TLC254Y TLC25L4Y TLC25M4		Υ	UNIT				
-	ARAWETER	123100	DNDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR	Slew rate at	C _L = 20 pF,	V _{I(PP)} = 1 V		3.6			0.03			0.43		V/us
SIT	unity gain	See Note 6	$V_{I(PP)} = 2.5 V$		2.9			0.03			0.40		ν/μ5
v _n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$		2.5			70			32		nV/√Hz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$	C _L = 20 pF,		320			5			55		kHz
В1	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF		1.7			0.085			0.525		MHz
φm	Phase margin	f = B ₁ , C _L = 20 pF	V _I = 10 mV,		46°			34°			40°		

NOTE 6: For low-bias mode, R_L = 1 M Ω , for medium-bias mode, R_L = 100 k Ω , and for high-bias mode, R_L = 10 k Ω .



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PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC25_4, TLC25_4A, and TLC25_4B are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

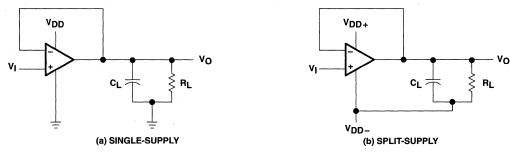


Figure 1. Unity-Gain Amplifier

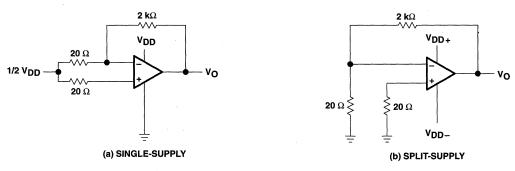


Figure 2. Noise-Test Circuit

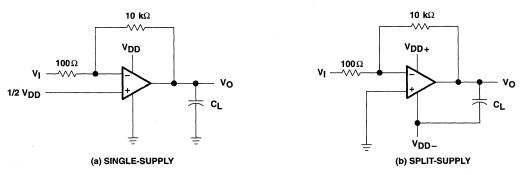


Figure 3. Gain-of-100 Inverting Amplifier



TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F - JUNE 1983 - REVISED AUGUST 1994

TYPICAL CHARACTERISTICS

Table of Graphs

				FIGURE
lDD	Supply current		vs Supply voltage vs Free-air temperature	4 5
		Low bias	vs Frequency	6
AVD	AVD Large-signal differential voltage amplification	Medium bias	vs Frequency	7
l		High bias	vs Frequency	8
		Low bias	vs Frequency	6
	Phase shift	Medium bias	vs Frequency	7
		High bias	vs Frequency	8

SUPPLY CURRENT

SUPPLY VOLTAGE

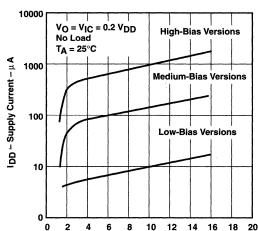


Figure 4

V_{DD} - Supply Voltage - V

SUPPLY CURRENT

FREE-AIR TEMPERATURE

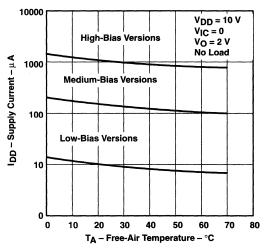


Figure 5

TYPICAL CHARACTERISTICS

LOW-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

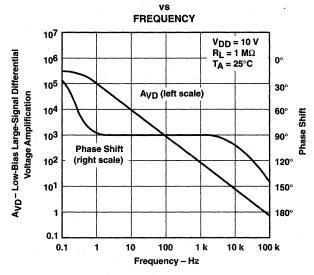


Figure 6

MEDIUM-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION **AND PHASE SHIFT**

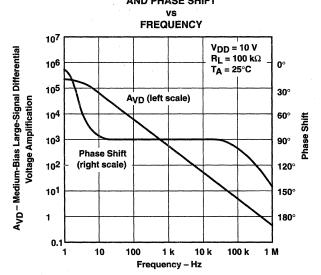


Figure 7

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOSTM QUAD OPERATIONAL AMPLIFIERS SLOS003F – JUNE 1983 – REVISED AUGUST 1994

TYPICAL CHARACTERISTICS

HIGH-BIAS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

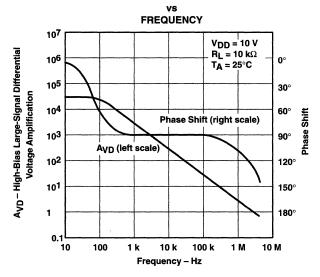


Figure 8

TLC254A, TLC254B, TLC254Y, TLC25L4, TLC25L4A, TLC25L4B TLC25L4Y, TLC25M4, TLC25M4A, TLC25M4B, TLC25M4Y LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION

latch-up avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNPN structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the operational amplifiers supplies should be established simultaneously with, or before, application of any input signals.

output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage (V_{OH}) is virtually independent of the I_{DD} selection and increases with higher values of V_{DD} and reduced output loading. The low-level output voltage (V_{OL}) decreases with reduced output current and higher input common-mode voltage. With no load, V_{OL} is essentially equal to the potential of V_{DD} _/GND.

supply configurations

Even though the TLC25_4C series is are characterized for single-supply operation, they can be used effectively in a split-supply configuration if the input common-mode voltage (V_{ICR}), output swing (V_{OL} and V_{OH}), and supply voltage limits are not exceeded.

circuit layout precautions

Whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup as well as excessive dc leakages.

TLC271, TLC271A, TLC271B LINCMOS™ PROGRAMMABLE LOW-POWER **OPERATIONAL AMPLIFIERS**

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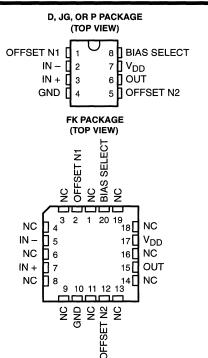
- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over **Specified Temperature Range:**

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 5 V to 16 V

- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix and I-Suffix Types)
- Low Noise . . . 25 nV/VHz Typically at f = 1 kHz (High-Bias Mode)
- **Output Voltage Range includes Negative** Rail
- High Input Impedance . . . $10^{12} \Omega$ Typ
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also** Available in Tape and Reel
- **Designed-In Latch-Up Immunity**

description

The TLC271 operational amplifier combines a wide range of input offset voltage grades with low offset voltage drift and high input impedance. In addition, the TLC271 offers a bias-select mode



NC - No internal connection

that allows the user to select the best combination of power dissipation and ac performance for a particular application. These devices use Texas Instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

AVAILABLE OPTIONS

			PACK	KAGE	
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	2 mV 5 mV 10 mV	TLC271BCD TLC271ACD TLC271CD	_	_	TLC271BCP TLC271ACP TLC271CP
-40°C to 85°C	2 mV 5 mV 10 mV	TLC271BID TLC271AID TLC271ID	_	_	TLC271BIP TLC271AIP TLC271IP
−55°C to 125°C	10 mV	TLC271MD	TLC271MFK	TLC271MJG	TLC271MP

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC271BCDR).

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TLC271, TLC271A, TLC271B LinCMOS™ PROGRAMMABLE LOW-POWER OPERATIONAL AMPLIFIERS

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DEVICE FEATURES

DADAMETER!	BIA	S-SELECT MO	DE	UNIT
PARAMETERT	HIGH	MEDIUM	LOW	ONII
PD	3375	525	50	μW
SR	3.6	0.4	0.03	V/μs
V _n	25	32	68	nV/√Hz
B ₁	1.7	0.5	0.09	MHz
AVD	23	170	480	V/mV

[†] Typical at VDD = 5 V, TA = 25°C

description (continued)

Using the bias-select option, these cost-effective devices can be programmed to span a wide range of applications that previously required BiFET, NFET or bipolar technology. Three offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC271 (10 mV) to the TLC271B (2 mV) low-offset version. The extremely high input impedance and low bias currents, in conjunction with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

In general, many features associated with bipolar technology are available in LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC271. The devices also exhibit low-voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

The device inputs and output are designed to withstand –100-mA surge currents without sustaining latch-up.

The TLC271 incorporates internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.

bias-select feature

The TLC271 offers a bias-select feature that allows the user to select any one of three bias levels depending on the level of performance desired. The tradeoffs between bias levels involve ac performance and power dissipation (see Table 1).

bias-select feature (continued)

Table 1. Effect of Bias Selection on Performance

	TYPICAL PARAMETER VALUES		MODE						
	T _A = 25°C, V _{DD} = 5 V	HIGH BIAS $R_L = 10 \text{ k}\Omega$	MEDIUM BIAS $R_L = 100 \text{ k}\Omega$	LOW BIAS $R_L = 1 M\Omega$	UNIT				
PD	Power dissipation	3.4	0.5	0.05	mW				
SR	Slew rate	3.6	0.4	0.03	V/μs				
٧n	Equivalent input noise voltage at f = 1 kHz	25	32	68	nV/√Hz				
B ₁	Unity-gain bandwidth	1.7	0.5	0.09	MHz				
φm	Phase margin	46°	40°	34°					
AVD	Large-signal differential voltage amplification	23	170	480	V/mV				

bias selection

Bias selection is achieved by connecting the bias select pin to one of three voltage levels (see Figure 1). For medium-bias applications, it is recommended that the bias select pin be connected to the midpoint between the supply rails. This procedure is simple in split-supply applications, since this point is ground. In single-supply applications, the medium-bias mode necessitates using a voltage divider as indicated in Figure 1. The use of large-value resistors in the voltage divider reduces the current drain of the divider from the supply line. However, large-value resistors used in conjunction with a large-value capacitor require significant time to charge up to the supply midpoint after the supply is switched on. A voltage other than the midpoint can be used if it is within the voltages specified in Figure 1.

bias selection (continued)

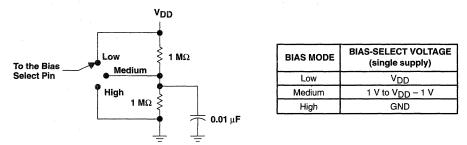


Figure 1. Bias Selection for Single-Supply Applications

high-bias mode

In the high-bias mode, the TLC271 series features low offset voltage drift, high input impedance, and low noise. Speed in this mode approaches that of BiFET devices but at only a fraction of the power dissipation. Unity-gain bandwidth is typically greater than 1 MHz.

medium-bias mode

The TLC271 in the medium-bias mode features low offset voltage drift, high input impedance, and low noise. Speed in this mode is similar to general-purpose bipolar devices but power dissipation is only a fraction of that consumed by bipolar devices.



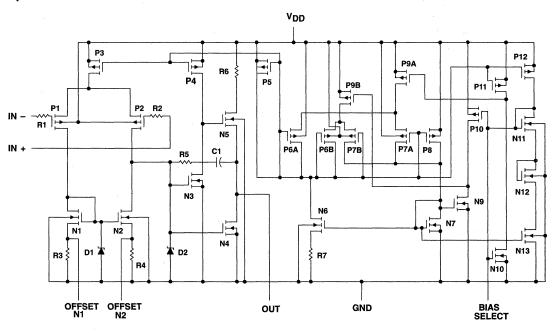
low-bias mode

In the low-bias mode, the TLC271 features low offset voltage drift, high input impedance, extremely low power consumption, and high differential voltage gain.

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equivalent schematic



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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Input voltage range, V _I (any input)	
Input current, I ₁	
Output current, IO	±30 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature, T _A : C suffix	0°C to 70°C
l suffix	– 40°C to 85°C
M suffix	– 55°C to 125°C
Storage temperature range	– 65°C to 150°C
Case temperature for 60 seconds: FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P packa	ge 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

		C SU	FFIX	I SUI	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	5	16	٧
Common mode input valtage V	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	$V_{DD} = 10 \text{ V}$	-0.2	8.5	-0.2	8.5	0	8.5	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

HIGH-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

					Т	LC271C	, TLC27	1AC, TL	IAC, TLC271BC				
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5 \	'	۷۲	D = 10	٧	UNIT		
			CONDINIONS		MIN	TYP	MAX	MIN	TYP	MAX			
		TLC271C		25°C		1.1	10		1.1	10			
		11.02/10	V _O = 1.4 V,	Full range			12			12			
V	Inner to offer at weltone	TLC271AC	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	/		
VIO	Input offset voltage	ILC2/TAC	$R_S = 50 \Omega$	Full range			6.5			6.5	mV		
		TI 0074 DO	R _L = 10 kΩ	25°C		0.34	2		0.39	2			
		TLC271BC		Full range			3			3			
αVIO	Average temperature of input offset voltage	coefficient		25°C to 70°C		1.8			2		μV/°C		
li a	Input offset surrent (se	o Noto 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1				
lo	Input offset current (se	ee Note 4)	$V_{IC} = V_{DD}/2$	70°C		7	300		7	300	рA		
1.=	Innuit biog gumant /oo	Note 4\	$V_O = V_{DD}/2$,	25°C		0.6			0.7		- 4		
ΙΒ	Input bias current (see	e Note 4)	$V_{IC} = V_{DD}/2$	70°C		40	600		50	600	рA		
					-0.2	-0.3		-0.2	-0.3				
				25°C	to 4	to 4.2		to 9	to 9.2		V		
VICR	Common-mode input	voltage			-0.2	4.2		-0.2	9.2				
VICH.	range (see Note 5)			Full range	-0.2 to			-0.2 to			V		
					3.5			8.5					
				25°C	3.2	3.8		8	8.5		,		
Voн	High-level output volta	ige	$V_{ID} = 100 \text{ mV},$ $R_{L} = 10 \text{ k}\Omega$	0°C	3	3.8		7.8	8.5		V		
			110 - 10 122	70°C	3	3.8		7.8	8.4				
				25°C		0	50		0	50			
VOL	Low-level output volta	ge	V _{ID} = -100 mV, I _{OL} = 0	0°C		0	50		0	50	mV		
			IOL - 0	70°C		0	50		0	50			
				25°C	5	23		10	36				
AVD	Large-signal differenti voltage amplification	al	$R_L = 10 \text{ k}\Omega$, See Note 6	0°C	4	27		7.5	42		V/mV		
	voltage amplification		See Note 0	70°C	4	20		7.5	32				
				25°C	65	80		65	85				
CMRR	Common-mode reject	ion ratio	V _{IC} = V _{ICR} min	0°C	60	84		60	88		dB		
				70°C	60	85		60	88				
				25°C	65	95		65	95				
ksvr	Supply-voltage rejecti	on ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	0°Ċ	60	94		60	94		dB		
	(ΔΛ ^{DD} /∇Λ ^{IO})		VO = 1.4 V	70°C	60	96		60	96				
I(SEL)	Input current (BIAS SI	ELECT)	V _{I(SEL)} = 0	25°C		-1.4			-1.9		μΑ		
<u> </u>			$V_O = V_{DD}/2$,	25°C		675	1600		950	2000			
IDD	Supply current		$V_{IC} = V_{DD}/2$,	0°C		775	1800		1125	2200	μΑ		
	· ·		No load	70°C		575	1300		750	1700			
F = "	nge is 0°C to 70°C			L									

†Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



HIGH-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

						TLC271	I, TLC27	1AI, TLO	C271BI		
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5 \	1	٧ _C	D = 10	٧	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
		TLC2711		25°C		1.1	10		1.1	10	
		11.02/11	V _O = 1.4 V,	Full range			13			13	
1/1-5	Input offset valtage	TLC271AI	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	mV
V _{IO}	Input offset voltage	ILC2/ IAI	$R_S = 50 \Omega$,	Full range			7			7	IIIV
		TLC271BI	$R_L = 10 \text{ k}\Omega$	25°C		0.34	2		0.39	2	
		ILO2/IBI		Full range			3.5			3.5	
αVIO	Average temperature of input offset voltage	coefficient		25°C to 85°C		1.8			2		μV/°C
li o	Input offset current (se	no Noto 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		рA
10	input onset current (si	ee Note 4)	$V_{IC} = V_{DD}/2$	85°C		24	1000		26	1000	PΑ
l.p	Input bias current (see	Note 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		рA
^I IB	input bias current (see	= NOIE 4)	$V_{IC} = V_{DD}/2$	85°C		200	2000		220	2000	PΑ
					-0.2	-0.3		-0.2	-0.3		
	0			25°C	to 4	to 4.2		to 9	to 9.2		V
VICR	Common-mode input voltage range (see No	ote 5)			-0.2	7.2		-0.2	3.2		
	vollago ralligo (coo rre	,,,,		Full range	to			to			V
					3.5			8.5			
			100 11	25°C	3.2	3.8		. 8	8.5		
VOH	High-level output volta	age	$V_{ID} = 100 \text{ mV},$ $R_{I} = 10 \text{ k}\Omega$	-40°C	3	3.8		7.8	8.5		. V
				85°C	3	3.8		7.8	8.5		
Ì			100)	25°C		0	50		0	50	
VOL	Low-level output volta	ge	V _{ID} = -100 mV, I _{OL} = 0	-40°C		0	50		0	50	mV
			OL 0	85°C		0	50		0	50	
l	Lauren et aus et aller aus et	-1	D 4010	25°C	5	23		10	36		
AVD	Large-signal differenti voltage amplification	aı	$R_L = 10 \text{ k}\Omega$, See Note 6	−40°C	3.5	32		7	46		V/mV
	Tonago ampimoanon		000110100	85°C	3.5	19		7	31		
				25°C	65	80		65	85		
CMRR	Common-mode reject	ion ratio	V _{IC} = V _{ICR} min	-40°C	60	81		60	87		dB
	•			85°C	60	86		60	88		
1	0		V 5 V4- 40 V	25°C	65	95		65	95		
ksvr	Supply-voltage rejecti (ΔVDD/ΔVIO)	on ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	−40°C	60	92		60	92		dB
	(= · DD/= · 10/		10=	85°C	60	96		60	96		
l(SEL)	Input current (BIAS S	ELECT)	V _{I(SEL)} = 0	25°C		-1.4			-1.9		μΑ
			$V_O = V_{DD}/2$,	25°C		675	1600		950	2000	
IDD	Supply current		$V_{IC} = V_{DD}/2$,	-40°C		950	2200		1375	2500	μΑ
			No load	85°C		525	1200		725	1600	

[†]Full range is -40°C to 85°C.

^{6.} At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

HIGH-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

						TLC2	71M			
	PARAMETER	TEST CONDITIONS	T _A †	V	DD = 5 \	/	V	D = 10	٧	UNIT
		CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V _O = 1.4 V, V _{IC} = 0 V,	25°C		1.1	10		1.1	10	mV
10	mpat onset voltage	$R_S = 50 \Omega$, $R_L = 10 k\Omega$	Full range			12	*		12	1114
αVIO	Average temperature coefficient of input offset voltage		25°C to 125°C		2.1			2.2		μV/°C
Ιο	Input offset current (see Note 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		pА
טוי	input onset current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		1.4	15		1.8	15	nA
lin	Input bias current (see Note 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		pА
lΒ	input bias current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		9	35		10	35	nA
Vion	Common-mode input voltage		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		V
VICR	range (see Note 5)		Full range	0 to 3.5			0 to 8.5			٧
			25°C	3.2	3.8		8	8.5		
Vон	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_L = 10 \text{ k}\Omega$	−55°C	3	3.8		7.8	8.5		ν .
		1112 - 10 1022	125°C	3	3.8		7.8	8.4		
			25°C		0	50		0	50	
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OL} = 0$	−55°C		0	50		0	50	mV
		1.0L = 0	125°C		0	50		0	50	
		D 4010	25°C	5	23		10	36		
AVD	Large-signal differential voltage amplification	R_L = 10 kΩ, See Note 6	−55°C	3.5	35		7	50		V/mV
			125°C	3.5	16		7	27		
			25°C	65	80		65	85		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	−55°C	60	81		60	87		dB
			125°C	60	84		60	86		
	0 1 11 11 11		25°C	65	95		65	95		
ksvr	Supply-voltage rejection ratio (ΔVDD/ΔVIO)	V _{DD} = 5 V to 10 V V _O = 1.4 V	−55°C	60	90		60	90		dB
	(- · DD/ - · 10)	1.0 = 1.1 +	125°C	60	97		60	97		
l(SEL)	Input current (BIAS SELECT)	V _{I(SEL)} = 0	25°C		-1.4			-1.9		μΑ
		$V_O = V_{DD}/2$,	25°C		675	1600		950	2000	
IDD	Supply current	$V_{IC} = V_{DD}/2$,	−55°C		1000	2500		1475	3000	μА
		No load	125°C		475	1100		625	1400	

[†] Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

^{6.} At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.

HIGH-BIAS MODE

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	ONDITIONS	TA	TLC271	C, TLC2 .C271B0		UNIT	
				"	MIN	TYP	MAX		
				25°C		3.6			
İ			V _{I(PP)} = 1 V	0°C		4			
SR	Close rate at units gain	$R_L = 10 \text{ k}\Omega$		70°C		3		Mus	
Sh	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		2.9		V/μs	
		J SSS , Iguillo	$V_{I(PP)} = 2.5 V$	0°C		3.1			
ļ				70°C		2.5			
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√Hz	
				25°C		320			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,	C _L = 20 pF,		0°C		340		kHz
į		n _L = 10 ks2,	See Figure 98	70°C		260			
				25°C		1.7			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	0°C		2		MHz	
		See Figure 100		70°C		1.3			
		Tv. 40 V	, 5	25°C		46°			
φm	Phase margin	$V_i = 10 \text{ mV},$ $C_i = 20 \text{ pF},$	f = B ₁ , See Figure 100	0°C		47°			
		SL = 25 pr ,	200guio 100	70°C		44°			

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CO	ONDITIONS	TA				UNIT
					MIN	5.3 5.9 4.3 4.6 5.1 3.8 25 200 220 140 2.2 2.5 1.8 49° 50°	MAX	
				25°C		5.3		
1			$V_{I(PP)} = 1 V$	0°C		5.9		
CD.	Clay rate at unity gain	$R_L = 10 \text{ k}\Omega$		70°C		4.3		V/110
SR	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		4.6		V/μs
			$V_{I(PP)} = 5.5 V$	0°C		5.1		
				70°C		3.8		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz
				25°C		200		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	0°C		220		kHz
		111 - 10 Ks2,	See Figure 30	70°C		140		
				25°C		2.2		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	0°C		2.5		MHz
		See rigule 100		70°C		1.8		
		(5		25°C		49°		
φm	Phase margin	$f = B_1,$ $C_L = 20 pF,$	V _I = 10 mV, See Figure 100	0°C		50°		
] p.,	222	70°C		46°		

HIGH-BIAS MODE

operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CO	NDITIONS	TA	TLC271I, TLC271AI, TLC271BI			UNIT
		,			MIN	TYP	MAX	
				25°C		3.6		
			V _{I(PP)} = 1 V	-40°C		4.5		
SR	Claw rate at unity gain	$R_L = 10 kΩ$, $C_L = 20 pF$,		85°C		2.8		V//
Sh	Slew rate at unity gain	See Figure 98		25°C		2.9		V/μs
			$V_{I(PP)} = 2.5 V$	-40°C		3.5		
				85°C		2.3		
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√Hz
				25°C		320		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	-40°C		380		kHz
		111 10 132,	See rigure 30	85°C		250		
				25°C		1.7		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-40°C		2.6		MHz
		See Figure 100		85°C		1.2		
		1, ,, ,,	, ,	25°C		46°		
φm		f = B ₁ , See Figure 100	-40°C		49°			
		JC - 20 pr,	200gaio 100	85°C		43°		

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	TA		II, TLC2 .C271BI		UNIT
				MIN	TYP	MAX		
				25°C		5.3		
			V _{I(PP)} = 1 V	-40°C		6.8		
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 20 \text{ pF}$,		85°C		4		V/μs
J Sh	Siew rate at unity gain	See Figure 98		25°C		4.6		V/μS
			$V_{I(PP)} = 5.5 V$	-40°C		5.8		
İ				85°C		3.5		
۷n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz
				25°C		200		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	-40°C		260		kHz
		TIL = 10 KS2,	Gee i igure 30	85°C		130		
				25°C		2.2		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-40°C		3.1	**	MHz
		Gee rigule 100		85°C		1.7		
		V 10 V	4.0	25°C		49°		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f= B ₁ , See Figure 100	-40°C		52°		
		оц = 20 рг,	235guio 100	85°C		46°		

HIGH-BIAS MODE

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

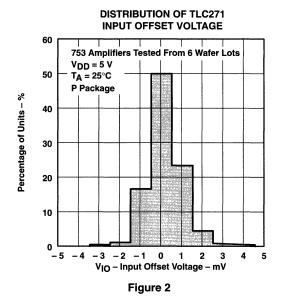
	DADAMETED	TEST 00	NDITIONS	-	TI	_C271M		LINUT
	PARAMETER	IEST CO	NDITIONS	TA	C 4.7 C 2.3 C 2.9 C 3.7 C 2 C 25 C 25 C 320 C 400 C 230 C 1.7	TYP	MAX	UNIT
				25°C		3.6		
		Ī	V _{I(PP)} = 1 V	-55°C		4.7		
SR	Clay rate at unity gain	R _L = 10 kΩ,		125°C		2.3		Who
Sh	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		2.9		V/μs
		Cooking and the	$V_{I(PP)} = 2.5 V$	−55°C		3.7		
				125°C		2		
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√Hz
				25°C		320		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	-55°C		400		kHz
		111_ = 10 K22,	See Figure 30	125°C		230		
				25°C		1.7		
B ₁	Unity-gain bandwidth $V_{\parallel} = 10 \text{ mV}, C_{\parallel} = 2 \text{ See Figure 100}$		-55°C		2.9		MHz	
		See Figure 100		125°C		1.1		
	Phase margin	10.34		25°C		46°		
φm		V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 100	-55°C		49°		
		SL = 23 pr,	200guio 100	125°C		41°		

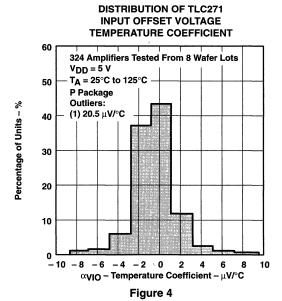
operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	-	TLC271M			UNIT
Ĺ	PARAMETER	1251 00	MDITIONS	TA	TL	TYP	MAX	UNIT
				25°C		5.3		
SR	Slew rate at unity gain	R_L = 10 kΩ, C_L = 20 pF, See Figure 98	V _{I(PP)} = 1 V	-55°C		7.1		V/μs
				125°C		3.1		
			V _{I(PP)} = 5.5 V	25°C		4.6		
				−55°C		6.1		
				125°C		2.7		
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		25		nV/√Hz
	Maximum output-swing bandwidth	V _O = V _{OH} , R _L = 10 kΩ,	C _L = 20 pF, See Figure 98	25°C		200		kHz
ВОМ				−55°C		280		
				125°C		110		
				25°C	°C 2.2	2.2		MHz
В1	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	C _L = 20 pF,	−55°C		3.4		
				125°C		1.6		
	Phase margin	f = B ₁ , C _L = 20 pF,	V _I = 10 mV, See Figure 100	25°C		49°		
φm				−55°C		52°		
				125°C		44°		

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	2, 3
ανιο	Temperature coefficient	Distribution	4, 5
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	6, 7 8 9
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	10, 11 12 13 14, 15
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	16 17 28, 29
lв	Input bias current	vs Free-air temperature	18
ΙO	Input offset current	vs Free-air temperature	18
VIC	Common-mode input voltage	vs Supply voltage	19
IDD	Supply current	vs Supply voltage vs Free-air temperature	20 21
SR	Slew rate	vs Supply voltage vs Free-air temperature	22 23
	Bias-select current	vs Supply voltage	24
VO(PP)	Maximum peak-to-peak output voltage	vs Frequency	25
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	26 27
AVD	Large-signal differential voltage amplification	vs Frequency	28, 29
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	30 31 32
Vn	Equivalent input noise voltage	vs Frequency	33
	Phase shift	vs Frequency	28, 29





DISTRIBUTION OF TLC271
INPUT OFFSET VOLTAGE

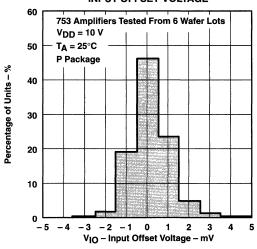


Figure 3

DISTRIBUTION OF TLC271 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

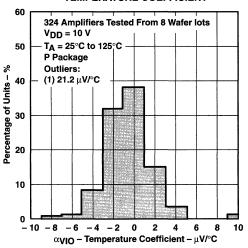
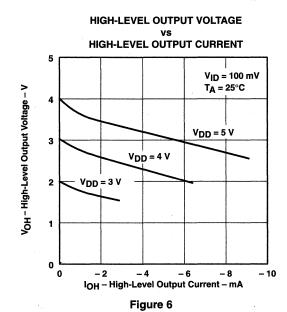
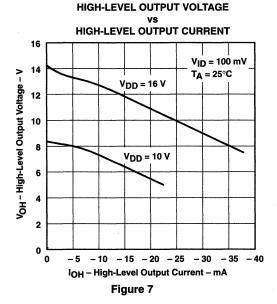


Figure 5

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.









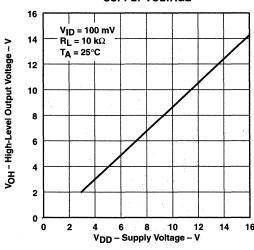


Figure 8

HIGH-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

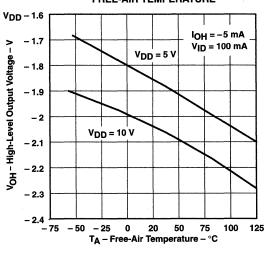
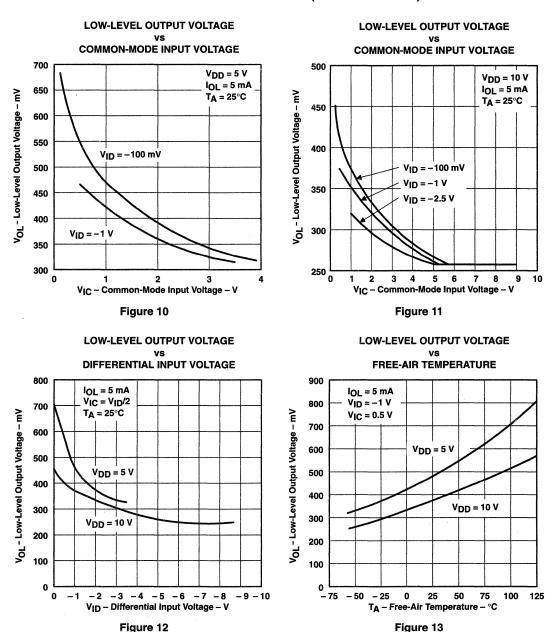


Figure 9

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



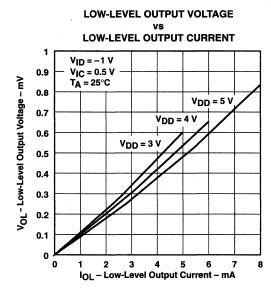
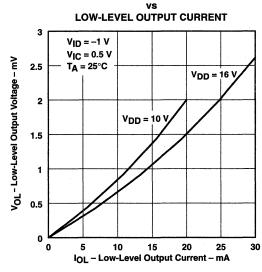


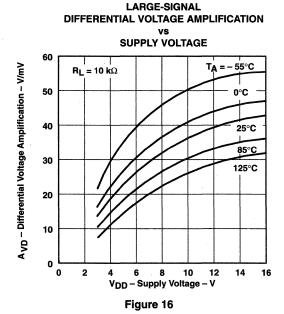
Figure 14



LOW-LEVEL OUTPUT VOLTAGE

Figure 15

LARGE-SIGNAL



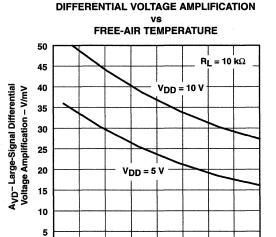


Figure 17

T_A - Free-Air Temperature - °C

100 125

0 25 50

-50 -25

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



COMMON-MODE INPUT VOLTAGE

(POSITIVE LIMIT)

TYPICAL CHARACTERISTICS (HIGH-BIAS MODE)†

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT FREE-AIR TEMPERATURE 10000 V_{DD} = 10 V V_{IC} = 5 V See Note A 1000 Ingand Ing – Input Bias and Input Offset Currents – nA 100 10 10 1 0.1 25 45 65 85 105

NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

TA

- Free-Air Temperature -



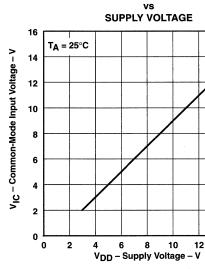
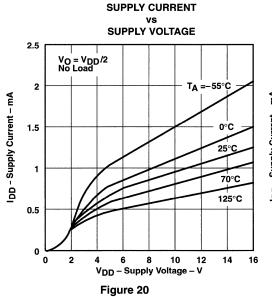
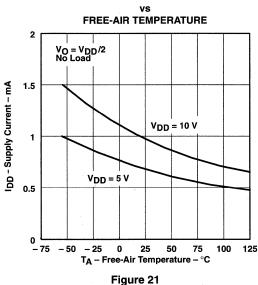


Figure 19

SUPPLY CURRENT

14 16

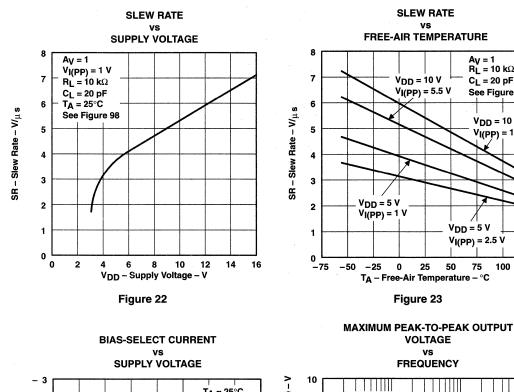


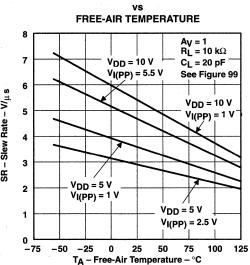


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



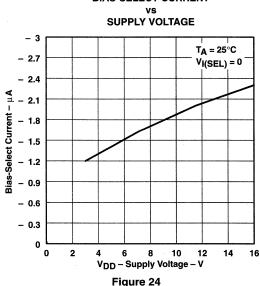
TYPICAL CHARACTERISTICS (HIGH-BIAS MODE)†

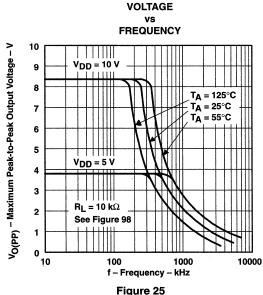




SLEW RATE

Figure 23



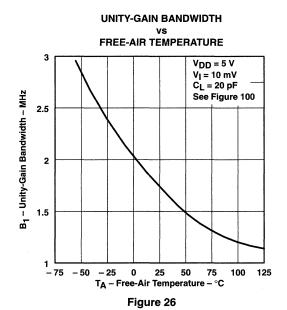


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



UNITY-GAIN BANDWIDTH

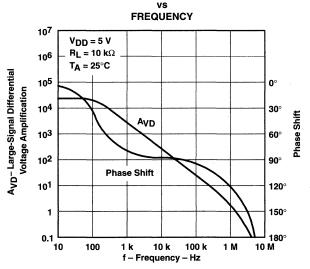
TYPICAL CHARACTERISTICS (HIGH-BIAS MODE)†



SUPPLY VOLTAGE 2.5 V_I = 10 mV C_L = 20 pF TA = 25°C B₁ - Unity-Gain Bandwidth - MHz See Figure 100 2 1.5 0 2 8 10 12 14 16 V_{DD} - Supply Voltage - V

Figure 27

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



Figure 28

TYPICAL CHARACTERISTICS (HIGH-BIAS MODE)†

LARGE-SCALE DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

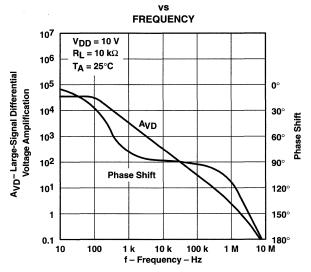
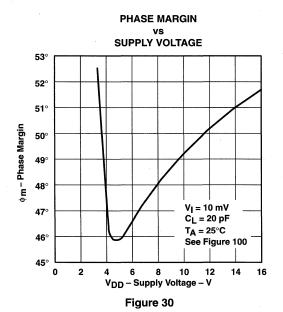
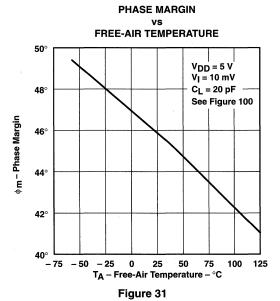


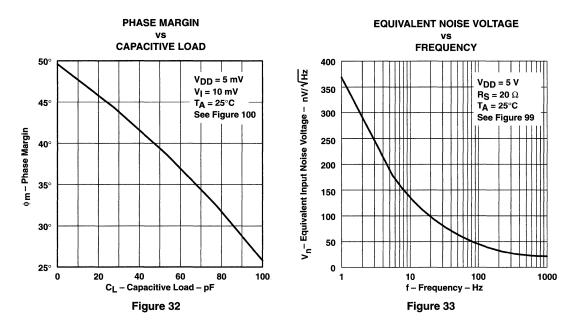
Figure 29





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

MEDIUM-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

					Т	LC271C	, TLC27	1AC, TL	C271BC		
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5 \	1	٧	D = 10	/	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	1
		TLC271C		25°C		1.1	10		1.1	10	
		1102/10	V _O = 1.4 V,	Full range			12			12	
V	lance office to calle an	TLC271AC	V _{IC} = 0	25°C		0.9	5		0.9	5	mV
VIO	Input offset voltage	ILU2/IAU	$R_S = 50 \Omega$,	Full range			6.5			6.5	mv
		TI 0074B0	$R_{l} = 100 \text{ k}\Omega$	25°C		0.25	2		0.26	2	
		TLC271BC		Full range		'	3			. 3	
ανιο	Average temperature of input offset voltage			25°C to 70°C		1.7			2.1		μV/°C
1		N-4- 4\	$V_O = V_{DD}/2$,	25°C		0.1			0.1		- 4
10	Input offset current (see Note 4)	V _{IC} = V _{DD} /2	70°C		7	300		7	300	pА
1	lancid bina accomunation	N-4- 4\	$V_O = V_{DD}/2$,	25°C		0.6			0.7		4
lв	Input bias current (s	ee Note 4)	V _{IC} = V _{DD} /2	70°C		40	600		50	600	pА
		-			-0.2	-0.3		-0.2	-0.3		
				25°C	to	to		to	to		V
Vice	Common-mode inpu				4	4.2		9	9.2		
	voltage range (see N	Note 5)		Full rongs	-0.2			-0.2			v
				Full range	to 3.5			to 8.5			V
		**************************************		25°C	3.2	3.9		8	8.7		
VOH	High-level output vol	tage	$V_{ID} = 100 \text{ mV},$	0°C	3	3.9		7.8	8.7		v
1011			$R_L = 100 \text{ k}\Omega$	70°C	3	4		7.8	8.7		
				25°C		0	50		0	50	
VOL	Low-level output vol	tage	$V_{ID} = -100 \text{ mV},$	0°C		0	50		0	50	mV
02	•	J	IOT = 0	70°C		0	50		0	50	
				25°C	25	170		25	275		
AVD	Large-signal differen		$R_L = 100 \text{ k}\Omega$	ö°C	15	200		15	320		V/mV
'-	voltage amplification		See Note 6	70°C	15	140		15	230		
				25°C	65	91		65	94		
CMRR	Common-mode reje	ction ratio	V _{IC} = V _{ICB} min	0°C	60	91		60	94		dB
				70°C	60	92		60	94		
				25°C	70	93		70	93		
ksvr	Supply-voltage reject	tion ratio	V _{DD} = 5 V to 10 V	0°C	60	92		60	92		dB
	(ΔV _{DD} /ΔV _{IO})		V _O = 1.4 V	70°C	60	94		60	94		
l(SEL)	Input current (BIAS	SELECT)	V _{I(SEL)} = V _{DD} /2	25°C		-130			-160		nA
		·····	$V_O = V_{DD}/2$,	25°C		105	280		143	300	
IDD	Supply current		$V_{IC} = V_{DD}/2$	0°C		125	320		173	400	μΑ
			No load	70°C		85	220		110	280	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



MEDIUM-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

			TEOT			TLC271	I, TLC27	'1AI, TLO			
	PARAMETER		TEST	T _A †	V	DD = 5 \	′	٧ _E	OD = 10	٧	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
		TLC2711		25°C		1.1	10		1.1	10	
		1202711	V _O = 1.4 V,	Full range			13			13	
V	Innut officet valtage	TI C071 A1	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	\/
VIO	Input offset voltage	TLC271AI	$R_S = 50 \Omega$	Full range			7			7	mV
		TI C071DI	$R_L = 100 \text{ k}\Omega$	25°C		0.25	2		0.26	2	
		TLC271BI		Full range			3.5			3.5	
ανιο	Average temperature of input offset voltage	coefficient		25°C to 85°C		1.7			2.1		μV/°C
1	Inner to effect as support (as	Note 4\	$V_O = V_{DD}/2$	25°C		0.1			0.1		^
lo	Input offset current (se	e Note 4)	$V_{IC} = V_{DD}/2$	85°C		24	1000		26	1000	рA
		N-4- 4\	$V_O = V_{DD}/2$,	25°C		0.6			0.7		- 4
lΒ	Input bias current (see	e Note 4)	$V_{IC} = V_{DD}/2$	85°C		200	2000		220	2000	рA
					-0.2	-0.3		-0.2	-0.3		
				25°C	to	to		to	to		٧
VICR	Common-mode input	 .		ļ	4	4.2		9	9.2		
	voltage range (see No	ote 5)		Full range	-0.2 to			-0.2 to			V
				Full larige	3.5			8.5			V
				25°C	3.2	3.9		8	8.7		
Vон	High-level output volta	ige	V _{ID} = 100 mV,	-40°C	3	3.9		7.8	8.7		v
0			$R_L = 100 \text{ k}\Omega$	85°C	3	4		7.8	8.7		
	ALAMA ANA ANA ANA ANA ANA ANA ANA ANA ANA			25°C		0	50		0	50	
VOL	Low-level output volta	ge	$V_{ID} = -100 \text{ mV},$	-40°C		0	50		0	50	mV
			IOT = 0	85°C		0	50		0	50	
				25°C	25	170		. 25	275		
AVD	Large-signal differenti voltage amplification	al	R_L = 100 kΩ, See Note 6	-40°C	15	270		15	390		V/mV
	voltage amplification		See Note 6	85°C	15	130		15	220		
				25°C	65	91		65	94		
CMRR	Common-mode reject	ion ratio	V _{IC} = V _{ICR} min	-40°C	60	90		60	93		dB
				85°C	60	90		60	94		
				25°C	70	93		70	93		
ksvr	Supply-voltage rejecti	on ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	-40°C	60	91		60	91		dB
	(ΔV _{DD} /ΔV _{IO})		VU = 1.4 V	85°C	60	94		60	94		
l(SEL)	Input current (BIAS SI	ELECT)	V _{I(SEL)} = V _{DD} /2	25°C		-130			-160		nA
			$V_O = V_{DD}/2$,	25°C		105	280		143	300	
lDD	Supply current		$V_{IC} = V_{DD}/2$,	-40°C		158	400		225	450	μΑ
			No load	85°C		80.	200		103	260	

[†]Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

^{6.} At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.

electrical characteristics at specified free-air temperature (unless otherwise noted)

				l		TLC2	71M			
	PARAMETER	TEST CONDITIONS	T _A †	V	DD = 5 \	<i>i</i>	٧	D = 10	V	UNIT
		CONDITIONS		MIN	TYP	MAX	MIN	TYP	10 12 15 35 50 50	· ·
Vio	Input offset voltage	V _O = 1.4 V, V _{IC} = 0 V,	25°C		1.1	10		1.1	10	mV
VIO	mput onset voltage	$R_S = 50 \Omega$, $R_L = 100 k\Omega$	Full range			12			12	
αVIO	Average temperature coefficient of input offset voltage		25°C to 125°C		1.7			2.1		μV/°C
1	Input offset surrent (see Note 4)	$V_O = V_{DD}/2$	25°C		0.1		-	0.1		pА
liO	Input offset current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		1.4	15		1.8	15	nA
1	Innut him surrent (see Note 4)	$V_O = V_{DD}/2$	25°C		0.6			0.7		pА
lΒ	Input bias current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		9	35		10	35	nA
\/·	Common-mode input		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		V
VICR	voltage range (see Note 5)		Full range	0 to 3.5			0 to 8.5			٧
			25°C	3.2	3.9		8	8.7		
Vон	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_{I} = 100 \text{ k}\Omega$	−55°C	3	3.9		7.8	8.6		V
		HL = 100 K22	125°C	3	4		7.8	8.6		
			25°C		0	50		0	50	
v_{OL}	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OL} = 0$	-55°C		0	50		0	50	mV
		IOL = 0	125°C		0	50		0	50	
			25°C	25	170		25	275		
Avd	Large-signal differential voltage amplification	$R_L = 10 \text{ k}\Omega$ See Note 6	−55°C	15	290		15	420		V/mV
	voltage amplification	See Note o	125°C	15	120		15	190		
			25°C	65	91		65	94		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	-55°C	60	89		60	93		dB
			125°C	60	91		60	93		
-			25°C	70	93		70	93		
ksvr	Supply-voltage rejection ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	−55°C	60	91		60	91		dB
	(ΔV _{DD} /ΔV _{IO})	1.4 V	125°C	60	94		60	94		
I(SEL)	Input current (BIAS SELECT)	$V_{I(SEL)} = V_{DD}/2$	25°C		-130			-160		nA
	The state of the s	$V_O = V_{DD}/2$,	25°C		105	280		143	300	
IDD	Supply current	$V_{IC} = V_{DD}/2$	−55°C		170	440		245	500	μΑ
		No load	125°C		70	180		90	240	1

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	TEST CONDITIONS			TLC271C, TLC271AC, TLC271BC		
					MIN	TYP	MAX	
				25°C		0.43		
			V _{I(PP)} = 1 V	0°C		0.46		
SR	Slew rate at unity gain	$R_L = 100 kΩ$, $C_L = 20 pF$,		70°C		0.36		\//\\c
J Sh	See Figure 98	25°C		0.40		V/μs		
			$V_{I(PP)} = 2.5 \text{ V}$	0°C		0.43		
				70°C		0.34		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√ Hz
				25°C		55		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	0°C		60		kHz
			See Figure 90	70°C	ļ	50		
				25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF,$	0°C		600		kHz
		Gee rigule 100		70°C		400		
		V 40 V		25°C		40°		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 100	0°C		41°		
		ο _L = 25 μι,		70°C		39°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST CO	NDITIONS	TA	TLC271	C, TLC2 C271B0		UNIT
					MIN	TYP	MAX	
				25°C		0.62		
			V _{I(PP)} = 1 V	0°C		0.67		
SR	Claus rate at units gain	$R_L = 100 \text{ k}\Omega$		70°C		0.51		1////
on .	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		0.56		V/μs
			$V_{I(PP)} = 5.5 V$	0°C		0.61		
				70°C		0.46		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√ Hz
				25°C		35		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	0°C		40		kHz
1		HL = 100 K32,	Gee i igule 30	70°C		30		
				25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF,$	0°C		710		kHz
		See riigure 100		70°C		510		
		V 40V	, D	25°C		43°		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 100	0°C		44°		
		- 20 p.,	70°C		42°			

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

	PARAMETER	TEST CO	NDITIONS	TA		II, TLC2 .C271BI		UNIT
					MIN	TYP	MAX	
				25°C		0.43		
			V _{I(PP)} = 1 V	-40°C		0.51		
SR	Slew rate at unity gain	$R_L = 100 kΩ$, $C_L = 20 pF$,		85°C		0.35		Mus
Sn	Siew rate at unity gain	See Figure 98	25°C 0.4	0.40		V/μs		
			$V_{I(PP)} = 2.5 \text{ V}$	-40°C		0.48		
				85°C		0.32	\	
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√ Hz
				25°C		55		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	-40°C		75		kHz
		TIL = 100 K32,	See Figure 90	85°C		45		
				25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-40°C		770		MHz
		See Figure 100		85°C		370		
		10 1/	4 D	25°C		40°		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 100	-40°C		43°		
		SL = 23 pr,	200gailo 100	85°C		38°		

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	TA	TLC271I, TLC271AI, TLC271BI			UNIT
					MIN	TYP	MAX	İ
				25°C		0.62		
			V _{I(PP)} = 1 V	-40°C		0.77		
SR	Claw rate at unity sain	$R_L = 100 \text{ k}\Omega$		85°C		0.47		V/
on	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		0.56		V/μs
			$V_{I(PP)} = 5.5 V$	-40°C		0.70		
				85°C		0.44		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
				25°C		35		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$,3 $R_I = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	-40°C		45		kHz
		TIL = 100 K22,	See i igule 90	85°C		25		}
				25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-40°C		880		kHz
		See Figure 100		85°C		480		1
		14 40 14	, 5	25°C		43°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 100	-40°C		46°		1
		J = 20 pi,	85°C		41°		1	

operating characteristics at specified free-air temperature, V_{DD} = 5 V

	DADAMETED	7507.00	MOITIONO	T -	TI	-C271M		
	PARAMETER	I EST CO	ONDITIONS	TA	MIN	TYP	MAX	UNIT
				25°C		0.43		
			V _{I(PP)} = 1 V	−55°C		0.54		
SR	Slow rate at unity gain	$R_L = 100 kΩ$, $C_L = 20 pF$,		125°C		0.29		V/μs
Jon	Slew rate at unity gain	See Figure 98		25°C		0.40		ν /μδ
			V _{I(PP)} = 2.5 V	−55°C		0.50		
				125°C		0.28		
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
				25°C		55		
Вом	Maximum output-swing bandwidth		C _L = 20 pF, See Figure 98	−55°C		80		kHz
			See Figure 90	125°C		40		
			_	25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-55°C		850		kHz
		See Figure 100		125°C		330		
		10.34	, 5	25°C		40°		
φm	Phase margin		f = B ₁ , See Figure 100	-55°C		43°		
		OL = 25 pr,	CCC rigate 100	125°C		36°		

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 10 V

	PARAMETER	TEST OF	NUDITIONS		T	LC271M		UNIT
1	PARAMETER	1EST CC	ONDITIONS	TA	MIN	TYP	MAX	UNIT
				25°C		0.62		
1			V _{I(PP)} = 1 V	−55°C		0.81		
SR	Clay rate at unity gain	$R_L = 100 \text{ k}\Omega$		125°C		0.38		1///
Jon	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		0.56		V/μs
			$V_{I(PP)} = 5.5 V$	−55°C		0.73		
				125°C		0.35		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
				25°C		35		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 98	−55°C		50		kHz
		111 = 100 K32,	See Figure 30	125°C		20		
				25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	−55°C		960		kHz
		See Figure 100		125°C		440		
		1, 10,	, 5	25°C		43°		
φm		V _I = 10 mV, C _I = 20 pF,	f = B ₁ , See Figure 100	−55°C		47°		
		OL = 20 μι,	125°C		39°			

TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)

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	Phase shift	vs Frequency	60, 61

TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†

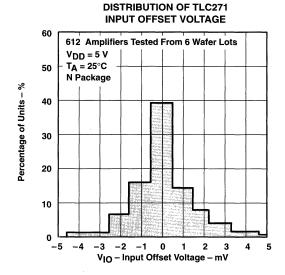


Figure 34

DISTRIBUTION OF TLC271

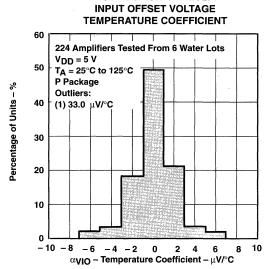


Figure 36

DISTRIBUTION OF TLC271 INPUT OFFSET VOLTAGE

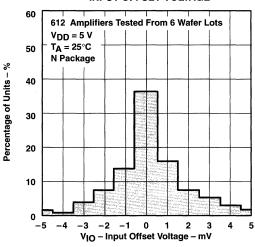


Figure 35

DISTRIBUTION OF TLC271 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

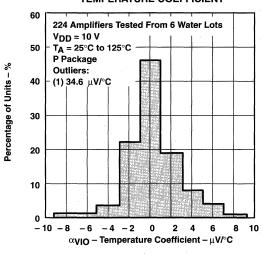
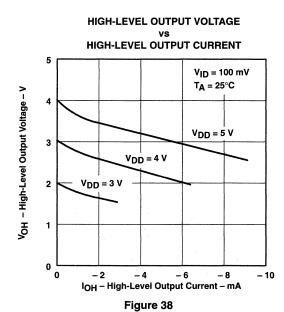


Figure 37

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†



HIGH-LEVEL OUTPUT VOLTAGE

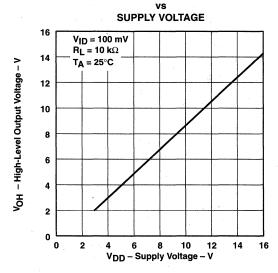


Figure 40

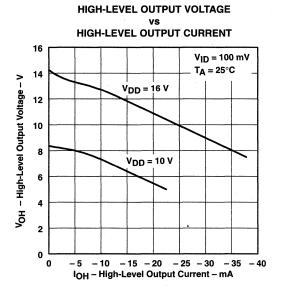
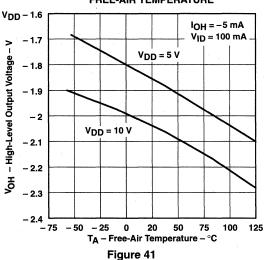


Figure 39

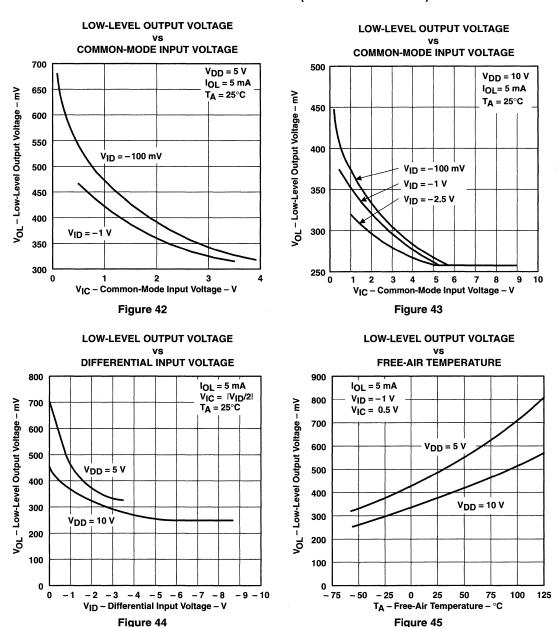
HIGH-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



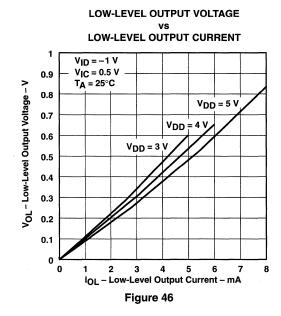
TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†

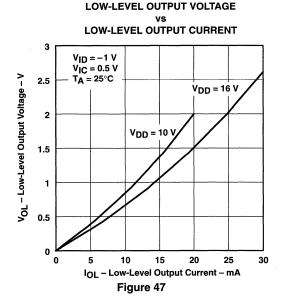


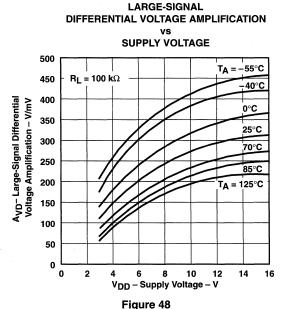
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

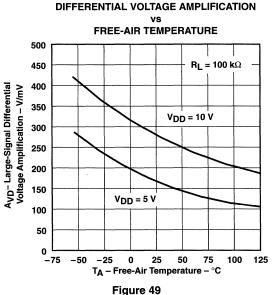


TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†









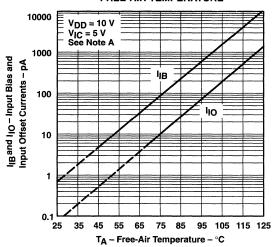
LARGE-SIGNAL

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT

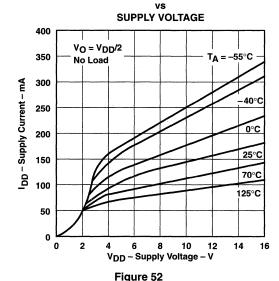
FREE-AIR TEMPERATURE



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 50

SUPPLY CURRENT



MAXIMUM INPUT VOLTAGE

SUPPLY VOLTAGE

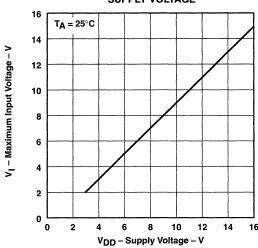
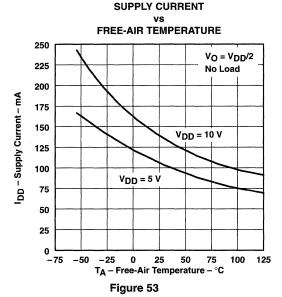


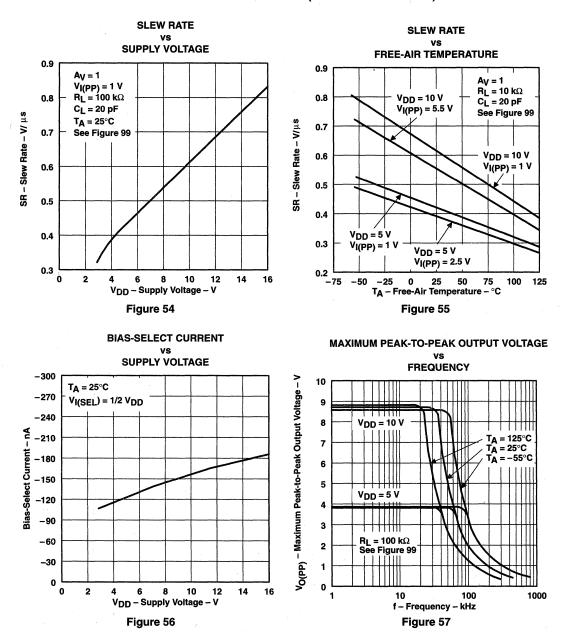
Figure 51



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



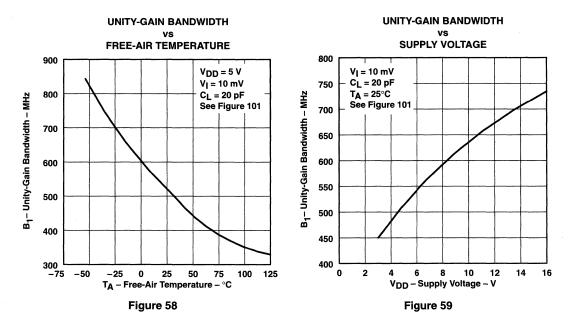
TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†



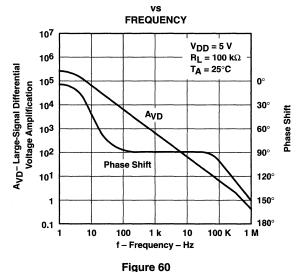
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



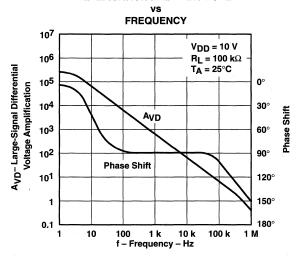
. .ga. 0 00

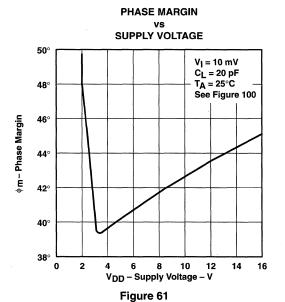
[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

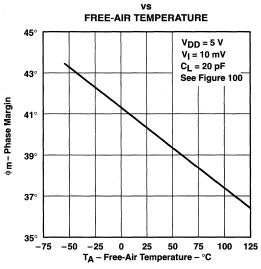


TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT





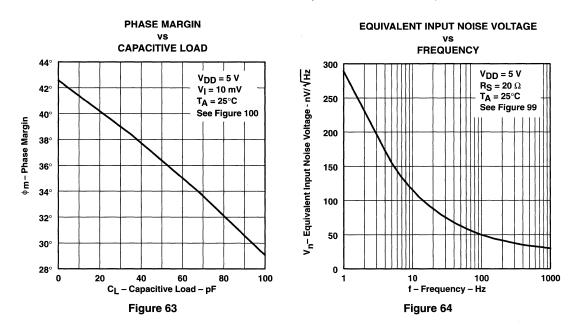


PHASE MARGIN

Figure 62

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS (MEDIUM-BIAS MODE)†



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

LOW-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

					1	LC2710	, TLC27	1AC, TLC271BC			
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5	/	V	DD = 10	٧	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
		TI 00710		25°C		1.1	10		1.1	-10	
		TLC271C	V _O = 1.4 V,	Full range			12			12	
V	Input offeet voltege	TI C071 AC	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	\/
VIO	Input offset voltage	TLC271AC	$R_S = 50 \Omega$,	Full range			6.5		•	6.5	mV
		TLC271BC	$R_{\parallel} = 1 M\Omega$	25°C		0.24	2		0.26	2	
		ILO2/IBC		Full range			3			3	
αΝΙΟ	Average temperature of input offset voltage	coefficient of	·	25°C to 70°C		1.1			1		μV/°C
li a	Innuit offset surrent (se	a Nata 4\	$V_O = V_{DD}/2$,	25°C		0.1			0.1		- ^
lio	Input offset current (se	e Note 4)	$V_{IC} = V_{DD}/2$	70°C		7	300		8	300	pΑ
l.=	Input bias current (see	Note 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		
lΒ	input bias current (see	Note 4)	$V_{IC} = V_{DD}/2$	70°C		40	600		50	600	рA
				25°C	-0.2 to	-0.3 to		-0.2 to	-0.3 to		٧.
	Common-mode input				4	4.2		9	9.2		•
VICR	voltage range (see Not	te 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			V
				25°C	3.2	4.1		8	8.9		
Vон	High-level output voltage	ge	V _{ID} = 100 mV,	0°C	3	4.1		7.8	8.9		V
0	, ,	•	R _L = 1 MΩ	70°C	3	4.2		7.8	8.9		
				25°C		0	50		0	50	
VOL	Low-level output voltage	je	V _{ID} = -100 mV,	0°C		0	50		0	50	mV
			IOL = 0	70°C		0	50		0	50	
	·			25°C	50	520		. 50	870		
A_{VD}	Large-signal differentia voltage amplification	ıl	$R_L=1 M\Omega$, See Note 6	0°C	50	700		50	1030		V/mV
	voltage amplification		See Note o	70°C	50	380		50	660		
			·	25°C	65	94		65	97		
CMRR	Common-mode rejection	on ratio	VIC = VICRmin	0°C	60	95		60	97		dB
				70°C	60	95		60	97		
				25°C	70	97		70	97		
ksvr	Supply-voltage rejection (ΔVDD/ΔVIO)	n ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	0°C	60	97		60	97		dB
			10-7.4	70°C	60	98		60	98		
I(SEL)	Input current (BIAS SE	LECT)	V _{I(SEL)} = V _{DD}	25°C		65			95		nA
			$V_O = V_{DD}/2$,	25°C		10	17		14	23	
DD	Supply current		$V_{IC} = V_{DD}/2$,	0°C		12	21		18	33	μА
			No load	70°C		8	14		11	20	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



LOW-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

			7507			TLC271	I, TLC27	71AI, TL	1AI, TLC271BI		
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5 \	/	٧ _I	DD = 10	٧	UNIT
			CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
		TLC2711		25°C		1.1	10		1.1	10	
		ILC2/11	V _O = 1.4 V,	Full range			13			13	
VIO	Input offset voltage	TLC271AI	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	mV
VIO	input onset voltage	ILO2/IAI	$R_S = 50 \Omega$,	Full range			7			7	1110
		TLC271BI	R _L = 1 MΩ	25°C		0.24	2		0.26	2	
		1602/161		Full range			3.5			3.5	
αVIO	Average temperature of input offset voltage			25°C to 85°C		1.1			1		μV/°C
1		N-t- 4\	$V_O = V_{DD}/2$,	25°C		0.1			0.1		- 4
10	Input offset current (s	see Note 4)	VIC = VDD/2	85°C		24	1000		26	1000	pΑ
L	lan. 4 bina	- M-4- 4)	$V_O = V_{DD}/2$	25°C		0.6			0.7		4
IB	Input bias current (se	e Note 4)	VIC = VDD/2	85°C		200	2000		220	2000	pΑ
					-0.2	-0.3		-0.2	-0.3		
				25°C	to 4	to 4.2		to 9	to 9.2		V
VICR	Common-mode input				-	4.2			9.2		
TICH	voltage range (see Note 5)			Full range	-0.2 to			-0.2 to			v
					3.5			8.5			_
	,			25°C	3	4.1		8	8.9		
VOH	High-level output volt	age	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	-40°C	3	4.1		7.8	8.9		V
			11[-110122	85°C	3	4.2		7.8	8.9		
				25°C		0	50		0	50	
VOL	Low-level output volta	age	V _{ID} = -100 mV, l _{OL} = 0	-40°C		0	50		. 0	50	mV
			I IOL - V	85°C		0	50		0	50	
				25°C	50	520		50	870		
AVD	Large-signal different voltage amplification	ial	R _L = 1 MΩ See Note 6	-40°C	50	900		50	1550		V/mV
	voltage amplification		OCC NOIC O	85°C	50	330		50	585		
				25°C	65	94		65	97		
CMRR	Common-mode rejec	tion ratio	V _{IC} = V _{ICR} min	-40°C	60	95		60	97		dB
				85°C	60	95		60	98		
				25°C	70	97		70	97		
ksvr	Supply-voltage reject (ΔVDD/ΔVIO)	ion ratio	V _{DD} = 5 V to 10 V V _O = 1.4 V	-40°C	60	97		60	97		dB
	(24DD)24IO)		1.7 V	85°C	60	98		60	98		
I(SEL)	Input current (BIAS S	ELECT)	VI(SEL) = VDD	25°C		65			95		nA
	7		$V_O = V_{DD}/2$,	° 25°C		10	17		14	23	
IDD	Supply current		$V_{IC} = V_{DD}/2$	-40°C		16	27		25	43	μΑ
			No load	85°C		17	13		10	18	

† Full range is -40 to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



LOW-BIAS MODE

electrical characteristics at specified free-air temperature (unless otherwise noted)

				TLC271M						
PARAMETER		TEST	T _A †	V	DD = 5	/	V _{DD} = 10 V			UNIT
		CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V _O = 1.4 V, V _{IC} = 0 V,	25°C		1.1	10		1.1	10	mV
VIO	input onset voltage	$R_S = 50 \Omega$, $R_L = 1 M\Omega$	Full range			12			12	IIIV
αVIO	Average temperature coefficient of input offset voltage		25°C to 125°C		1.4			1.4		μV/°C
10	Input offset current (see Note 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		pА
טוי	input onset current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		1.4	15		1.8	15	nA
lin	Input bias current (see Note 4)	$V_O = V_{DD}/2$	25°C		0.6			0.7		pА
lВ	input bias current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		9	35		10	35	nA
	Common-mode input		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		٧
VICR	voltage range (see Note 5)		Full range	0 to 3.5			0 to 8.5		**************************************	V
	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	25°C	3.2	4.1		8	8.9		
۷он			-55°C	3	4.1		7.8	8.8		V
		n[= M22	125°C	3	4.2		7.8	9		
			25°C		0	50		. 0	50	
V_{OL}	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OL} = 0$	-55°C		0	50		0	50	mV
	v.	IOL = 0	125°C		0	50		0	50	
			25°C	50	520		50	870		
A_{VD}	Large-signal differential voltage amplification	R _L = 1 MΩ, See Note 6	−55°C	25	1000		25	1775		V/mV
	voltage amplification	See Note o	125°C	25	200		25	380		
			25°C	65	94		65	97		
CMRR	Common-mode rejection ratio	rejection ratio $V_{IC} = V_{ICR}$ min -55° C	−55°C	60	95		60	97		dB
]	125°C	60	85		60	91		
			25°C	70	97		70	97		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _{DD} = 5 V to 10 V V _O = 1.4 V	−55°C	60	97		60	97		dB
	עייטטייין (טייטע	1.7 V	125°C	60	98		60	98		
I(SEL)	Input current (BIAS SELECT)	VI(SEL) = VDD	25°C		65			95		nA
		$V_O = V_{DD}/2$,	25°C		10	17		14	. 23	
lDD	Supply current	$V_{IC} = V_{DD}/2$	-55°C		17	30		28	48	μА
		No load	125°C		7	12		9	15	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

LOW-BIAS MODE

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	TA	TLC271C, TLC271AC, TLC271BC			UNIT	
l			,			TYP	MAX	
				25°C		0.03		
			V _{I(PP)} = 1 V	0°C		0.04		
CD.	Clay rate at unity gain	$R_L = 1 M\Omega$, $C_1 = 20 pF$,		70°C		0.03		1////
SR	Slew rate at unity gain	See Figure 98		25°C		0.03		V/μs
		l coo v (gaine co	V _{I(PP)} = 2.5 V	0°C		0.03		
				70°C		0.02		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
			C _L = 20 pF, See Figure 98	25°C		5		
ВОМ	Maximum output-swing bandwidth			0°C	0°C	6		kHz
				70°C		4.5		
				25°C		85		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	0°C		100		kHz
		See Figure 100		70°C		65		
		1014	, D	25°C		34°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\perp} = 20 \text{ pF},$	t = B ₁ , See Figure 100	0°C		36°		
		SL = 23 pr ,	200 . Igaio 100	70°C		30°		

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

PARAMETER		TEST CO	TA	TLC271C, TLC271AC, TLC271BC			UNIT					
					MIN	TYP	MAX					
				25°C		0.05						
		_	V _{I(PP)} = 1 V	0°C		0.05						
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		70°C		0.04		Muo				
Jon J	Siew rate at unity gain	See Figure 98		25°C		0.04		V/μs				
l			$V_{I(PP)} = 5.5 V$	0°C		0.05						
				70°C		0.04						
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		68		nV/√Hz				
		$V_O = V_{OH}$, $R_L = 1 M\Omega$,		25°C		1						
ВОМ	Maximum output-swing bandwidth		VO = VOH,	VO = VOH,	VO = VOH,	VO = VOH,	C _L = 20 pF, See Figure 98	0°C		1.3		kHz
			See Figure 30	70°C		0.9						
		14 40 14		25°C		110						
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	0°C		125		kHz				
É		See Figure 100		70°C		90						
		V 40 V	, D	25°C		38°						
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 100	0°C		40°						
		= 20 p.,	223 i igaio 100	70°C		34°						

LOW-BIAS MODE

operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CO	TA	TLC271I, TLC271AI, TLC271BI			UNIT		
			İ			TYP	MAX		
				25°C		0.03			
		4	V _{I(PP)} = 1 V	-40°C		0.04			
SR	Slow rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		85°C		0.03		V/μs	
on .	Slew rate at unity gain	See Figure 98		25°C		0.03		V/μS	
		Cook igails of	V _{I(PP)} = 2.5 V	-40°C		0.04		1	
				85°C		0.02			
ν _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		68		nV/√Hz	
			C _L = 20 pF, See Figure 98	25°C		5			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 1 M\Omega$,			-40°C		7		kHz
		T = 1 M22,		85°C		4			
				25°C		85			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-40°C		130		MHz	
		Gee i igure 100		85°C		55			
		10 -14	, D	25°C		34°			
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 100	-40°C		38°			
			222	85°C		28°			

operating characteristics at specified free-air temperature, $V_{\mbox{DD}}$ = 10 V

	PARAMETER	TEST CO	TA	TLC271C, TLC271AC, TLC271BC			UNIT		
				MIN	TYP	MAX			
				25°C		0.05			
			V _{I(PP)} = 1 V	-40°C		0.06			
SR	Clays rate at units gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		85°C		0.03		V/μs	
on	Slew rate at unity gain	See Figure 98		25°C		0.04		V/μS	
			V _{I(PP)} = 5.5 V	-40°C		0.05			
				85°C		0.03			
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		68		nV/√Hz	
			C _L = 20 pF, See Figure 98	25°C		1			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,			-40°C		1.4		kHz
1		n_ = 1 lvis2,		85°C		0.8			
				25°C	٠.	110			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 \text{ pF},$	-40°C		155		MHz	
		See Figure 100		85°C		80			
		10 11	4 D	25°C		38°			
φm	Phase margin	$V_{\parallel} = 10 \text{ mV,l}$ $C_{\parallel} = 20 \text{ pF,}$	f = B ₁ , See Figure 100	-40°C		42°			
				85°C		32°			

LOW-BIAS MODE

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	DADAMETED		MOITIONO	_	T	LC271M							
	PARAMETER	I IESI CC	ONDITIONS	TA	MIN	TYP	MAX	UNIT					
				25°C		0.03							
			V _{I(PP)} = 1 V	−55°C		0.04							
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		125°C		0.02		V/μs					
on	Siew rate at unity gain	See Figure 98		25°C		0.03		ν/μ5					
			$V_{I(PP)} = 2.5 V$	−55°C		0.04							
				125°C		0.02							
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$	25°C		68		nV/√Hz					
		l., .,		25°C		5							
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	VO = VOH,	VO = VOH,	VO = VOH,	VO = VOH,	VO = VOH,	C _L = 20 pF, See Figure 98	−55°C		8		kHz
			Oee i igule 30	125°C		3							
				25°C		85							
B ₁		V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-55°C		140		kHz					
		See Figure 100		125°C		45							
		10 -14	·	25°C		34°							
φm	Phase margin	$V_{I} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF},$	f = B ₁ , See Figure 100	−55°C		39°							
		ο <u>ι</u> = 23 μι,		125°C		25°							

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	DADAMETER TEXT CONDITIONS				TA TLC271M			LINUT									
	PARAMETER	PARAMETER TEST CONDITIONS			MIN	TYP	MAX	UNIT									
				25°C		0.05											
			V _{I(PP)} = 1 V	-55°C		0.06											
CD.	Class voto at units main	$R_L = 1 M\Omega$,		125°C		0.03		V/									
SR	Slew rate at unity gain	C _L = 20 pF, See Figure 98		25°C		0.04		V/μs									
			$V_{I(PP)} = 5.5 V$	−55°C		0.06											
			` '	125°C		0.03											
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 99	$R_S = 20 \Omega$,	25°C		68		nV/√ Hz									
		$V_O = V_{OH}$, $R_L = 1 M\Omega$,	V _O = V _{OH} ,	V _O = V _{OH} ,	V _O = V _{OH} ,	VO = VOH,	V _O = V _{OH} ,	V _O = V _{OH} , C _L :	I				25°C		1		
ВОМ	Maximum output-swing bandwidth								C _L = 20 pF, See Figure 98	-55°C		1.5		kHz			
			See Figure 96	125°C		0.7											
				25°C		110											
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 100	$C_L = 20 pF$,	-55°C		165		kHz									
l		See rigule 100		125°C		70											
		., ., .,	, 5	25°C		38°											
φm	Phase margin	$V_I = 10 \text{ mV},$ $C_I = 20 \text{ pF},$	f = B ₁ , See Figure 100	-55°C		43°											
		5L 25 pr,		125°C		29°											

TYPICAL CHARACTERISTICS (LOW-BIAS MODE)

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	66, 67
αΛΙΟ	Temperature coefficient	Distribution	68, 69
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	70, 71 72 73
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	74, 75 76 77 78, 79
A _{VD}	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	80 81 92, 93
I _{IB}	Input bias current	vs Free-air temperature	82
l _{IO}	Input offset current	vs Free-air temperature	82
Vı	Maximum input voltage	vs Supply voltage	83
IDD	Supply current	vs Supply voltage vs Free-air temperature	84 85
SR	Slew rate	vs Supply voltage vs Free-air temperature	86 87
	Bias-select current	vs Supply voltage	88
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	89
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	90 91
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	94 95 96
Vn	Equivalent input noise voltage	vs Frequency	97
	Phase shift	vs Frequency	92, 93

TYPICAL CHARACTERISTICS (LOW-BIAS MODE)†

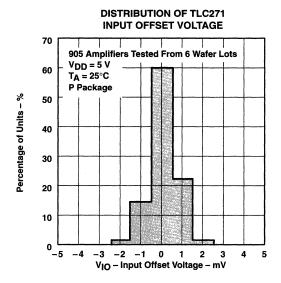


Figure 65

DISTRIBUTION OF TLC271

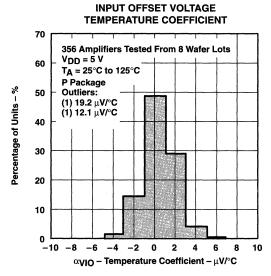


Figure 67

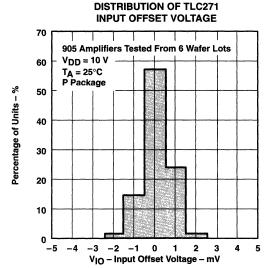


Figure 66

DISTRIBUTION OF TLC271 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

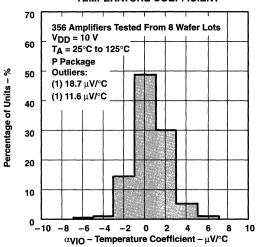
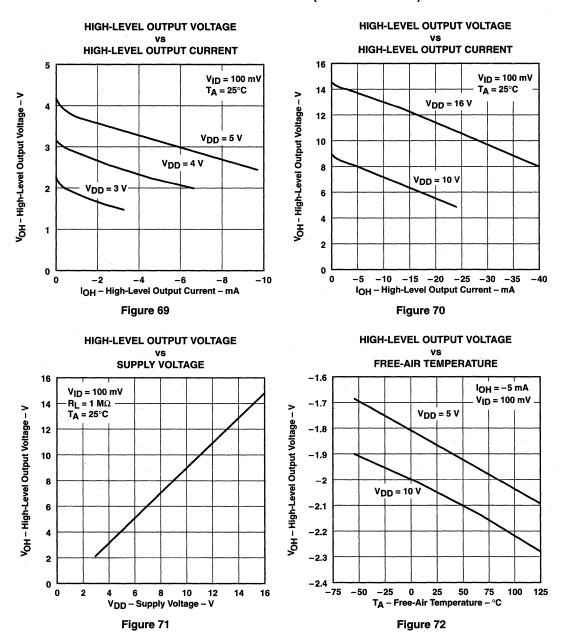


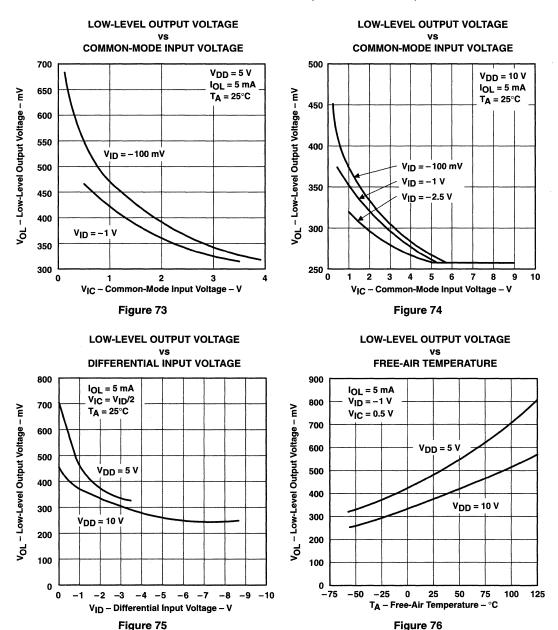
Figure 68

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



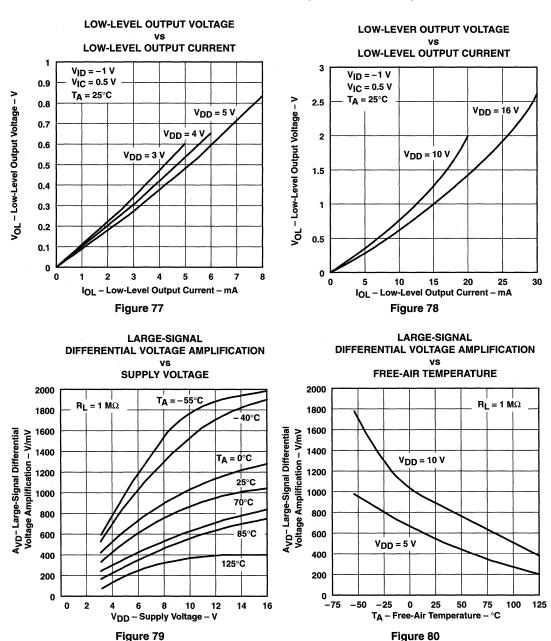
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS (LOW-BIAS MODE)†

CURRENT VS FREE-AIR TEMPERATURE 10000 $V_{DD} = 10 V$ VIC = 5 V See Note A 1000 I_{IB} and I_{IO} – Input Bias and Input Offset Currents – pA lв 100 lю 10 1 0.1 25 35 45 65 85 95 105 115 125 75

INPUT BIAS CURRENT AND INPUT OFFSET

T_A – Free-Air Temperature – °C NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.



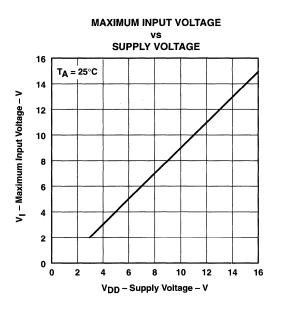
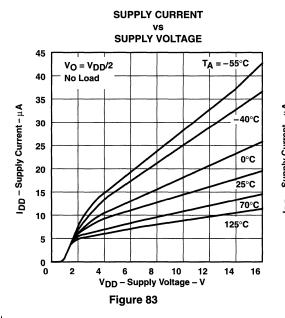
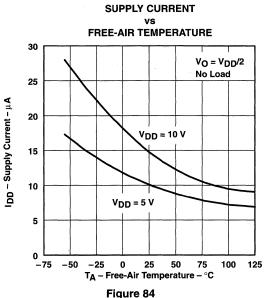


Figure 82

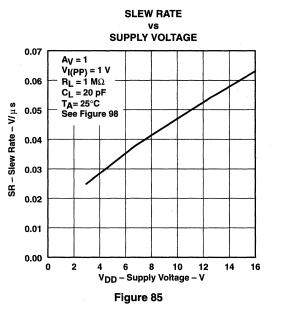


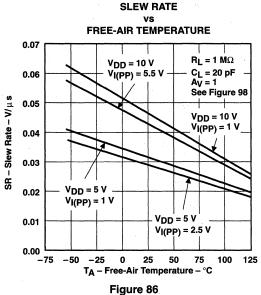


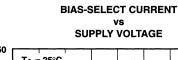
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

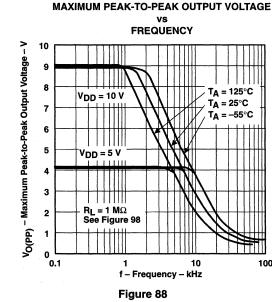


TYPICAL CHARACTERISTICS (LOW-BIAS MODE)†

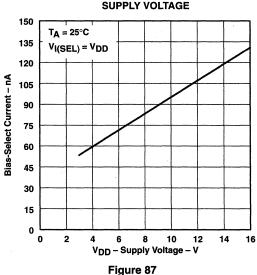








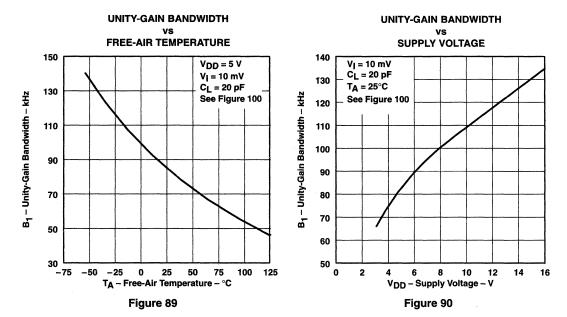
100



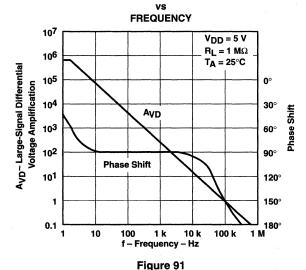
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS (LOW-BIAS MODE)†



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS (LOW-BIAS MODE)†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

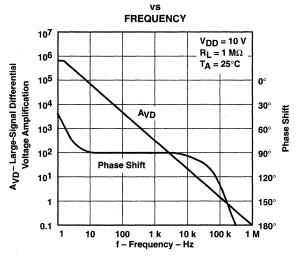
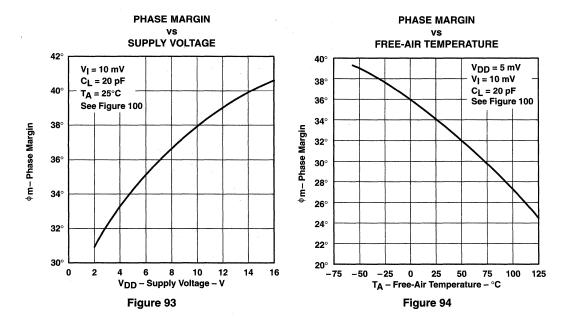
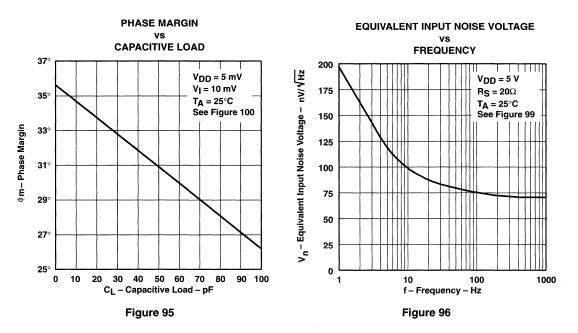


Figure 92



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC271 is optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

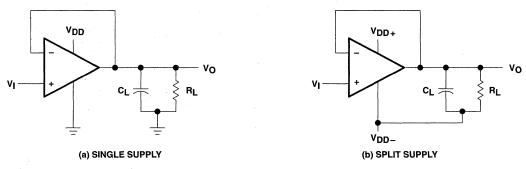


Figure 97. Unity-Gain Amplifier

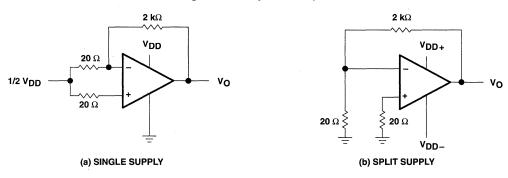


Figure 98. Noise-Test Circuit

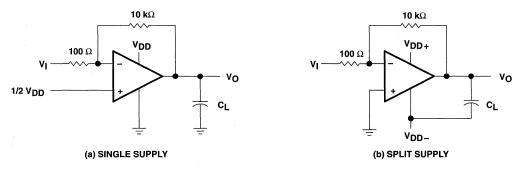


Figure 99. Gain-of-100 Inverting Amplifier



PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC271 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 101). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers us the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

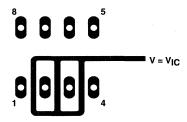


Figure 100. Isolation Metal Around Device inputs (JG and P packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise is necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to the Typical Characteristics section of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

PARAMETER MEASUREMENT INFORMATION

full-power response

Full-power response, the frequency above which the amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measuredby monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 98. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 102). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.

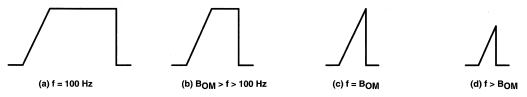


Figure 101. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices, and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

APPLICATION INFORMATION

single-supply operation

While the TLC271 performs well using dual power supplies (also called balanced or split supplies). the design is optimized for single-supply operation. This includes an input common mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

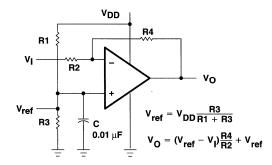


Figure 102. Inverting Amplifier With Voltage Reference



APPLICATION INFORMATION

single-supply operation (continued)

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 103). The low input bias current consumption of the TLC271 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC271 works well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- 1. Power the linear devices from separate bypassed supply lines (see Figure 104); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, RC decoupling may be necessary in high-frequency applications.

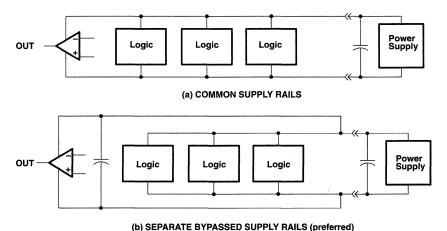


Figure 103. Common Versus Separate Supply Rails

APPLICATION INFORMATION

input offset voltage nulling

The TLC271 offers external input offset null control. Nulling of the input off set voltage may be achieved by adjusting a 25-k Ω potentiometer connected between the offset null terminals with the wiper Connected as shown in Figure 105. The amount of nulling range varies with the bias selection. In the high-bias mode, the nulling range allows the maximum offset voltage specified to be trimmed to zero. In low-bias and medium-bias modes, total nulling may not be possible.

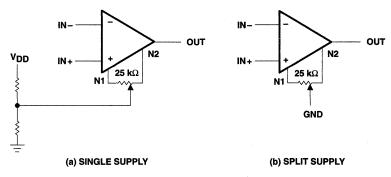


Figure 104. Input Offset Voltage Null Circuit

bias selection

Bias selection is achieved by connecting the bias select pin to one of the three voltage levels (see Figure 106). For medium-bias applications, R is recommended that the bias select pin be connected to the mid-point between the supply rails. This is a simple procedure in split-supply applications, since this point is ground. In single-supply applications, the medium-bias mode necessitates using a voltage divider as indicated. The use of large-value resistors in the voltage divider reduces the current drain of the divider from the supply line. However, large-value resistors used in conjunction with a large-value capacitor requires significant time to charge up to the supply midpoint after the supply is switched on. A voltage other than the midpoint may be used if it is within the voltages specified in the table of Figure 106.

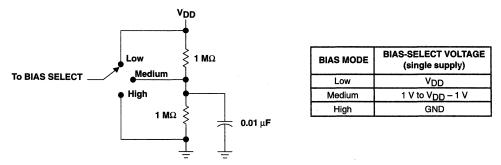


Figure 105. Bias Selection for Single-Supply Applications



APPLICATION INFORMATION

input characteristics

The TLC271 is specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD} - 1$ V at $T_A = 25$ °C and at $V_{DD} - 1.5$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC271 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 µV/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC271 is well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 101 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 107).

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC271 results in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

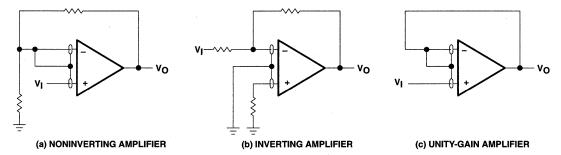


Figure 106. Guard-Ring Schemes

APPLICATION INFORMATION

feedback

Operational amplifier circuits almost always employ feedback, and since feedback is the first prerequisite for oscillation, a little caution is appropriate. Most oscillation problems result from driving capacitive loads and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 108). The value of this capacitor is optimized empirically.

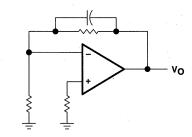


Figure 107. Compensation for Input Capacitance

electrostatic discharge protection

The TLC271 incorporates an internal electrostatic-discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC271 inputs and output were designed to withstand -100-mA surge currents without sustaining latchup; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not by design be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

output characteristics

The output stage of the TLC271 is designed to sink and source relatively high amounts of current (see Typical Characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

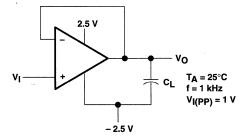


Figure 108. Test Circuit for Output Characteristics



APPLICATION INFORMATION

output characteristics (continued)

All operating characteristics of the TLC271 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figures 110, 111, and 112). In many cases, adding some compensation in the form of a series resistor in the feedback loop alleviates the problem.

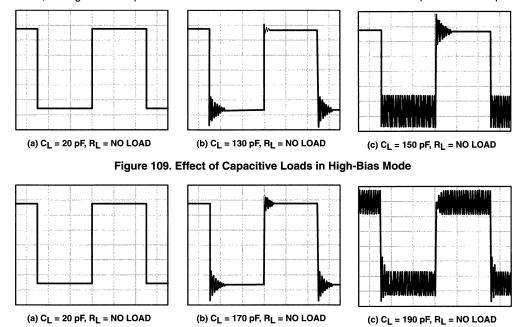


Figure 110. Effect of Capacitive Loads in Medium-Bias Mode

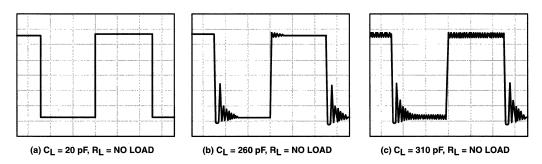


Figure 111. Effect of Capacitive Loads in Low-Bias Mode



APPLICATION INFORMATION

output characteristics (continued)

Although the TLC271 possesses excellent high-level output voltage and current capability, methods are available for boosting this capability, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 113). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor, N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately 60 Ω and 180 Ω , depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Secondly, pullup resistor RP acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

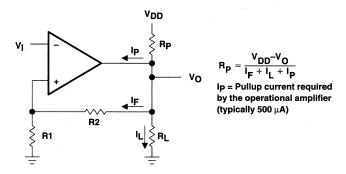
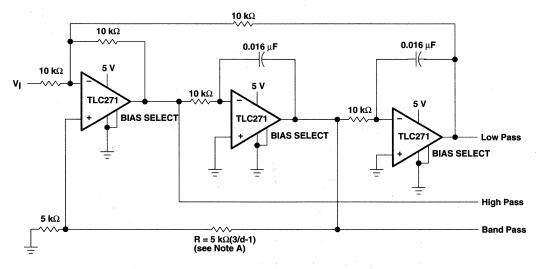


Figure 112. Resistive Pullup to Increase VOH



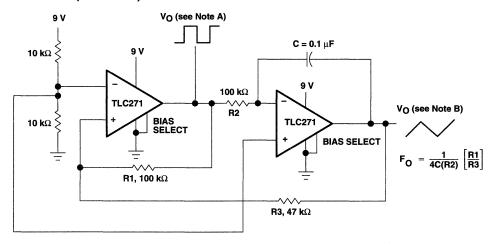
NOTE B: d = damping factor, I/O

Figure 113. State-Variable Filter



APPLICATION INFORMATION

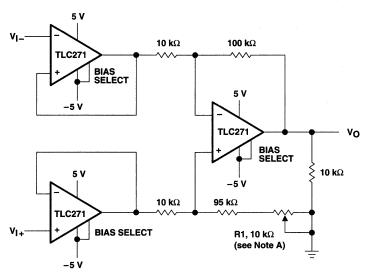
output characteristics (continued)



NOTES: A. V_{O(PP)} = 8 V B. V_{O(PP)} = 4 V

Figure 114. Single-Supply Function Generator

APPLICATION INFORMATION (HIGH-BIAS MODE)



NOTE A: CMRR adjustment must be noninductive.

Figure 115. Low-Power Instrumentation Amplifier

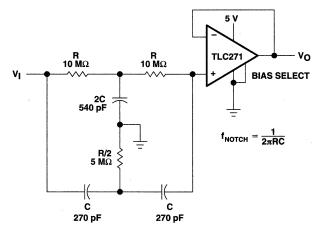
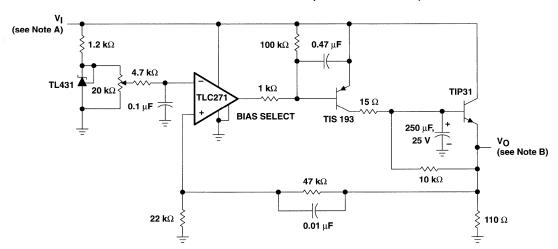


Figure 116. Single-Supply Twin-T Notch Filter

APPLICATION INFORMATION (HIGH-BIAS MODE)



NOTES: A. $V_I = 3.5 \text{ to } 15 \text{ V}$ B. $V_O = 2.0 \text{ V}$, 0 to 1 A

Figure 117. Logic-Array Power Supply

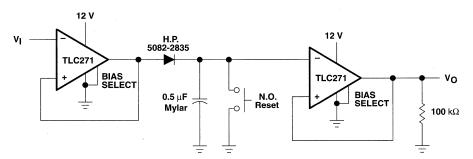
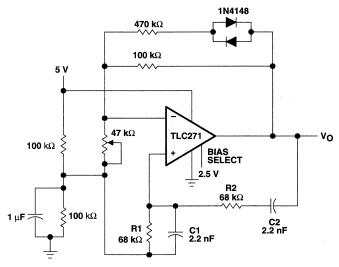


Figure 118. Positive-Peak Detector

APPLICATION INFORMATION (MEDIUM-BIAS MODE)



NOTES: A.
$$V_{O(PP)}$$
 = 2 V
B. $f_{O} = \frac{1}{2\pi\sqrt{R1R2C1C2}}$

Figure 119. Wein Oscillator

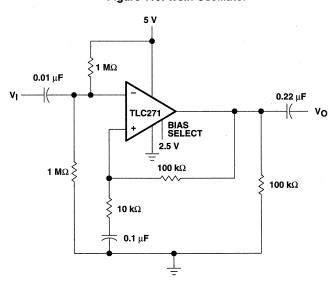
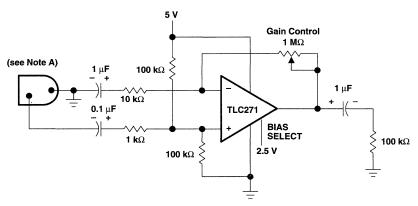


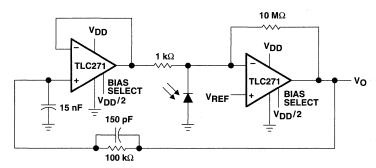
Figure 120. Single-Supply AC Amplifier

APPLICATION INFORMATION (MEDIUM-BIAS MODE)



NOTE A: Low to medium impedance dynamic mike

Figure 121. Microphone Preamplifier



NOTES: A. NOTES: $V_{DD} = 4 \text{ V to } 15 \text{ V}$ B. $V_{ref} = 0 \text{ V to } V_{DD} - 2 \text{ V}$

Figure 122. Photo-Diode Amplifier With Ambient Light Rejection

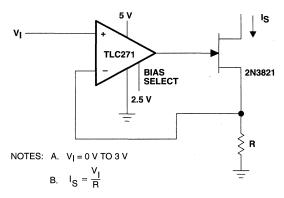
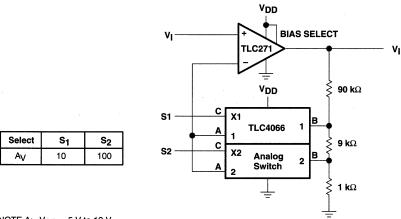


Figure 123. Precision Low-Current Sink



APPLICATION INFORMATION (LOW-BIAS MODE)



NOTE A: $V_{DD} = 5 \text{ V to } 12 \text{ V}$

Figure 124. Amplifier With Digital Gain Selection

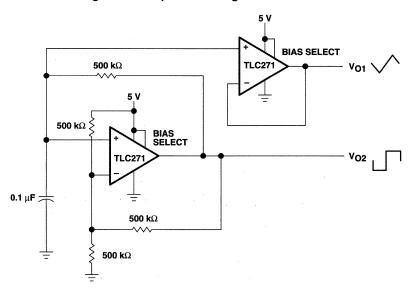
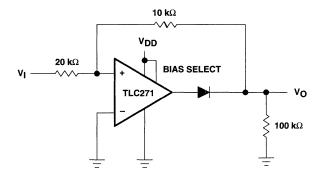


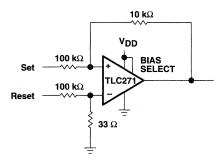
Figure 125. Multivibrator

APPLICATION INFORMATION (LOW-BIAS MODE)



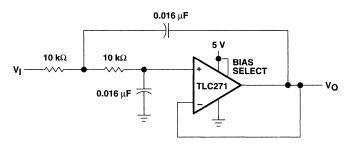
NOTE A: $V_{DD} = 5 \text{ V to } 16 \text{ V}$

Figure 126. Full-Wave Rectifier



NOTE A: $V_{DD} = 5 \text{ V to } 16 \text{ V}$

Figure 127. Set/Reset Flip-Flop



NOTE A: Normalized to FC = 1 kHz and RL = 10 k Ω

Figure 128. Two-Pole Low-Pass Butterworth Filter

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• Trimmed Offset Voltage:

TLC277 . . . 500 μ V Max at 25°C, V_{DD} = 5 V

- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over Specified Temperature Range:

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 4 V to 16 V

- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, I-Suffix types)
- Low Noise . . . Typically 25 nV/√Hz at f = 1 kHz
- Output Voltage Range Includes Negative
 Rail
- High Input impedance . . . $10^{12} \Omega$ Typ
- ESD-Protection Circuitry
- Small-Outline Package Option Also Available in Tape and Reel
- Designed-in Latch-Up Immunity

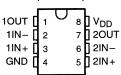
description

The TLC272 and TLC277 precision dual operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, low noise, and speeds approaching that of general-purpose BiFET devices.

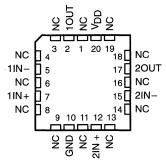
These devices use Texas instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, and high slew rates make these costeffective devices ideal for applications which have previously been reserved for BiFET and NFET products. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the



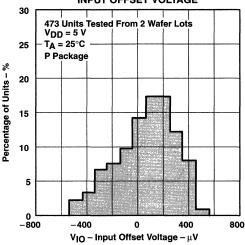


FK PACKAGE (TOP VIEW)



NC - No internal connection

DISTRIBUTION OF TLC277 INPUT OFFSET VOLTAGE



low-cost TLC272 (10 mV) to the high-precision TLC277 (500 μ V). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

LinCMOS is a trademark of Texas Instruments Incorporated.

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AVAILABLE OPTIONS

			PAC	KAGED DEVIC	CES		CHIP
T _A	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)	FORM (Y)
0°C to 70°c	500 μV 2 mV 5 mV 10mV	TLC277CD TLC272BCD TLC272ACD TLC272CD	- - -	·	TLC277CP TLC272BCP TLC272ACP TLC272CP	— — — TLC272CPW	— — — TLC272Y
-40°C to 85°C	500 μV 2 mV 5 mV 10 mV	TLC277ID TLC272BID TLC272AID TLC272ID	_ _ _ _	_ _ _ _	TLC277IP TLC272BIP TLC272AIP TLC272IP	— — — —	— — — —
-55°C to 125°C	500 μV 10 mV	TLC277MD TLC272MD	TLC277MFK TLC272MFK	TLC277MJG TLC272MJG	TLC277MP TLC272MP	_	-

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC277CDR).

description (continued)

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC272 and TLC277. The devices also exhibit low voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

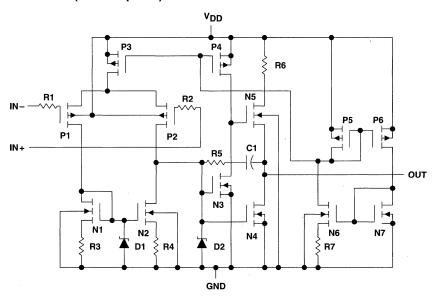
A wide range of packaging options is available, including small-outline and chip carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC272 and TLC277 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

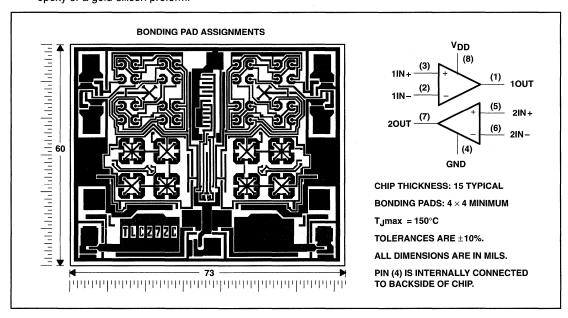
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

equivalent schematic (each amplifier)



TLC272Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC272C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1)	±V _{DD} 0.3 V to V _{DD} ±5 mA
Total current into V _{DD}	45 mA
Total current out of GND	45 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature, T _A : C suffix	
I suffix	
l suffix	40°C to 85°C
M suffix	–40°C to 85°C –55°C to 125°C
	40°C to 85°C 55°C to 125°C 65°C to 150°C
M suffix Storage temperature range	40°C to 85°C 55°C to 125°C 65°C to 150°C 260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	N/A
FK	1375 mW	11 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	N/A
PW	525 mW	4.2 mW/°C	336 mW	N/A	N/A

recommended operating conditions

		c su	FFIX	ISUF	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	4	16	V
Common modeline de la Maria Maria	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5	ľ
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONDI	TIONS	T _A †	TLC272 TLC272			UNIT
						MIN	TYP	MAX	
		TLC272C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		11.02720	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
		TI 007040	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mv
V. a	Input offset voltage	TLC272AC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	
VIO	input onset voltage	TLC272BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		230	2000	
		TLUZIZBU	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3000	μV
ĺ		TLC277C	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	500	μν
		1202770	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			1500	
ανιο	Temperature coefficient of input of	offset voltage			25°C to 70°C		1.8		μV/°C
lio	Input offset current (see Note 4)	,	V _O = 2.5 V,	V _{IC} = 2.5 V	25°C		0.1		nΛ
ΙO	input onset current (see Note 4)		V() = 2.5 V,	AIC = 5.9 A	70°C		7	300	pΑ
len.	Input bias current (see Note 4)		Va - 2 5 V	V _{IC} = 2.5 V	25°C		0.6		pА
lΒ	input bias current (see Note 4)		$V_0 = 2.5 \text{ V},$	VIC = 2.5 V	70°C		40	600	PΑ
						-0.2	-0.3		
ľ					25°C	to 4	to 4.2		V
VICR	Common-mode input voltage ran (see Note 5)	ge	İ			-0.2	4.2		
	(555 11515 5)				Full range	to			v
						3.5			
					25°C	3.2	3.8		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	3	3.8		٧
					70°C	3	3.8		
					25°C		0	50	
VOL	Low-level output voltage		$V_{1D} = -100 \text{ mV},$	IOL = 0	0°C		, 0	50	mV
					70°C		0	50	
					25°C	5	23		
AVD	Large-signal differential voltage a	mplification	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	0°C	4	27		V/mV
					70°C	4	20		
					25°C	65	80		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		0°C	60	84		dB
					70°C	60	85		
	0				25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
	(, OO)				70°C	60	96		
			V _O = 2.5 V,	V:0 - 5 V	25°C		1.4	3.2	
IDD	Supply current (two amplifiers)		VO = 2.5 V, No load	$V_{IC} = 5 V$	0°C		1.6	3.6	mA
					70°C		1.2	2.6	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONDI	TIONS	T _A †	TLC272 TLC272	C, TLC2 BC, TLC		UNIT
						MIN	TYP	MAX	
		TLC272C	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		1.1	10	
		1202720	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
		TLC272AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	1110
VIO	Input offset voltage	TEOZIZAC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	
VIO	input onset voltage	TLC272BC	$V_0 = 1.4 \text{ V},$	V _{IC} = 0,	25°C		290	2000	
		12027280	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			3000	μV
		TLC277C	V _O = 1.4 V,	V _{IC} = 0,	25°C		250	800	μν
		1202770	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			1900	
ανιο	Temperature coefficient of input of	ffset voltage			25°C to 70°C		2		μV/°C
li o	Input offset ourrent (see Note 4)		V _O = 5 V,	V:0 - 5 V	25°C		0.1		pА
ΙΟ	Input offset current (see Note 4)	*	VO = 5 V,	V _{IC} = 5 V	70°C		7	300	PΑ
1	Input bigg gurrent (age Note 4)		V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		рA
IB	Input bias current (see Note 4)		νO = 5 ν,	AIC = 2 A	70°C		50	600	pΑ
			,			-0.2	-0.3		
					25°C	to 9	to 9.2		V
VICR	Common-mode input voltage ran (see Note 5)	ge				-0.2	9.2		
	(366 14016 3)				Full range	-0.2 to			V
						8.5			
	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,				25°C	. 8	8.5		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	7.8	8.5		٧
					70°C	7.8	8.4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		. 0	50	mV -
ı					70°C		0	50	
					25°C	10	36		
A_{VD}	Large-signal differential voltage a	mplification	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	0°C	7.5	42		V/mV
					70°C	7.5	32		
					25°C	65	85		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		0°C	60	88		dB
					70°C	60	88		
					25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
	(~, DD, ¬, IO)				70°C	60	96		
					25°C		1.9	4	
IDD	Supply current (two amplifiers)		V _O = 2.5 V, No load	$V_{IC} = 5 V$	0°C		2.3	4.4	mA
			1		70°C		1.6	3.4	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST COND	TIONS	TΑ [†]		21, TLC2 2BI, TL0		UNIT
						MIN	TYP	MAX	
		TI 00701	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC272I	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			13	
		TI 007041	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
	to and offer about the man	TLC272AI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			7	
VIO	Input offset voltage	TI 0070DI	V _O = 1.4 V,	V _{IC} = 0,	25°C		230	2000	
		TLC272BI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3500	μV
İ		TLC2771	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	500	μν
		ILC2//I	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			2000	
ανιο	Temperature coefficient of input	offset voltage			25°C to 85°C		1.8		μV/°C
li o	Input offset surrent (see Note 4)		V _O = 2.5 V,	V _{IC} = 2.5 V	25°C		0.1		pA
ΙO	Input offset current (see Note 4)	·	VO = 2.5 V,	AIC = 5.9 A	85°C		24	15	þΑ
1	Input bice current (see Note 4)		V- 25V	V 0.5.V	25°C		0.6		рA
IB	Input bias current (see Note 4)		$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	85°C		200	35	pΑ
						-0.2	-0.3		
					25°C	to 4	to 4.2		٧
VICR	Common-mode input voltage rar (see Note 5)	nge					4.2		
,	(See Note 5)		ļ		Full range	-0.2 to			v
						3.5			•
					25°C	3.2	3.8		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	-40°C	3	3.8		V
					85°C	3	3.8		
			T		25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	-40°C		0	50	mV
					85°C		0	50	
					25°C	5	23		
AVD	Large-signal differential voltage	amplification	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	-40°C	3.5	32		V/mV
					85°C	3.5	19		
					25°C	65	80		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		-40°C	60	81		dB
					85°C	60	86		
	0 1 11 11 11				25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	92		dB
					85°C	60	96		
			V _O = 5 V,	V _{IC} = 5 V,	25°C		1.4	3.2	
I_{DD}	Supply current (two amplifiers)		No load	AIC = 2 A	-40°C		1.9	4.4	mA
					85°C		1.1	2.4	

[†] Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONDI	TIONS	T _A †		21, TLC2 2BI, TLC		UNIT
						MIN	TYP	MAX	,
		TI 00701	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
1		TLC272I	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			13	
		TI 007041	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
.	toward offer about the co-	TLC272AI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			7	
VIO	Input offset voltage	TI C070BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		290	2000	
		TLC272BI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3500	μV
ļ		TLC2771	V _O = 1.4 V,	V _{IC} = 0,	25°C		250	800	μν
		ILUZ//I	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			2900	
ανιο	Temperature coefficient of input of	offset voltage			25°C to 85°C		2		μV/°C
lio.	Input offset current (see Note 4)		V _O = 5 V,	V _{IC} = 5 V	25°C		0.1		рA
ΙΟ	input onset current (see Note 4)		VO = 5 V,	AIC = 2 A	85°C		26	1000	PΑ.
lin	Input bias current (see Note 4)		V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		pA
lВ	mput bias current (see Note 4)		VO = 5 V,	AIC = 2 A	85°C		220	2000	pΑ
						-0.2	-0.3		
					25°C	to 9	to 9.2		V
VICR	Common-mode input voltage ran (see Note 5)	ge	ŀ				9.2		
1	(366 (4016 3)				Full range	-0.2 to			v
						8.5			-
					25°C	8	8.5		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	-40°C	7.8	8.5		V
					85°C	7.8	8.5		
					25°C		.0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-40°C		0	50	mV
					85°C		0	50	
					25°C	10	36		
AVD	Large-signal differential voltage a	mplification	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	−40°C	7	46		V/mV
L					85°C	7	31		
					25°C	65	85		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		-40°C	60	87		ďB
					85°C	60	88		
	Cumply valiance unication water				25°C	65	95		
ksvr.	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	92		dB
	(- · DD/ · IO/				85°C	60	96		
			V _O = 5 V,	V _{IC} = 5 V,	25°C		1.4	4	
lDD	Supply current (two amplifiers)		No load	νIC = ο ν,	-40°C		2.8	5	mA
<u></u>	200 in 40°C to 25°C				85°C		1.5	3.2	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETER		TEOT COLLS	TEST CONDITIONS		TLC27	2M, TLC	277M	
	PARAMETER		TEST COND	ITIONS	T _A †	MIN	TYP	MAX	UNIT
		TLC272M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	m\/
V: 0	Input offset voltage	TLC2/2M	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
V _{IO}	input onset voltage	TLC277M	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	500	μV
		TLOZ77W	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3750	μ ν
αVIO	Temperature coefficient of input or voltage	ffset			25°C to 125°C		2.1		μV/°C
Iю	Input offset current (see Note 4)		V _O = 2.5 V	V _{IC} = 2.5 V	25°C		0.1		pА
טוי	input onset current (see Note 4)		V() = 2.5 V	vIC = 2.5 v	125°C		1.4	15	nA
I _{IB}	Input bias current (see Note 4)		V _O = 2.5 V	V _{IC} = 2.5 V	25°C		0.6		pА
אוי	input bias current (see Note 4)		V() = 2.5 V	VIC = 2.5 V	125°C		9	35	nA
.,	Common-mode input voltage ran	ae			25°C	0 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)	3			Full range	0 to 3.5			V
					25°C	3.2	3.8		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	−55°C	3	3.8		V
					125°C	3	3.8		
			·		25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	−55°C		0	50	mV
					125°C		0	50	
					25°C	5	23		
AVD	Large-signal differential voltage a	mplification	$V_O = 0.25 \text{ V to 2 V}$	$R_L = 10 \text{ k}\Omega$	−55°C	3.5	35		V/mV
					125°C	3.5	16		
					25°C	65	80		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		−55°C	60	81		dB
					125°C	60	84		
	Supply-voltage rejection ratio				25°C	65	95		
ksvr	(ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-55°C	60	90		dB
	. 22 10/	- Carren		***************************************	125°C	60	97		
			V _O = 2.5 V,	V _{IC} = 2.5 V,	25°C		1.4	3.2	
lDD	Supply current (two amplifiers)		No load	√10 - 2.0 V,	−55°C		2	5	mA
			İ		125°C		1	2.2	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	DADAMETED		TEST SOME	UTIONS	T. +	TLC27	2M, TLC	277M	UNIT
	PARAMETER		TEST COND	IIIONS	T _A †	MIN	TYP	MAX	UNII
		TLC272M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
14	looned offeet wells as	I LC2/2IVI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	mv
VIO	Input offset voltage	TI 007714	V _O = 1.4 V,	V _{IC} = 0,	25°C		250	800	
		TLC277M	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			4300	μV
ανιο	Temperature coefficient of input voltage	offset			25°C to 125°C		2.2		μV/°C
li o	Input offset current (see Note 4)		V _O = 5 V,	V _{IC} = 5 V	25°C		0.1		рA
ΙΟ	input onset current (see Note 4)		VO = 5 V,	AIC = 2 A	125°C		1.8	15	nA
l	Innut bigg gumant (age Note 4)		V- 5.V	V E.V.	25°C		0.7		pА
lΒ	Input bias current (see Note 4)		$V_O = 5 V$,	$V_{IC} = 5 V$	125°C		10	35	nA
V	Common-mode input voltage ra	nge			25°C	0 to 9	-0.3 to 9.2		V
VICR	(see Note 5)				Full range	0 to 8.5	,		٧
					25°C	8	8.5		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	−55°C	7.8	8.5		V
					125°C	7.8	8.4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-55°C		0	50	mV
					125°C		0	50	
					25°C	10	36		
AVD	Large-signal differential voltage amplification		$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	−55°C	7	50		V/mV
	amplineation				125°C	7	27		
					25°C	65	85	***************************************	
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		−55°C	60	87		dB
					125°C	60	86		
					25°C	65	95		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-55°C	60	90		dB
	(\articles \DD\\\articles \DD\\\\articles \DD\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\				125°C	60	97		
					25°C		1.9	4	
IDD	Supply current (two amplifiers)		V _O = 5 V, No load	$V_{IC} = 5 V$	-55°C		3	6	mA
			140 1040		125°C		1.3	2.8	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	PARAMETER	TEST COM	OITIONS	Т	LC272Y		UNIT
	PARAMETER	TEST CON	JITIONS	MIN	TYP	MAX	UNII
VIO	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $R_{S} = 50 \Omega,$	$V_{IC} = 0$, $R_L = 10 \text{ k}\Omega$		1.1	10	mV
ανιο	Temperature coefficient of input offset voltage				1.8		μV/°C
IЮ	Input offset current (see Note 4)	$V_0 = 2.5 V$,	V _{IC} = 2.5 V		0.1		рA
lв	Input bias current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.6		рA
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 4	-0.3 to 4.2		٧
VOH	High-level output voltage	V _{ID} = 100 mV,	R _L = 10 kΩ	3.2	3.8		٧
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	IOL = 0		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 0.25 V to 2 V	R _L = 10 kΩ	5	23		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	80		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	65	95		dB
lDD	Supply current (two amplifiers)	V _O = 2.5 V, No load	V _{IC} = 2.5 V,		1.4	3.2	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

electrical characteristics, $V_{DD} = 10 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	DADAMETED	TEST COM	DITIONS	T	LC272Y		LINUT
	PARAMETER	TEST CON	DITIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $R_{S} = 50 \Omega,$	$V_{IC} = 0$, $R_L = 10 \text{ k}\Omega$		1.1	10	mV
α_{VIO}	Temperature coefficient of input offset voltage				1.8		μV/°C
lio	Input offset current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.1		pА
lВ	Input bias current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.7		pА
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 9	-0.3 to 9.2		٧
VOH	High-level output voltage	V _{ID} = 100 mV,	R _L = 10 kΩ	8	8.5		V
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	IOL = 0		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 6 V,	R _L = 10 kΩ	10	36		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	85		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	65	95		dB
I _{DD}	Supply current (two amplifiers)	V _O = 5 V, No load	V _{IC} = 5 V,		1.9	4	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

^{5.} This range also applies to each input individually.

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

	PARAMETER		NDITIONS	TA	TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT				
			-	MIN	TYP	MAX						
				25°C		3.6						
				0°C		4						
SR	Clausesta at units main	$R_L = 10 \text{ k}\Omega$		70°C		3		11/100				
SR	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		2.9		V/μs				
			V _{IPP} = 2.5 V	0°C		3.1						
							70°C		2.5			
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz				
		output-swing bandwidth VO = VOH, CL = 20 pF			25°C		320					
ВОМ	Maximum output-swing bandwidth			VO = VOH, $R_{\parallel} = 10 \text{ k}\Omega$,						0°C		340
		H_ = 10 K32,	sz, See rigule i	70°C		260						
					25°C		1.7					
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		2		MHz				
		See Figure 3		70°C		1.3						
		10 11	, D	25°C		46°						
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$		0°C		47°						
		OL - LO pr ,	ccc . iguic o	70°C		43°						

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER		TEST CONDITIONS		TLC272C, TLC272AC, TLC272BC, TLC277C			UNIT				
				TA	MIN	TYP	MAX					
				25°C		5.3						
1		<u> </u>	V _{IPP} = 1 V	0°C		5.9						
SR	Slow rate at unity main	R_L = 10 kΩ, C_L = 20 pF, See Figure 1	70°C		4.3		V/μs					
Sn .	Slew rate at unity gain			25°C		4.6		V/μS				
İ			V _{IPP} = 5.5 V	0°C		5.1						
					70°C		3.8					
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz				
		timum output-swing bandwidth						25°C		200		
ВОМ	Maximum output-swing bandwidth		OH, $C_L = 20$ pF,		0°C		220		kHz			
		HE = 10 K32,		70°C		140						
				25°C		2.2						
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		2.5		MHz				
		See rigure 3		70°C		1.8		1 1				
			, 5	25°C		49°						
φm	Phase margin	V _I = 10 mV,			$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$			f = B ₁ , See Figure 3	0°C		50°	
	-	J = 20 pr,	See Figure 3	70°C		46°						

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operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER		NDITIONS	TA	TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT					
					MIN	TYP	MAX						
				25°C		3.6							
			V _{IPP} = 1 V	-40°C		4.5							
SR		R _L = 10 kΩ, C _L = 20 pF,		85°C		2.8		V/40					
Jon	Slew rate at unity gain	See Figure 1	See Figure 1		25°C		2.9		V/μs				
				V _{IPP} = 2.5 V	-40°C		3.5						
							85°C		2.3				
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz					
				25°C		320							
ВОМ	Maximum output-swing bandwidth	VO = VOH,	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,		-40°C		380		kHz				
		IT_ = 10 K32,	10 K32, See Figure 1	85°C		250							
				25°C		1.7							
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	-40°C		2.6		MHz					
		See Figure 3		85°C		1.2							
		V 40 V	, 5	25°C		46°							
φm	Phase margin	$V_{i} = 10 \text{ mV},$	$V_1 = 10 \text{ mV},$	V ₁ = 10 mV,	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	V _I = 10 mV,	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	f = B ₁ , See Figure 3	-40°C		49°		
) OL - 20 pr,	Coo i iguio o	85°C		43°							

operating characteristics at specified free-air temperature, $V_{\mbox{DD}}$ = 10 V

	PARAMETER		TEST CONDITIONS		TLC272I, TLC272AI, TLC272BI, TLC277I			UNIT			
L		1		TA	MIN	TYP	MAX				
				25°C		5.3					
		ľ	V _{IPP} = 1 V	-40°C		6.8					
SR	Claw rate at unity rain	$R_L = 10 \text{ k}\Omega$		85°C		4		V/μs			
) on	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		4.6		V/μS			
			V _{IPP} = 5.5 V	-40°C		5.8					
			85°C		3.5						
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz			
				25°C		200					
Вом	Maximum output-swing bandwidth	VO = VOH,	VO = VOH,	VO = VOH, $R_1 = 10 \text{ k}\Omega$,	VO = VOH,	C _L = 20 pF,	-40°C		260		kHz
		11 = 10 KS2,	See rigure r	85°C		130					
				25°C		2.2					
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	-40°C		3.1		MHz			
		See Figure 3		85°C		1.7					
		V 40 V		25°C		49°					
φm	Phase margin	$V_1 = 10 \text{ mV},$	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$				-40°C		52°		
	-	ο <u>ι</u> – 20 μι,	occ i iguio o	85°C		46°					

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operating characteristics at specified free-air temperature, V_{DD} = 5 V

PARAMETER		TEST CO	TEST CONDITIONS		TLC272M, TLC277M			LINUT					
	PARAMETER	1EST CO	TEST CONDITIONS		MIN	TYP	MAX	UNIT					
				25°C		3.6							
			V _{IPP} = 1 V	−55°C		4.7							
SR	Slow rate at unity main	B_L = 10 kΩ, C_L = 20 pF,	125°C		2.3		V/μs						
Jon J	Slew rate at unity gain	See Figure 1		25°C		2.9		ν/μ5					
			V _{IPP} = 2.5 V	−55°C		3.7							
				125°C		2							
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz					
				25°C		320							
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,		−55°C		400		kHz					
		TIL = 10 K32,	Gee rigure r	. 125°C		230							
				25°C		1.7							
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	−55°C		2.9		MHz					
		Gee rigure 5		125°C		1.1							
		V 40 V	, 5	25°C		46°							
φm	Phase margin	$V_{I} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF},$	$V_1 = 10 \text{ mV},$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	r = B ₁ , See Figure 3	−55°C		49°		
	-		occ i igule o	125°C		41°							

operating characteristics at specified free-air temperature, $V_{\mbox{DD}}$ = 10 V

	DADAMETED		NOITIONO	_	TLC272	M, TLC	277M			
	PARAMETER	IEST CO	NDITIONS	TA	MIN	TYP	MAX	UNIT		
				25°C		5.3				
			V _{IPP} = 1 V	−55°C		7.1				
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_1 = 20 \text{ pF}$,		125°C		3.1		Muo		
Sh	See Figure 1		25°C		4.6		V/μs			
			VIPP = 5.5 V	−55°C	,	6.1				
				125°C		2.7				
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz		
		$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,			25°C		200			
ВОМ	Maximum output-swing bandwidth			−55°C		280		kHz		
				125°C		110				
				25°C		2.2				
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	−55°C		3.4		MHz		
		See Figure 3		125°C		1.6				
				25°C		49°				
φm	Phase margin					−55°C		52°		
			Occ rigule o	125°C		44°				

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operating characteristics, V_{DD} = 5 V, T_A = 25°C

	DADAMETED	_	TEST CONDITIONS			TLC272Y				
	PARAMETER	'				TYP	MAX	UNIT		
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$	= 10 k Ω , C_{\parallel} = 20 pF,		$R_I = 10 \text{ k}\Omega$, $C_I = 20 \text{ pF}$, $V_{IPP} = 1 \text{ V}$			3.6		V/µs
on	Siew rate at unity gain	See Figure 1	See Figure 1	-	V _{IPP} = 2.5 V		2.9		V/μs	
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	See Figure 2		25		nV/√Hz		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	C _L = 20 pF,	$R_L = 10 \text{ k}\Omega$,		320		kHz		
В1	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF,	See Figure 3		1.7		MHz		
φm	Phase margin	V _I = 10 mV, See Figure 3	f = B ₁ ,	C _L = 20 pF,		46°				

operating characteristics, V_{DD} = 10 V, T_A = 25°C

	PARAMETER		TEST CONDITIONS			TLC272Y		
	PANAMETEN	<u>'</u>				TYP	MAX	UNIT
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 20 pF,	V _{IPP} = 1 V		5.3		V/us
Jon	Siew rate at unity gain	See Figure 1		V _{IPP} = 5.5 V	4.6			ν/μ5
Vn	Equivalent input noise voltage	f ≈ 1 kHz,	$R_S = 20 \Omega$,	See Figure 2		25		nV/√Hz
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	C _L = 20 pF,	$R_L = 10 \text{ k}\Omega$,		200		kHz
B ₁	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF,	See Figure 3		2.2		MHz
φm	Phase margin	V _I = 10 mV, See Figure 3	f = B ₁ ,	C _L = 20 pF,		49°		

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC272 and TLC277 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

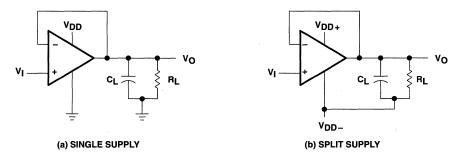


Figure 1. Unity-Gain Amplifier

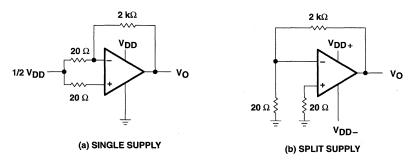


Figure 2. Noise-Test Circuit

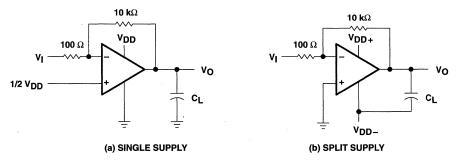


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC272 and TLC277 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

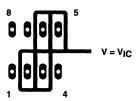


Figure 4. Isolation Metal Around Device Inputs (JG and P packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.



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PARAMETER MEASUREMENT INFORMATION

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.



Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	6, 7
αVIO	Temperature coefficient of input offset voltage	Distribution	8, 9
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
VOL	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
lв	Input bias current	vs Free-air temperature	22
lio	Input offset current	vs Free-air temperature	22
VIC	Common-mode input voltage	vs Supply voltage	23
I _{DD}	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	29
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	34 35 36
Vn	Equivalent input noise voltage	vs Frequency	37
	Phase shift	vs Frequency	32, 33

60

50

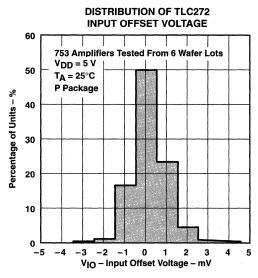
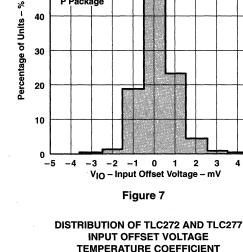


Figure 6

DISTRIBUTION OF TLC272 AND TLC277



 $V_{DD} = 10 V$

T_A = 25°C

P Package

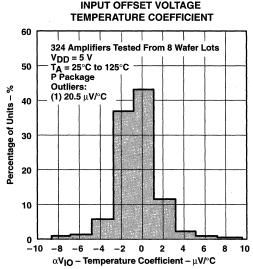
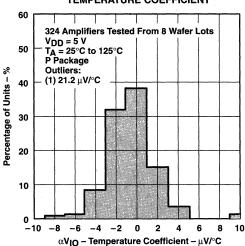


Figure 8



DISTRIBUTION OF TLC272 INPUT OFFSET VOLTAGE

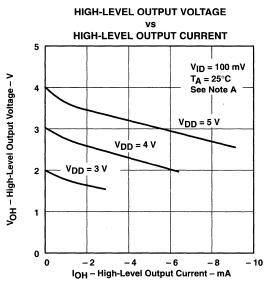
2

1

4

753 Amplifiers Tested From 6 Wafer Lots

Figure 9



NOTE A: The 3-V curve only applies to the C version.

Figure 10

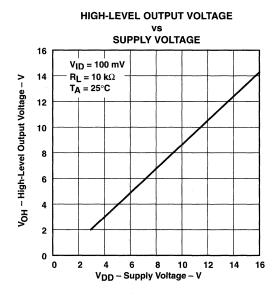


Figure 12

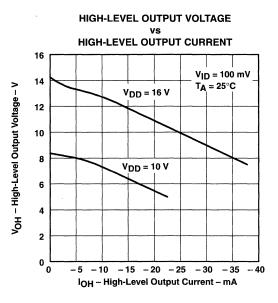


Figure 11

HIGH-LEVEL OUTPUT VOLTAGE

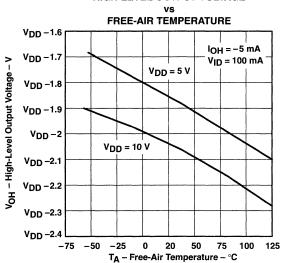
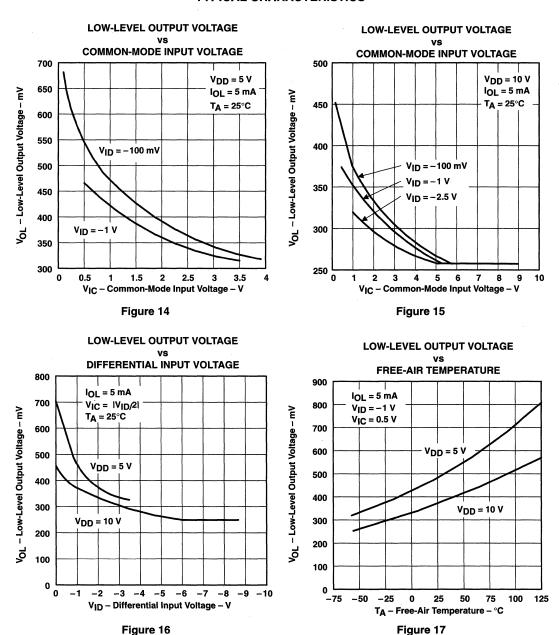


Figure 13

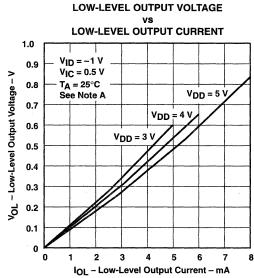
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]



NOTE A: The 3-V curve only applies to the C version. Figure 18

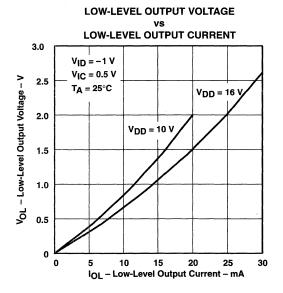
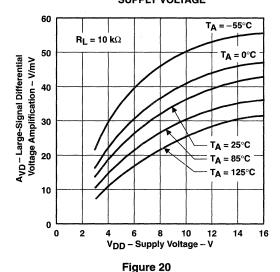


Figure 19





LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION FREE-AIR TEMPERATURE**

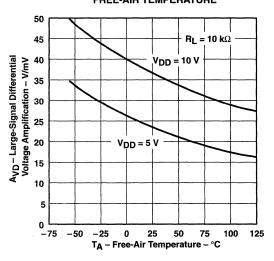


Figure 21

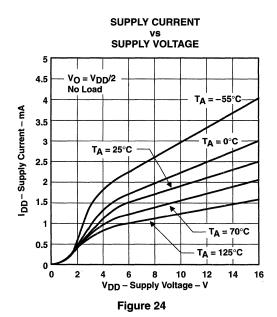
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT **FREE-AIR TEMPERATURE** 10000 IB and I/O - Input Bias and Offset Currents - pA $V_{DD} = 10 \text{ V}$ V_{IC} = 5 V See Note A 1000 lв 100 10 0.1 25 35 55 65 75 85 95 105 115 125 T_A - Free-Air Temperature - °C

NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.





COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT

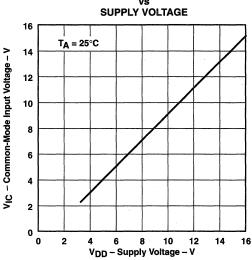


Figure 23

SUPPLY CURRENT

FREE-AIR TEMPERATURE $V_O = V_{DD}/2$ 3.5 No Load 3 DD - Supply Current - mA 2.5 V_{DD} = 10 V 2 1.5 $V_{DD} = 5 V$ 1 0.5 -50 25 50 T_A - Free-Air Temperature - °C

Figure 25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

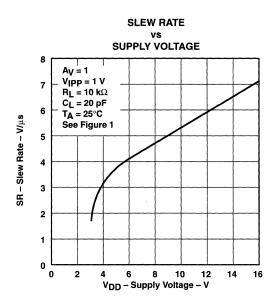


Figure 26

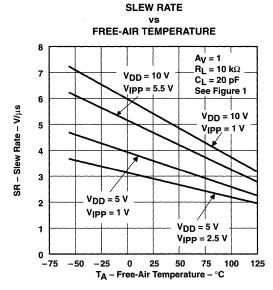


Figure 27

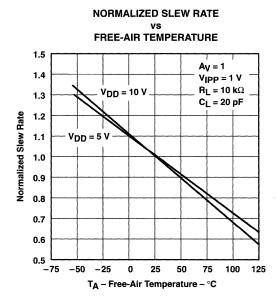


Figure 28

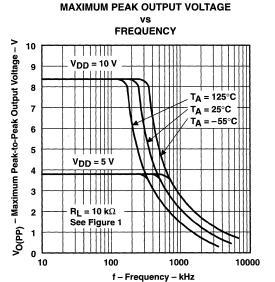
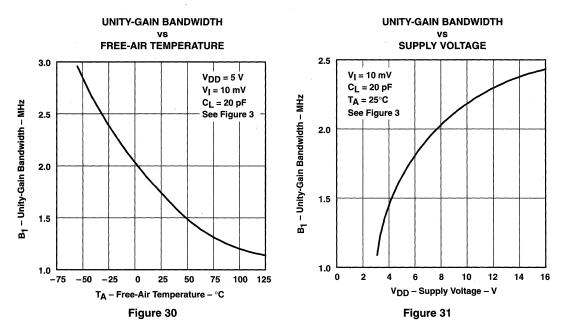


Figure 29

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]



LARGE-SIGNAL DIFFERENTIAL VOLTAGE **AMPLIFICATION AND PHASE SHIFT**

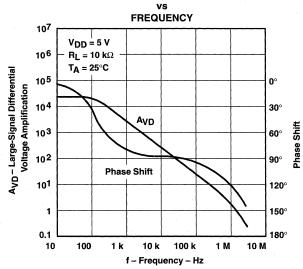


Figure 32

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

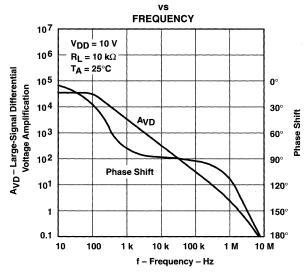
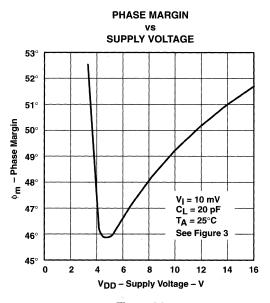


Figure 33



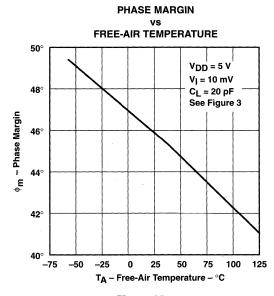


Figure 34

Figure 35

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

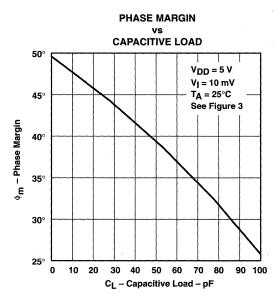


Figure 36

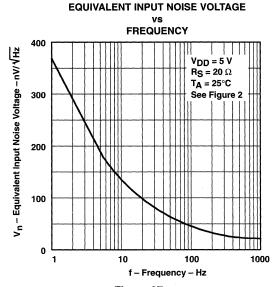


Figure 37

APPLICATION INFORMATION

single-supply operation

While the TLC272 and TLC277 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC272 and TLC277 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC272 and TLC277 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

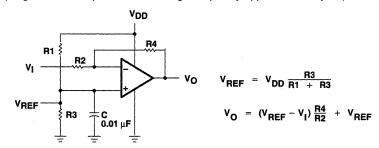


Figure 38. Inverting Amplifier With Voltage Reference

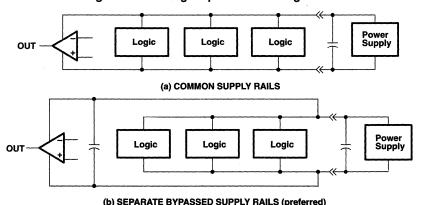


Figure 39. Common vs Separate Supply Rails

APPLICATION INFORMATION

input characteristics

The TLC272 and TLC277 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD} - 1$ V at $T_{A} = 25$ °C and at $V_{DD} - 1.5$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC272 and TLC277 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC272 and TLC277 are well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC272 and TLC277 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

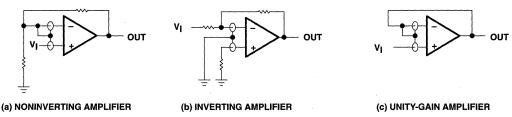


Figure 40. Guard-Ring Schemes

output characteristics

The output stage of the TLC272 and TLC277 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC272 and TLC277 are measured using a 20-pF load. The devices can drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.



APPLICATION INFORMATION

output characteristics (continued)

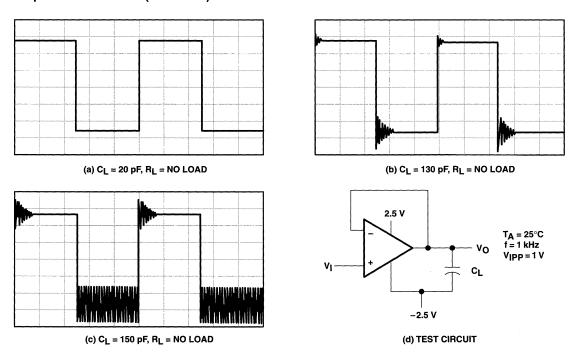
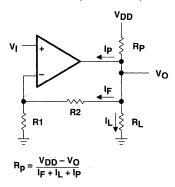


Figure 41. Effect of Capacitive Loads and Test Circuit

Although the TLC272 and TLC277 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on resistance between approximately 60 Ω and 180 Ω , depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

APPLICATION INFORMATION

output characteristics (continued)



Ip = Pullup current required by the operational amplifier (typically 500 uA)

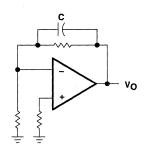


Figure 42. Resistive Pullup to Increase VOH

Figure 43. Compensation for Input Capacitance

feedback

Operational amplifier circuits almost always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

electrostatic discharge protection

The TLC272 and TLC277 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC272 and TLC277 inputs and outputs were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

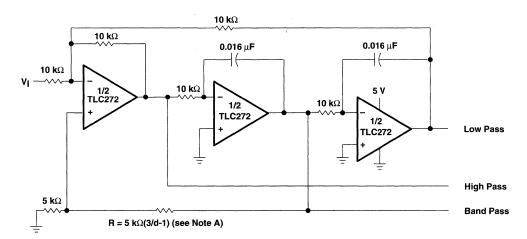
The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.



TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION



NOTE A: d = damping factor, 1/Q

Figure 44. State-Variable Filter

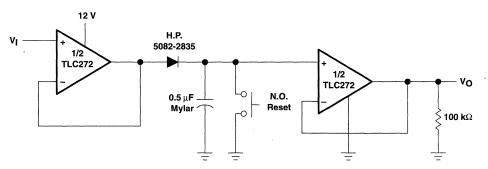
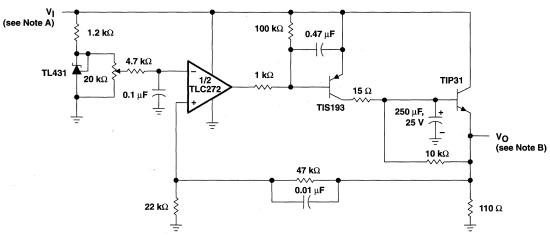


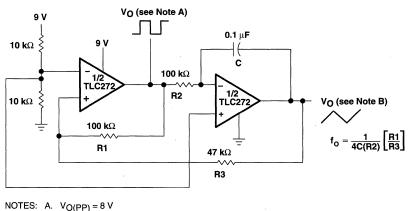
Figure 45. Positive-Peak Detector

APPLICATION INFORMATION



NOTES: A. $V_I = 3.5$ to 15 V B. $V_O = 2$ V, 0 to 1 A

Figure 46. Logic-Array Power Supply



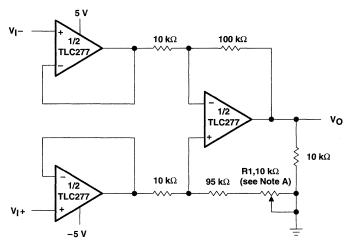
NOTES: A. $V_{O(PP)} = 8 \text{ V}$ B. $V_{O(PP)} = 4 \text{ V}$

Figure 47. Single-Supply Function Generator

TLC272, TLC272A, TLC272B, TLC272Y, TLC277 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION



NOTE B: CMRR adjustment must be noninductive.

Figure 48. Low-Power Instrumentation Amplifier

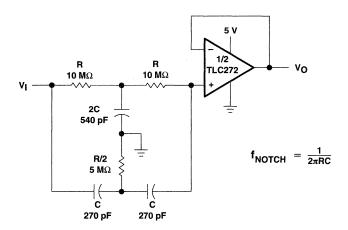


Figure 49. Single-Supply Twin-T Notch Filter

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- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over **Specified Temperature Range:**

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 5 V to 16 V

- Single-Supply Operation
- Common-Mode Input Voltage Range **Extends Below the Negative Rail (C-Suffix** and I-Suffix Types)

- Low Noise . . . 68 nV/√Hz Typically at f = 1 kHz
- **Output Voltage Range includes Negative**
- High Input Impedance . . . $10^{12} \Omega$ Typ
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also** Available in Tape and Reel
- **Designed-In Latch-Up Immunity**

description

The TLC27L1 operational amplifier combines a wide range of input offset-voltage grades with low offset-voltage drift and high input impedance. In addition, the TLC27L1 is a low-bias version of the TLC271 programmable amplifier. These devices use the Texas Instruments silicon-gate LinCMOS™ technology, which provides offset-voltage stability far exceeding the stability available with conventional metal-gate processes.

Three offset-voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC27L1 (10 mV) to the TLC27L1B (2 mV) low-offset version. The extremely high input impedance and low bias currents, in conjunction with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

In general, many features associated with bipolar technology are available in LinCMOS™ operational amplifiers. without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC27L1. The devices also exhibit low-voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input-voltage range includes the negative rail.

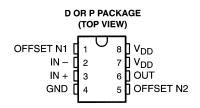
The device inputs and output are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC27L1 incorporates internal electrostatic-discharge (ESD) protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

AVAILABLE OPTIONS

		PACK	AGE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)
0°C to 70°C	2 mV 5 mV 10 mV	TLC27L1BCD TLC27L1ACD TLC27L1CD	TLC27L1BCP TLC27L1ACP TLC27L1CP
-40°C to 85°C	2 mV 5 mV 10 mV	TLC27L1BID TLC27L1AID TLC27L1ID	TLC27L1BIP TLC27L1AIP TLC27L1IP
−55°C to 125°C	10 mV	TLC27L1MD	TLC27L1MP

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC27L1BCDR).



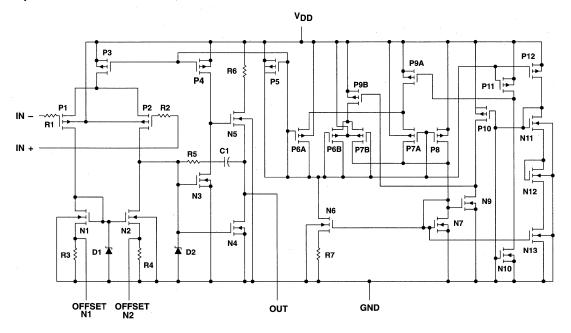
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description (continued)

The C-suffix devices are characterized for operation from 0° C to 70° C. The I-suffix devices are characterized for operation from -40° C to 85° C. The M-suffix devices are characterized for operation over the full military temperature range of -55° C to 125° C.

equivalent schematic



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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	o V
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input)	– 0.3 V to V _{DD}
Input current, I ₁	
Output current, IO	
Duration of short-circuit current at (or below) 25°C (see Note 3)	
Continuous total power dissipation	
Operating free-air temperature, TA: C suffix	
I suffix	– 40°C to 85°C
M suffix	– 55°C to 125°C
Storage temperature range, T _{stq}	– 65°C to 150°C
Case temperature for 60 seconds, T _C : FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P packa	age 260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

		C SU	FFIX	I SUI	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	5	16	٧
Common mode input valtage Vi-	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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electrical characteristics at specified free-air temperature (unless otherwise noted)

			TEAT		TLC	27L1C,	TLC27	L1AC, T	LC27L1	вс	
	PARAMETER		TEST CONDITIONS	T _A †	V	DD = 5	٧	ν[D = 10	٧	UNIT
			COMBINIONS		MIN	TYP	MAX	MIN	TYP	MAX	
		TLC27L1C		25°C		1.1	10		1.1	10	
		ILC2/LIC	V _O = 1.4 V,	Full range			12			12	
V	Innut officet voltage	TI C071 1 A C	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	mV
VIO	Input offset voltage	TLC27L1AC	$R_S = 50 \Omega$	Full range			6.5			6.5	mv
		TI CO71 1DC	$R_j = 1 M\Omega$	25°C		0.24	2		0.26	2	
		TLC27L1BC		Full range			3			3	
αΝΙΟ	Average temperature co	pefficient of		25°C to 70°C		1.1			1		μV/°C
		N-1- 4	$V_O = V_{DD}/2$,	25°C		0.1			0.1		
ΙΟ	Input offset current (see	Note 4)	$V_{IC} = V_{DD}/2$	70°C		7	300		8	300	pА
1	Innut biog gurrent /	vlata 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		
lв	Input bias current (see I	Note 4)	$V_{IC} = V_{DD}/2$	70°C		40	600		50	600	рA
		-			-0.2	-0.3		-0.2	-0.3		
	_			25°C	to 4	to 4.2		to 9	to 9.2		V
VICR	Common-mode input voltage range (see Note	. 5)			ļi	4.2			9.2		
	voilage range (see Note	; 3)		Full range	-0.2 to			-0.2 to			v
				l all range	3.5			8.5			ľ
				25°C	3.2	4.1		8	8.9		
Vон	High-level output voltag	e	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	0°C	3	4.1		7.8	8.9		V
				70°C	3	4.2		7.8	8.9		
				25°C		0	50		0	50	
VOL	Low-level output voltage	e	V _{ID} = -100 mV, I _{OL} = 0	0°C		0	50		0	50	mV
			IOL - 0	70°C		0	50		0	50	
				25°C	50	520		50	870		
AVD	Large-signal differential voltage amplification		R _L = 1 MΩ, See Note 6	0°C	50	700		50	1030		V/mV
	voltage amplification		Gee Note o	70°C	50	380		50	660	,	
	a			25°C	65	94		65	97		
CMRR	Common-mode rejectio	n ratio	V _{IC} = V _{ICR} min	0°C	60	95		60	97		dB
				70°C	60	95		60	97		
				25°C	70	97		70	97		
ksvr	Supply-voltage rejection (ΔVDD/ΔVIO)	ratio	V _{DD} = 5 V to 10 V, V _O = 1.4 V	0°C	60	97		60	97		dB
	(= * DD/		· U = 1.4 V	70°C	60	98		60	98		
l(SEL)	Input current (BIAS SEL	ECT)	V _{I(SEL)} = V _{DD}	25°C		65			95		nA
			$V_O = V_{DD}/2$,	25°C		10	17		14	23	
I _{DD}	Supply current		$V_{IC} = V_{DD}/2$,	0°C		- 12	21		18	33	μА
			No load	70°C		8	14		11	20	1

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.

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electrical characteristics at specified free-air temperature (unless otherwise noted)

			TEST				, TLC27	L1AI, T	LC27L1	ВІ	
	PARAMETER		CONDITIONS	TA [†]	٧	DD = 5	٧	V	DD = 10	٧	UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
		TLC27L1I		25°C		1.1	10		1.1	10	
		ILC2/LII	V _O = 1.4 V,	Full range			13			13	
		TI 0071 441	V _{IC} = 0 V,	25°C		0.9	5		0.9	5	
VIO	Input offset voltage	TLC27L1AI	$R_S = 50 \Omega$,	Full range			7			7	mV
		TI 0071 471	R _L = 1 MΩ	25°C		0.24	2		0.26	2	
		TLC27L1BI		Full range			3.5		***************************************	3.5	
αVIO	Average temperature co	pefficient		25°C to 85°C		1.1			1		μV/°C
		N	$V_O = V_{DD}/2$,	25°C		0.1			0.1		
ΙO	Input offset current (see	Note 4)	V _{IC} = V _{DD} /2	85°C		24	1000		26	1000	рA
			$V_O = V_{DD}/2$,	25°C		0.6			0.7		
İΒ	Input bias current (see I	Note 4)	V _{IC} = V _{DD} /2	85°C		200	2000		220	2000	pΑ
	Common-mode input	-		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		V
VICR	voltage range (see Note	9 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			٧
				25°C	3	4.1		8	8.9		
VOH	High-level output voltag	е	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	-40°C	3	4.1		7.8	8.9		V
			112-11111	85°C	3	4.2		7.8	8.9		
				25°C		0	50		0	50	
VOL	Low-level output voltage	Э	V _{ID} = -100 mV, I _{OL} = 0	-40°C		0	50		0	50	mV
			I OL - V	85°C		0	50		0	50	
				25°C	50	520		50	870		
AVD	Large-signal differential voltage amplification		R _L = 1 MΩ See Note 6	-40°C	50	900		50	1550		V/mV
	vollage amplification		200 14016 0	85°C	50	330		50	585		
				25°C	65	94		65	97		
CMRR	Common-mode rejectio	n ratio	V _{IC} = V _{ICR} min	-40°C	60	95		60	97		dB
				85°C	60	95		60	98		
				25°C	70	97		70	97		
ksvr	Supply-voltage rejection (ΔVDD/ΔVIO)	n ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$ $V_{O} = 1.4 \text{ V}$	-40°C	60	97		60	97		dB
	(\DD/\DV)		VO = 1.4 V	85°C	60	98		60	98		
I(SEL)	Input current (BIAS SEL	ECT)	V _{I(SEL)} = V _{DD}	25°C		65			95		nA
			$V_O = V_{DD}/2$,	25°C		10	17		14	23	
dal	Supply current		$V_{IC} = V_{DD}/2$,	-40°C		16	27		25	43	μΑ
-			No load	85°C		17	13		10	18	

†Full range is -40 to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

- 5. This range also applies to each input individually.
- 6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.



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electrical characteristics at specified free-air temperature (unless otherwise noted)

						TLC2	7L1M			
	PARAMETER	TEST	T _A †	V	DD = 5	٧	٧ _l	DD = 10	V	UNIT
	·	CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
VIO	Input offset voltage	V _O = 1.4 V, V _{IC} = 0 V,	25°C		1.1	10		1.1	10	mV
Ç	input onset voltage	$R_S = 50 \Omega$, $R_L = 1 M\Omega$	Full range			12			12	•
ανιο	Average temperature coefficient of input offset voltage	,	25°C to 125°C		1.4			1.4		μV/°C
lio	Input offset current (see Note 4)	$V_O = V_{DD}/2$,	25°C		0.1			0.1		рA
lO	input offset current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		1.4	. 15		1.8	15	nΑ
lin	Input bias current (see Note 4)	$V_O = V_{DD}/2$,	25°C		0.6			0.7		pА
lΒ	input bias current (see Note 4)	$V_{IC} = V_{DD}/2$	125°C		9	35		10	35	nA
V:	Common-mode input		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		٧
VICR	voltage range (see Note 5)		Full range	0 to 3.5			0 to 8.5			٧
			25°C	3.2	4.1		8	8.9		
VOH	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	−55°C	3	4.1		7.8	8.8		٧
		11[-114122	125°C	3	4.2		7.8	9		
			25°C		0	50		. 0	50	
VOL	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0	−55°C		0	50		0	50	mV
		1000	125°C		0	50		0	50	
			25°C	50	520		50	870		
A_{VD}	Large-signal differential voltage amplification	R _L = 1 MΩ, See Note 6	−55°C	25	1000		25	1775		V/mV
	Tonago ampinoador	000 .1000	125°C	25	200		25	380		
	•	·	25°C	65	94		65	97		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	−55°C	60	95		60	97		dB
			125°C	60	85		60	91		
			25°C	70	97		70	97		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	$V_{DD} = 5 \text{ V to } 10 \text{ V},$ $V_{O} = 1.4 \text{ V}$	−55°C	60	97		60	97		dB
	(6616)		125°C	60	98		60	98		
I _I (SEL)	Input current (BIAS SELECT)	V _{I(SEL)} = V _{DD}	25°C		65			95		nA
		$V_{O} = V_{DD}/2$	25°C		10	17		14	23	
IDD	Supply current	$V_{IC} = V_{DD}/2$	−55°C		17	30		28	48	μΑ
		No load	125°C		7	12		9	15	·

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

	PARAMETER	TEST CO	ONDITIONS	TA	TLC27 TLC27 TLC27	-1AC	,	UNIT
					MiN T	/P	MAX	
				25°C	0.	03		
ļ			V _{I(PP)} = 1 V	0°C	0.	04		
SR	Claus rate at units gain	$R_L = 1 M\Omega$, $C_1 = 20 pF$,		70°C	0.	03		V/μs
3	Slew rate at unity gain	See Figure 33		25°C	0.	03		ν /μS
			$V_{I(PP)} = 2.5 V$	0°C	0.	03		
				70°C	0.	02		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 34	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
				25°C		5		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 33	0°C		6		kHz
ŀ	•	111 - 1 10152,	See Figure 33	70°C	4	1.5		
				25°C		85		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 35	$C_L = 20 pF$,	0°C	1	00		kHz
		See Figure 33		70°C		65		
		101/	4 5	25°C	3	4°		
φm	Phase margin	V _I = 10 mV, C _I = 20 pF,	f = B ₁ , See Figure 35	0°C	3	6°		
		SE = 25 pi,	200gaio 00	70°C	3	0°		

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 10 V

	PARAMETER	TEST CO	ONDITIONS	TA	TLO	C27L1C C27L1A C27L1B	Ċ,	UNIT
					MIN	TYP	MAX	
				25°C		0.05		
1]	V _{I(PP)} = 1 V	0°C		0.05		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		70°C		0.04		V/μs
Jon J	Siew rate at unity gain	See Figure 33		25°C		0.04		V/μS
			V _{I(PP)} = 5.5 V	0°C		0.05		
			<u> </u>	70°C		0.04		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 34	R _S = 20 Ω,	25°C		68		nV/√Hz
		1		25°C		1		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 33	0°C		1.3		kHz
		=	See Figure 33	70°C		0.9		
		V 40 V		25°C		110		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	$C_L = 20 pF$,	0°C		125		kHz
		See Figure 35		70°C		90		
		V 40V		25°C		38°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 35	0°C		40°		
		5 - 25 pr.,		70°C		34°		

TLC27L1, TLC27L1A, TLC27L1B LinCMOS™ LOW-POWER OPERATIONAL AMPLIFIERS SLOS154 – DECEMBER 1995

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	ONDITIONS	TA	TL	.C27L1I C27L1A .C27L1B	l,	UNIT
	`				MIN	TYP	MAX	
				25°C		0.03		
		*	V _{I(PP)} = 1 V	-40°C		0.04	,	
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		85°C		0.03		V/μs
on .	Siew rate at unity gain	See Figure 33		25°C		0.03		ν/μδ
ŀ			$V_{I(PP)} = 2.5 V$	-40°C		0.04		
				85°C		0.02		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 34	$R_S = 20 \Omega$,	25°C		68		nV/√ Hz
				25°C		5		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 33	-40°C		7		kHz
		11[- 1 14122,	Oee rigare oo	85°C		4		
				25°C		85		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 35	$C_L = 20 pF$,	-40°C		130		MHz
		See Figure 33		85°C		55		
		V: 40 m)/	4 B	25°C		34°		
φm	Phase margin	Phase margin $V_{I} = 10 \text{ mV},$ $C_{I} = 20 \text{ pF},$	f = B ₁ , See Figure 35	-40°C		38°		
			255garo 00	85°C		28°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST CO	ONDITIONS	TA	TLC	C27L1C C27L1AC C27L1B) ,	UNIT
					MIN	TYP	MAX	
				25°C		0.05		
			V _{I(PP)} = 1 V	-40°C		0.06		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$,		85°C		0.03		V/μs
J Sn	Siew rate at unity gain	See Figure 33		25°C		0.04		ν/μ5
			V _{I(PP)} = 5.5 V	-40°C		0.05		
				85°C		0.03		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 34	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
				25°C		1		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 1 M\Omega$,	C _L = 20 pF, See Figure 33	-40°C		1.4		kHz
	•		Gee rigure 55	85°C		0.8		
				25°C		110		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 35	$C_L = 20 pF$,	-40°C		155		MHz
		See rigure 55		85°C		80		
		10	4 D	25°C		38°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV,l}$ $C_{\parallel} = 20 \text{ pF,}$	f = B ₁ , See Figure 35	-40°C		42°		
		JE = 23 pr ,	Seegare oo	85°C		32°.		

TLC27L1, TLC27L1A, TLC27L1B LinCMOS™ LOW-POWER OPERATIONAL AMPLIFIERS SLOS154 - DECEMBER 1995

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

	PARAMETER	TEST 6/	ONDITIONS	-	TL	.C27L1N	1	UNIT													
	PARAMETER	IEST CO	ONDITIONS	TA	MIN	TYP	MAX	UNIT													
				25°C		0.03															
			V _{I(PP)} = 1 V	-55°C		0.04															
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,		125°C		0.02		Mus													
on .	Siew rate at unity gain	C _L = 20 pF, See Figure 33		25°C		0.03		V/μs													
			$V_{I(PP)} = 2.5 V$	−55°C		0.04															
				125°C		0.02															
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 34	$R_S = 20 \Omega$,	25°C		68		nV/√Hz													
				25°C		5															
Вом	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_i = 1 M\Omega$,	C _L = 20 pF, See Figure 33	−55°C		8		kHz													
		n_ = 1 10/52,	See Figure 33	125°C		3															
				25°C		85															
В1	Unity-gain bandwidth	V _I = 10 mV, See Figure 35	$C_L = 20 pF$,	−55°C		140		kHz													
		See Figure 35		125°C		45															
			, 5	25°C		34°															
φm	Phase margin	$V_{I} = 10 \text{ mV},$	$V_{l} = 10 \text{ mV},$	$V_{l} = 10 \text{ mV},$ $C_{l} = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$	$V_{l} = 10 \text{ mV},$	$V_1 = 10 \text{ mV},$	$V_1 = 10 \text{ mV},$	$V_{I} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ 1	V = 10 mV, f	$V_{l} = 10 \text{ mV},$		$V_{l} = 10 \text{ mV},$ $C_{l} = 20 \text{ pF}$	$V_{l} = 10 \text{ mV},$ $C_{l} = 20 \text{ pF}$	$f = 10 \text{ mV}, \qquad f = B_1,$ $C_1 = 20 \text{ pF}, \qquad \text{See Figure 35}$	−55°C		39°		
		SL = 25 pi,	Coo i iguie oo	125°C		25°															

operating characteristics at specified free-air temperature, V_{DD} = 10 V

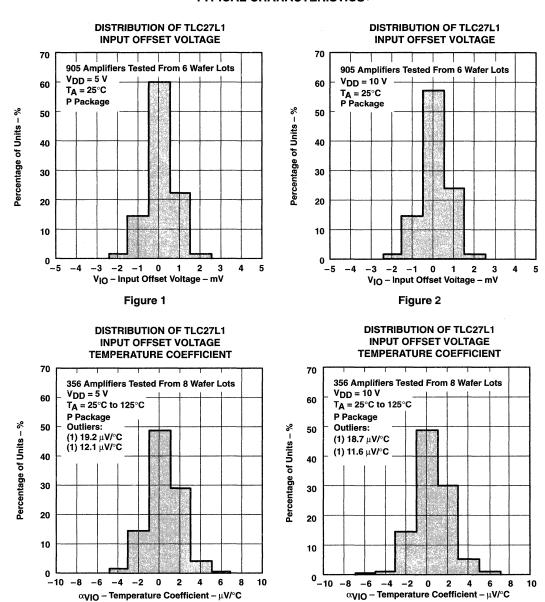
	DADAMETED	TEST CONDITIONS		TA	TLC27L1M			
	PARAMETER				MIN	TYP	MAX	UNIT
				25°C		TYP MAX 0.05 0.06 0.03 0.04 0.06 0.03 68 1 1.5 0.7		V/μs
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$, See Figure 33	V _{I(PP)} = 1 V	-55°C		0.06		
				125°C		0.03		
			V _{I(PP)} = 5.5 V	25°C		0.04		
				−55°C		0.06		
				125°C		0.03		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 34	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
			_	25°C		1		kHz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 33	-55°C		1.5		
				125°C		0.7		
	Unity-gain bandwidth	V _I = 10 mV, See Figure 35	C _L = 20 pF,	25°C		110		kHz
B ₁				−55°C		165		
				125°C		70		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 35	25°C		38°		
				−55°C		43°		
				125°C		29°		

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	1, 2
αVIO	Temperature coefficient	Distribution	3, 4
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	5, 6 7 8
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	9, 10 11 12 13, 14
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	15 16 27, 28
lв	Input bias current	vs Free-air temperature	17
lio	Input offset current	vs Free-air temperature	17
VI	Maximum input voltage	vs Supply voltage	18
DD	Supply current	vs Supply voltage vs Free-air temperature	19 20
SR	Slew rate	vs Supply voltage vs Free-air temperature	21 22
	Bias-select current	vs Supply voltage	23
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	24
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	25 26
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Capacitance load	29 30 31
٧n	Equivalent input noise voltage	vs Frequency	32
	Phase shift	vs Frequency	27, 28

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TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 3



Figure 4

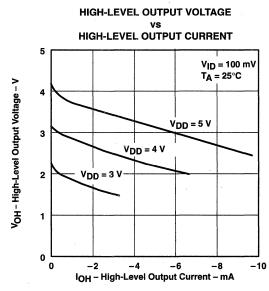
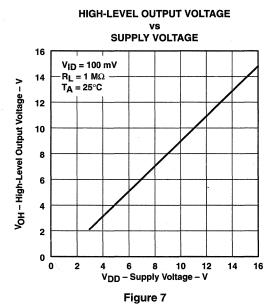


Figure 5



HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

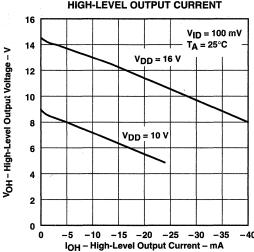
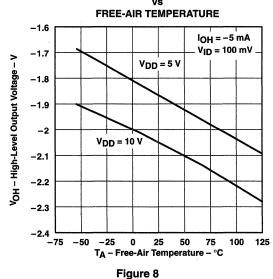


Figure 6

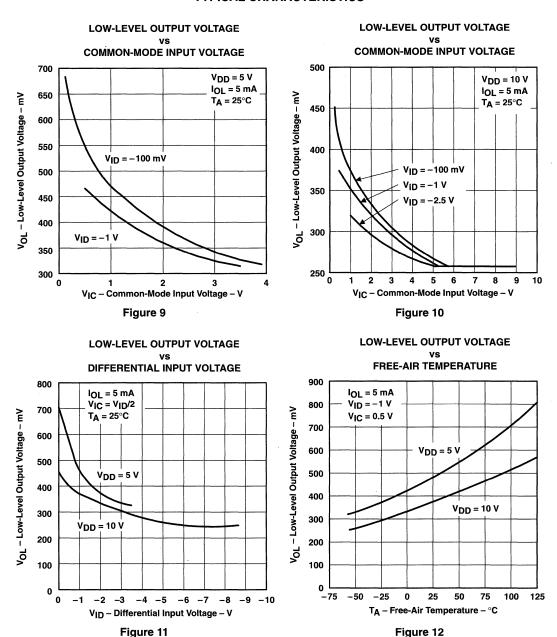
HIGH-LEVEL OUTPUT VOLTAGE



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



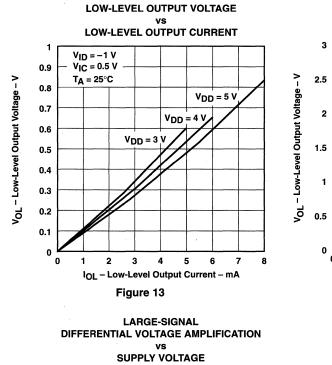
TYPICAL CHARACTERISTICS[†]

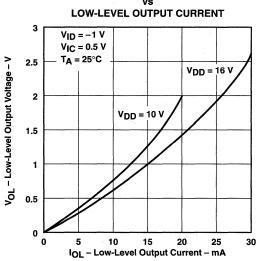


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

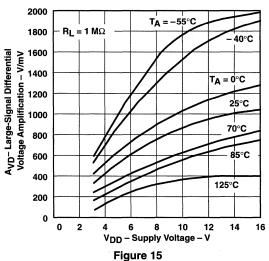


TYPICAL CHARACTERISTICS[†]



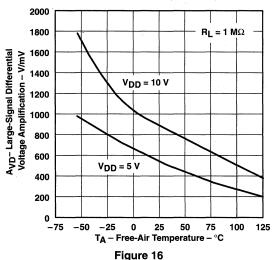


LOW-LEVEL OUTPUT VOLTAGE



LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION FREE-AIR TEMPERATURE**

Figure 14



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



MAXIMUM INPUT VOLTAGE

SUPPLY VOLTAGE

8 10 12 14 16

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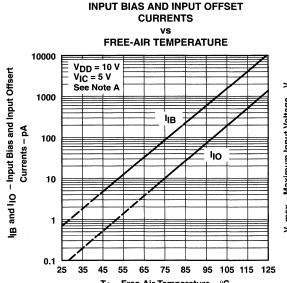
TYPICAL CHARACTERISTICS†

16

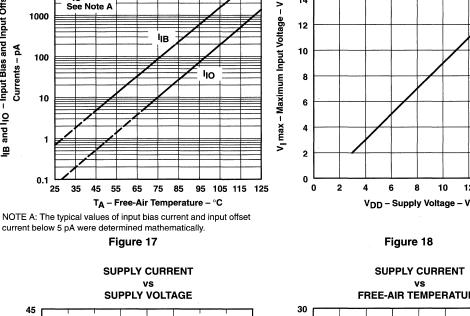
14

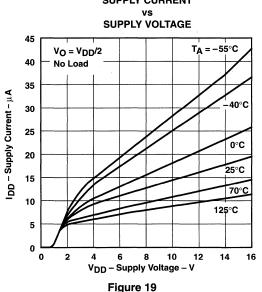
12

 $T_A = 25^{\circ}C$



current below 5 pA were determined mathematically.





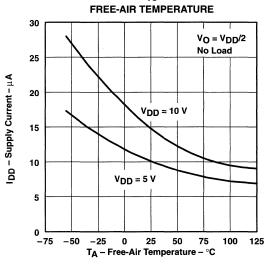


Figure 20

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



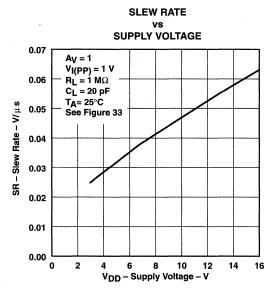


Figure 21

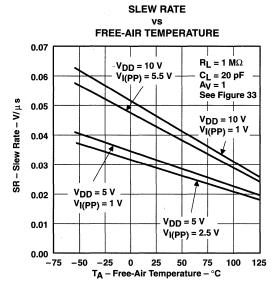
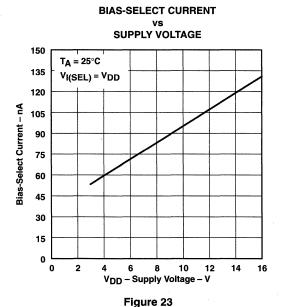


Figure 22



MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE

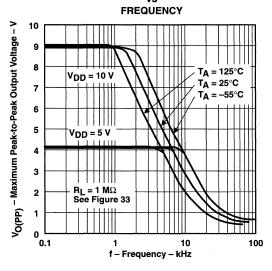


Figure 24

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS†

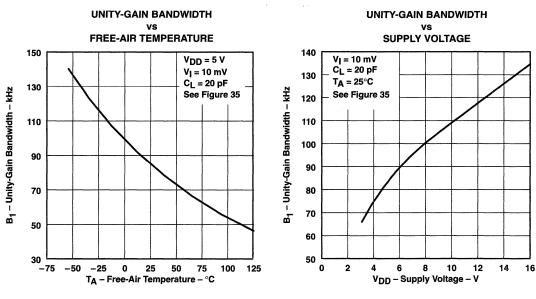


Figure 25

Figure 26

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

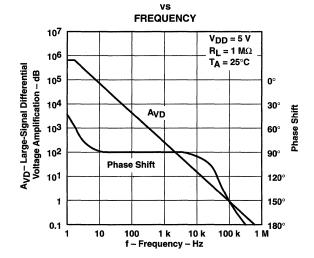


Figure 27

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

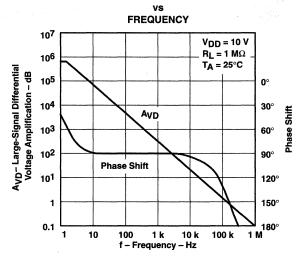
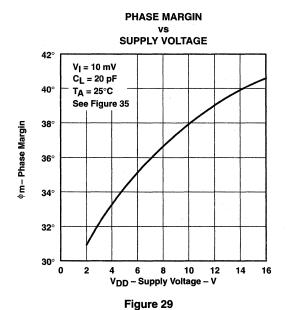
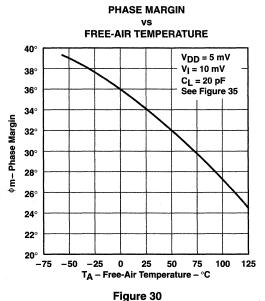


Figure 28



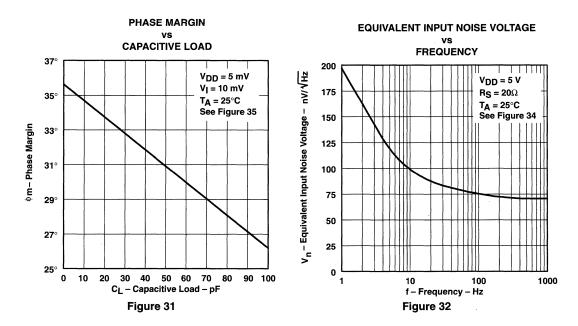


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS[†]



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC27L1 is optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

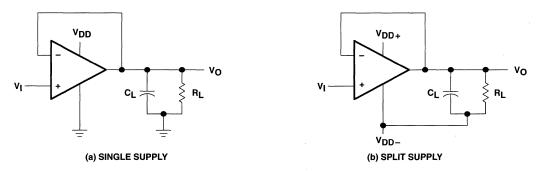


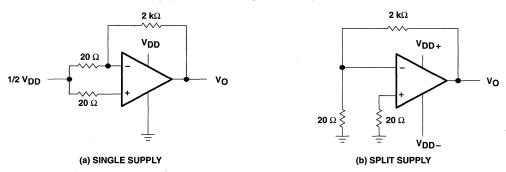
Figure 33. Unity-Gain Amplifier



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single-supply versus split-supply test circuits (continued)



PARAMETER MEASUREMENT INFORMATION

Figure 34. Noise-Test Circuit

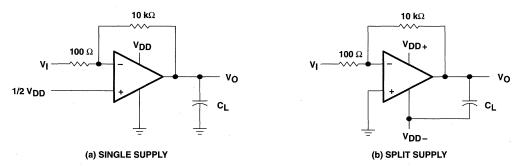


Figure 35. Gain-of-100 Inverting Amplifier

input bias current

Due to the high input impedance of the TLC27L1 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 36). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias-current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.



PARAMETER MEASUREMENT INFORMATION

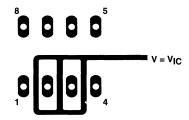


Figure 36. Isolation Metal Around Device Inputs (JG and P packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise is necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. When conditions other than these are to be used, please refer to the Typical Characteristics section of this data sheet.

input offset-voltage temperature coefficient

Erroneous readings often result from attempts to measure the temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset-voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance which can cause erroneous input offset-voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

full-power response

Full-power response, the frequency above which the amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Since there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit in Figure 33. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 37). A square wave allows a more accurate determination of the point at which the maximum peak-to-peak output is reached.



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PARAMETER MEASUREMENT INFORMATION

full-power response (continued)

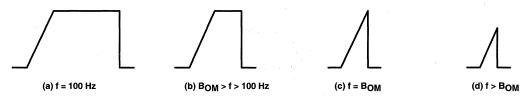


Figure 37. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices, and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

APPLICATION INFORMATION

single-supply operation

While the TLC27L1 performs well using dual power supplies (also called balanced or split supplies). the design is optimized single-supply operation. This includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS: however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a

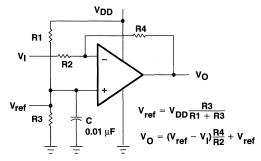


Figure 38. Inverting Amplifier With Voltage

voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low-input bias-current consumption of the TLC27L1 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27L1 works well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- 1. Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, RC decoupling may be necessary in high-frequency applications.



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APPLICATION INFORMATION

single-supply operation (continuted)

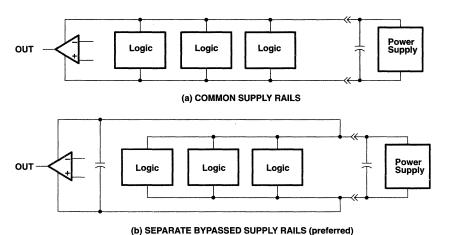


Figure 39. Common Versus Separate Supply Rails

input offset voltage nulling

The TLC27L1 offers external input-offset null control. Nulling of the input-offset voltage may be achieved by adjusting a $25-k\Omega$ potentiometer connected between the offset null terminals with the wiper connected as shown in Figure 40. Total nulling may not be possible.

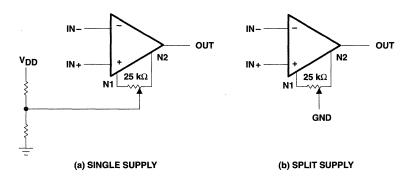


Figure 40. Input Offset-Voltage Null Circuit

input characteristics

The TLC27L1 is specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD}-1$ V at $T_A=25^{\circ}C$ and at $V_{DD}-1.5$ V at all other temperatures.



input characteristics (continued)

The use of the polysilicon-gate process and the careful input circuit design gives the TLC27L1 very good input offset-voltage drift characteristics relative to conventional metal-gate processes. Offset-voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset-voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias-current requirements, the TLC27L1 is well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias-current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 36 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 41).

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low-input bias-current requirements of the TLC27L1 results in a very-low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

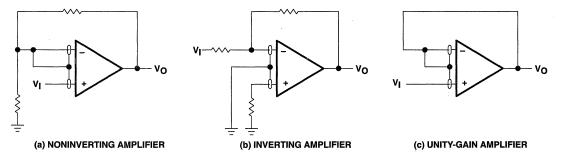


Figure 41. Guard-Ring Schemes

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APPLICATION INFORMATION

feedback

Operational amplifier circuits almost always employ feedback, and since feedback is the first prerequisite for oscillation, a little caution is appropriate. Most oscillation problems result from driving capacitive loads and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 42). The value of this capacitor is optimized empirically.

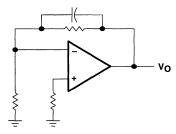


Figure 42. Compensation for Input Capacitance

electrostatic discharge protection

The TLC27L1 incorporates an internal ESD protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC27L1 inputs and output were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not by design be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μ F typical) located across the supply rails as close to the device as possible.

The current path established when latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

output characteristics

The output stage of the TLC27L1 is designed to sink and source relatively high amounts of current (see Typical Characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage (see Figure 43).

All operating characteristics of the TLC27L1 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 44). In many cases, adding some compensation in the form of a series resistor in the feedback loop alleviates the problem.

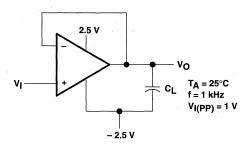
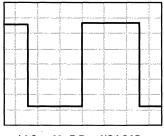
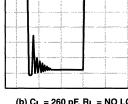


Figure 43. Test Circuit for Output Characteristics







(a) $C_L = 20 pF$, $R_L = NO LOAD$ (b) $C_L = 260 \text{ pF}$, $R_L = NO \text{ LOAD}$

(c) $C_L = 310 \text{ pF}$, $R_L = NO \text{ LOAD}$

Figure 44. Effect of Capacitive Loads in Low-Bias Mode

Although the TLC27L1 possesses excellent high-level output voltage and current capability, methods are available for boosting this capability, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 45). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor, N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately 60 Ω and 180 Ω , depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Secondly, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

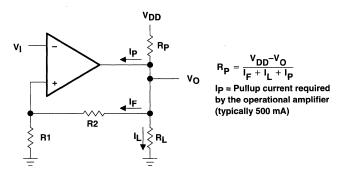
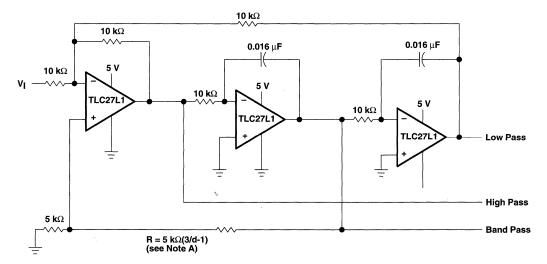
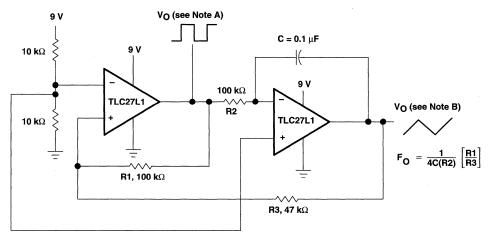


Figure 45. Resistive Pullup to Increase VOH



NOTE A: d = damping factor, I/O

Figure 46. State-Variable Filter



NOTES: A. $V_{O(PP)} = 8 \text{ V}$ B. $V_{O(PP)} = 4 \text{ V}$

Figure 47. Single-Supply Function Generator

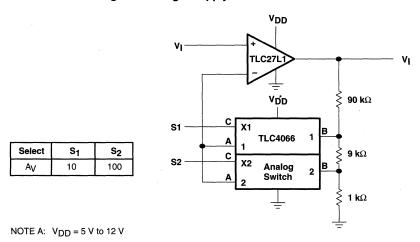


Figure 48. Amplifier With Digital-Gain Selection

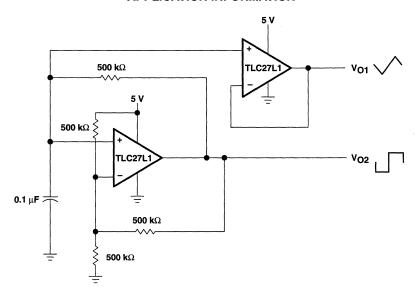
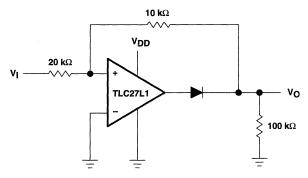


Figure 49. Multivibrator

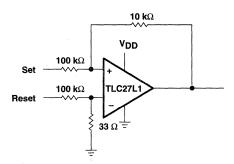


NOTE A: $V_{DD} = 5 \text{ V to } 16 \text{ V}$

Figure 50. Full-Wave Rectifier

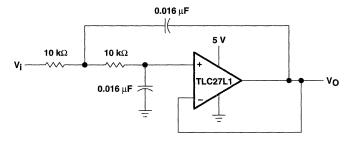
SLOS154 - DECEMBER 1995

APPLICATION INFORMATION



NOTE A: $V_{DD} = 5 V \text{ to } 16 V$

Figure 51. Set/Reset Flip-Flop



NOTE A: Normalized to $F_C = 1$ kHz and $R_L = 10$ k Ω

Figure 52. Two-Pole Low-Pass Butterworth Filter

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- Trimmed Offset Voltage: TLC27L7...500 μV Max at 25°C, V_{DD} = 5 V
- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, including the First 30 Days
- Wide Range of Supply Voltages Over Specified Temperature Range:

0°C to 70°C ... 3 V to 16 V -40°C to 85°C ... 4 V to 16 V -55°C to 125°C ... 4 V to 16 V

- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, I-Suffix Types)
- Ultra-Low Power . . . Typically 95 μW at 25°C, V_{DD} = 5 V
- Output Voltage Range includes Negative Rail
- High Input Impedance . . . 10¹² Ω Typ
- ESD-Protection Circuitry
- Small-Outline Package Option Also Available in Tape and Reel
- Designed-In Latch-Up immunity

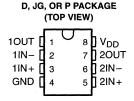
description

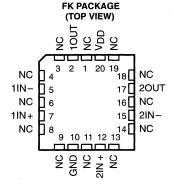
The TLC27L2 and TLC27L7 dual operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, extremely low power, and high gain.

AVAILABLE OPTIONS

			PACK	AGE	,
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	500 μV 2 mV 5 mV 10 mV	TLC27L7CD TLC27L2BCD TLC27L2ACD TLC27L2CD	-	_	TLC27L7CP TLC27L2BCP TLC27L2ACP TLC27L2CP
-40°C to 85°C	500 μV 2 mV 5 mV 10 mV	TLC27L7ID TLC27L2BID TLC27L2AID TLC27L2ID	_	_	TLC27L7IP TLC27L2BIP TLC27L2AIP TLC27L2IP
-55°C to 125°C	500 μV 10 mV	TLC27L7MD TLC27L2MD	TLC27L7MFK TLC27L2MFK	TLC27L7MJG TLC27L2MJG	TLC27L7MP TLC27L2MP

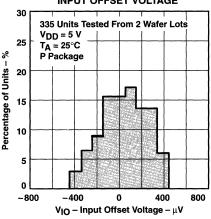
The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC27L7CDR).





NC - No internal connection

DISTRIBUTION OF TLC27L7 INPUT OFFSET VOLTAGE



LinCMOS is a trademark of Texas Instruments Incorporated

TEXAS INSTRUMENTS

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description (continued)

These devices use Texas Instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, and low power consumption make these cost-effective devices ideal for high gain, low frequency, low power applications. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC27L2 (10 mV) to the high-precision TLC27L7 (500 μ V). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

In general, many features associated with bipolar technology are available in LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC27L2 and TLC27L7. The devices also exhibit low voltage single-supply operation and ultra-low power consumption, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

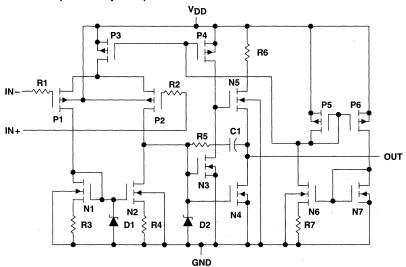
A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up.

The TLC27L2 and TLC27L7 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

The C-Suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

equivalent schematic (each amplifier)



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1) Differential input voltage (see Note 2) Input voltage range, V _I (any input) Input current, I _I ±	V _{DD}
Output current, In (each output) ±3	
Total current into V _{DD} 4	
Total current out of GND	5 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	nited
Continuous total dissipation	
Continuous total dissipation	lable
Operating free-air temperature, T _A : C suffix	
	70°C
Operating free-air temperature, T _A : C suffix	70°C 85°C
Operating free-air temperature, T _A : C suffix	70°C 85°C 25°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	_
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	

recommended operating conditions

		C SU	FFIX	I SUF	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	4	16	V
Common mode input voltage Vi-	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5]
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT	TL:	C27L2C C27L2A C27L2B C27L7C	C C	UNIT
						MIN	TYP	MAX	
		TLC27L2C	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		1.1	10	
		12027220	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	mV
		TLC27L2AC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.9	5	1110
VIO	Input offset voltage	TEGETEERO	$R_S = 50 \Omega$	$R_L = 1 M\Omega$	Full range			6.5	
1.10	input onoot voltago	TLC27L2BC	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		204	2000	
		120272200	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			3000	μV
		TLC27L7C	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		170	500	μν
		112027270	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			1500	
αVIO	Average temperature coe offset voltage	fficient of input			25°C to 70°C		1.1		μV/°C
		1-1-4	v 05V	05.4	25°C		0.1		- 4
IIO	Input offset current (see N	Note 4)	$V_{O} = 2.5 \text{ V},$	V _{IC} = 2.5 V	70°C		7	300	pΑ
1	land this a summant (see NI	-4- 4\	V 05V	V- 05V	25°C		0.6		^
IB	Input bias current (see No	ote 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	70°C		50	600	pΑ
	Common-mode input volt	age range			25°C	-0.2 to 4	-0.3 to 4.2		V
VICR	(see Note 5)				Full range	-0.2 to 3.5			V
					25°C	3.2	4.1		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 1 M\Omega$	0°C	3	4.1		V
					70°C	3	4.2		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
		-			70°C		0	50	
					25°C	50	700		
AVD	Large-signal differential v amplification	oltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	0°C	50	700		V/mV
	ampinication				70°C	50	380		
					25°C	65	94		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		0°C	60	95		dB
					70°C	60	95		
					25°C	70	97		
ksvr	Supply-voltage rejection $(\Delta V_{DD}/\Delta V_{IO})$	atio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
	*UD'*IO)				70°C	60	98		
			V 05V		25°C		20	34	
IDD	Supply current (two ampl	ifiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V,$	0°C		24	42	μΑ
					70°C		16	28	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT	TL: TL:	C27L2C C27L2A C27L2B C27L7C	С	UNIT
						MIN	TYP	MAX	
		TLC27L2C	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		1.1	10	
			$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	mV
		TLC27L2AC	$V_0 = 1.4 \text{ V},$	$V_{IC} = 0$,	25°C		0.9	5	
Vio	Input offset voltage		$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			6.5	
1,0	par on correnage	TLC27L2BC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		235	2000	
			$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3000	μV
		TLC27L7C	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		190	800	
		1,505,570	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			1900	
αVIO	Average temperature of offset voltage	pefficient of input			25°C to 70°C		1		μV/°C
1	lanut effect compat (co.	N=4= 4\	V- 5V	V - 5 V	25°C		0.1		4
10	Input offset current (see	Note 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	70°C		8	300	рA
1	1	N-4- A	V 5V		25°C		0.7		
ΙΒ	Input bias current (see	Note 4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	70°C		50	600	pΑ
.,	Common-mode input v	oltage range			25°C	-0.2 to 9	-0.3 to 9.2		V
VICR	(see Note 5)				Full range	-0.2 to 8.5			٧
					25°C	8	8.9		
VOH	High-level output voltag	je	$V_{ID} = 100 \text{ mV},$	$R_L = 1 M\Omega$	0°C	7.8	8.9		V
					70°C	7.8	8.9		
					25°C	-	0	50	
VOL	Low-level output voltag	е	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
					25°C	50	860		
AVD	Large-signal differential amplification	voltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	0°C	50	1025		V/mV
	ampilioalion				70°C	50	660		
					25°C	65	97		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min		0°C	60	97		dB
					70°C	60	97		
					25°C	70	97		
ksvr	Supply-voltage rejection (ΔV _{DD} /ΔV _{IO})	n ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
	(21D)(21D)				70°C	60	98		
					25°C		29	46	
IDD	Supply current (two am	plifiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	0°C		36	66	μΑ
					70°C		22	40	

†Full range is 0°C to 70°C.

NOTES: 4 The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5 This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TL TL	C27L2I C27L2A C27L2B C27L7I		UNIT
	•					MIN	TYP	MAX	
		TLC27L2I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC2/L2I	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			13	mV
		TLC27L2AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	1110
V _{IO}	Input offset voltage	TEOZ/EZAI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			7	
VIO	input onset voltage	TLC27L2BI	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		240	2000	
		TEOZYCZBI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3500	μV
		TLC27L7I	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		170	500	μν
		12027271	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			2000	
αΛΙΟ	Average temperature c input offset voltage	oefficient of			25°C to 85°C		1.1		μV/°C
1	land 4 affect a	- N-4- 4\	V- 05V	V- 05V	25°C		0.1		^
lo	Input offset current (se	e Note 4)	$V_0 = 2.5 \text{ V},$	$V_{iC} = 2.5 V$	85°C		24	1000	рA
1	land this summet (see	Note 4)	V- 05V	V:- 05V	25°C		0.6		- 4
ΙΒ	Input bias current (see	Note 4)	$V_0 = 2.5 V$,	V _{IC} = 2.5 V	85°C		200	2000	pА
W -	Common-mode input v	oltage range			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)				Full range	-0.2 to 3.5			V
					25°C	3.2	4.1		
Vон	High-level output voltage	ge	$V_{ID} = 100 \text{ mV},$	$R_L = 1 M\Omega$	-40°C	3	4.1		V
					85°C	3	4.2		
					25°C		0	50	
VOL	Low-level output voltag	е	$V_{1D} = -100 \text{ mV},$	I _{OL} = 0	-40°C		0	50	mV
					85°C		0	50	
					25°C	50	480		
AVD	Large-signal differentia voltage amplification	l	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	-40°C	50	900		V/mV
					85°C	50	330		
					25°C	65	94		
CMRR	Common-mode rejection	on ratio	V _{IC} = V _{ICR} min		-40°C	60	95		dB
					85°C	60	95		
	0				25°C	70	97		
ksvr	Supply-voltage rejectio (ΔV _{DD} /ΔV _{IO})	n ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	97		dB
	(\OU / \O)				85°C	60	98		
			Vo = 2.5.V	V10 = 2 5 V	25°C		20	34	
IDD	Supply current (two arr	plifiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V,$	-40°C		31	54	μΑ
					85°C		15	26	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TL:	C27L2I C27L2A C27L2B C27L7I		UNIT
						MIN	TYP	MAX	
		TLC27L2I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC2/L2I	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			13	mV
		TLC27L2AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	IIIV
V _{IO}	Input offset voltage	TLOZ/LZAI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			7	
٧IO	iliput oliset voltage	TLC27L2BI	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		235	2000	
		TEOZYEZDI	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			3500	μV
		TLC27L7I	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		190	800	μν
		TEOZYEYI	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			2900	
ανιο	Average temperature co offset voltage	efficient of input			25°C to 85°C		1		μV/°C
1 -	l	NI-1- 4\			25°C		0.1		
li0	Input offset current (see	Note 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	85°C		26	1000	pА
•		1-1- 1	., .,	., 5,,	25°C		0.7		
lВ	Input bias current (see N	iote 4)	$V_{O} = 5 V$,	$V_{IC} = 5 V$	85°C		220	2000	pΑ
	Common-mode input vo	Itage range			25°C	-0.2 to 9	-0.3 to 9.2		V
VICR	(see Note 5)				Full range	-0.2 to 8.5			٧
					25°C	8	8.9		
Vон	High-level output voltage	•	V _{ID} = 100 mV,	$R_L = 1 M\Omega$	-40°C	7.8	8.9		V
			}		85°C	7.8	8.9		
					25°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	-40°C		0	50	mV
					85°C		0	50	
					25°C	50	860		
A_{VD}	Large-signal differential amplification	voltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	-40°C	50	1550		V/mV
	ampilioation				85°C	50	585		
					25°C	65	97		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		-40°C	60	97		dB
		,			85°C	60	98		
	0				25°C	70	97		
ksvr	Supply-voltage rejection (ΔV _{DD} /ΔV _{IO})	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	97		dB
	(= · DD, = • IO)				85°C	60	98		
			V- EV	V F.V	25°C		29	46	
IDD	Supply current (two amp	lifiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	-40°C		49	86	μΑ
					85°C		20	36	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT		.C27L2N .C27L7N		UNIT
						MIN	TYP	MAX	
		TLC27L2M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
V	Innut offert veltore	TLC2/L2IVI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	l my
VIO	Input offset voltage	TLC27L7M	V _O = 1.4 V,	V _{IC} = 0,	25°C		170	500	
′		TLO27L7IVI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3750	μV
αVIO	Average temperature input offset voltage	coefficient of			25°C to 125°C		1.4		μV/°C
	1	NI-1- 4\	V 05V		25°C		0.1		pА
ΙO	Input offset current (s	ee Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C	1	1.4	15	nA
	l	- N-+- 4\	V 05V	V 0.5.V	25°C		0.6		pА
ΙΒ	Input bias current (se	e Note 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	125°C		9	35	nA
V	Common-mode input	voltage range			25°C	0 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)				Full range	0 to 3.5			٧
					25°C	3.2	4.1		
Vон	High-level output volta	age	$V_{ID} = 100 \text{ mV},$	$R_L = 1 M\Omega$	−55°C	3	4.1		V.
					125°C	3	4.2		1
					25°C		0	50	
v_{OL}	Low-level output volta	ıge	$V_{ID} = -100 \text{ mV},$	IOL = 0	−55°C		0	50	mV
					125°C		0	50	
					25°C	50	500		
A_{VD}	Large-signal differenti amplification	iai voitage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	−55°C	25	1000		V/mV
	ampinication				125°C	25	200		
					25°C	65	94		
CMRR	Common-mode reject	tion ratio	VIC = VICRmin		−55°C	60	95		dB
					125°C	60	85		l
	Supply-voltage rejecti	ion rotio			25°C	70	97		
ksvr	(ΔV _{DD} /ΔV _{IO})	OITIALIO	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	97		dB
	(= · DD/ = · 10/				125°C	60	98		
			V _O = 2.5 V,	V _{IC} = 2.5 V,	25°C		20	34	
I_{DD}	Supply current (two a	mplifiers)	VO = 2.5 V, No load	VIC = 2.5 V,	−55°C		35	60	μΑ
					125°C		14	24	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †		.C27L2N		UNIT
		,			1 "	MIN	TYP	MAX	
		TI 0071 014	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
.,	l	TLC27L2M	$R_S = 50 \Omega$	$R_L = 1 M\Omega$	Full range			12	mV
VIO	Input offset voltage	TI 0071 7M	V _O = 1.4 V,	V _{IC} = 0,	25°C		190	800	
		TLC27L7M	$R_S = 50 \Omega$	$R_L = 1 M\Omega$	Full range			4300	μV
ανιο	Average temperature of input offset voltage	coefficient of			25°C to 125°C		1.4		μV/°C
			., .,		25°C		0.1		pA
10	Input offset current (se	e Note 4)	$V_{O} = 5 V$,	$V_{IC} = 5 V$	125°C		1.8	15	nA
	1	NI-1- 4\	V 5.V	V 5V	25°C		0.7		pA
lΒ	Input bias current (see	Note 4)	$V_{O} = 5 V$,	$V_{IC} = 5 V$	125°C		10	35	nA
.,	Common-mode input v	oltage range			25°C	0 to 9	-0.3 to 9.2		V
VICR	(see Note 5)				Full range	0 to 8.5			V
					25°C	8	8.9		
Vон	High-level output volta	ge	$V_{ID} = 100 \text{ mV},$	$R_L = 1 M\Omega$	-55°C	7.8	8.8		V
					125°C	7.8	9		
					25°C		0	50	
v_{OL}	Low-level output voltag	ge	$V_{ID} = -100 \text{ mV},$	IOL = 0	−55°C		0	50	mV
					125°C		0	50	
	Large signal differentia	l voltogo			25°C	50	860		
A_{VD}	Large-signal differentia amplification	ii voitage	$V_O = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	−55°C	25	1750		V/mV
					125°C	25	380		
					25°C	65	97		
CMRR	Common-mode rejection	on ratio	V _{IC} = V _{ICR} min		−55°C	60	97		dB
					125°C	60	91		
	Supply-voltage rejection	on ratio	1		25°C	70	97		
ksvr	(ΔV _{DD} /ΔV _{IO})	n ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	97		dB
	· DD 10/				125°C	60	98		
			V _O = 5 V,	V _{IC} = 5 V,	25°C		29	46	
IDD	Supply current (two an	nplifiers)	No load	10 9 1,	−55°C		56	96	μΑ
					125°C		18	30	

† Full range is -55 °C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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operating characteristics, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	TA	TLC27L2C TLC27L2AC TLC27L2BC TLC27L7C			UNIT
<u> </u>			T	25°C	MIN	TYP 0.03	MAX	
			V _{VDD} = 1 V	0°C		0.03		
		$R_L = 1 M\Omega$,	$V_{I(PP)} = 1 V$	70°C	ļ	0.04		
SR	Slew rate at unity gain	$C_{L} = 20 \text{ pF},$		25°C		0.03		V/μs
		See Figure 1	V _{I(PP)} = 2.5 V	0°C	l	0.03		
			VI(PP) - 2.5 V	70°C				
ν _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		0.02 68		nV/√Hz
				25°C		5		
ВОМ	Maximum output-swing bandwidth	VO = VOH,		0°C		6		kHz
		$R_L = 1 M\Omega$,	See Figure 1	70°C		4.5		
				25°C		85		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 \text{ pF},$	0°C		100		kHz .
		See Figure 3		70°C		65		1
				25°C		34°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 3	0°C		36°		
		C 20 pi ,	CCC i iguio o	70°C		30°		1

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CO	NDITIONS	TA	TLC27L2C TLC27L2AC TLC27L2BC TLC27L7C			UNIT
		,	_		MIN	TYP	MAX	
				25°C		0.05		
			V _{I(PP)} = 1 V	0°C		0.05]
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,		70°C		0.04		V/μs
J Sh	Siew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.04		ν/μs
		"	$V_{I(PP)} = 5.5 V$	0°C		0.05		
				70°C		0.04		
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
		l		25°C		1		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1	0°C		1.3		kHz
		TIL = T IVIS2,	Oee rigure r	70°C		0.9		
				25°C		110		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		125		kHz
İ		Joee rigure 5		70°C		90]
		10 11	, 5	25°C		38°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 3	0°C		40°		
		,		70°C		34°		

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operating characteristics, $V_{DD} = 5 \text{ V}$

PARAMETER		TEST CONDITIONS		TA	TLC27L2I TLC27L2AI TLC27L2BI TLC27L7I MIN TYP MAX			UNIT
<u> </u>			1	25°C	IVIIIA	0.03	WAX	
			V _{I(PP)} = 1 V	-40°C		0.04		
		$R_L = 1 M\Omega$,		85°C		0.03		
SR	Slew rate at unity gain	C _L = 20 pF,		25°C		0.03		V/μs
		See Figure 1	V _{I(PP)} = 2.5 V	-40°C		0.04		V/μs nV/√ Hz
		ĺ	(,,,,	85°C		0.02		
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
			C _L = 20 pF, See Figure 1	25°C		5		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,		-40°C		7		kHz
l		n_ = 1 ivisz,	See Figure 1	85°C		4		
		V _I = 10 mV, See Figure 3	C _L = 20 pF,	25°C		85		
B ₁	Unity-gain bandwidth			-40°C		130		kHz
	See Figure 3		55					
φm		T.,	, 5	25°C		34°		
	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 3	-40°C		38°		
				85°C		29°		

operating characteristics, V_{DD} = 10 V

PARAMETER		TEST CO	ONDITIONS	TA	TLC27L2I TLC27L2AI TLC27L2BI TLC27L7I			UNIT		
					MIN	TYP	MAX			
			1	25°C		0.05				
		1	V _{I(PP)} = 1 V	-40°C		0.06				
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,		85°C		0.03		1 1//10		
SIT	Siew rate at unity gam	C _L = 20 pF, See Figure 1		25°C		0.04		ν/μ5		
		Joseph	J Coo : .guo :	$V_{I(PP)} = 5.5 \text{ V}$	-40°C		0.05		V/μs nV/√Hz	
			\ \ \ \ \ \ \ \	85°C		0.03				
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		68		nV/√Hz		
		V _O = V _{OH} ,		25°C		1				
Вом	Maximum output-swing bandwidth		$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1	-40°C		1.4		kHz	
	HL=1	111 1 10152,	Gee rigule i	85°C		0.8		1		
		V _I = 10 mV, See Figure 3		25°C		110				
B ₁	Unity-gain bandwidth		$C_L \approx 20 \text{ pF},$	-40°C		155		kHz		
		See Figure 3	ł	85°C		80		1		
φm				25°C		38°				
	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	-40°C		42°		1		
		OL = 20 pr,	See Figure 3	85°C		32°		1		

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operating characteristics, $V_{DD} = 5 \text{ V}$

PARAMETER		TEST CO	TEST CONDITIONS		TLC27L2M TLC27L7M			UNIT
		'				MIN TYP M		AX
				25°C		0.03		
			$V_{I(PP)} = 1 V$	-55°C		0.04		
on	Olevanska skumika seda	$R_L = 1 M\Omega$,		125°C		0.02		\//
SR	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.03		V/μs
		Joseph Marie V	$V_{I(PP)} = 2.5 V$	-55°C		0.04	***************************************	
			` '	125°C		0.02		
٧ _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
				25°C		5		
Вом	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 1 M\Omega$,	C _L = 20 pF, See Figure 1	−55°C		8	*************************	kHz
			See Figure 1	125°C		3		
				25°C		85		
B ₁		V _I = 10 mV, See Figure 3	$C_L = 20 \text{ pF},$	-55°C		140		kHz
		See Figure 3		125°C		45		
	,			25°C		34°		
φm	Phase margin	$V_{i} = 10 \text{ mV},$ $C_{i} = 20 \text{ pF},$	f = B ₁ , See Figure 3	−55°C		39°		
		OL = 20 β1,	Coe rigure o	125°C	T	25°		

operating characteristics, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CONDITIONS		TA	TLC27L2M TLC27L7M			UNIT
				• •	MIN	TYP	MAX	
				25°C		0.05		
		V _{I(PP)} = 1 V	−55°C		0.06			
00.	Slow rate at unity gain	$R_L = 1 M\Omega$,		125°C		0.03	MAX	Wus
SR	Slew rate at unity gain	C _L = 20 pF, See Figure 1	V _{I(PP)} = 5.5 V	25°C		0.04		V/μs
				−55°C		0.06		
		125°C		0.03				
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		68		nV/√Hz
,				25°C		1		kHz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1	−55°C		1.5		
			See Figure 1	125°C		0.7		
		V _I = 10 mV, See Figure 3	_	25°C		110		
В1	Unity-gain bandwidth		$C_L = 20 pF$,	−55°C		165		kHz
		See Figure 3		125°C		70		
		1		25°C		38°		
φm	Phase margin	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF},$	f = B ₁ , See Figure 3	–55°C		43°		
	·	J		125°C		29°		<u> </u>

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PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC27L2 and TLC27L7 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

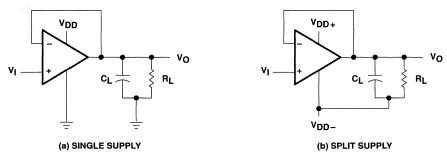


Figure 1. Unity-Gain Amplifier

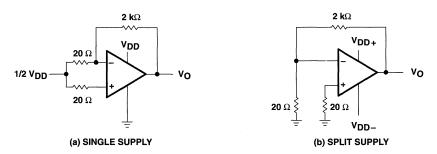


Figure 2. Noise-Test Circuit

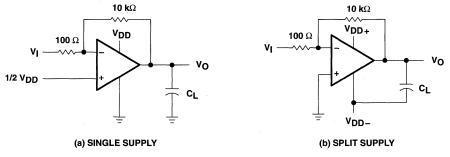


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC27L2 and TLC27L7 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

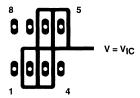


Figure 4. Isolation Metal Around Device Inputs (JG and P packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.



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PARAMETER MEASUREMENT INFORMATION

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.

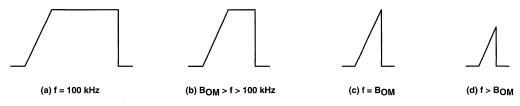


Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	6, 7
αVIO	Temperature coefficient of input offset voltage	Distribution	8, 9
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
A _{VD}	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
lΒ	Input bias current	vs Free-air temperature	22
lio	Input offset current	vs Free-air temperature	22
VIC	Common-mode input voltage	vs Supply voltage	23
IDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	29
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
φm -	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	34 35 36
Vn	Equivalent input noise voltage	vs Frequency	37
	Phase shift	vs Frequency	32, 33

TYPICAL CHARACTERISTICS

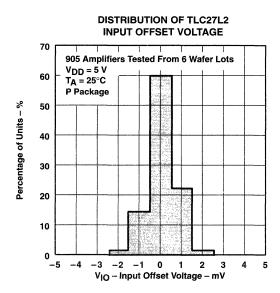


Figure 6

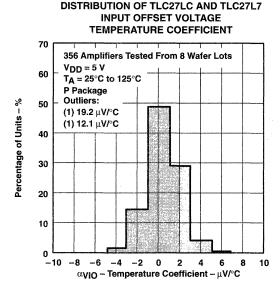


Figure 8

INPUT OFFSET VOLTAGE 70 905 Amplifiers Tested From 6 Wafer Lots $V_{DD} = 10 V$ TA = 25°C P Package

DISTRIBUTION OF TLC27L2

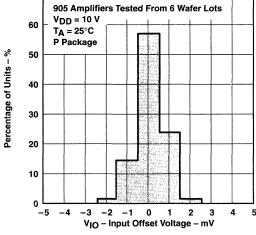


Figure 7

DISTRIBUTION OF TLC27LC AND TLC27L7 INPUT OFFSET VOLTAGE **TEMPERATURE COEFFICIENT**

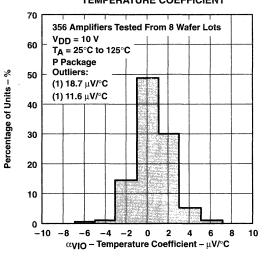
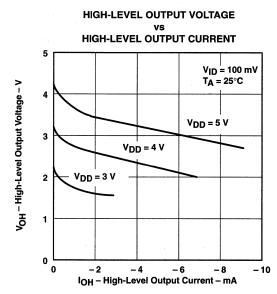


Figure 9

TYPICAL CHARACTERISTICS†



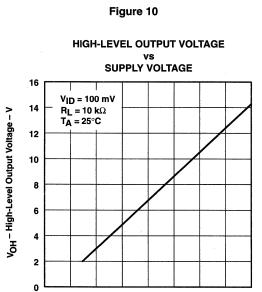


Figure 12

8 10

V_{DD} - Supply Voltage - V

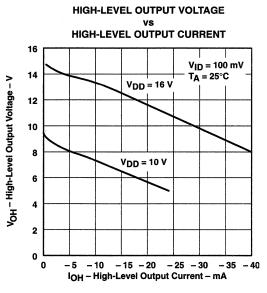


Figure 11

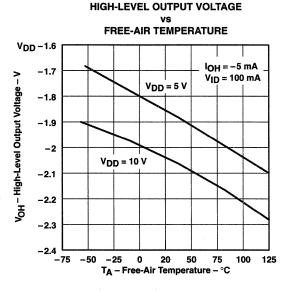


Figure 13

16



0 2

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS[†]

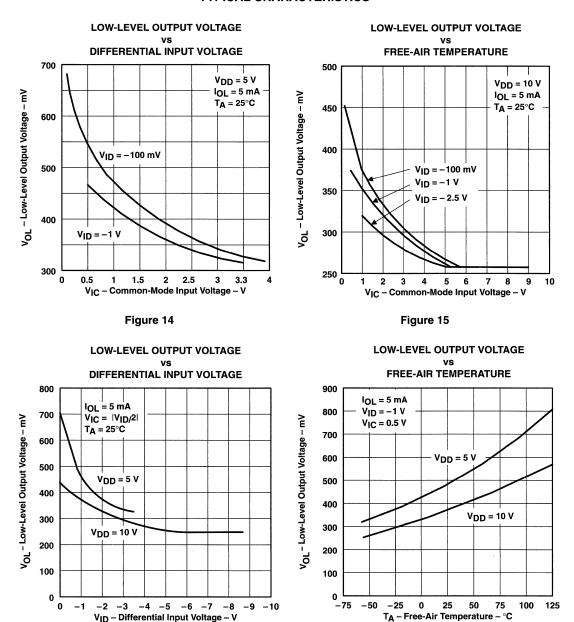


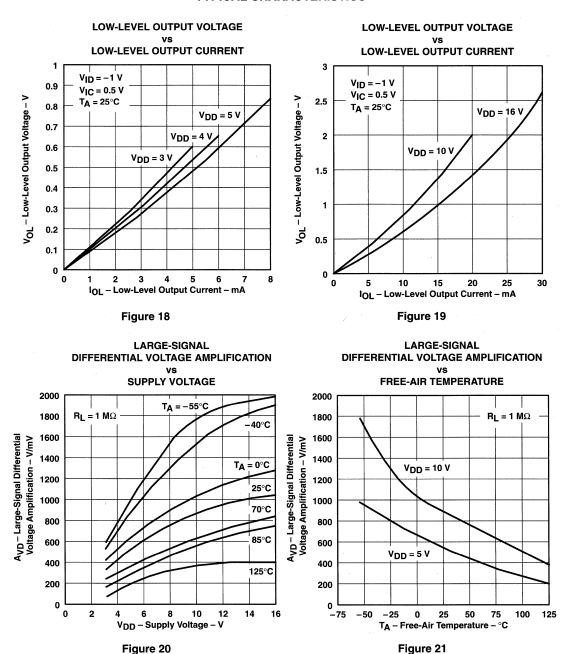
Figure 16



Figure 17

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS[†]

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT FREE-AIR TEMPERATURE 10000 IB and IO - Input Bias and Offset Currents - pA V_{DD} = 10 V VIC = 5 V See Note A 1000 lв 100 10 1 0.1 L 25 45 65 85 105 125

NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 22

TA - Free-Air Temperature - °C

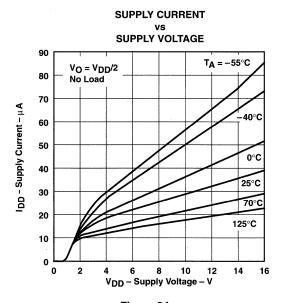


Figure 24

COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT

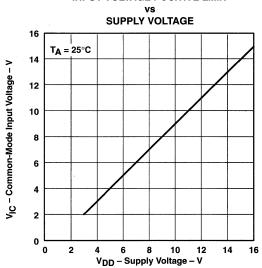


Figure 23

SUPPLY CURRENT vs

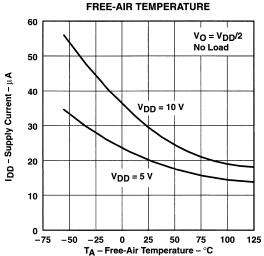
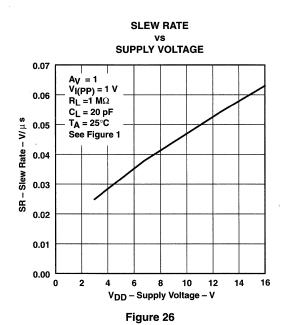


Figure 25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]



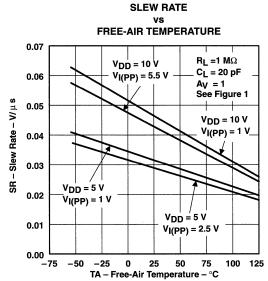


Figure 27

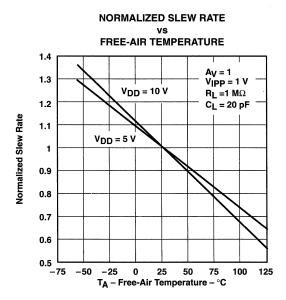


Figure 28

MAXIMUM-PEAK-TO-PEAK OUTPUT VOLTAGE

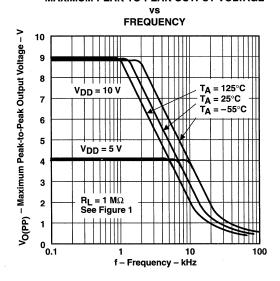


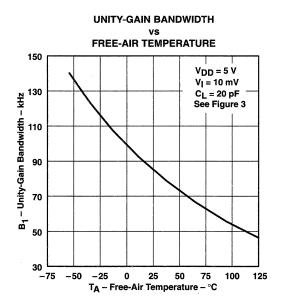
Figure 29

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS[†]



UNITY-GAIN BANDWIDTH vs SUPPLY VOLTAGE 140 $V_I = 10 \text{ mV}$ 130 C_L = 20 pF B₁ - Unity-Gain Bandwidth - kHz T_A = 25°C 120 See Figure 3 110 100 90 80 70 60 50 0 2 16 6 8 10 12 14 V_{DD} -- Supply Voltage -- V

Figure 30

Figure 31

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

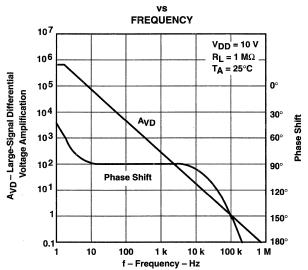


Figure 32

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

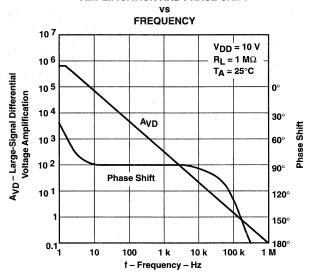
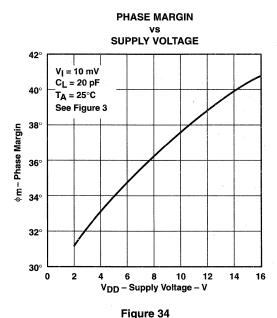


Figure 33



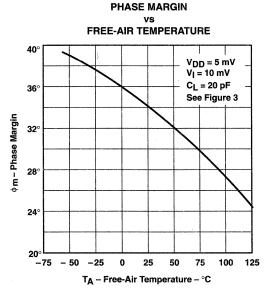


Figure 35

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS

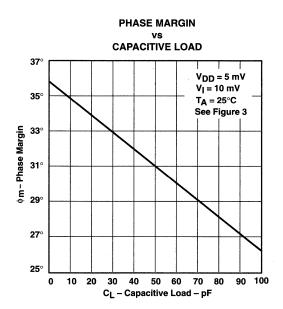


Figure 36

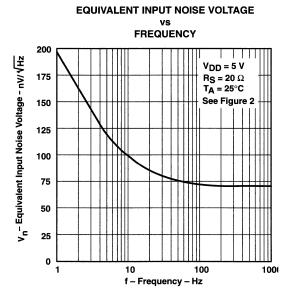


Figure 37

APPLICATION INFORMATION

single-supply operation

While the TLC27L2 and TLC27L7 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC27L2 and TLC27L7 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27L2 and TLC27L7 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

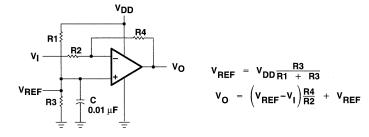


Figure 38. Inverting Amplifier With Voltage Reference

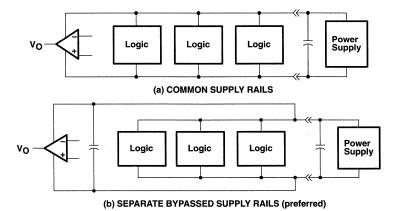


Figure 39. Common Versus Separate Supply Rails



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APPLICATION INFORMATION

input characteristics

The TLC27L2 and TLC27L7 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at V_{DD} –1 V at T_A = 25°C and at V_{DD} –1.5 V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC27L2 and TLC27L7 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC27L2 and TLC27L7 are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC27L2 and TLC27L7 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

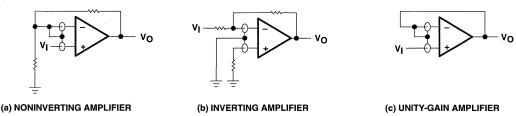


Figure 40. Guard-Ring Schemes

output characteristics

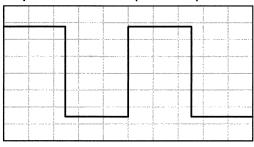
The output stage of the TLC27L2 and TLC27L7 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC27L2 and TLC27L7 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.

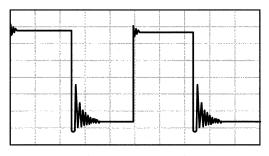


APPLICATION INFORMATION

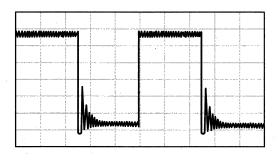
output characteristics (continued)



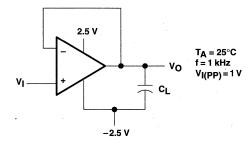
(a) C_L = 20 pF, R_L = NO LOAD



(b) $C_L = 260 \text{ pF}$, $R_L = NO \text{ LOAD}$



(c) $C_L = 310 \text{ pF}$, $R_L = NO \text{ LOAD}$



(d) TEST CIRCUIT

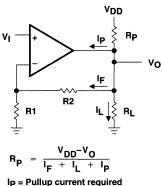
Figure 41. Effect of Capacitive Loads and Test Circuit

Although the TLC27L2 and TLC27L7 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately $60~\Omega$ and $180~\Omega$, depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

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APPLICATION INFORMATION

output characteristics (continued)



Ip = Pullup current required by the operational amplifier (typically 500 μA)

v_o

Figure 43. Compensation for Input Capacitance

Figure 42. Resistive Pullup to Increase VOH

feedback

Operational amplifier circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

electrostatic discharge protection

The TLC27L2 and TLC27L7 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices, as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC27L2 and TLC27L7 inputs and outputs were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μ F typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

APPLICATION INFORMATION

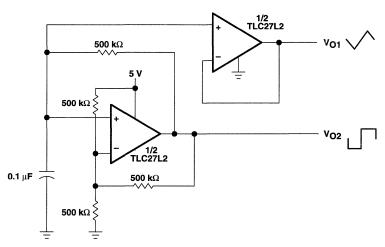
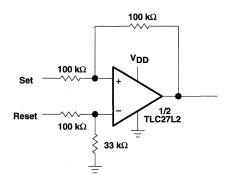


Figure 44. Multivibrator

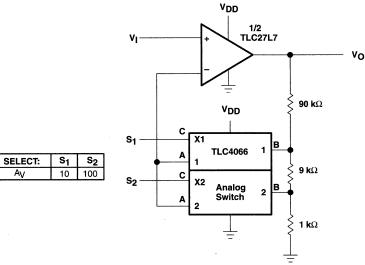


NOTE: $V_{DD} = 5 \text{ V to } 16 \text{ V}$

Figure 45. Set/Reset Flip-Flop

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APPLICATION INFORMATION



NOTE: $V_{DD} = 5 \text{ V to } 12 \text{ V}$

Figure 46. Amplifier With Digital Gain Selection

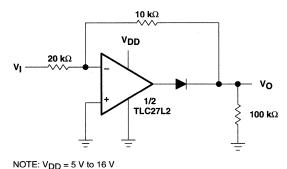
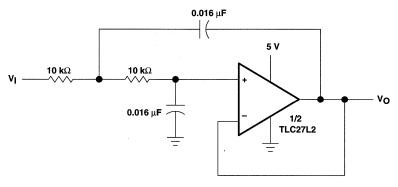


Figure 47. Full-Wave Rectifier

APPLICATION INFORMATION



NOTE: Normalized to f_{C} = 1 kHz and R_{L} = 10 $k\Omega$

Figure 48. Two-Pole Low-Pass Butterworth Filter

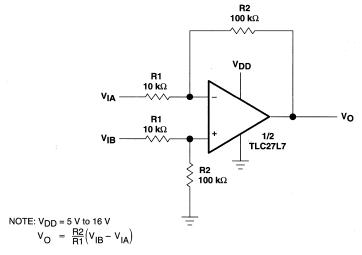


Figure 49. Difference Amplifier

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 Trimmed Offset Voltage: TLC27M7...500 μV Max at 25°C,

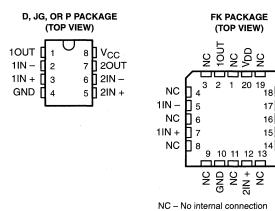
 $V_{DD} = 5 \text{ V}$

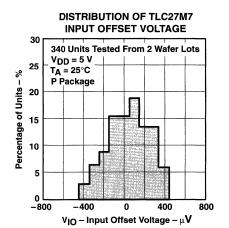
- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over Specified Temperature Ranges:

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 4 V to 16 V

- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, I-Suffix Types)

- Low Noise . . . Typically 32 nV/√Hz at f = 1 kHz
- Low Power . . . Typically 2.1 mW at 25°C, V_{DD} = 5 V
- Output Voltage Range Includes Negative Rail
- High Input impedance . . . $10^{12} \Omega$ Typ
- ESD-Protection Circuitry
- Small-Outline Package Option Also Available in Tape and Reel
- Designed-In Latch-Up Immunity





AVAILABLE OPTIONS

NC

NC

2IN

NC

20UT

	Viemov		PACKA	GE	
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
	500 μV	TLC27M7CD	_		TLC27M7CP
0°C to 70°C	2 mV	TLC27M2BCD		_	TLC27M2BCP
00.0700	5 mV	TLC27M2ACD			TLC27M2ACP
	10 mV	TLC27M2CD			TLC27M2CP
	500 μV	TLC27M7ID	_	_	TLC27M7IP
-40°C to 85°C	2 mV	TLC27M2BID	_		TLC27M2BIP
-40°C 10 85°C	5 mV	TLC27M2AID		_	TLC27M2AIP
	10 mV	TLC27M2ID			TLC27M2IP
-55°C to 125°C	500 μV	TLC27M7MD	TLC27M7MFK	TLC27M7MJG	TLC27M7MP
-55 0 10 125 0	10 mV	TLC27M2MD	TLC27M2MFK	TLC27M2MJG	TLC27M2MP

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC27M7CDR).

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description

The TLC27M2 and TLC27M7 dual operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, low noise, and speeds approaching that of general-purpose bipolar devices. These devices use Texas instruments silicon-gate LinCMOS technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, and high slew rates make these cost-effective devices ideal for applications which have previously been reserved for general-purpose bipolar products,but with only a fraction of the power consumption. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC27M2 (10 mV) to the high-precision TLC27M7 (500 μ V). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC27M2 and TLC27M7. The devices also exhibit low voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

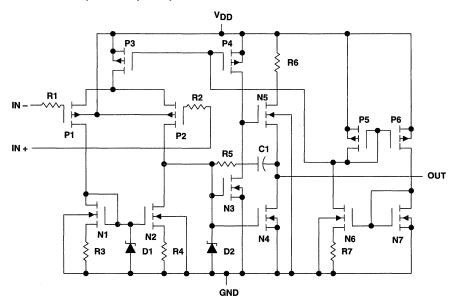
The device inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC27M2 and TLC27M7 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

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equivalent schematic (each amplifier)



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)±V _{DD})
Input voltage range, V _I (any input))
Input current, I ₁	
Output current, I _O (each output) ±30 mA	١
Total current into V _{DD}	
Total current out of GND	
Duration of short-circuit current at (or below) 25°C (see Note 3)	t
Continuous total dissipation	Э
Operating free-air temperature, T _A : C suffix)
I suffix	
M suffix	
Storage temperature range65°C to 150°C)
Case temperature for 60 seconds: FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package)
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package)

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	

recommended operating conditions

		C SU	FFIX	ISU	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	4	16	V
Common mode innut voltage V	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	. 0	8.5	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TI TI	.C27M2 .C27M2 .C27M2 .C27M7	AC BC	UNIT
						MIN	TYP	MAX	
		TLC27M2C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TEOZTWZO	$R_S = 50 \Omega$,	$R_{\parallel} = 100 \text{ k}\Omega$	Full range			12	mV
		TLC27M2AC	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		0.9	5] """
Vio	Input offset voltage	TEOZINIZAO	$R_S = 50 \Omega$,	$R_{\parallel} = 100 \text{ k}\Omega$	Full range			6.5	
*10	input onset voltage	TLC27M2BC	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		220	2000	1
		TEGETWIZEG	$R_S = 50 \Omega$,	$R_{\parallel} = 100 \text{ k}\Omega$	Full range			3000	μV
		TLC27M7C	V _O = 1.4 V,	V _{IC} = 0,	25°C		185	500	μν
		TEGZ/W/7C	$R_S = 50 \Omega$,	$R_{\parallel} = 100 \text{ k}\Omega$	Full range			1500	
αVIO	Average temperature co offset voltage	pefficient of input			25°C to 70°C		1.7		μV/°C
					25°C		0.1		
lo	Input offset current (see	Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	pΑ
•		N. 1 - 4	.,		25°C		0.6		
lΒ	Input bias current (see	Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		40	600	pΑ
						-0.2	-0.3		
					25°C	to	to		V
VICR	Common-mode input vo	oltage range				4	4.2	_	
	(see Note 5)				Full range	-0.2 to			l _v
					I un range	3.5			
					25°C	3.2	3.9		
Vон	High-level output voltag	e	V _{ID} = 100 mV,	$R_I = 100 \text{ k}\Omega$	0°C	3	3.9		l v
011	, ,		"	_	70°C	3	4		1
				·	25°C		0	50	
VOL	Low-level output voltage	Э	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
02	,		"	OL.	70°C		0	50	1
					25°C	25	170		
AVD	Large-signal differential	voltage	$V_{O} = 0.25 \text{ V to 2 V},$	$R_1 = 100 \text{ k}\Omega$	0°C	15	200		V/mV
••	amplification			_	70°C	15	140		ĺ
					25°C	65	91		†
CMRR	Common-mode rejectio	n ratio	V _{IC} = V _{ICR} min		0°C	60	91		dB
	-1				70°C	60	92		İ
					25°C	70	93		İ
ksvr	Supply-voltage rejection	n ratio	V _{DD} = 5 V to 10 V,	VO = 1.4 V	0°C	60	92		dB
3411	(ΔV _{DD} /ΔV _{IO})			3	70°C	60	94		
					25°C		210	560	
l _{DD}	Supply current (two am	olifiers)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$,	0°C		250	640	μА
00		,	No load		70°C		170	440	1

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TL TL	.C27M2 .C27M2 .C27M2 .C27M7	AC BC	UNIT
						MIN	TYP	MAX	
		TLC27M2C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLO2/WZC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	mV
		TLC27M2AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	1117
ν _{IO}	Input offset voltage	TEOZTWIZAG	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	
10	input onset voltage	TLC27M2BC	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		224	2000	
		TEOZYWIZBO	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3000	μV
		TLC27M7C	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		190	800	μν
		TEOZ/W/C	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			1900	
αΛΙΟ	Average temperature co offset voltage	efficient of input			25°C to 70°C		2.1		μV/°C
1	l	NI-t- (I)	V- 5.V		25°C		0.1		- 4
ΙO	Input offset current (see	Note 4)	$V_{O} = 5 V$,	$V_{IC} = 5 V$	70°C		7	300	pΑ
	1		.,		25°C		0.7		
IB	Input bias current (see N	lote 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	70°C		50	600	pΑ
	Common-mode input vo	Itage range			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)				Full range	-0.2 to 8.5			V
					25°C	8	8.7		
VOH	High-level output voltage	Э	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	0°C	7.8	8.7		V
					70°C	7.8	8.7		
					25°C		0	50	
VOL	Low-level output voltage	•	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
					25°C	25	275		
AVD	Large-signal differential amplification	voltage	$V_O = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	0°C	15	320		V/mV
	amplification				70°C	15	230		
					25°C	65	94		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min		0°C	60	94		dB
				·	70°C	60	94		
	0 1 1				25°C	70	93		
ksvR	Supply-voltage rejection (ΔV _{DD} /ΔV _{IO})	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	92		dB
	(4,00,4,10)				70°C	60	94		
			V- 5V	V 5.V	25°C		285	600	
IDD	Supply current (two amp	olifiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	0°C		345	800	μΑ
					70°C		220	560]

[†] Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	TAT	TL TL	.C27M2 .C27M2 .C27M2 .C27M7	AI BI	UNIT
						MIN	TYP	MAX	
		TLC27M2I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLO2/IVIZI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			13	mV
		TLC27M2AI	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		0.9	5	l ''''
V _{IO}	Input offset voltage	TEOZ/WIZAI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			7	
VIO	input onset voltage	TLC27M2BI	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		220	2000	
		TEOZYWEDI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3500	μV
		TLC27M7I	$V_0 = 1.4 V$	V _{IC} = 0,	25°C		185	500	μv
		TLOZ/W//	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			2000	
ανιο	Average temperature co offset voltage	efficient of input			25°C to 85°C		1.7		μV/°C
					25°C		0.1		
ΙO	Input offset current (see	Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	85°C		24	1000	pА
			0.51/	0.5.1/	25°C		0.6		
lВ	Input bias current (see N	lote 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	85°C		200	2000	рA
	Common-mode input vo	tago rango			25°C	-0.2 to 4	-0.3 to 4.2		V
VICR	(see Note 5)	nage range			Full range	-0.2 to 3.5			V
					25°C	3.2	3.9		
VOH	High-level output voltage)	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	-40°C	3	3.9		V
					85°C	3	4		1
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-40°C		0	50	mV
					85°C		0	50	
		_		-	25°C	25	170		
AVD	Large-signal differential amplification	voltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	-40°C	15	270		V/mV
	απριπισαιιστι				85°C	15	130]
					25°C	65	91		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		-40°C	60	90		dB
					85°C	60	90		1
	_				25°C	70	93		
ksvr	Supply-voltage rejection	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	-40°C	60	91		dB
	(ΔV _{DD} /ΔV _{IO})				85°C	60	94		1
					25°C		210	560	ĺ
IDD	Supply current (two amp	lifiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	-40°C		315	800	μΑ
			140 IOau		85°C		160	400	1

†Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT	TI TI TI	_C27M2 _C27M2 _C27M2 _C27M7	AI BI	UNIT
						MIN	TYP	MAX	
		TLC27M2I	V _O = 1.4 V,	$V_{IC} = 0$	25°C		1.1	10	
			$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			13	mV
		TLC27M2AI	V _O = 1.4 V,	V _{IC} = 0,	25°C	_	0.9	5	
VIO	Input offset voltage		$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			7	
		TLC27M2BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		224	2000	
			$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3500	μV
		TLC27M7I	V _O = 1.4 V,	V _{IC} = 0,	25°C		190	800	
	· · · · · · · · · · · · · · · · · · ·	<u> </u>	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range	ļ		2900	
αVIO	Average temperature coeffi offset voltage	cient of input			25°C to 85°C		2.1		μV/°C
Ιιο	Input offset current (see No	to 4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.1		pА
P	input onset current (see No		VO = 5 V,	VIC = 3 V	85°C		26	1000	PΑ
					25°C		0.7		
lΒ	Input bias current (see Note	e 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	85°C		220	200 0	рA
.,	Common-mode input voltage	ge range			25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)	, · · · ·			Full range	-0.2 to 8.5			٧
					25°C	8	8.7		
VOH	High-level output voltage		$V_{ID} = 100 \text{ mV},$	$R_L = 100 \text{ k}\Omega$	-40°C	7.8	8.7		٧
					85°C	7.8	8.7		
					25°C		. 0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-40°C		0	50	mV
					85°C		0	50	
					25°C	25	275		
AVD	Large-signal differential vol amplification	tage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	-40°C	15	390		V/mV
	amplification				85°C	15	220		
					25°C	65	94		
CMRR	Common-mode rejection ra	tio	V _{IC} = V _{ICR} min		-40°C	60	93		dB
					85°C	60	94		
					25°C	70	93		
ksvr	Supply-voltage rejection ra (ΔV _{DD} /ΔV _{IO})	tio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	91		dB
	(טויאי(טעיאט)				85°C	60	94		
					25°C		285	600	
lDD	Supply current		V _O = 5 V, No load	$V_{IC} = 5 V$	-40°C		450	900	μΑ
			110 1000		85°C		205	520	1

[†] Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	T _A †		.C27M2 .C27M7		UNIT
					"	MIN	TYP	MAX	
		TLC27M2M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
V	land offert colleges	TLC2/M2M	$R_S = 50 \Omega$	$R_L = 100 \text{ k}\Omega$	Full range			12	mV
VIO	Input offset voltage	TI 00714714	V _O = 1.4 V,	V _{IC} = 0,	25°C		185	500	mv
		TLC27M7M	$R_S = 50 \Omega$	$R_L = 100 \text{ k}\Omega$	Full range			3750	
αVIO	Average temperature coeff offset voltage	icient of input			25°C to 125°C		1.7		μV/°C
1	In a state of the	4\	V- 05V		25°C		0.1		pА
li0	Input offset current (see No	ne 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C		1.4	. 15	nA
L-	Innuit him augus t /a.a. Nat	- 4\	V- 05V	V- 05V	25°C		0.6		pА
lВ	Input bias current (see Not	e 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C		9	35	nA
	Common-mode input volta	ge range			25°C	0 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)				Full range	0 to 3.5			٧
					25°C	3.2	3.9		
۷он	High-level output voltage		$V_{ID} = 100 \text{ mV},$	$R_L = 100 \text{ k}\Omega$	−55°C	3	3.9		٧
					125°C	3	4		
					25°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	-55°C		0	50	mV
					125°C		0	50	
					25°C	25	170		
A_{VD}	Large-signal differential vol amplification	tage	$V_0 = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	−55°C	15	290		V/mV
	ampilioation				125°C	15	120		
					25°C	65	91		
CMRR	Common-mode rejection ra	atio	V _{IC} = V _{ICR} min		−55°C	60	89		dB
					125°C	60	91		
					25°C	70	93		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVIO)	tio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	91		dB
					125°C	60	94		
			V 05V	V 05V	25°C		210	560	
DD	Supply current (two amplific	ers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$	−55°C		340	880	μΑ
			1		125°C		140	360	

†Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †		C27M2N C27M7N		UNIT
						MIN	TYP	MAX	
		TLC27M2M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
V	Innut offeet veltere	TLC2/W2W	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	mV
VIO	Input offset voltage	TLC27M7M	V _O = 1.4 V,	V _{IC} = 0,	25°C		190	800	mv
		I LOZ/WI/WI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			4300	
αVIO	Average temperature coeffic offset voltage	ient of input			25°C to 125°C		2.1		μV/°C
li o	Input offset current (see Note	- 4\	V _O = 5 V,	V: 5 V	25°C		0.1		ρA
lo	input onset current (see Not	3 4)	VO = 5 V,	$V_{IC} = 5 V$	125°C		1.8	15	рA
l	Innuit bing assessed (and Nata	4\	V- 5V	V 5.V	25°C		0.7		- 0
lΒ	Input bias current (see Note	4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	125°C		10	35	рA
	Common-mode input voltage	e range			25°C	0 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)	_			Full range	0 to 8.5			٧
					25°C	8	8.7		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	−55°C	7.8	8.6		V
					125°C	7.8	8.8		
					25°C		0	50	
VOL	Low-level output voltage		V _{ID} = -100 mV,	IOL = 0	−55°C		0	50	mV
					125°C		0	50	
				.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	25°C	25	275		
AVD	Large-signal differential volta amplification	ige	$V_{O} = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	−55°C	15	420		V/mV
	ampinication				125°C	15	190		
					25°C	65	94		
CMRR	Common-mode rejection rati	o	V _{IC} = V _{ICR} min		−55°C	60	93		dB
					125°C	60	93		
	_				25°C	70	93		
ksvr	Supply-voltage rejection ratio (ΔVDD/ΔVIO)		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	91		dB
	(AADD\AAIO)				125°C	60	94		
					25°C		285	600	
'loo	Supply current (two amplifier	rs)	V _O = 5 V, No load	$V_{IC} = 5 V$	−55°C		490	1000	μΑ
			140 1040		125°C		180	480	

[†] Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

	PARAMETER	TEST CO	TA	TLC27M2C TLC27M2AC TLC27M2BC TLC27M7C			UNIT	
			·		MIN	TYP	MAX	
		ļ		25°C		0.43		
			V _{I(PP)} = 1 V	0°C		0.46		
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$	1	70°C		0.36		V/μs
Jon	Siew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.40		V/μS
l		l seegae .	$V_{I(PP)} = 2.5 V$	0°C		0.43		ĺ
ļ				70°C		0.34		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
				25°C		55		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,		0°C		60		kHz
		N_ = 100 Ks2,	See Figure 1	70°C		50		
				25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		600		kHz
		Gee i igule 3		70°C		400		
			, ,	25°C		40°		
φm	Phase margin	V _I = 10 mV, C _I = 20 pF,	f = B ₁ , See Figure 3	0°C		41°		
		о_ = 20 рг,		70°C		39°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST C	TA	TLC27M2C TLC27M2AC TLC27M2BC TLC27M7C			UNIT		
					MIN	TYP	MAX		
				25°C		0.62			
		1	$V_{I(PP)} = 1 V$	0°C		0.67			
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$		70°C		0.51		V/μs	
Jon	Siew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.56		ν/μ5	
				$V_{I(PP)} = 5.5 \text{ V}$	0°C		0.61		
		Į	1 '	70°C					
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz	
				25°C		35			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	0°C		40		kHz	
		TIL = 100 KS2,	See i iguie i	70°C	30				
				25°C		635			
В1	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		710		kHz	
	, , , , , , , , , , , , , , , , , , , ,	Gee i igule 3		70°C		510			
				25°C		43°			
φ _m Phase margin	Phase margin	$V_{I} = 10 \text{ mV},$ $C_{I} = 20 \text{ pF},$	f = B ₁ , See Figure 3	0°C		44°	*****		
		= 20 pr,	CCO riguio o	70°C		42°			

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operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

PARAMETER		TEST CONDITIONS		TA	TLC27M2I TLC27M2AI TLC27M2BI TLC27M7I			UNIT
	·		Т	25°C	MIN	TYP 0.43	MAX	
		i	V _I (PP) = 1 V	-40°C		0.43		
		$R_1 = 100 \text{ k}\Omega$						
SR	Slew rate at unity gain	$C_L = 20 \text{ pF},$		85°C		0.35		V/μs
	Cion rate at anny gain	See Figure 1		25°C		0.40		ν,μο
			$V_{I(PP)} = 2.5 \text{ V}$	-40°C		0.48		
				85°C		0.32		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
				25°C		55		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	-40°C		75		kHz
		TIL = 100 K32,	Gee rigure r	85°C		45		
				25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	-40°C		770		MHz
		Oce i iguie o		85°C		370		
φm			. 5	25°C		40°		
	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	f = B ₁ , See Figure 3	-40°C		43°		
		,		85°C		38°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

PARAMETER		TEST CONDITIONS		TA	TLC27M2I TLC27M2AI TLC27M2BI TLC27M7I		UNIT		
					MIN	TYP	MAX		
			V _{I(PP)} = 1 V	25°C		0.62			
				-40°C		0.77			
ep.	Clay rate at unity gain	$R_L = 100 \text{ k}\Omega$		85°C		0.47		V/vo	
SR Slew rate at unity gain CL = 20 pF, See Figure 1		25°C		0.56		V/μs			
			$V_{I(PP)} = 5.5 V$	-40°C		0.70			
	·	, ,	85°C		0.44		1		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz	
		I	C _L = 20 pF, See Figure 1	25°C		35			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 100 \text{ k}\Omega$,		-40°C		45		kHz	
		11 = 100 KS2,	See rigule i	85°C		25			
		V _I = 10 mV,		25°C		635			
B ₁	Unity-gain bandwidth			V _I = 10 mV, (See Figure 3		-40°C		880	
		See Figure 3		85°C		480		1	
				25°C		43°			
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	-40°C		46°			
		J = 20 pr,	See . Iguie o	85°C		41°		1	

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

PARAMETER		TEST CONDITIONS		TA	TLC27M2M TLC27M7M		UNIT			
					MIN TYP MAX					
		R_L = 100 kΩ, C_L = 20 pF, See Figure 1		25°C		0.43				
			V _{I(PP)} = 1 V	−55°C		0.54				
SR	Class rate at units gain			125°C		0.29		V/v.a		
on	Slew rate at unity gain			25°C		0.40		V/μs		
			V _{I(PP)} = 2.5 V	−55°C		0.49				
1				125°C		0.28				
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz		
				25°C		55				
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 100 \text{ k}\Omega$,		−55°C		80		kHz		
		TIL = 100 KS2,	See Figure 1	125°C		40				
		V _I = 10 mV, C _L = 20 pF, —55°C —55°C		525						
B ₁	Unity-gain bandwidth			V _I = 10 mV, See Figure 3		C _L = 20 pF,	−55°C		850	
		See rigule 3		125°C		330				
фm				25°C		40°				
	Phase margin	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}.$	f = B ₁ , See Figure 3	−55°C		44°				
		OL - 20 pr,	ecc. galo o	125°C		36°				

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

PARAMETER		TEST CONDITIONS		TA	TLC27M2M TLC27M7M			UNIT						
					MIN	TYP	MAX							
				25°C 0.62										
			V _{I(PP)} = 1 V	−55°C		0.81								
SR	$R_L = 100 \text{ k}\Omega$, ,	125°C		0.38		1//							
Jon J	Slew rate at unity gain	See Figure 1			25°C		0.56		V/μs					
				Cooking and it	Cooking and it	l see i igaire i	See	Cook inguity	J cook igains i	$V_{I(PP)} = 5.5 V$	−55°C		0.73	
			` ,	125°C		0.35								
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√ Hz						
				25°C		35								
ВОМ	Maximum output-swing bandwidth					$V_O = V_{OH}$, $C_L = 20 \text{ pF}$, $R_L = 100 \text{ k}\Omega$, See Figure 1		−55°C		50		kHz		
							11L = 100 K22,	NL = 100 K22,	TIL = 100 ksz, Geerigule i	See rigure r	125°C		20	
				25°C		635								
B ₁	Unity gain bandwidth	V _I = 10 mV, See Figure 3						C _L = 20 pF,	-55°C		960		kHz	
		See rigare 3		125°C		440								
		V 40 V	4 D	25°C		43°								
φm	Phase margin	$V_{I} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF},$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	T = B1, See Figure 3	−55°C		47°			
				125°C		39°								

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC27M2 and TLC27M7 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

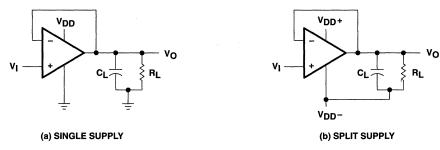


Figure 1. Unity-Gain Amplifier

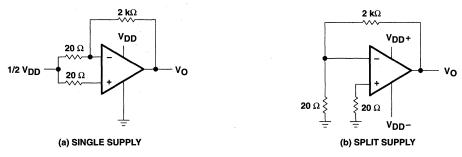


Figure 2. Noise-Test Circuit

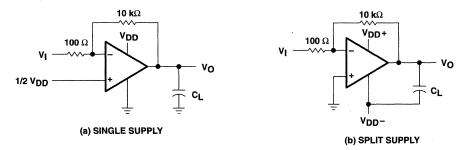


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC27M2 and TLC27M7 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution ... many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

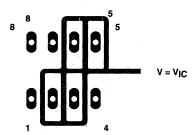


Figure 4. Isolation Metal Around Device Inputs (JG and P packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

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PARAMETER MEASUREMENT INFORMATION

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.



Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	6, 7
αVIO	Temperature coefficient	Distribution	8, 9
V _{OH}	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
AVD	Differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
I _{IB} /I _I O	Input bias and input offset current	vs Free-air temperature	22
V _{IC}	Common-mode input voltage	vs Supply voltage	23
IDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	29
В1	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Capacitive loads	
Vn	Equivalent input noise voltage	vs Frequency	37
ф	Phase shift	vs Frequency	32, 33

TYPICAL CHARACTERISTICS

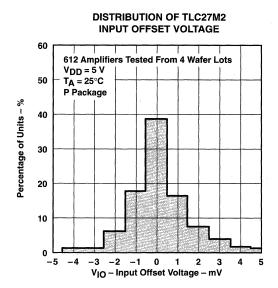


Figure 6

DISTRIBUTION OF TLC27M2 AND TLC27M7 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

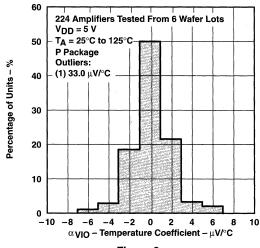


Figure 8

DISTRIBUTION OF TLC27M2 INPUT OFFSET VOLTAGE

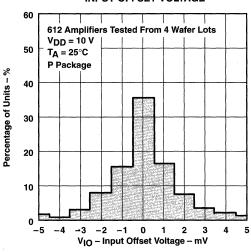


Figure 7

DISTRIBUTION OF TLC27M2 AND TLC27M7 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

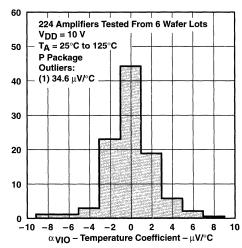
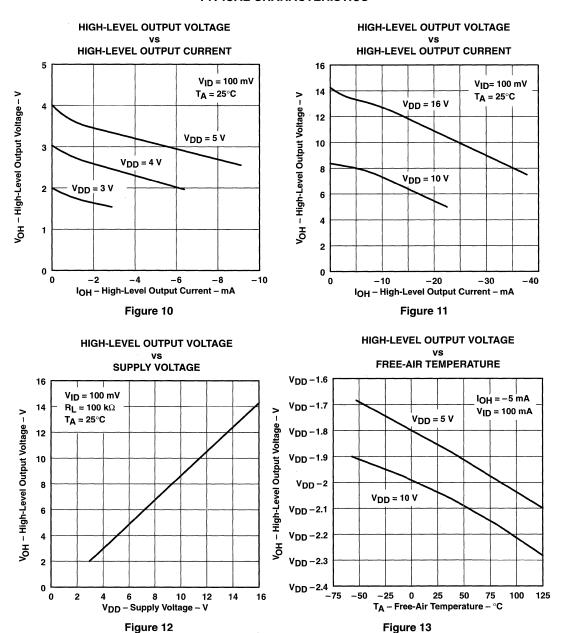


Figure 9

Percentage of Units - %

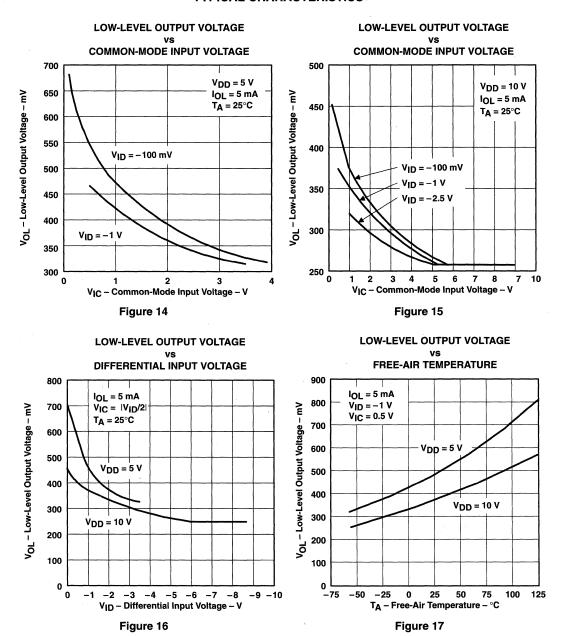
TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



 $V_{ID} = -1 V$

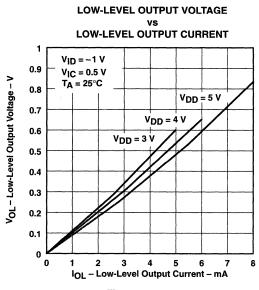
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LOW-LEVEL OUTPUT VOLTAGE

LOW-LEVEL OUTPUT CURRENT

TYPICAL CHARACTERISTICS[†]

3



V_{OL} - Low-Level Output Voltage - V V_{IC} = 0.5 V 2.5 V_{DD} = 16 V $T_A = 25^{\circ}C$ 2 V_{DD} = 10 V 1.5 1 0.5 0 0 15

Figure 18



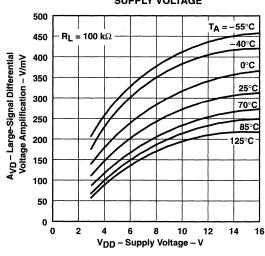


Figure 20

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION FREE-AIR TEMPERATURE**

IOL - Low-Level Output Current - mA

Figure 19

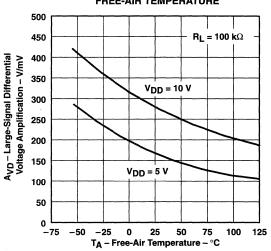
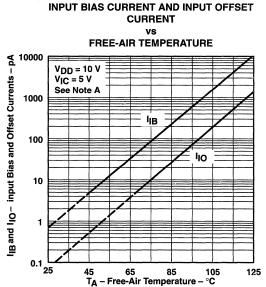


Figure 21

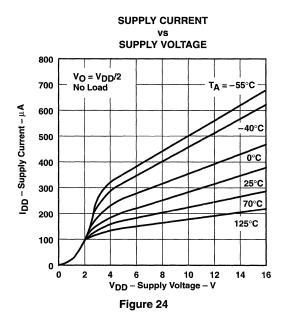
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 22



COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT VS

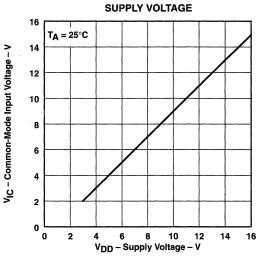
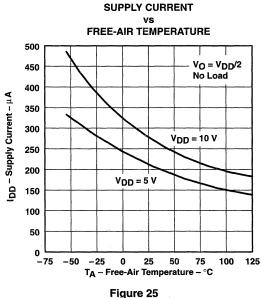


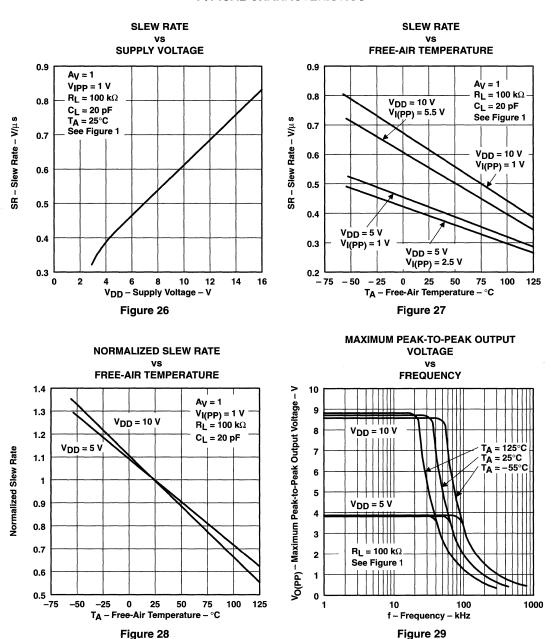
Figure 23



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



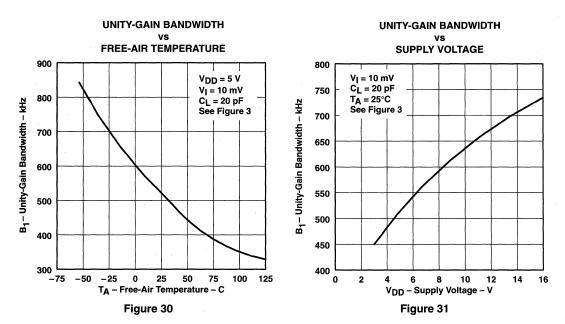
TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†



LARGE-SCALE DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

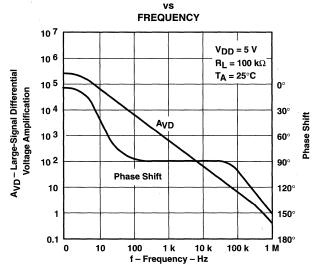


Figure 32

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

LARGE-SCALE DIFFERENTIAL VOLTAGE **AMPLIFICATION AND PHASE SHIFT**

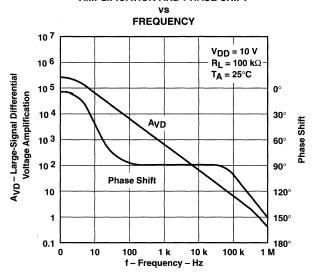
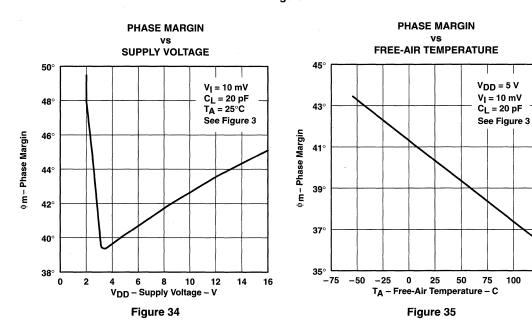


Figure 33



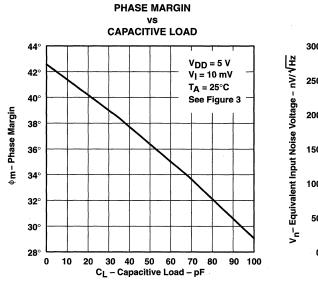
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



75

100 125

TYPICAL CHARACTERISTICS



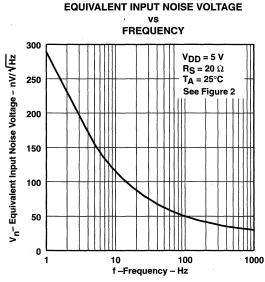


Figure 37

Figure 36

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APPLICATION INFORMATION

single-supply operation

While the TLC27M2 and TLC27M7 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC27M2 and TLC27M7 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27M2 and TLC27M7 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- 1. Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

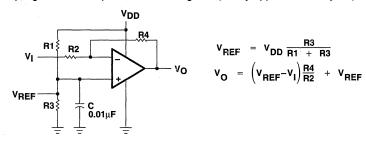
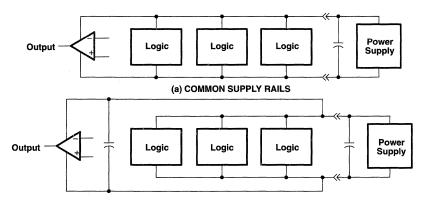


Figure 38. Inverting Amplifier With Voltage Reference



(b) SEPARATE BYPASSED SUPPLY RAILS (preferred)

Figure 39. Common Versus Separate Supply Rails



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APPLICATION INFORMATION

input characteristics

The TLC27M2 and TLC27M7 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at V_{DD} –1 V at T_A = 25°C and at V_{DD} –1.5 V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC27M2 and TLC27M7 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1µV/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC27M2 and TLC27M7 are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC27M2 and TLC27M7 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

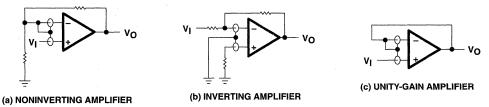


Figure 40. Guard-Ring Schemes

output characteristics

The output stage of the TLC27M2 and TLC27M7 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC27M2 and TLC27M7 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.



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APPLICATION INFORMATION

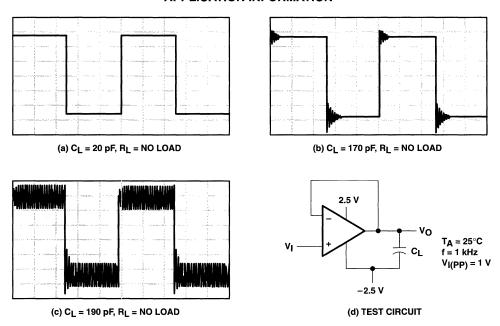


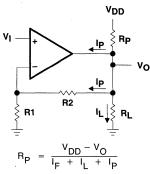
Figure 41. Effect of Capacitive Loads and Test Circuit

output characteristics (continued)

Although the TLC27M2 and TLC27M7 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately $60\,\Omega$ and $180\,\Omega$, depending on how hard the op amp input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

APPLICATION INFORMATION

output characteristics (continued)



Ip = Pullup current required by the operational amplifier (typically 500 μ A)

v_c

Figure 42. Resistive Pullup to Increase VOH

Figure 43. Compensation for Input Capacitance

feedback

Operational amplifier circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

electrostatic-discharge protection

The TLC27M2 and TLC27M7 incorporate an internal electrostatic-discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC27M2 and TLC27M7 inputs and outputs were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μ F typical) located across the supply rails as close to the device as possible.

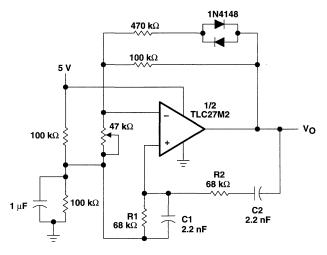
The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.



TLC27M2, TLC27M2A, TLC27M2B, TLC27M7 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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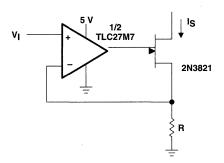
APPLICATION INFORMATION



NOTES:
$$V_{O(PP)} \approx 2 \text{ V}$$

$$f_{O} = \frac{1}{2\pi \sqrt{R1R2C1C2}}$$

Figure 44. Wien Oscillator

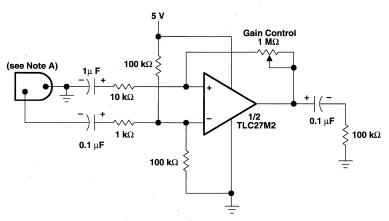


NOTES:
$$V_I = 0 \text{ V to } 3 \text{ V}$$

$$I_S = \frac{V_I}{R}$$

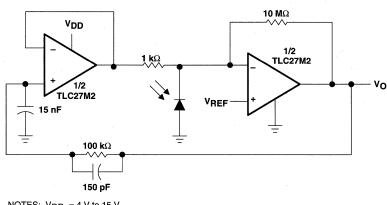
Figure 45. Precision Low-Current Sink

APPLICATION INFORMATION



NOTE A: Low to medium impedance dynamic mike

Figure 46. Microphone Preamplifier



NOTES: $V_{DD} = 4 \text{ V to } 15 \text{ V}$ $V_{ref} = 0 \text{ V to } V_{DD} - 2 \text{ V}$

Figure 47. Photo-Diode Amplifier With Ambient Light Rejection

TLC27M2, TLC27M2A, TLC27M2B, TLC27M7 LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION

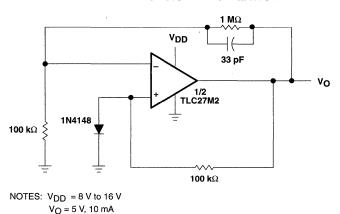


Figure 48. 5-V Low-Power Voltage Regulator

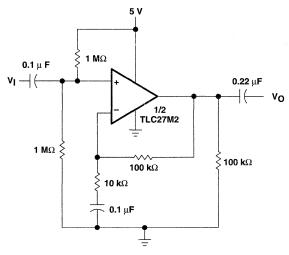


Figure 49. Single-Rail AC Amplifiers

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Trimmed Offset Voltage:

TLC279 . . . 900
$$\mu$$
V Max at 25°C, V_{DD} = 5 V

- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over Specified Temperature Range:

- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix and I-Suffix Versions)
- Low Noise . . . Typically 25 nV/√Hz at f = 1 kHz
- Output Voltage Range Includes Negative Rail
- High Input Impedance . . . $10^{12} \Omega$ Typ
- ESD-Protection Circuitry
- Small-Outline Package Option Also Available in Tape and Reel
- Designed-In Latch-Up Immunity

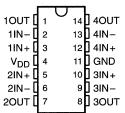
description

The TLC274 and TLC279 quad operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, low noise, and speeds approaching that of general-purpose BiFET devices.

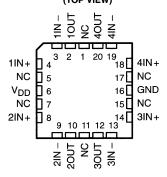
These devices use Texas Instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, and high slew rates make these cost-effective devices ideal for applications which have previously been reserved for BiFET and NFET products. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC274 (10 $\mu V)$ to the high-precision TLC279 (900 $\mu V)$. These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

D, J, N, OR PW PACKAGE (TOP VIEW)

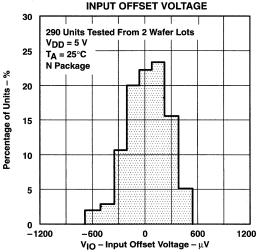


FK PACKAGE (TOP VIEW)



NC - No internal connection

DISTRIBUTION OF TLC279



LinCMOS is a trademark of Texas Instruments Incorporated.

TEXAS INSTRUMENTS

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description (continued)

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC274 and TLC279. The devices also exhibit low voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC274 and TLC279 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

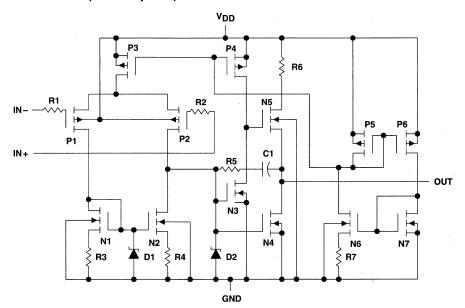
AVAILABLE OPTIONS

			AVAILABL				
			PA	CKAGED DEV	ICES		CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)	FORM (Y)
	900 μV 2 mV	TLC279CD TLC274BCD	_	_	TLC279CN TLC274BCN	_	_
0°C to 70°C	5 mV 10 mV	TLC274ACD TLC274CD	_		TLC274ACN TLC274CN	— TLC274CPW	— TLC274Y
-40°C to 85°C	900 μV 2 mV 5 mV	TLC279ID TLC274BID TLC274AID		<u>-</u> -	TLC279IN TLC274BIN TLC274AIN	_ _ _	_ _ _
	10 mV	TLC274ID			TLC274IN		_
−55°C to 125°C	900 μV 10 mV	TLC279MD TLC274MD	TLC279MFK TLC274MFK	TLC279MJ TLC274MJ	TLC279MN TLC274MN	_	

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC279CDR).

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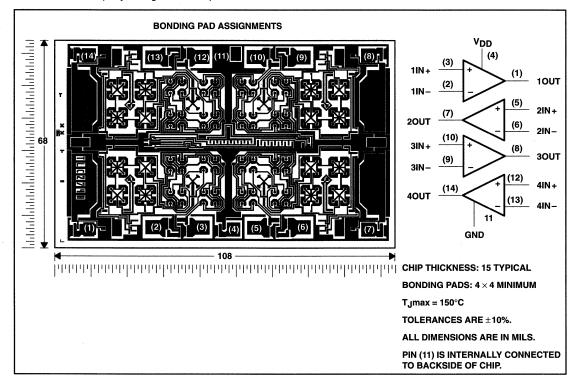
equivalent schematic (each amplifier)



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TLC274Y chip information

These chips, when properly assembled, display characteristics similar to the TLC274C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input)	0.3 V to V _{DD}
Input current, I ₁	±5 mA
Output current, IO (each output)	±30 mA
Total current into V _{DD}	45 mA
Total current out of GND	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation S	See Dissipation Rating Table
Operating free-air temperature, T _A : C suffix	
I suffix	40°C to 85°C
M suffix	–55°C to 125°C
Storage temperature range	65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or PW page	ckage 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 - 2. Differential voltages are at the noninverting input with respect to the inverting input.
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW	
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
N	1575 mW	12.6 mW/°C	1008 mW	819 mW	
PW	700 mW	5.6 mW/°C	448 mW	_	_

recommended operating conditions

		C SU	FFIX	I SUF	FIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD}		3	16	4	16	4	16	٧
Common mode input voltage V	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5	V
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	T _A †	TLC274 TLC274	C, TLC2 IBC, TL		UNIT
						MIN	TYP	MAX	
		TI 00740	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC274C	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			12	>/
		TI 007440	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
		TLC274AC	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			6.5	
V _{IO}	Input offset voltage	TI 0074D0	V _O = 1.4 V,	V _{IC} = 0,	25°C		340	2000	
		TLC274BC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3000	
		TI 00700	V _O = 1.4 V,	V _{IC} = 0,	25°C		320	900	μV
		TLC279C	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			1500	
ανιο	Average temperature coeffice offset voltage	cient of input			25°C to 70°C		1.8		μV/°C
1	long to offer at a company (a.e. Alas	- 4)	V- 05V	V 0.5.V	25°C		0.1		1
IIO .	Input offset current (see Not	e 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	pΑ
1	Innut biog assessed (and Note	4Ý	V- 05V	V:- 0.5.V	25°C		0.6		^
IB .	Input bias current (see Note	4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	70°C		40	600	pΑ
-						-0.2	-0.3		
					25°C	to 4	to 4.2		V
VICR	Common-mode input voltag (see Note 5)	e range			ļ	ļ	4.2		
	(366 14016 3)				Full range	-0.2 to			v
						3.5			
					25°C	3.2	3.8		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	3	3.8		٧
					70°C	3	3.8		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
					25°C	5	23		
AVD	Large-signal differential volt amplification	age	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	0°C	4	27		V/mV
	аттриноалогі				70°C	4	20		
					25°C	65	80		
CMRR	Common-mode rejection rate	io	V _{IC} = V _{ICR} min		0°C	60	84		dB
			<u> </u>		70°C	60	85		
					25°C	65	95		
ksvr	Supply-voltage rejection rati (ΔV _{DD} /ΔV _{IO})	0	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
	(A*DD/A*IO)				70°C	60	96		
			V. 05.V	V - 0.5.V	25°C		2.7	6.4	
lDD	Supply current (four amplifie	ers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	0°C		3.1	7.2	mA
					70°C	l	2.3	5.2	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †	TLC274	C, TLC2		UNIT
					1	MIN	TYP	MAX	
		TLC274C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC274C	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
		TI C0744C	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mv
\	lanut affaat valtaan	TLC274AC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			6.5	
VIO	Input offset voltage	TLC274BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		390	2000	
		1LC2/4BC	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3000	μV
		TLC279C	V _O = 1.4 V,	.V _{IC} = 0,	25°C		370	1200	μν
		1102/90	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			1900	
αVIO	Average temperature coeff input offset voltage	icient of			25°C to 70°C		2		μV/°C
	1	-1- 4\	V 5V	V 5V	25°C		0.1		- 4
lιο	Input offset current (see No	ote 4)	V _O =.5 V,	$V_{IC} = 5 V$	70°C		7	300	рA
		- 4\	V 5V		25°C		0.7		- 4
lΒ	Input bias current (see Not	e 4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	70°C		50	600	pΑ
						-0.2	-0.3		
					25°C	to	to 9.2		V
VICR	Common-mode input volta (see Note 5)	ge range				9	9.2		
	(see Note 5)				Full range	-0.2 to			v
					1	8.5			-
					25°C	8	8.5		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	0°C	7.8	8.5		٧
					70°C	7.8	8.4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
					25°C	10	36		
AVD	Large-signal differential vo amplification	Itage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	0°C	7.5	42		V/mV
	amplification				70°C	7.5	32		
			;		25°C	65	85		
CMRR	Common-mode rejection ra	atio	V _{IC} = V _{ICR} min		0°C	60	88		dB
					70°C	60	88		
					25°C	65	95		
ksvr	Supply-voltage rejection ra (ΔV _{DD} /ΔV _{IO})	tio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	94		dB
	(A,00,2410)				70°C	60	96		
				.,	25°C		3.8	8	
IDD	Supply current (four amplif	iers)	V _O = 5 V, No load	$V_{IC} = 5 V$	0°C		4.5	8.8	mA
					70°C		3.2	6.8	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	TAT		4I, TLC2 4BI, TL0		UNIT
						MIN	TYP	MAX	
		TLC2741	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		11.02/41	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			13	mV
		TI CO7441	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mv
V/	lanut affactualtana	TLC274AI	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			7	
VIO	Input offset voltage	TLC274BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		340	2000	
		ILC2/4BI	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3500	μV
		TLC279I	V _O = 1.4 V,	V _{IC} = 0,	25°C		320	900	μν
		11.02/91	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			2000	
αΝΙΟ	Average temperature coefficie offset voltage	ent of input			25°C to 85°C		1.8		μV/°C
1	lance office at a command (a.e. Nada	4)	V- 05V	V 0.5.V	25°C		0.1		^
10	Input offset current (see Note	4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	85°C		24	1000	рA
	North March 1997		V 05V		25°C		0.6		4
lΒ	Input bias current (see Note 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	85°C		200	2000	рA
	Common-mode input voltage	range			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)				Full range	-0.2 to 3.5			٧
					25°C	3.2	3.8		
Vон	High-level output voltage		$V_{ID} = 100 \text{ mV},$	$R_L = 10 \text{ k}\Omega$	-40°C	3	3.8		V
					85°C	3	3.8		
		· · · · · · · · · · · · · · · · · · ·			25°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-40°C		0	50	mV
					85°C		0	50	
		***************************************			25°C	5	23		
A_{VD}	Large-signal differential voltage amplification	je	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	-40°C	3.5	32		V/mV
	amplification				85°C	3.5	19		
					25°C	65	80		
CMRR	Common-mode rejection ratio	١.	V _{IC} = V _{ICR} min		-40°C	60	81		dB
					85°C	60	86		
	_		·		25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	92		dB
	(\(\text{\O}\) \(\text{\O}\)				85°C	60	96		
					25°C		2.7	6.4	
I _{DD}	Supply current (four amplifiers	5)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	-40°C		3.8	8.8	mA
			1.10 1000		85°C		2.1	4.8	1

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †		4I, TLC2 4BI, TLC		UNIT
						MIN	TYP	MAX	
		TLC2741	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		1LG2/41	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			13	
		TI 007441	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
.,	land official colleges	TLC274AI	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			7	
VIO	Input offset voltage	TI 0074DI	V _O = 1.4 V,	V _{IC} = 0,	25°C		390	2000	
		TLC274BI	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			3500	
		TI 00701	V _O = 1.4 V,	V _{IC} = 0,	25°C		370	1200	μV
		TLC279I	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			2900	
αVIO	Average temperature coefficient offset voltage	ent of input			25°C to 85°C		2		μV/°C
_					25°C		0.1		
ΙΟ	Input offset current (see Note	4)	$V_O = 5 V$,	$V_{IC} = 5 V$	85°C		26	1000	pΑ
					25°C		0.7		
^I IB	Input bias current (see Note	1)	$V_0 = 5 V$,	$V_{IC} = 5 V$	85°C		220	2000	pΑ
				···	25°C	-0.2 to	-0.3 to		٧
VICR	Common-mode input voltage	range				9	9.2		
1011	(see Note 5)				Full range	-0.2 to 8.5			٧
					25°C	8	8.5		
V _{OH}	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	-40°C	7.8	8.5		V
			-		85°C	7.8	8.5		
				-	25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	-40°C		0	50	mV
					85°C		0	50	
					25°C	10	36		
AVD	Large-signal differential voltage	ge	$V_{O} = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	-40°C	7	47		V/mV
	amplification				85°C	7	31		
	,				25°C	65	85		
CMRR	Common-mode rejection ratio)	V _{IC} = V _{ICR} min		-40°C	60	87		dB
					85°C	60	88		
					25°C	65	95		
ksvr	Supply-voltage rejection ratio		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	-40°C	60	92		dB
	(ΔV _{DD} /ΔV _{IO})				85°C	60	96		
					25°C		3.8	8	
lDD	Supply current (four amplifier	s)	V _O = 5 V, No load	$V_{IC} = 5 V$	-40°C		5.5	10	mA
			140 1040		85°C		2.9	6.4	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETER		7507.00	NITION O		TLC27	4M, TLC	279M	
	PARAMETER		TEST CONI	DITIONS	T _A †	MIN	TYP	MAX	UNIT
		TLC274M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	m\/
V	lanut offest voltage	TLC2/4W	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
V _{IO}	Input offset voltage	TI C070M	V _O = 1.4 V,	V _{IC} = 0,	25°C		320	900	μV
		TLC279M	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			3750	μν
αΛΙΟ	Average temperature coefficie offset voltage	nt of input			25°C to 125°C		2.1		μV/°C
1	Input offset surrent (see Note	4)	Va 0.5.V	V:- 2 E V	25°C		0.1		pА
ΙΟ	Input offset current (see Note	4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C		1.4	15	nA
1	Input hise current (see Note 4	\	Va - 0.5.V	V:- 2 E V	25°C		0.6		, pA
lΒ	Input bias current (see Note 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C		9	35	nA
\\.	Common-mode input voltage	range			25°C	0 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)				Full range	0 to 3.5			٧
	and the same of th				25°C	3.2	3.8		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	−55°C	3	3.8		٧
					125°C	3	3.8		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-55°C		0	50	mV
					125°C		0	50	
					25°C	5	23		
A_{VD}	Large-signal differential voltage amplification	je	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 10 \text{ k}\Omega$	−55°C	3.5	35		V/mV
•	ampinioation				125°C	3.5	16		
					25°C	65	80		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		−55°C	60	81		dB
					125°C	60	84		
					25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	90		dB
	(A 100/A 10)				125°C	60	97		
			V- 05V	V 05V	25°C		2.7	6.4	
I_{DD}	Supply current (four amplifiers	s)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	−55°C		4	10	mA
			1		125°C		1.9	4.4	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless) otherwise noted)

	DADAMETED		7507.001	OITION O		TLC27	4M, TLC	279M	UNIT
	PARAMETER		TEST CONI	DITIONS	T _A †	MIN	TYP	MAX	UNII
		TLC274M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	m\/
V	lament officet violes as	TLC2/4M	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			12	mV
V _{IO}	Input offset voltage	TLC279M	V _O = 1.4 V,	V _{IC} = 0,	25°C		370	1200	μV
		1102/910	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			4300	μν
αVIO	Average temperature coefficie offset voltage	nt of input			25°C to 125°C		2.2		μV/°C
li o	Input offset current (see Note	4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.1		pА
10	input offset current (see Note	4)	VO = 2 V,	AIC = 2 A	125°C		1.8	15	nA
lin.	Input bias current (see Note 4	١	V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		pА
lΒ	input bias current (see Note 4)	VO = 5 V,	AIC = 2 A	125°C		10	35	nA
\\\	Common-mode input voltage	range			25°C	0 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)				Full range	0 to 8.5			٧
					25°C	8	8.5		
VOH	High-level output voltage		V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	−55°C	7.8	8.5		٧
					125°C	7.8	8.4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	−55°C		0	50	mV
					125°C		0	50	
					25°C	10	36		
A_{VD}	Large-signal differential voltage amplification	е	$V_0 = 1 \text{ V to 6 V},$	$R_L = 10 \text{ k}\Omega$	−55°C	7	50		V/mV
	ampimoation				125°C	7	27		
					25°C	65	85		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		-55°C	60	87		dB
					125°C	60	86		
	•				25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	90		dB
	(= · UU/= · IU/				125°C	60	97		
			V- 5.V	V 5 V	25°C		3.8	8	
DD	Supply current (four amplifiers	s)	V _O = 5 V, No load	$V_{IC} = 5 V$,	−55°C		6.0	12	m A
					125°C		2.5	5.6	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST C	ONDITIONS	TA	TLC274C, TLC TLC274 TLC274BC, T	AC,	UNIT
					MIN TYP	MAX	
				25°C	3.6	3	
			V _{IPP} = 1 V	0°C	4	,	
SR	Class rate at units anim	$R_L = 10 \Omega$		70°C	3	3	V/μs
on	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C	2.9)	V/μS
			V _{IPP} = 2.5 V	0°C	3.		
				70°C	2.5	5	
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C	25	;	nV/√Hz
				25°C	320)	
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	0°C	340)	kHz
		11L = 10 Ks2,	Gee rigare r	70°C	260)	1
				25°C	1.3	,	
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C	2	MHz	
		See rigule 5		70°C	1.0	3	
		V 40 - V		25°C	46	>	
φm	Phase margin	$V_{ } = 10 \text{ mV},$ $C_{ } = 20 \text{ pF},$	f = B ₁ ,	0°C	47	•	
		SE = 20 PI,		70°C	. 44	>	

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST CONDITIONS		TA	TLC274C, TLC274AC, TLC274AC, TLC274BC, TLC279C			UNIT
	·		,		MIN	TYP	MAX	
				25°C		5.3		
			V _{IPP} = 1 V	0°C		5.9		
SR	Clays rate at units gain	$R_L = 10 \Omega$		70°C		4.3		V/uo
SH .	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		4.6		V/μs
		J Cook inguitor	V _{IPP} = 5.5 V	0°C	5.1			
				70°C		3.8		
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz
				25°C		200		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	0°C		220		kHz
		TL = 10 K32,	See rigule r	70°C		140		
				25°C		2.2		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		2.5		MHz
		1 See Figure S		70°C		1.8		
		10 11	, 5	25°C		49°		
φm		V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	0°C		50°		
				70°C		46°		

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operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

	PARAMETER	TEST CO	ONDITIONS	TA		4I, TLC2 4BI, TLC		UNIT			
					MIN	TYP	MAX				
			25°C		3.6						
1		V _{IPP} = 1 V	V _{IPP} = 1 V	-40°C		4.5					
SR	Slow rate at unity agin	$R_L = 10 \text{ k}\Omega$		85°C		2.8		Who			
on	Slew rate at unity gain	CL = 20 pF, See Figure 1 V _I pp = 2.5 V		25°C		2.9	2.9	V/μs			
			-40°C		3.5						
			" '			2.3					
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz			
	`	$V_O = V_{OH},$ $C_L = 20 \text{ pF},$ $R_L = 10 \text{ k}\Omega,$ See Figure 1	V _O = V _{OH} ,		_	25°C		320			
ВОМ	Maximum output-swing bandwidth				-40°C		380		kHz		
	Til ~ 10 ksz, See rigule i		85°C		250						
				25°C		1.7					
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 PF$,	-40°C		2.6		MHz			
		See Figure 3		85°C		1.2					
		V ₁ = 10 mV, f = B ₁ ,	25°C		46°						
φm	Phase margin			V _I ≈ 10 mV, C _I ≈ 20 pF,			t = B ₁ , See Figure 3	-40°C		49°	
		0L = 20 pr,	_ 20 pr, See rigule 3			43°					

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST CO	ONDITIONS	TA	TLC274I, TLC274AI, TLC274BI, TLC279I		UNIT		
					MIN	TYP	MAX		
				25°C		5.3			
			V _{IPP} = 1 V	-40°C		6.7			
SR	Clausesta at unity gain	$R_L = 10 \Omega$,		85°C		4		1////	
on	Slew rate at unity gain	C _L ≈ 20 pF, See Figure 1		25°C		4.6		V/μs	
l		V _{IPP} = 5.5 V	-40°C		5.8				
				85°C		3.5			
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√Hz	
				25°C		200			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	-40°C		260		kHz	
		N_ = 10 Ks2,	See Figure 1	85°C		130			
	-			25°C		2.2			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 \text{ pF},$	-40°C		3.1		MHz	
		See Figure S	85°C		1.7				
			, 5	25°C		49°			
φm	Phase margin			t = B ₁ , See Figure 3	-40°C		52°		
		OL = 20 pr, See rigure 3		85°C		46°			

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operating characteristics at specified free-air temperature, $V_{\mbox{DD}}$ = 5 V

	DADAMETED	TEST CO	NOTIONS	7.	TLC274	TLC274M, TLC279M		UNIT														
	PARAMETER	I EST CO	NDITIONS	TA	MIN	TYP	MAX	UNIT														
				25°C		3.6		,														
			V _{IPP} = 1 V	−55°C		4.7																
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$		125°C		2.3		V/μs														
Jon J	Slew rate at unity gain $C_L = 20 \text{ pF},$ See Figure 1		25°C		2.9		ν/μδ															
			V _{IPP} = 2.5 V	−55°C		3.7																
				125°C		2																
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz														
				25°C		320																
ВОМ	Maximum output-swing bandwidth													VO = VOH,		th $VO = VOH$, $R_1 = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	-55°C		400		kHz
		110 10 102,	TL = 10 K32, See Figure 1	125°C		230																
		1.,		25°C		1.7																
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	−55°C		2.9		MHz														
		Gee Iguic 0		125°C		1.1																
		V 40 - V	, ,	25°C		46°																
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF}$	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF}$	$V_I = 10 \text{ mV},$ $C_I = 20 \text{ pF}$	$V_I = 10 \text{ mV},$ $C_I = 20 \text{ pF}$	$V_{\parallel} = 10 \text{ mV},$ $C_{\perp} = 20 \text{ pF},$	$V_1 = 10 \text{ mV},$ $C_1 = 20 \text{ pF}$	V = 10 mV, C = 20 pF	f = B ₁ , See Figure 3	−55°C		49°										
		-L =3 p.,	SL - 20 Pi, Gee i iguie 3	125°C		41°																

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	DADAMETED	TEST 00	NOTIONS	_	TLC274	TLC274M, TLC		UNIT		
	PARAMETER	lesico	NDITIONS	TA	MIN	TYP	MAX	UNIT		
				25°C		5.3				
			V _{IPP} = 1 V	−55°C		7.1				
SR	Clausesta at units again	$R_L = 10 \Omega$,		125°C		3.1		V/μs		
Jon	Slew rate at unity gain	Cլ = 20 pF, See Figure 1		25°C		4.6		ν/μ5		
			V _{IPP} = 5.5 V	−55°C		6.1				
					125°C		2.7			
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		25		nV/√ Hz		
				25°C		200				
ВОМ	Maximum output-swing bandwidth $VO = VO$	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	−55°C		280		kHz		
		Title 10 kaz, Georigano i	1.5 1.3 1.3 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5	125°C		110				
				25°C		2.2				
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	−55°C		3.4		MHz		
		Dec i igure o		125°C		1.6				
		se margin $V_{\parallel} = 10 \text{ mV}, f = B_{1},$ $C_{\parallel} = 20 \text{ pF} \text{See Figure 3}$					25°C 49°	49°		
φm	Phase margin					$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	r = B ₁ , See Figure 3	−55°C		52°
				125°C		44°				

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electrical characteristics, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEST COM	TEST CONDITIONS				
	PARAMETER	IEST CONL	TEST CONDITIONS		TYP	MAX	UNIT
V _{IO}	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $R_{S} = 50 \Omega,$	V _{IC} = 0, R _L = 10 kΩ		1.1	10	mV
lio	Input offset current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.1		pА
lв	Input bias current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.6		pА
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 4	-0.3 to 4.2		٧
VOH	High-level output voltage	V _{ID} = 100 mV,	R _L = 10 kΩ	3.2	3.8		V
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	I _{OL} = 0		0	50	mV
AVD	Large-signal differential voltage amplification	$V_O = 0.25 \text{ V to 2 V},$	R _L = 10 kΩ	5	23		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	80		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V,	V _O = 1.4 V	65	95		dB
I _{DD}	Supply current (four amplifiers)	V _O = 2.5 V, No load	V _{IC} = 2.5 V,		2.7	6.4	mA

electrical characteristics, V_{DD} = 10 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST COM	DITIONS	T	LC274Y		UNIT
	PARAMETER	TEST CON	TEST CONDITIONS		TYP	MAX	UNIT
V _{IO}	Input offset voltage	$V_O = 1.4 \text{ V},$ $R_S = 50 \Omega,$	$V_{IC} = 0$, $R_L = 10 \text{ k}\Omega$		1.1	10	mV
10	Input offset current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.1		pА
1 _{IB}	Input bias current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.7		pΑ
V _{ICR}	Common-mode input voltage range (see Note 5)			-0.2 to 9	-0.3 to 9.2		V
Vон	High-level output voltage	V _{ID} = 100 mV,	$R_L = 10 \text{ k}\Omega$	8	8.5		٧
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	I _{OL} = 0		0	50	mV
AVD	Large-signal differential voltage amplification	$V_{O} = 1 \text{ V to 6 V},$	R _L = 10 kΩ	10	36		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	85		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	65	95		dB
1DD	Supply current (four amplifiers)	V _O = 5 V, No load	V _{IC} = 5 V,		3.8	8	mA

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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operating characteristics, V_{DD} = 5 V, T_A = 25°C

	PARAMETER		TEST CONDITIO	NC	Т	LC274Y		UNIT		
	PARAMETER		TEST CONDITIONS			TYP	MAX	UNII		
SR	Slow rate at unity gain	R _L = 10 kΩ,	$R_L = 10 \text{ k}\Omega$, $C_L = 20 \text{ pF}$,		$R_{I} = 10 \text{ k}\Omega$, $C_{I} = 20 \text{ pF}$, V_{I}			3.6		V/µs
on	Slew rate at unity gain	See Figure 1 V _{IPP} = 2.5 \		V _{IPP} = 2.5 V	= 2.5 V 2.] v/μs		
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2		25		nV/√Hz		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	C _L = 20 pF,	$R_L = 10 \text{ k}\Omega$,		320		kHz		
B ₁	Unity-gain bandwidth	V _I = 10 mV,	C _L = 20 pF,	See Figure 3		1.7		MHz		
φm	Phase margin	V _I = 10 mV, See Figure 3	f = B ₁ ,	C _L = 20 _P F,		46°				

operating characteristics, V_{DD} = 10 V, T_A = 25°C

	PARAMETER		TEST CONDITIONS		TLC274Y			UNIT		
			TEST CONDITIONS			TYP	MAX	ONLI		
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 20 pF,	V _{IPP} = 1 V		5.3		V/µs		
L Sh	Siew rate at unity gain			See Figure 1		V _{IPP} = 5.5 V		4.6		V /μS
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$,	See Figure 2		25		nV/√ Hz		
ВОМ	Maximum output-swing bandwidth	V _O = V _{OH} , See Figure 1	C _L = 20 _P F,	$R_L = 10 \text{ k}\Omega$,		200		kHz		
B ₁	Unity-gain bandwidth	$V_{\parallel} = 10 \text{ mV},$	C _L = 20 _P F,	See Figure 3		2.2		MHz		
φm	Phase margin	V _I = 10 mV, See Figure 3	f = B ₁ ,	C _L = 20 pF,		49°				

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC274 and TLC279 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

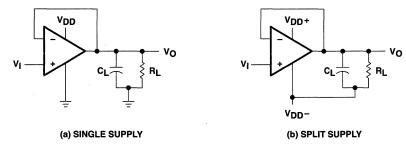


Figure 1. Unity-Gain Amplifier

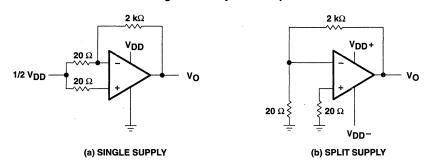


Figure 2. Noise-Test Circuit

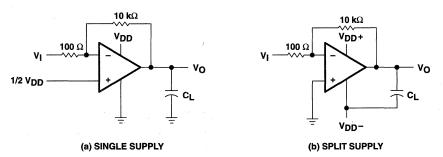


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC274 and TLC279 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- 2. Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

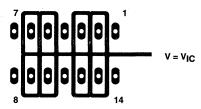


Figure 4. Isolation Metal Around Device Inputs (J and N packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.



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PARAMETER MEASUREMENT INFORMATION

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.

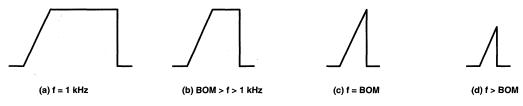


Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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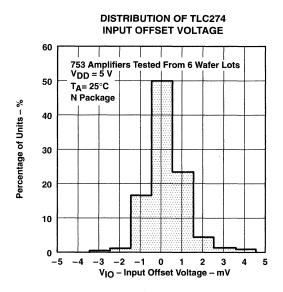
TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	6, 7
αVIO	Temperature coefficient of input offset voltage	Distribution	8, 9
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 ² 21 32, 33
lв	Input bias current	vs Free-air temperature	22
lio	Input offset current	vs Free-air temperature	22
VIC	Common-mode input voltage	vs Supply voltage	23
lDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
VO(PP)	Maximum peak-to-peak output voltage	vs Frequency	29
В1	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	34 35 36
Vn	Equivalent input noise voltage	vs Frequency	37
	Phase shift	vs Frequency	32, 33

DISTRIBUTION OF TLC274

TYPICAL CHARACTERISTICS



INPUT OFFSET VOLTAGE 60 753 Amplifiers Tested From 6 Wafer Lots $V_{DD} = 10 V$ 50 T_A = 25°C N Package Percentage of Units – % 40 30 20 10 0 -2 -1 -5 0

Figure 6

60

50

40

30

20

10

Percentage of Units - %

DISTRIBUTION OF TLC274 AND TLC279

INPUT OFFSET VOLTAGE

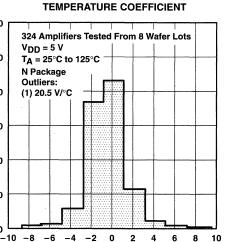


Figure 7



ViO - Input Offset Voltage - mV

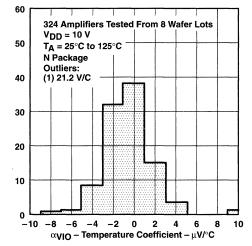


Figure 8

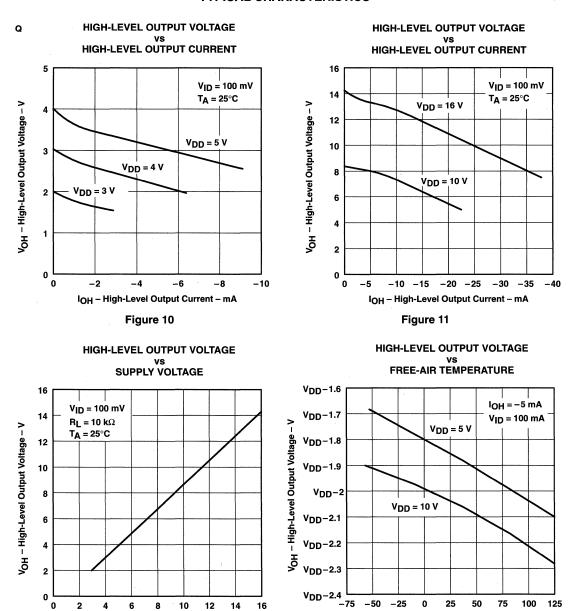
 α_{VIO} - Temperature Coefficient - $\mu V/^{\circ}C$

Figure 9



Percentage of Units – %

TYPICAL CHARACTERISTICS†



V_{DD} - Supply Voltage - V Figure 12

TA - Free-Air Temperature - °C

Figure 13



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]

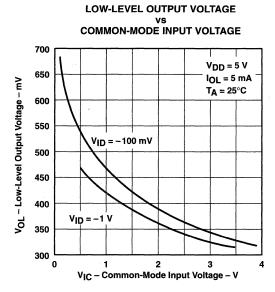


Figure 14

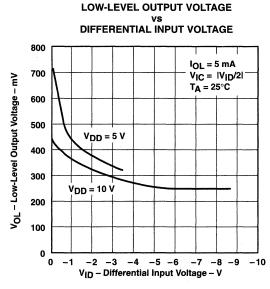


Figure 16

LOW-LEVEL OUTPUT VOLTAGE vs COMMON-MODE INPUT VOLTAGE

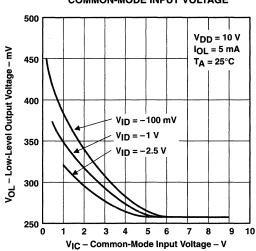


Figure 15

LOW-LEVEL OUTPUT VOLTAGE

FREE-AIR TEMPERATURE

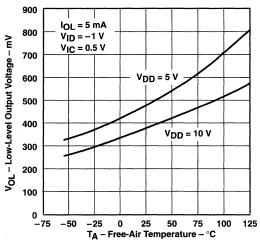
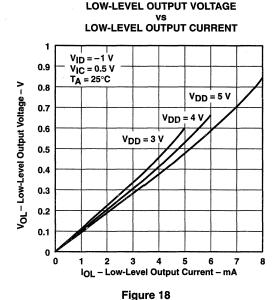


Figure 17

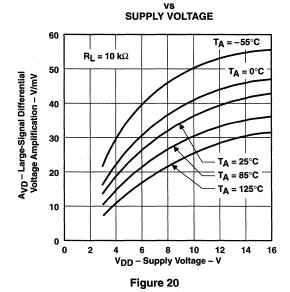
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



LARGE-SIGNAL

DIFFERENTIAL VOLTAGE AMPLIFICATION



LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

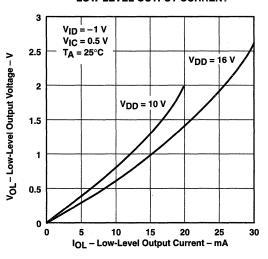


Figure 19

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs

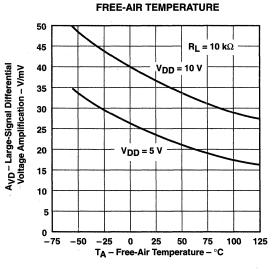
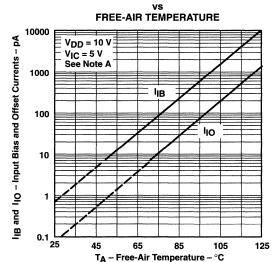


Figure 21

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 22

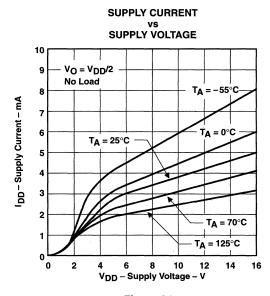


Figure 24

COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT

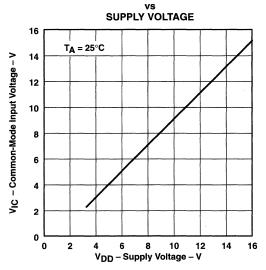


Figure 23

SUPPLY CURRENT vs

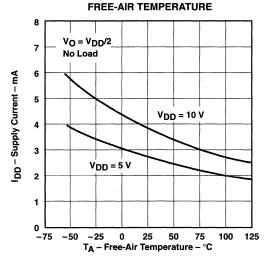
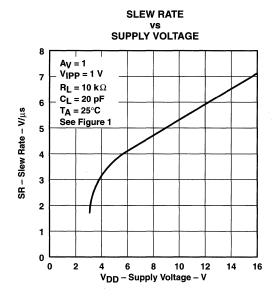


Figure 25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

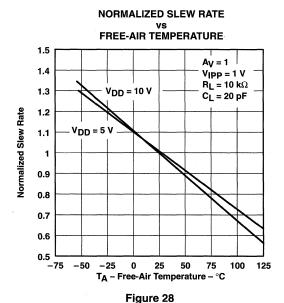


FREE-AIR TEMPERATURE Ay = 1. $R_L = 10 \text{ k}\Omega$ 7 V_{DD} = 10 V C_L = 20 pF V_{IPP} = 5.5 V See Figure 1 6 SR - Slew Rate - V/µs V_{DD} = 10 V 5 V_{IPP} = 1 V 4 3 $V_{DD} = 5 V$ 2 $V_{IPP} = 1 V$ V_{DD} = 5 V 1 $V_{IPP} = 2.5 V$ 0 _75 -50 -25 0 25 50 75 100 125 TA - Free-Air Temperature - °C

SLEW RATE

Figure 26





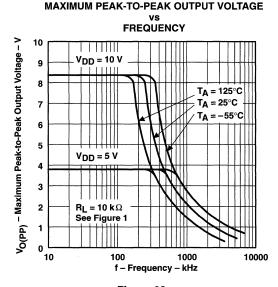


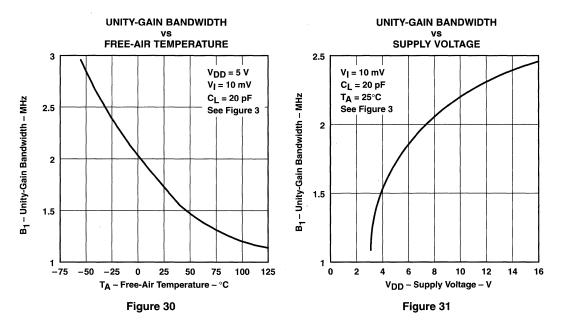
Figure 29

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

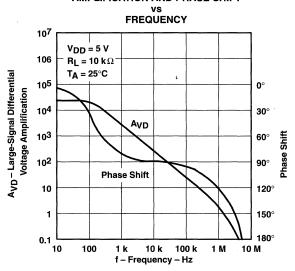


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TYPICAL CHARACTERISTICS[†]



LARGE-SIGNAL DIFFERENTIAL VOLTAGE **AMPLIFICATION AND PHASE SHIFT**



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 32



TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

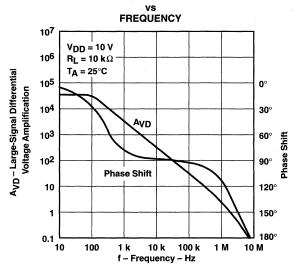
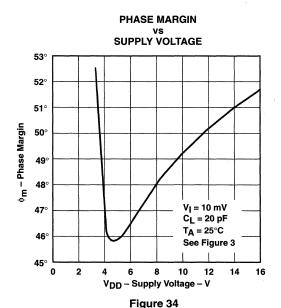


Figure 33



FREE-AIR TEMPERATURE 50° 48° VDD = 5 V VI = 10 mV CL = 20 pF See Figure 3 40° -75 -50 -25 0 25 50 75 100 125 TA - Free-Air Temperature - °C

PHASE MARGIN

Figure 35

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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TYPICAL CHARACTERISTICS

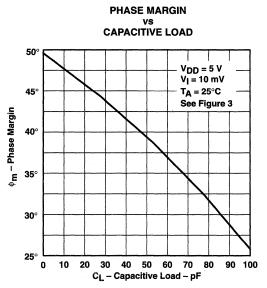


Figure 36

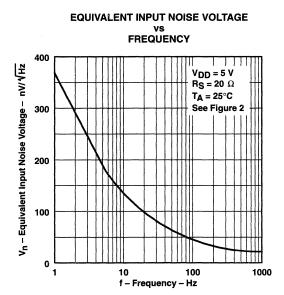


Figure 37

APPLICATION INFORMATION

single-supply operation

While the TLC274 and TLC279 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC274 and TLC279 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC274 and TLC279 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require R_C decoupling.

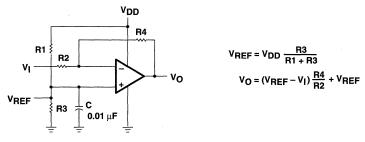


Figure 38. Inverting Amplifier With Voltage Reference

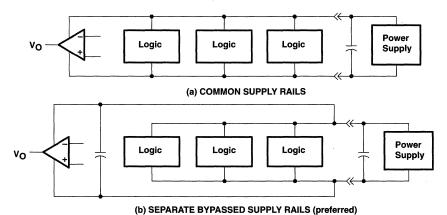


Figure 39. Common Versus Separate Supply Rails

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APPLICATION INFORMATION

input characteristics

The TLC274 and TLC279 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD} - 1$ V at $T_A = 25$ °C and at $V_{DD} - 1.5$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC274 and TLC279 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μV/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC274 and TLC279 are well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC274 and TLC279 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.

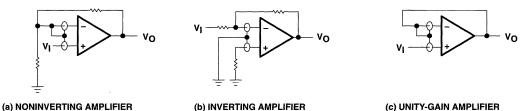


Figure 40. Guard-Ring Schemes

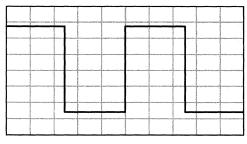
output characteristics

The output stage of the TLC274 and TLC279 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

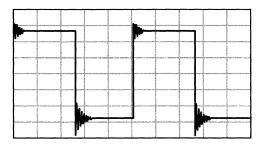
All operating characteristics of the TLC274 and TLC279 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.



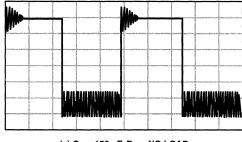
output characteristics (continued)



(a) C_L = 20 pF, R_L = NO LOAD



(b) $C_L = 130 \text{ pF}$, $R_L = NO \text{ LOAD}$



(c) $C_L = 150 \text{ pF}$, $R_L = NO \text{ LOAD}$

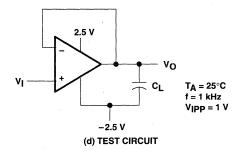
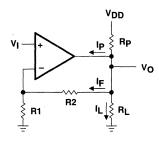


Figure 41. Effect of Capacitive Loads and Test Circuit

Although the TLC274 and TLC279 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately 60 Ω and 180 Ω , depending on how hard the op amp input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

output characteristics (continued)



$$Rp = \frac{V_{DD} - V_{O}}{I_{F} + I_{L} + I_{P}}$$

Ip = Pullup current required by the operational amplifier (typically 500 uA)

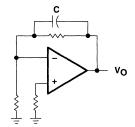


Figure 43. Compensation for **Input Capacitance**

Figure 42. Resistive Pullup to Increase VOH

feedback

Operational amplifier circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

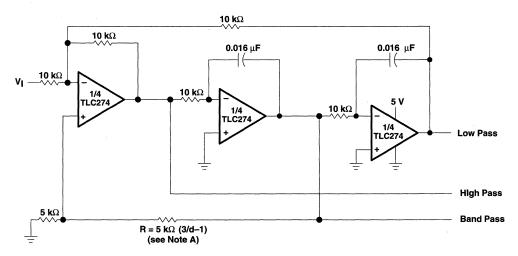
electrostatic discharge protection

The TLC274 and TLC279 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature-dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC274 and TLC279 inputs and outputs were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.



NOTE A: d = damping factor, 1/Q

Figure 44. State-Variable Filter

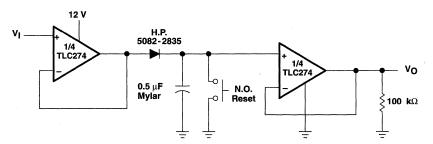
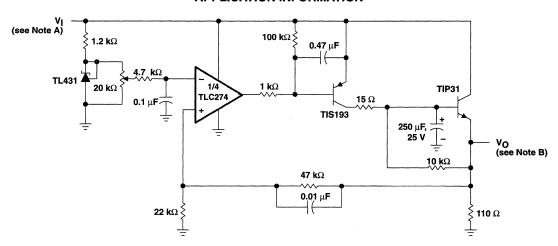
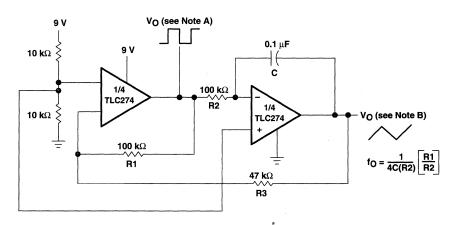


Figure 45. Positive-Peak Detector



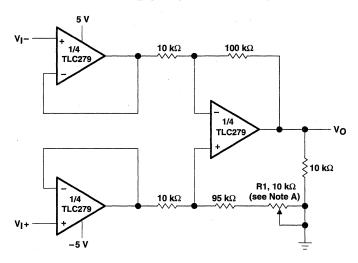
NOTES: B. $V_I = 3.5 \text{ V to } 15 \text{ V}$ C. $V_O = 2 \text{ V}, 0 \text{ to } 1 \text{ A}$

Figure 46. Logic-Array Power Supply



NOTES: A. $V_{O(PP)} = 8 \text{ V}$ B. $V_{O(PP)} = 4 \text{ V}$

Figure 47. Single-Supply Function Generator



NOTE C: CMRR adjustment must be noninductive.

Figure 48. Low-Power Instrumentation Amplifier

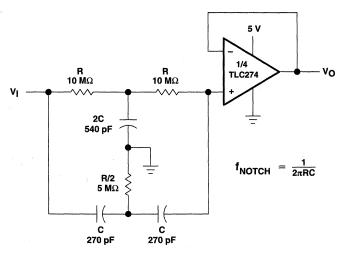


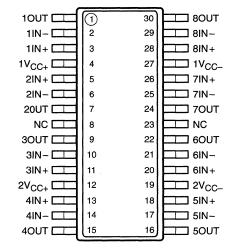
Figure 49. Single-Supply Twin-T Notch Filter

- Trimmed Offset Voltage
 10 mV Max at T_A = 25°C, V_{DD} = 5 V
- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages 3 V to 16 V
- Single-Supply Operation
- Common-Mode Input Voltage Range Extends Below the Negative Rail
- Low Noise . . . Typically 25 nV/√Hz at f = 1 kHz
- Output Voltage Range Includes Negative Rail
- ESD-Protection Circuitry
- Small-Outline Package Option Also Available in Tape and Reel
- Designed-In Latch-Up Immunity

description

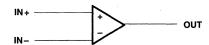
The TLC274x2 octal operational amplifier incorporates low offset-voltage drift, high input impedance, low noise, and speeds approaching that of general-purpose BiFET devices into a single package. This device uses Texas Instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

DB PACKAGE (TOP VIEW)



NC - No internal connection

symbol (each amplifier)



The extremely high input impedance, low bias currents, and high slew rates make this a cost-effective device ideal for applications that have previously been reserved for BiFET and NFET products. These advantages, in combination with good common-mode rejection and supply-voltage rejection, make this device a good choice for new state-of-the-art designs as well as for upgrading existing designs.

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC274x2. The device also exhibits low-voltage single-supply operation, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail. The device inputs and outputs are designed to withstand −100-mA surge currents without sustaining latch-up.

AVAILABLE OPTION

		PACKAGE
TA	V _{IO} max AT 25°C	SMALL OUTLINE (DB) [†]
0°C to 70°C	10 mV	TLC274x2DBLE

† The DB package is only available left-end taped and reeled.

LinCMOS is a trademark of Texas Instruments Incorporated.

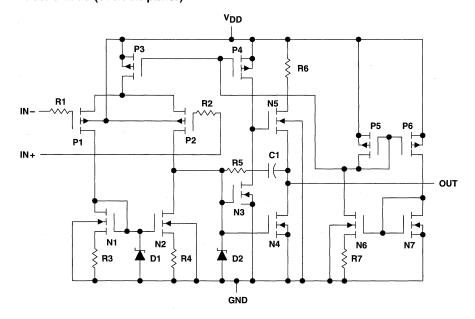
TEXAS INSTRUMENTS

description (continued)

The TLC274x2 incorporates internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, exercise care in handling this device as exposure to ESD can result in the degradation of the device parametric performance.

The TLC274x2 is characterized for operation from 0°C to 70°C.

equivalent schematic (each amplifier)



COMPONENT COUNT				
Resistors	56			
Transistors	80			
Diodes	16			
Capacitors	8			

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	18 V
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input)	–0.3 V to V _{DD}
Input current, I ₁	±5 mA
Output current, IO (each output)	±30 mA
Total current into V _{DD}	45 mA
Total current out of GND	45 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	. See Dissipation Rating Table
Operating free-air temperature, T _A	
Storage temperature range	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

2. Differential voltages are at IN+ with respect to IN-.

3. The output can be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING
DB	1024 mW	8.2 mW/° C	655 mW

recommended operating conditions

·		MIN	MAX	UNIT
Supply voltage, V _{DD}		3	16	V
Common-mode input voltage, V _{IC}	V _{DD} = 5 V	-0.2	3.5	V
	V _{DD} = 10 V	-0.2	8.5	· V
Operating free-air temperature, TA		0	70	°C

electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONE	DITIONS	T _A †	MIN	TYP	MAX	UNIT
V. a	Input offset voltage	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
VIO	input offset voltage	$R_S = 50 \Omega$	$R_L = 10 \text{ k}\Omega$	Full range			12	·
αΝΙΟ	Average temperature coefficient of input offset voltage			25°C to 70°C		1.8		μV/°C
1 -		V 05 V	V . 05V	25°C		0.1		4
lo	Input offset current (see Note 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	70°C		7	300	рA
l	Input bigg gurrent (one Note 4)	V- 05V	V:- 0.5.V	25°C		0.6		
^I IB	Input bias current (see Note 4)	$V_O = 2.5 V$,	AIC = 5.2 A	70°C		40	600	рA
	Common-mode input voltage range			25°C	-0.2 to 4	-0.3 to 4.2		V
VICR	(see Note 5)			Full range	-0.2 to 3.5			٧
	High-level output voltage	V _{ID} = 100 mV,	R _L = 10 kΩ	25°C	3.2	3.8		V
Vон				0°C	. 3	3.8		
				70°C	3	3.8		
	Low-level output voltage	V _{ID} = -100 mV,	I _{OL} = 0	25°C		0	50	
V_{OL}				0°C		0	50	mV
				70°C		0	50	
		V _O = 0.25 V to 2 V,	R _L = 10 kΩ	25°C	5	23		
A_{VD}	Large-signal differential voltage amplification			0°C	4	27		V/mV
	amplification			70°C	4	20		
				25°C	65	80		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		0°C	60	84		dB
				70°C	60	85		1
				25°C	65	95		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	0°C	60	94		dB
	(-100/4/10)			70°C	60	96		
		V- 25V	V _{IC} = 2.5 V,	25°C		2.7	6.4	
IDD	Supply current (four amplifiers)	V _O = 2.5 V, No load		0°C		3.1	7.2	mA
				70°C		2.3	5.2	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER	TEST CONI	DITIONS	T _A †	MIN	TYP	MAX	UNIT
VIO	Input offset voltage	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
VIO	Input diset voltage	$R_S = 50 \Omega$,	$R_L = 10 \text{ k}\Omega$	Full range			12	IIIV
αVIO	Average temperature coefficient of input offset voltage			25°C to 70°C		2		μV/°C
1	Input offset current (see Note 4)	VO = 0.5 V,	V _{IC} = 5 V	25°C		0.1		- ^
10	input offset current (see Note 4)	VO = 0.5 V,	ΔIC = 2 Λ	70°C		7	300	рA
lun.	Input bias current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		pА
lВ	input bias current (see Note 4)	VO = 5 V,	AIC = 2 A	70°C		50	600	PΑ
	Common-mode input voltage range			25°C	-0.2 to 9	-0.3 to 9.2		V
VICR	(see Note 5)			Full range	-0.2 to 8.5			٧
	High-level output voltage	V _{ID} = 100 mV,	R _L = 10 kΩ	25°C	8	8.5		V
VOH				0°C	7.8	8.5		
				70°C	7.8	8.4		
	Low-level output voltage	V _{ID} = -100 mV,		25°C		0	50	mV
VOL			IOL = 0	0°C		0	50	
				70°C		0	50	
	Large-signal differential voltage amplification			25°C	10	36		
AVD		$V_0 = 1 \text{ V to 6 V},$	R _L = 10 kΩ	0°C	7.5	42		V/mV
				70°C	7.5	32		
				25°C	65	85		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		0°C	60	88		dB
				70°C	60	88		
	0 1 11 11 11 11			25°C	65	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	0°C	60	94		dB
				70°C	60	96		
		Vo = 5 V	V10 = 5 V	25°C		3.8	8	
IDD	Supply current (four amplifiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	0°C		4.5	8.8	mA
				70°C		3.2	6.8	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST C	TEST CONDITIONS		MIN TYP	MAX	UNIT
				25°C	3.6		
			$V_{I(PP)} = 1 V$	0°C	4		
SR	Clause rate at units again	$R_L = 10 \Omega$,		70°C	3		1////
l on	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C	2.9		V/µs
			$V_{I(PP)} = 2.5 V$	0°C	3.1		
				70°C	2.5		
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C	25		nV/√Hz
			C _L = 20 pF, See Figure 1	25°C	320		kHz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_I = 10 \text{ k}\Omega$,		0°C	340		
		TIL = 10 K32,		70°C	260		
				25°C	1.7		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C	2		MHz
		See rigule 5		70°C	1.3		
		14 40 -14	, ,	25°C	46°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$	$f = B_1$	0°C	47°		
		5 = 20 PI,		70°C	44°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST C	ONDITIONS	TA	MIN TYP	MAX	UNIT
				25°C	5.3		
			$V_{I(PP)} = 1 V$	0°C	5.9		
SR	Clausete et units gein	$R_L = 10 \Omega$,		70°C	4.3		1////
Jon J	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C	4.6		V/μs
-		g	$V_{I(PP)} = 5.5 V$	0°C	5.1		
				70°C	3.8		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C	25		nV/√Hz
		V _O = V _{OH} , R _L = 10 kΩ,	C _L = 20 pF, See Figure 1	25°C	200		kHz
ВОМ	Maximum output-swing bandwidth			0°C	220		
				70°C	140		
				25°C	2.2		MHz
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C	2.5		
ł		Oce rigure 5		70°C	1.8		
		V 40 V	, 5	25°C	49°		
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	0°C	50°		
		-3 F1,		70°C	46°		

PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC274x2 is optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

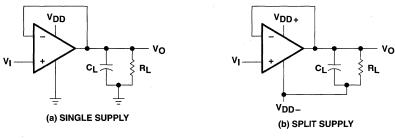


Figure 1. Unity-Gain Amplifier

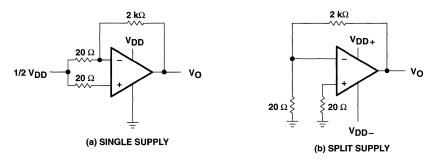


Figure 2. Noise-Test Circuit

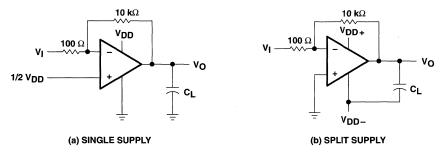


Figure 3. Gain-of-100 Inverting Amplifier



Table of Graphs

			FIGURE
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	4, 5 6 7
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	8, 9 10 11 12, 13
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	14 15 26, 27
lв	Input bias current	vs Free-air temperature	16
10	Input offset current	vs Free-air temperature	16
VIC	Common-mode input voltage	vs Supply voltage	17
lDD	Supply current	vs Supply voltage vs Free-air temperature	18 19
SR	Slew rate	vs Supply voltage vs Free-air temperature	20 21
	Normalized slew rate	vs Free-air temperature	22
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	23
B ₁	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	24 25
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	28 29 30
Vn	Equivalent input noise voltage	vs Frequency	31
	Phase shift	vs Frequency	26, 27

TYPICAL CHARACTERISTICS

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

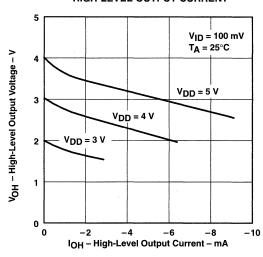


Figure 4

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

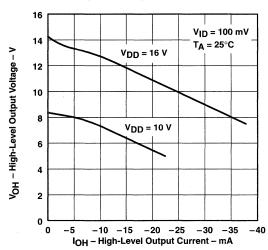


Figure 5

HIGH-LEVEL OUTPUT VOLTAGE

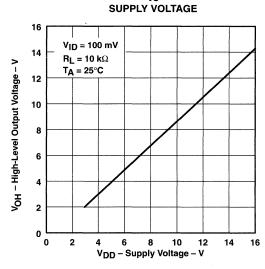


Figure 6

HIGH-LEVEL OUTPUT VOLTAGE

VS FREE-AIR TEMPERATURE

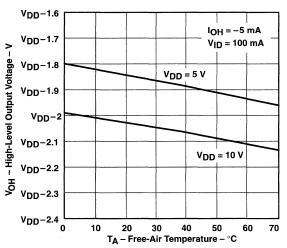


Figure 7

LOW-LEVEL OUTPUT VOLTAGE **COMMON-MODE INPUT VOLTAGE** 700 $V_{DD} = 5 V$ 650 IOL = 5 mAV_{OL} - Low-Level Output Voltage - mV T_A = 25°C 600 550 $V_{ID} = -100 \text{ mV}$ 500 450 400 $V_{ID} = -1 V$ 350 300 0 V_{IC} - Common-Mode Input Voltage - V

Figure 8

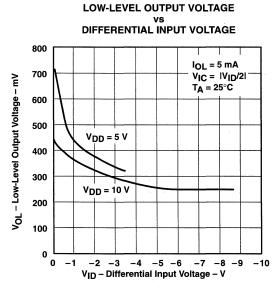


Figure 10

LOW-LEVEL OUTPUT VOLTAGE vs COMMON-MODE INPUT VOLTAGE

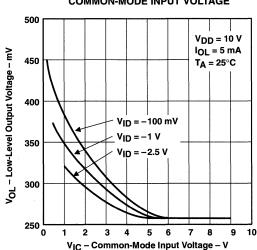


Figure 9

LOW-LEVEL OUTPUT VOLTAGE vs

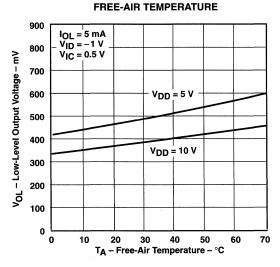


Figure 11

LOW-LEVEL OUTPUT VOLTAGE LOW-LEVEL OUTPUT CURRENT

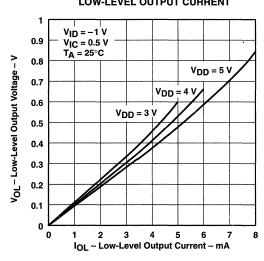


Figure 12

LOW-LEVEL OUTPUT VOLTAGE **LOW-LEVEL OUTPUT CURRENT**

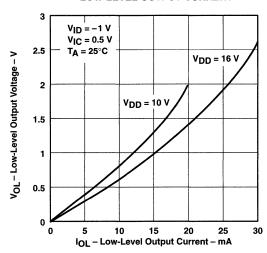


Figure 13

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION**

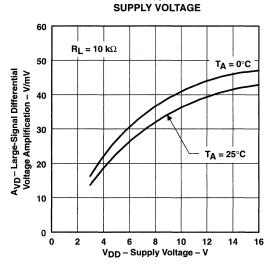


Figure 14

LARGE-SIGNAL **DIFFERENTIAL VOLTAGE AMPLIFICATION** FREE-AIR TEMPERATURE

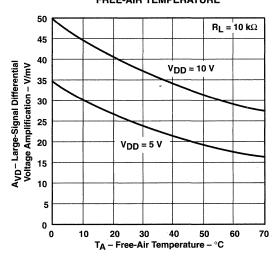
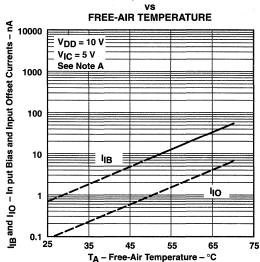


Figure 15

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 16

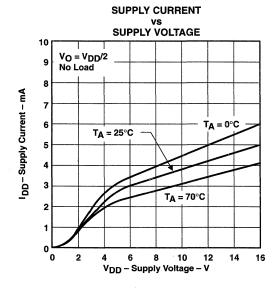


Figure 18

COMMON-MODE INPUT VOLTAGE

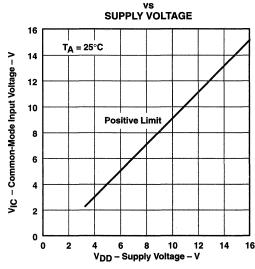


Figure 17

SUPPLY CURRENT

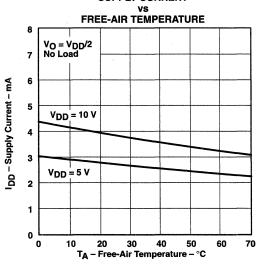


Figure 19

SLEW RATE SUPPLY VOLTAGE $A_V = 1$ $V_{I(PP)} = 1 V$ 7 $R_L = 10 \text{ k}\Omega$ C_L = 20 pF 6 $T_A = 25^{\circ}C$ SR – Slew Rate – V/μs See Figure 1 5 4 3 2 1 0 0 2 12 14 16 8 10 V_{DD} - Supply Voltage - V

Figure 20

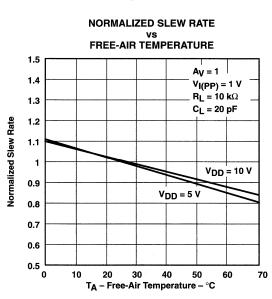
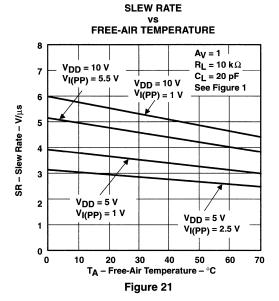


Figure 22



MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE

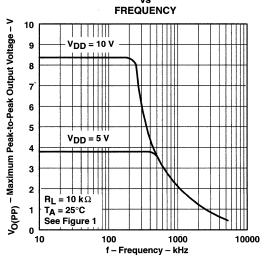


Figure 23

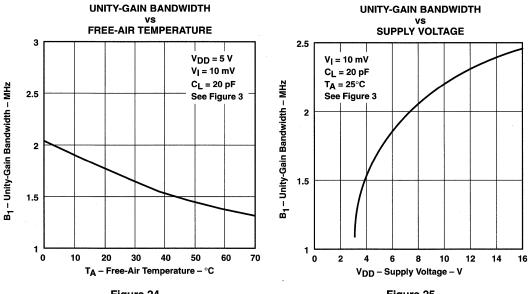


Figure 24

Figure 25

LARGE-SIGNAL DIFFERENTIAL VOLTAGE **AMPLIFICATION AND PHASE SHIFT**

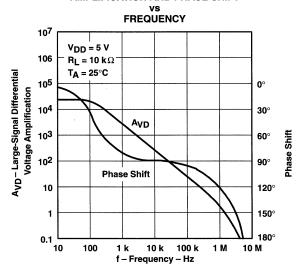


Figure 26

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

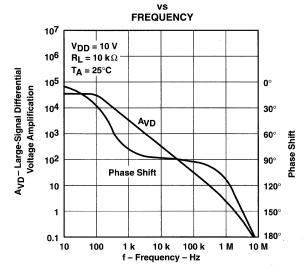
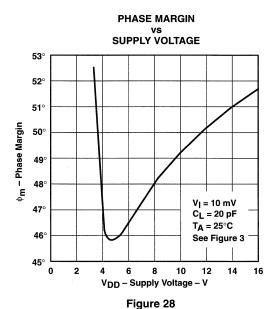
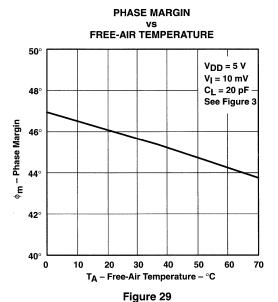


Figure 27





TEXAS INSTRUMENTS

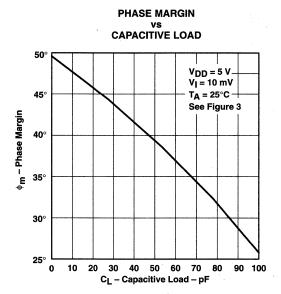


Figure 30

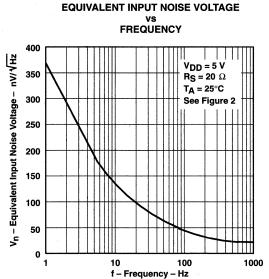


Figure 31

20UT 1 7

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8 30UT

Trimmed Offset Voltage:

TLC27L9 . . . 900 μV Max at 25°C, $V_{DD} = 5 V$

- Input Offset Voltage Drift . . . Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over **Specified Temperature Range:**

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 4 V to 16 V

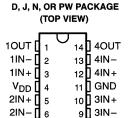
- **Single-Supply Operation**
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, **I-Suffix Types**)
- Ultra-Low Power . . . Typically 195 μ W at 25°C, V_{DD} = 5 V
- **Output Voltage Range includes Negative**
- High Input Impedance . . . $10^{12} \Omega$ Typ
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also** Available in Tape and Reel
- **Designed-In Latch-Up Immunity**

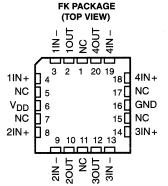
description

The TLC27L4 and TLC27L9 quad operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, extremely low power, and high gain.

These devices use Texas instruments silicon-gate LinCMOS™ technology, which provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

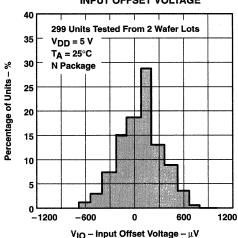
The extremely high input impedance, low bias currents, and low-power consumption make these cost-effective devices ideal for high-gain. low- frequency, low-power applications. Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost TLC27L4 (10 mV) to the high-precision TLC27L9 (900 μV). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.





NC - No internal connection

DISTRIBUTION OF TLC27L9 INPUT OFFSET VOLTAGE



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description (continued)

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC27L4 and TLC27L9. The devices also exhibit low voltage single-supply operation and ultra-low power consumption, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC27L4 and TLC27L9 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices, as exposure to ESD may result in the degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation from -55°C to 125°C.

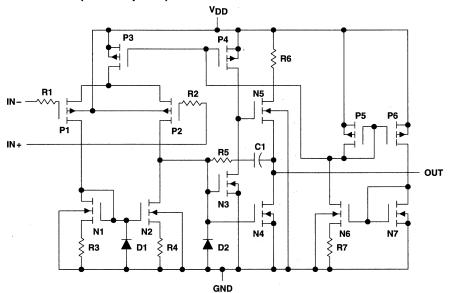
AVAILABLE OPTIONS

			CHIP				
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)	FORM (Y)
	900 μV	TLC27L9CD	_		TLC27L9CN		
0°C to 70°C	2 mV	TLC27L4BCD	_	_	TLC27L4BCN	_	
0 0 10 70 0	5 mV	TLC27L4ACD	_		TLC27L4ACN	_	-
	10 mV	TLC27L4CD			TLC27L4CN	TLC27L4CPW	TLC27L4Y
	900 μV	TLC27L9ID	_		TLC27L9IN		
-40°C to 85°C	2 mV	TLC27L4BID			TLC27L4BIN	_	
-40 C to 65 C	5 mV	TLC27L4AID	_	_	TLC27L4AIN	_	
	10 mV	TLC27L4ID	_	_	TLC27L4IN		
-55°C to 125°C	900 μV	TLC27L9MD	TLC27L9MFK	TLC27L9MJ	TLC27L9MN	_	
-55 C to 125 C	10 mV	TLC27L4MD	TLC27L4MFK	TLC27L4MJ	TLC27L4MN	<u> </u>	

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC27L9CDR).

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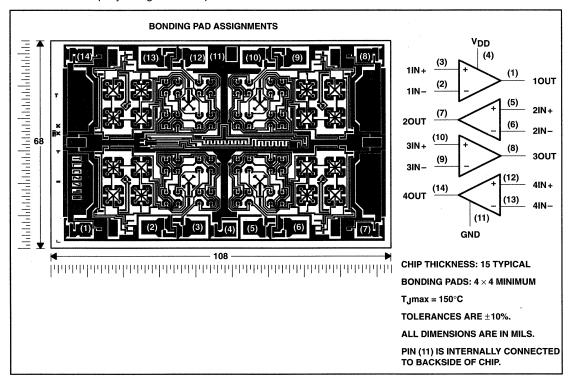
equivalent schematic (each amplifier)



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TLC27L4Y chip information

These chips, when properly assembled, display characteristics similar to the TLC27L4C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input current, I ₁	±5 mA
Output current, IO (each output)	
Total current into V _{DD}	
Total current out of GND	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature, TA: C suffix	0°C to 70°C
I suffix	40°C to 85°C
M suffix	55°C to 125°C
Storage temperature range	65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or P	W package 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	9 300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

2. Differential voltages are at IN+ with respect to IN-.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A ≈ 125°C POWER RATING
D .	950 mW	7.6 mW/°C	608 mW	494 mW	
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
j	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
, N	1575 mW	12.6 mW/°C	1008 mW	819 mW	
PW	700 mW	5.6 mW/°C	448 mW		

recommended operating conditions

		C SU	FFIX	I SUI	FFIX	M SU	FFIX	UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	UNII
Supply voltage, V _{DD}		3	16	4	16	4	16	V
	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V
Common-mode input voltage, V _{IC}	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5	V.
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †	TL TL	.C27L40 .C27L4 <i>A</i> .C27L4E .C27L90	C C	UNIT
			1		1	MIN	TYP	MAX	
		TLC27L4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC2/L4C	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	mV
		TLC27L4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	IIIV
Via	Input offset voltage	TLC27L4AC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			6.5	
V _{IO}	input onset voltage	TLC27L4BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		240	2000	
		TECZ/L4BC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3000	μV
		TLC27L9C	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	900	μν
		TLC27L9C	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			1500	
αΛΙΟ	Average temperature co offset voltage	efficient of input			25°C to 70°C		1.1		μV/°C
I		Nata 4	V- 05V	V - 0.5.V	25°C		0.1		1
ΙΟ	Input offset current (see	Note 4)	V _O = 2.5 V,	$V_{IC} = 2.5 V$	70°C		7	300	pА
1			V- 05V	V - 0.5.V	25°C		0.6		1
lΒ	Input bias current (see I	Note 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		40	600	рA
	Common mode input vo	Itage range			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)	gc			Full range	-0.2 to 3.5			٧
					25°C	3.2	4.1		
Vон	High-level output voltage	Э	V _{ID} = 100 mV,	$R_L = 1 M\Omega$	0°C	3	4.1		V
					70°C	3	4.2		
					25°C		0	50	
V_{OL}	Low-level output voltage)	$V_{1D} = -100 \text{ mV},$	$I_{OL} = 0$	0°C		0	50	mV
					70°C		0	50	
	1				25°C	50	520		
A_{VD}	Large-signal differential amplification	voitage	$V_0 = 2.5 \text{ V to 2 V},$	$R_L = 1 M\Omega$	0°C	50	680		V/mV
					70°C	50	380		
					25°C	65	94		
CMRR	Common-mode rejection	n ratio	VIC = VICRmin		0°C	60	95		dB
-					70°C	60	95		
	Supply-voltage rejection	ratio			25°C	70	97		
ksvr	(ΔVDD/ΔVIO)	TauO	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
	. 55 10/				70°C	60	98		
			V _O = 2.5 V,	V _{IC} = 2.5 V,	25°C		40	68	
IDD	Supply current (four am	plifiers)	No load	VIC - 2.5 V,	0°C		48	84	μΑ
					70°C		31	56	L

† Full range is 0°C to 70°C.



NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER	,	TEST CON	DITIONS	TAT	TI TI	.C27L40 .C27L4A .C27L4E .C27L90	AC BC	UNIT
						MIN	TYP	MAX	
		TLC27L4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC27L4C	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	m∨
		TLC27L4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	///v
V	Innut offeet veltees	TLC27L4AC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			6.5	
V _{IO}	Input offset voltage	TLC27L4BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		260	2000	
		TLC27L4BC	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3000	μV
		TLC27L9C	V _O = 1.4 V,	V _{IC} = 0,	25°C		210	1200	μν
		TLO27L9C	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			1900	
αΛΙΟ	Average temperature co input offset voltage	efficient of			25°C to 70°C		1		μV/°C
1	Input offset surrent (see	nput offset current (see Note 4)		V. S. V.	25°C		0.1		
lo	input onset current (see			V _{IC} = 5 V	70°C		7	300	pА
l	Input bias current (see I	loto 4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.7		рA
^I IB	input bias current (see i	vote 4)	VO = 5 V,	AIC = 2 A	70°C		50	600	l PA
	Common-mode input voltage range				25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)				Full range	-0.2 to 8.5	.,,,,,,,		٧
					25°C	8	8.9		
V_{OH}	High-level output voltage	Э	V _{ID} = 100 mV,	$R_L = 1 M\Omega$	0°C	7.8	8.9		V
					70°C	7.8	8.9		
					25°C		0	50	
V_{OL}	Low-level output voltage	•	$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
					25°C	50	870		
A_{VD}	Large-signal differential amplification	voltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	0°C	50	1020		V/mV
	ampimoation				70°C	50	660		
					25°C	65	97		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min		0°C	60	97		dB
				:	70°C	- 60	97		
	0 1 11 11				25°C	70	97		
ksvr	Supply-voltage rejection (ΔV _{DD} /ΔV _{IO})	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	97		dB
	~-·UU/(U/			,	70°C	60	98		<u> </u>
		ply current (four amplifiers) $V_O = 5 \text{ V,}$ No load	V _{IC} = 5 V,	25°C		57	92		
DD				0°C		72	132	μΑ	
				70°C		44	80		

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †	TL TL	.C27L4I .C27L4 <i>I</i> .C27L4E .C27L9I	N Bi	UNIT
		1				MIN	TYP	MAX	
		TLC27L4I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		1LU27L41	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			13	mV
		TLC27L4AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mv
1/10	Input offset voltage	TEO27E4AI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			7	
VIO	input onset voltage	TLC27L4BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		240	2000	
		TLO27L4BI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			3500	μV
		TLC27L9i	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	900	μν
		TLO27L9I	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			2000	
ανιο	Average temperature co offset voltage	efficient of input			25°C to 85°C		1.1		μV/°C
l	15 m . d . df . a d	NI-t- 4\	V- 05V	V - 0.5.V	25°C		0.1		^
lο	Input offset current (see	Note 4)	$V_{O} = 2.5 V$,	$V_{IC} = 2.5 V$	85°C		24	1000	pΑ
	I	1.1.4	v 05.v		25°C		0.6		
liB	Input bias current (see N	lote 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	85°C		200	2000	рA
	Common-mode input vo	Itage range			25°C	-0.2 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)	age rainge			Full range	-0.2 to 3.5			V
					25°C	3.2	4.1		
Vон	High-level output voltage	Э	V _{ID} = 100 mV,	$R_L = 1 M\Omega$	-40°C	3	4.1		V.
					85°C	3	4.2		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	-40°C		0	50	mV
					85°C		0	50	
					25°C	50	480		
AVD	Large-signal differential amplification	voltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	-40°C	50	900		V/mV
	апринован				85°C	50	330		
					25°C	65	94		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min		-40°C	60	95		dB
					85°C	60	95		
	0				25°C	70	97		
ksvr	Supply-voltage rejection (ΔVDD/ΔVIO)	ratio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	97		dB
	\~ • DD/△ • (O)				85°C	60	98		
			V- 05V	V - 0.5.V	25°C		39	68	
I_{DD}	Supply current (four am	Supply current (four amplifiers) $V_{O} = 2.5 \text{ V}, \text{No load}$ $V_{IC} = 2.5 \text{ V}, \text{No load}$		V _{IC} = 2.5 V,	-40°C		62	108	μА
				85°C		29	52		

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	TAT	TL TL	.C27L4I .C27L4A .C27L4E .C27L9I	Ni Bi	UNIT
						MIN	TYP	MAX	
		TLC27L4I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC27L4I	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			13	mV
		TLC27L4AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mv
V	Input offset voltage	TLC2/L4AI	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			7	
V _{IO}	input onset voltage	TLC27L4BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		260	2000	
		10271461	$R_S = 50 \Omega$	$R_L = 1 M\Omega$	Full range			3500	μV
		TLC27L9I	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		210	1200	μν
		TEOZYESI	$R_S = 50 \Omega$,	R _L = 1 MΩ	Full range			2900	
αVIO	Average temperature coe offset voltage	efficient of input			25°C to 85°C		1		μV/°C
lio	Input offset current (see I	Note 4)	V _O = 5 V,	V _{IC} = 5 V	25°C		0.1		рA
lio	input onset current (see i	Note 4)	VO = 5 V,	AIC = 2 A	85°C		26	1000	PΑ
IB	Input bias current (see N	oto 4)	V _O = 5 V,	V _{IC} =.5 V	25°C		0.7		рA
שוי	input bias current (see N	ote 4)	VO = 5 V,	AIC =:2 A	85°C		220	2000	Þζ
	Common-mode input voltage range				25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)				Full range	-0.2 to 8.5			٧
					25°C	8	8.9		
Vон	High-level output voltage		$V_{ID} \approx 100 \text{ mV},$	$R_L = 1 M\Omega$	-40°C	7.8	8.9		V
					85°C	7.8	8.9		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} \approx -100 \text{ mV},$	IOL = 0	-40°C		0	50	mV
					85°C		0	50	
		- 14			25°C	50	800		
A_{VD}	Large-signal differential v amplification	roitage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	-40°C	50	1550		V/mV
					85°C	50	585		
					25°C	65	97		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		-40°C	60	97		dB
					85°C	60	98		
	Supply-voltage rejection	ratio			25°C	70	97		
ksvr	(ΔV _{DD} /ΔV _{IO})	aut	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	97		dB
	5 10				85°C	60	98		
			Vo = 5 V	V10 = 5 V	25°C		57	92	
IDD	Supply current (four amplifiers)	urrent (four amplifiers) $V_O = 5 \text{ V}, \text{No load}$ $V_{IC} = 5 \text{ V}, \text{No load}$	VIC = 5 V,	-40°C	<u> </u>	98	172	μΑ	
					85°C		40	72	

[†] Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	T _A †		_C27L4N _C27L9N		UNIT
						MIN	TYP	C27L9M	
		TLC27L4M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
V	Input offset voltage	TLC2/L4W	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	IIIV
V _{IO}	input onset voltage	TI 0071 0M	V _O = 1.4 V,	V _{IC} = 0,	25°C		200	900	
		TLC27L9M	$R_S = 50 \Omega$	$R_L = 1 M\Omega$	Full range			3750	μV
ανιο	Average temperature coef offset voltage	ficient of input			25°C to 125°C		1.4		μV/°C
L.		-1- 4\	V- 05V	V . 0.5.V	25°C		0.1		pА
lo lo	Input offset current (see N	ote 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	125°C		1.4	15	nA
			V 05V	0.5.1/	25°C		0.6		pА
lВ	Input bias current (see No	te 4)	$V_0 = 2.5 V$,	$V_{IC} = 2.5 V$	125°C		9	35	nA
Vian	Common-mode input volta	age range			25°C	-0.2 to 4	to		V
VICR	(see Note 5)				Full range	-0.2 to 3.5			٧
				<u></u>	25°C	3.2	4.1		
۷он	High-level output voltage		V _{ID} = 100 mV,	$R_L = 1 M\Omega$	−55°C	3	4.1		V
					125°C	3	4.2		
					25°C		0	50	
V_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	−55°C		0	50	mV
					125°C		0	50	
					25°C	50	480		
A_{VD}	Large-signal differential vo amplification	oltage	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 1 M\Omega$	−55°C	25	950		V/mV
	apoation				125°C	25	200		
					25°C	65	94		
CMRR	Common-mode rejection r	atio	V _{IC} = V _{ICR} min		−55°C	60	95		dB
					125°C	60	85		
					25°C	70	97		
ksvr	Supply-voltage rejection ra (ΔVDD/ΔVIO)	atio	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	97		dB
	(=:DD,=:10)				125°C	60	98		
			.,		25°C		39	68	
I_{DD}	Supply current (four ampli	fiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 \text{ V},$	−55°C		69	120	μΑ
			INO load	125°C		27	48		

†Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CON	DITIONS	T _A †		.C27L4N .C27L9N		UNIT
						MIN	TYP	MAX	
		TI 0071 414	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
V	land to offer at welto are	TLC27L4M	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			12	mV
VIO	Input offset voltage	TLC27L9M	V _O = 1.4 V,	V _{IC} = 0,	25°C		210	1200	μV
		TLC2/L9W	$R_S = 50 \Omega$,	$R_L = 1 M\Omega$	Full range			4300	μ ν
αΛΙΟ	Average temperature coefinput offset voltage	ficient of			25°C to 125°C		1.4		μV/°C
1	Input offset current (see N	loto 4)	V- 5V	V _{IC} = 5 V	25°C		0.1		pΑ
ΙΟ	input onset current (see N	ote 4)	$V_0 = 5 V$,	ΛIC = 2 Λ	125°C		1.8	15	nA
L	Innut high gurrant (ago Na	nput bias current (see Note 4)		V _{IC} = 5 V	25°C		0.7		pА
lΒ	input bias current (see No	nte 4)	V _O = 5 V,	ΔIC ≡ 2 Δ	125°C		10	35	nA
VICR	Common-mode input volta	age range			25°C	0 to 9	-0.3 to 9.2		٧
VICH	(see Note 5)				Full range	0 to 8.5			V
					25°C	8	8.9		
V_{OH}	High-level output voltage		V _{ID} = 100 mV,	$R_L = 1 M\Omega$	−55°C	7.8	8.8		, V
					125°C	7.8	9		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	−55°C		0	50	mV
					125°C		0	50	
	1				25°C	50	800		
A_{VD}	Large-signal differential vo amplification	oitage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	−55°C	25	1750		V/mV
					125°C	25	380		
					25°C	65	97		
CMRR	Common-mode rejection	ratio	V _{IC} = V _{ICR} min		−55°C	60	97		dB
					125°C	60	91		
	Cumply voltage rejection :	ntio			25°C	70	97		
ksvr	Supply-voltage rejection re $(\Delta V_{DD}/\Delta V_{IO})$	auo	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	97		dB
					125°C	60	98		
					25°C		57	92	
IDD	Supply current (four amplifiers)	$V_O = 5 V$, V_{IC} No load	V _{IC} = 5 V,	−55°C		111	192	μΑ	
					125°C		35	60	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and Input offset current below 5 pA were determined mathematically.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CON	OITIONS	TI	_C27L4\	1	UNIT
	PARAMETER	IES! CON	DITIONS	MIN	TYP	MAX	ONLI
V _{IO}	Input offset voltage	$V_O = 1.4 \text{ V},$ $R_S = 50 \Omega,$	V _{IC} = 0, R _L = 1 MΩ		1.1	10	mV
αVIO	Average temperature coefficient of input offset voltage	T _A = 25°C to 70°C			1.1		μV/°C
110	Input offset current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.1		рA
I _{IB}	Input bias current (see Note 4)	$V_0 = 2.5 \text{ V},$	V _{IC} = 2.5 V		0.6		pА
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 4	-0.3 to 4.2		V
Vон	High-level output voltage	V _{ID} = 100 mV,	R _L = 1 MΩ	3.2	4.1		V
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	I _{OL} = 0		0	50	mV
AVD	Large-signal differential voltage amplification	$V_O = 0.25 \text{ V to 2 V},$	R _L = 1 MΩ	50	520		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	94		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	70	97		dB
IDD	Supply current (four amplifiers)	V _O = 2.5 V, No load	V _{IC} = 2.5 V,		40	68	μΑ

electrical characteristics at specified free-air temperature, V_{DD} = 10 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CON	OITIONE	TI	LC27L4Y	′	UNIT
	PANAMETER	IESI CON	JIIIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $R_{S} = 50 \Omega,$	$V_{IC} = 0$, $R_L = 1 M\Omega$		1.1	10	mV
ανιο	Average temperature coefficient of input offset voltage	T _A = 25°C to 70°C			1		μV/°C
Iю	Input offset current (see Note 4)	$V_0 = 5 V$,	V _{IC} = 5 V		0.1		pА
lв	Input bias current (see Note 4)	$V_0 = 5 V$,	V _{IC} = 5 V		0.7		pА
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 9	-0.3 to 9.2		V
Vон	High-level output voltage	V _{ID} = 100 mV,	R _L = 1 MΩ	8	8.9		٧
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	I _{OL} = 0		0	50	mV
AVD	Large-signal differential voltage amplification	$V_O = 1 \text{ V to 6 V},$	$R_L = 1 M\Omega$	50	870		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	97		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	70	97		dB
IDD .	Supply current (four amplifiers)	V _O = 5 V, No load	V _{IC} = 5 V,		57	92	μА

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

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operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CO	TA	TLC27L4C TLC27L4AC TLC27L4BC TLC27L9C MIN TYP MAX			UNIT	
				25°C		0.03		
			V _{IPP} = 1 V	0°C		0.04		
SR	Claw rate at unity gain	$R_L = 1 M\Omega$,		70°C		0.03	V/	
on	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.03		V/μs
	,		V _I PP = 2.5 V	0°C		0.03		
				70°C		0.02		Ì
Vn	Equivalent input noise voltage	f = 1 kHZ, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√Hz
				25°C		5		
ВОМ	Maximum output-swing bandwidth		C _L = 20 pF, See Figure 1	0°C		6		kHz
		TI_ = 1 10152,	See Figure 1	70°C	4.5			1
				25°C		85		
Βį	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		100		kHz
		occ i igule o		70°C		65		
		V 40V	, ,	25°C		34°		
φm	Phase margin	$V_{\parallel} = 10 \text{ mV},$ $C_{\parallel} = 20 \text{ pF},$		0°C	36°		1	
		SL = 20 pr,	ccc. garo o	70°C		30°		1

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 10 V

	PARAMETER	TEST CO	TA	TLC27L4C TLC27L4AC TLC27L4BC TLC27L9C			UNIT	
		_	·		MIN	TYP	MAX	
		ł		25°C		0.05		
l			V _{JPP} = 1 V	0°C		0.05		
SR	Clauseta at units sain	$R_L = 1 M\Omega$,		70°C		0.04		V/v.o
Sn.	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.04		V/μs
		Goo : .gao :	V _{IPP} = 5.5 V	0°C		0.05		
				70°C		0.04		ı
ν _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√Hz
				25°C		1		
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1	0°C		1.3		kHz
		111 1 10132,	Oee rigure r	70°C		0.9		
				25°C		110		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 \text{ pF},$	0°C		125		kHz
		occ i igule s		70°C		90		
		V 40	, D	25°C		38°		
φm	Phase margin			0°C		40°		
		0L - 20 p.,	230 i igai 0 0	70°C		34°		

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operating characteristics at specified free-air temperature, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS		TA	TLC27L4I TLC27L4AI TLC27L4BI TLC27L9I			UNIT	
ļ		<u> </u>		25°C	MIN	TYP 0.03	MAX		
1	Slew rate at unity gain	R _L = 1 MΩ, C _L = 20 pF, See Figure 1	V _{IPP} = 1 V			0.03			
l				-40°C	ļ				
SR				85°C		0.03		V/μs	
			V _{IPP} = 2.5 V	25°C		0.03		ν/μο	
				-40°C		0.04			
				85°C		0.02			
v _n	Equivalent input noise voltage	f = 1 HZ, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√Hz	
	Maximum output-swing bandwidth	$V_O = V_{OH},$ $R_L = 1 M\Omega,$	C _L = 20 pF, See Figure 1	25°C		5		kHz	
ВОМ				-40°C		7			
				85°C		4			
	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,	25°C		85			
В1				-40°C		130		kHz	
				85°C	C 55				
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	25°C		34°			
				-40°C		38°			
				85°C		28°			

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

PARAMETER		TEST CONDITIONS		ТД	TLC27L4I TLC27L4AI TLC27L4BI TLC27L9I			UNIT
					MIN	TYP	MAX	
į	Slew rate at unity gain	R _L = 1 MΩ, C _L = 20 pF, See Figure 1	V _{IPP} = 1 V	25°C		0.05		- V/μs
į				-40°C		0.06		
SR				85°C		0.03		
Jon J			V _I PP = 2.5 V	25°C		0.04		
l				-40°C		0.05		
ł				85°C		0.03		
Vn	Equivalent input noise voltage	f = 1 HZ, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√Hz
	Maximum output-swing bandwidth	$V_O = V_{OH},$ $R_L = 1 M\Omega,$	C _L = 20 pF, See Figure 1	25°C		. 1		kHz
ВОМ				-40°C		1.4		
				85°C		0.8		
	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,	25°C		110		
B ₁				-40°C		155		kHz
Į				85°C		80		
	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	25°C		38°		
φm				-40°C		42°		
				85°C		32°		

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operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

PARAMETER		TEST CO	ТА	TLC27L4M TLC27L9M			UNIT	
				MIN	TYP	MAX		
	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$, See Figure 1	V _{IPP} = 1 V	25°C		0.03		
1				−55°C		0.04		
SR				125°C		0.02		
Sn			V _{IPP} = 2.5 V	25°C		0.03		V/μs
				−55°C		0.04		
				125°C		0.02		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√ Hz
	Maximum output-swing bandwidth	$V_O = V_{OH},$ $R_L = 1 M\Omega,$		25°C		5		kHz
ВОМ				−55°C		8		
				125°C		3		
	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,	25°C		85		
B ₁				-55°C		140		kHz
				125°C		45		
	Phase margin	V _i = 10 mV, C _i = 20 pF,		25°C		34°		
φm				-55°C		39°		
				125°C		25°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

PARAMETER		TEST CONDITIONS		TA	TLC27L4M TLC27L9M			UNIT
					MIN	TYP	MAX	
	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_L = 20 pF$, See Figure 1	V _{IPP} = 1 V	25°C		0.05		•
1				−55°C		0.06		- V/μs
SR				125°C		0.03		
J Sh			V _I PP = 5.5 V	25°C		0.04		
ł.				-55°C		0.06		
				125°C		0.03		
V _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		70		nV/√Hz
	Maximum output-swing bandwidth	$V_O = V_{OH},$ $R_L = 1 M\Omega,$		25°C		1		
Вом				−55°C		1.5		kHz
				125°C		0.7		
	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,	25°C		110		
B ₁				-55°C		165		kHz
				125°C		70		1
	Phase margin	V _I = 10 mV, C _I = 20 pF,		25°C		38°		
φm				−55°C		43°]
				125°C		29°		

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operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CO	TEST CONDITIONS			TLC27L4Y		
:	PARAMETER	lesi co	MIN	TYP	MAX	UNIT		
SR			V _{IPP} = 1 V	0.03			V/µs	
Jon J			V _{IPP} = 2.5 V		0.03		ν/μδ	
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,		70		nV/√Hz	
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1		5		kHz	
В1	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,		85		kHz	
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3		34°			

operating characteristics, $V_{DD} = 10 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CO	NDITIONS	TL	,	UNIT	
	PARAMETER	TEST CO	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $C_1 = 20 pF$,	V _{IPP} = 1 V		0.05		V/µs
Jon L			V _{IPP} = 5.5 V		0.04		ν/μδ
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,		70		nV/√Hz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1		1		kHz
В1	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,		110		kHz
φm	Phase margin	$V_{i} = 10 \text{ mV},$ $C_{L} = 20 \text{ pF},$	f = B ₁ , See Figure 3		38°		

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PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC27L4 and TLC27L9 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

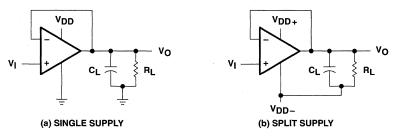


Figure 1. Unity-Gain Amplifier

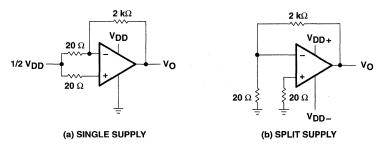


Figure 2. Noise-Test Circuit

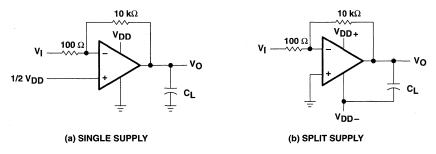


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC27L4 and TLC27L9 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

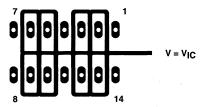


Figure 4. Isolation Metal Around Device Inputs (J and N packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.



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PARAMETER MEASUREMENT INFORMATION

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.



Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
ViO	Input offset voltage	Distribution	6, 7
α _{VIO}	Temperature coefficient	Distribution	8, 9
Voн	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
AVD	Differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
IB/IO	Input bias and input offset current	vs Free-air temperature	22
V _{IC}	Common-mode input voltage	vs Supply voltage	23
lDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	29
В1 .	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
^ф т	Phase margin	vs Supply voltage vs Free-air temperature vs Capacitive loads	34 35 36
Vn	Equivalent input noise voltage	vs Frequency	37
ф	Phase shift	vs Frequency	32, 33

TYPICAL CHARACTERISTICS

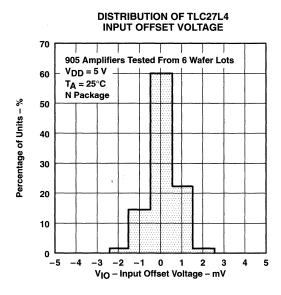


Figure 6

DISTRIBUTION OF TLC27L4 AND TLC27L9

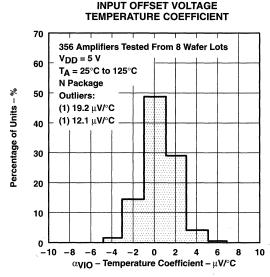


Figure 8

DISTRIBUTION OF TLC27L4 INPUT OFFSET VOLTAGE

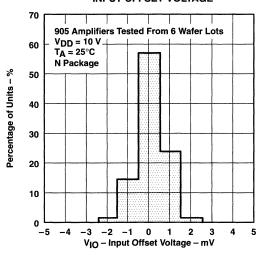


Figure 7

DISTRIBUTION OF TLC27L4 AND TLC27L9 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

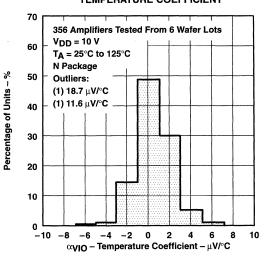


Figure 9

TYPICAL CHARACTERISTICS[†]

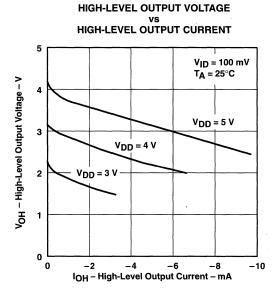
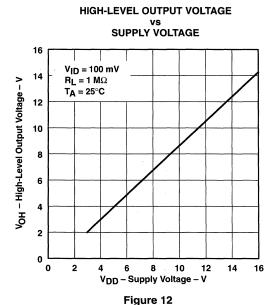


Figure 10



HIGH-LEVEL OUTPUT VOLTAGE
vs

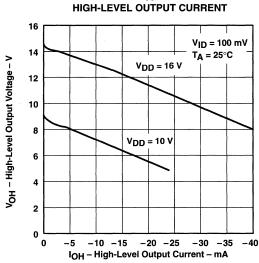
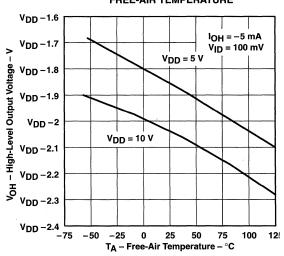


Figure 11

HIGH-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

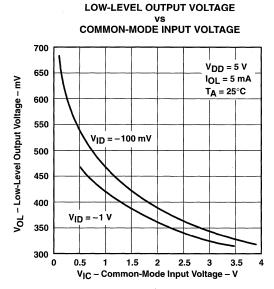


Figure 14

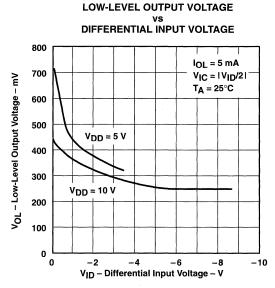


Figure 16

LOW-LEVEL OUTPUT VOLTAGE **COMMON-MODE INPUT VOLTAGE**

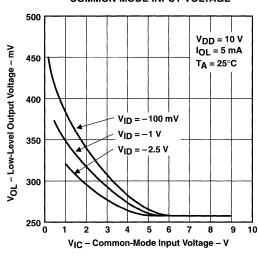


Figure 15

LOW-LEVEL OUTPUT VOLTAGE

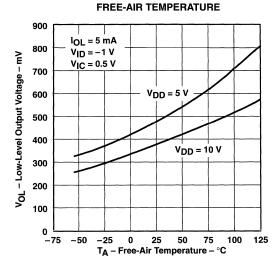


Figure 17

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

LOW-LEVEL OUTPUT VOLTAGE

TYPICAL CHARACTERISTICS[†]

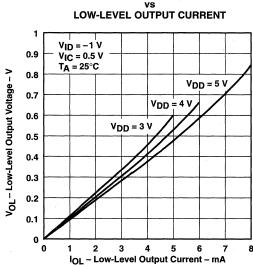
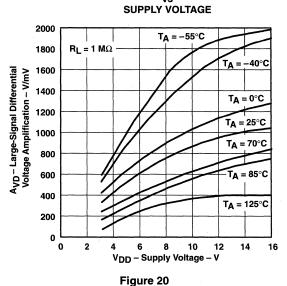


Figure 18

DIFFERENTIAL VOLTAGE AMPLIFICATION

8

LARGE-SIGNAL



vs LOW-LEVEL OUTPUT CURRENT

LOW-LEVEL OUTPUT VOLTAGE

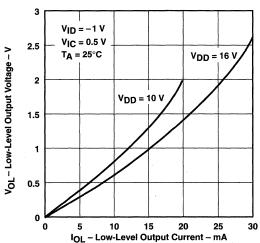


Figure 19

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs

FREE-AIR TEMPERATURE

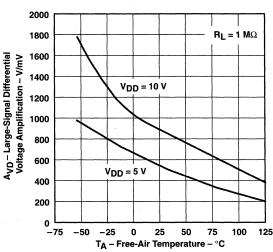


Figure 21

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

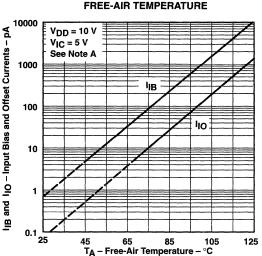


TYPICAL CHARACTERISTICS†

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT FREE-AIR TEMPERATURE 10000 V_{DD} = 10 V V_{IC} = 5 V See Note A 1000 lв 100 10 10

NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 22



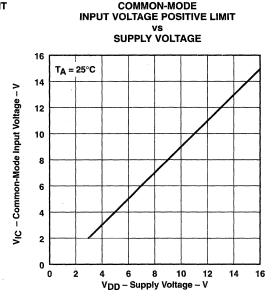
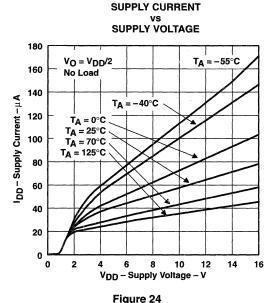
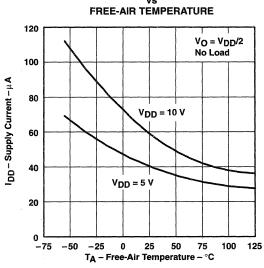


Figure 23

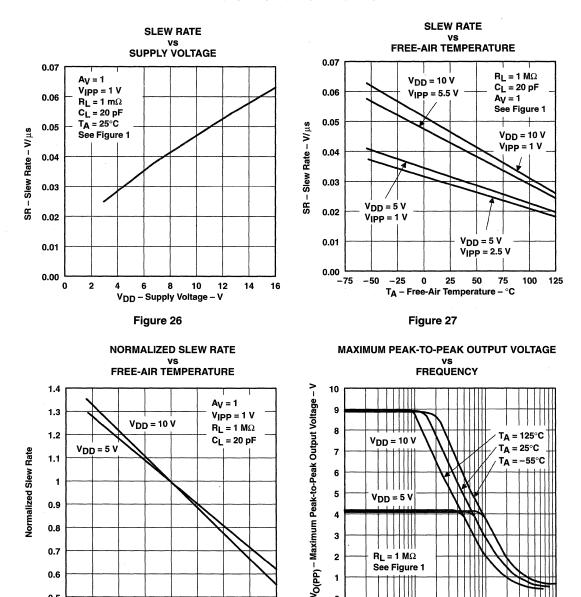
SUPPLY CURRENT





† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



2

0.1

 $R_L = 1 M\Omega$ See Figure 1

10

f - Frequency - kHz

Figure 29

100

0.7

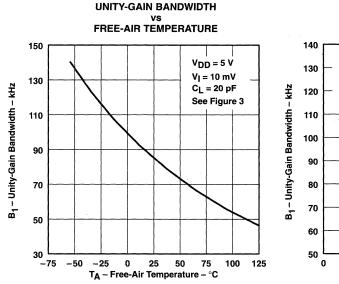
0.6 0.5 -75 -50 -25

0 25 50 75 100 125

TA - Free-Air Temperature - °C

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TYPICAL CHARACTERISTICS†



UNITY-GAIN BANDWIDTH
VS
SUPPLY VOLTAGE

140

130

VI = 10 mV

CL = 20 pF

120

TA = 25°C

See Figure 3

100

90

0

2

4

6

0

0

2

4

6

8

10

12

14

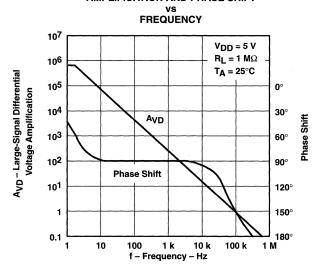
16

VDD - Supply Voltage - V

Figure 30

Figure 31

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

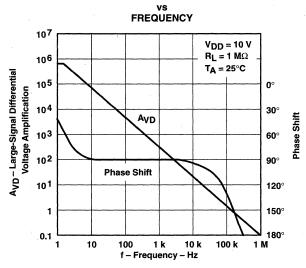
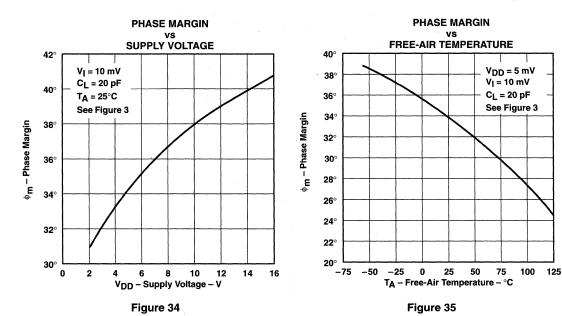


Figure 33



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS

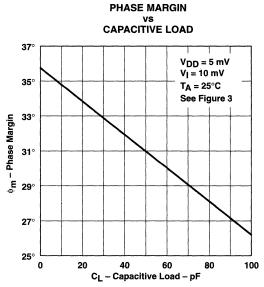


Figure 36

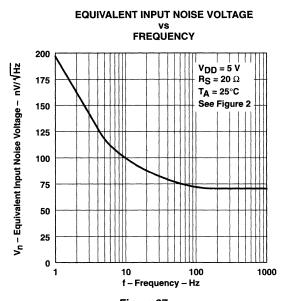


Figure 37

APPLICATION INFORMATION

single-supply operation

While the TLC27L4 and TLC27L9 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC27L4 and TLC27L9 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27L4 and TLC27L9 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

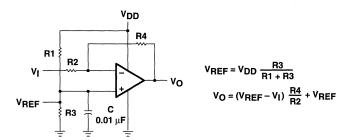


Figure 38. Inverting Amplifier With Voltage Reference

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APPLICATION INFORMATION

single-supply operation (continued)

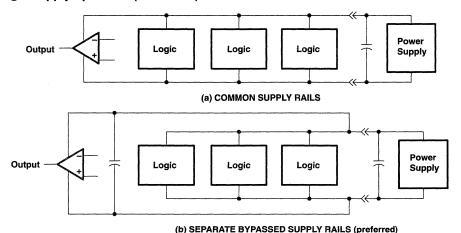


Figure 39. Common Versus Separate Supply Rails

input characteristics

The TLC27L4 and TLC27L9 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD} - 1$ V at $T_A = 25^{\circ}$ C and at $V_{DD} - 1.5$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC27L4 and TLC27L9 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC27L4 and TLC27L9 are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC27L4 and TLC27L9 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 k Ω , since bipolar devices exhibit greater noise currents.



APPLICATION INFORMATION

noise performance (continued)

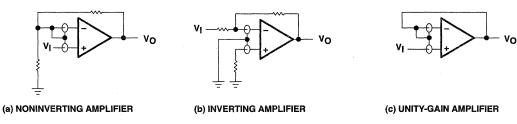


Figure 40. Guard-Ring Schemes

output characteristics

The output stage of the TLC27L4 and TLC27L9 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC27L4 and TLC27L9 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.

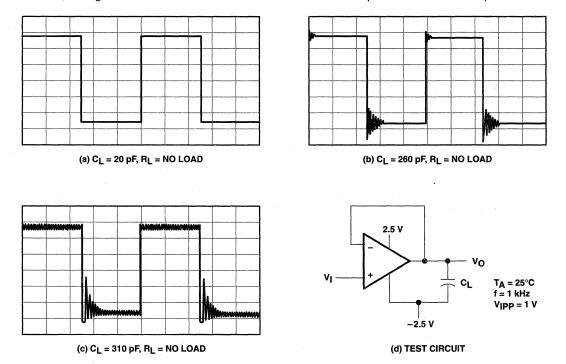


Figure 41. Effect of Capacitive Loads and Test Circuit

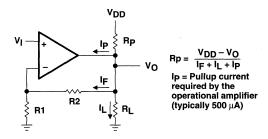


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output characteristics (continued)

Although the TLC27L4 and TLC27L9 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rb) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately $60~\Omega$ and $180~\Omega$, depending on how hard the operational amplifier input is driven. With very low values of Rp, a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.



vo

Figure 42. Resistive Pullup to Increase VOH

Figure 43. Compensation for Input Capacitance

feedback

Operational amplifier circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

electrostatic discharge protection

The TLC27L4 and TLC27L9 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices, as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC27L4 and TLC27L9 inputs and outputs were designed to withstand $-100\mbox{-}mA$ surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μF typical) located across the supply rails as close to the device as possible.

APPLICATION INFORMATION

latch-up (continued)

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

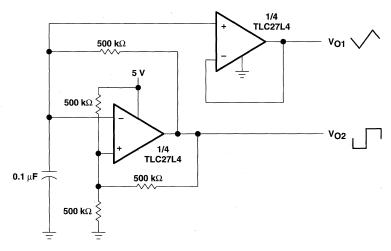
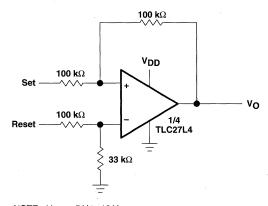


Figure 44. Multivibrator

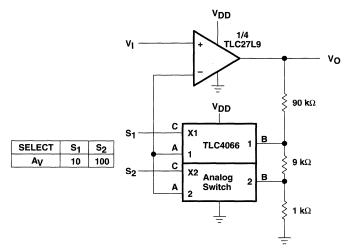


NOTE: $V_{DD} = 5 \text{ V to } 16 \text{ V}$

Figure 45. Set/Reset Flip-Flop

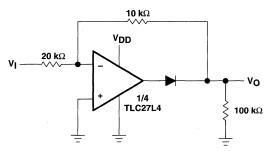
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NOTE: $V_{DD} = 5 \text{ V to } 12 \text{ V}$

Figure 46. Amplifier With Digital Gain Selection

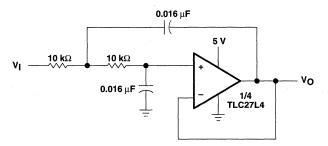


NOTE: V_{DD} = 5 V to 16 V

Figure 47. Full-Wave Rectifier

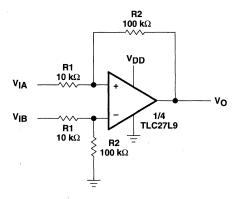
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NOTE: Normalized to FC = 1 kHz and RL = 10 k Ω

Figure 48. Two-Pole Low-Pass Butterworth Filter



NOTE: $V_{DD} = 5 \text{ V to } 16 \text{ V}$ $V_{O} = \frac{R2}{R1} (V_{IB} - V_{IA})$

Figure 49. Difference Amplifier

10UT [] 1

1IN- [] 2

1IN+ [] 3

V_{DD} [] 4

2IN+ [5

2IN- [] 6

20UT / 7

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14 1 40UT

13 4IN-

12 4IN+

11 GND

10 3IN+

9[] 3IN-

3OUT

D. J. N. OR PW PACKAGE

(TOP VIEW)

Trimmed Offset Voltage:

TLC27M9 . . . 900 μ V Max at T_A = 25°C, $V_{DD} = 5 V$

- Input Offset Voltage Drift . . . Typically 0.1 µV/Month. Including the First 30 Days
- Wide Range of Supply Voltages Over **Specified Temperature Range:**

0°C to 70°C . . . 3 V to 16 V -40°C to 85°C . . . 4 V to 16 V -55°C to 125°C . . . 4 V to 16 V

- **Single-Supply Operation**
- Common-Mode Input Voltage Range Extends Below the Negative Rail (C-Suffix, **I-Suffix Types**)
- Low Noise . . . Typically 32 nV/√Hz at f = 1 kHz
- Low Power . . . Typically 2.1 mW at $T_{\Delta} = 25^{\circ}C, V_{DD} = 5 \text{ V}$
- **Output Voltage Range Includes Negative**
- High Input Impedance . . . $10^{12} \Omega$ Typ
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also** Available in Tape and Reel
- **Designed-In Latch-Up Immunity**

FK PACKAGE (TOP VIEW) 11N -10UT NC 40UT 41N -3 2 1 20 19 1IN+ ∏ 4IN+ NC NC 17 GND V_{DD} 16 NC NC 15П 2IN+ 1 8 3IN+ 9 10 11 12 13 NC - No internal connection

description

The TLC27M4 and TLC27M9 quad operational amplifiers combine a wide range of input offset voltage grades with low offset voltage drift, high input impedance, low noise, and speeds comparable to that of general-purpose bipolar devices. These devices use Texas Instruments silicon-gate LinCMOS™ technology. provides offset voltage stability far exceeding the stability available with conventional metal-gate processes.

The extremely high input impedance, low bias currents, make these cost-effective devices ideal for applications that have previously been reserved for general-purpose bipolar products, but with only a fraction of the power consumption.

Four offset voltage grades are available (C-suffix and I-suffix types), ranging from the low-cost

DISTRIBUTION OF TLC27M9 INPUT OFFSET VOLTAGE 40 301 Units Tested From 2 Wafer Lots 35 $V_{DD} = 5 V$ T_A = 25°C 30 N Package Percentage of Units 25 20 15 10 5 -1200--600 n 600 1200 V_{IO} - Input Offset Voltage - μV

TLC27M4 (10 mV) to the high-precision TLC27M9 (900 μV). These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs.

LinCMOS is a trademark of Texas Instruments Incorporated

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description (continued)

In general, many features associated with bipolar technology are available on LinCMOS™ operational amplifiers, without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are easily designed with the TLC27M4 and TLC27M9. The devices also exhibit low voltage single-supply operation, and low power consumption, making them ideally suited for remote and inaccessible battery-powered applications. The common-mode input voltage range includes the negative rail.

A wide range of packaging options is available, including small-outline and chip-carrier versions for high-density system applications.

The device inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up.

The TLC27M4 and TLC27M9 incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

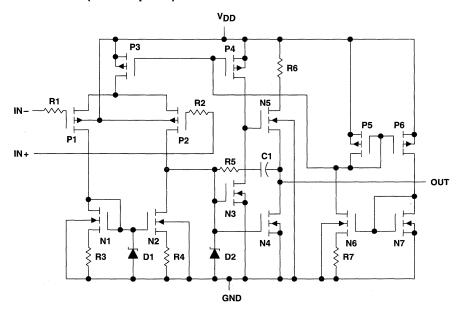
AVAILABLE OPTIONS

				PACKAGE			01110
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)	CHIP FORM (Y)
	900 μV	TLC27M9CD	-	, -	TLC27M9CN	_	_
0°C to 70°C	2 mV	TLC27M4BCD			TLC27M4BCN	_	-
0-0 10 70 0	5 mV	TLC27M4ACD			TLC27M4ACN	_	_
	10 mV	TLC27M4CD	_		TLC27M4CN	TLC27M4CPW	TLC27M4Y
-	900 μV	TLC27M9ID	_	_	TLC27M9IN	_	_
-40°C to 85°C	2 mV	TLC27M4BID	<u>-</u>	_	TLC27M4BIN	_	_
-40°C to 85°C	5 mV	TLC27M4AID	- .	_	TLC27M4AIN	_	_
	10 mV	TLC27M4ID		_	TLC27M4IN	_	_
-55°C to 125°C	900 μV	TLC27M9MD	TLC27M9MFK	TLC27M9MJ	TLC27M9MN	_	· -
-55 C to 125 C	10 mV	TLC27M4MD	TLC27M4MFK	TLC27M4MJ	TLC27M4MN	_	_

The D package is available taped and reeled. Add R suffix to the device type (e.g., TLC279CDR).

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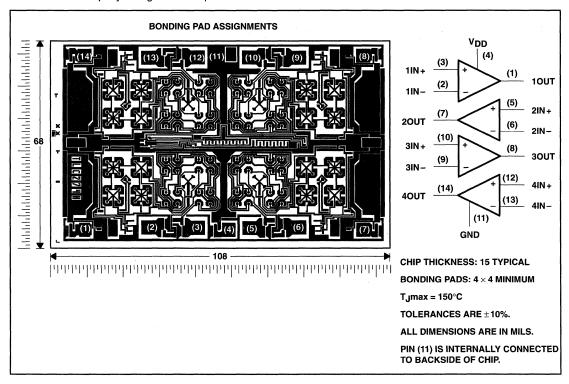
equivalent schematic (each amplifier)



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TLC27M4Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC27M4C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

2. Differential voltages are at IN+ with respect to IN-.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application section).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A ≈ 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW	
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
N	1575 mW	12.6 mW/°C	1008 mW	819 mW	_
PW	700 mW	5.6 mW/°C	448 mW		_

recommended operating conditions

		C SU	FFIX	I SUF	FIX	M SUFFIX		UNIT	
		MIN MAX MIN MAX MIN MAX				UNII			
Supply voltage, V _{DD}		3	16	4	16	4 16		٧	
Common-mode input voltage, V _{IC}	V _{DD} = 5 V	-0.2	3.5	-0.2	3.5	0	3.5	V	
	V _{DD} = 10 V	-0.2	8.5	-0.2	8.5	0	8.5		
Operating free-air temperature, TA		0	70	-40	85	-55	125	°C	

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electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER		TEST CONE	DITIONS	T _A †	TL Ti	.C27M40 .C27M4/ .C27M4I .C27M90	AC BC	UNIT
						MIŅ	TYP	MAX	
	. '	TLC27M4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TEO27W4O	$R_S = 50 \Omega$,	R _L = 100 kΩ	Full range			12	mV
		TLC27M4AC	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		0.9	5	1117
V _{IO}	Input offset voltage	TEOZINIAAO	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	
VIO	input onoct voltage	TLC274BC	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		250	2000	
		12027480	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3000	μV
		TLC279C	$V_0 = 1.4 V$,	$V_{IC} = 0$,	25°C		210	900	μν
		1202790	$R_S = 50 \Omega$,	R _L = 100 kΩ	Full range			1500	
ανιο	Average temperature coeffici offset voltage	ent of input			25°C to 70°C		1.7		μV/°C
li a	Input officet ourrent (one Note	. 4)	V- 05V	V 0 F V	25°C		0.1		n 1
lo	Input offset current (see Note	÷ 4)	$V_{O} = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	70°C		7	300	рA
li-	Input bigg current (age Note	4)	V _O = 2.5 V,	V _{IC} = 2.5 V	25°C		0.6		nΛ
ΙΒ	Input bias current (see Note	+)	V() = 2.5 V,	AIC = 5.2 A	70°C		40	600	рA
V	Common-mode input voltage	range			25°C	-0.2 to 4	-0.3 to 4.2		V
VICR	(see Note 5)				Full range	-0.2 to 3.5			٧
					25°C	3.2	3.9		
Vон	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	0°C	3	3.9		V
					70°C	3	4		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
			,		25°C	25	170		
AVD	Large-signal differential volta amplification	ge	$V_0 = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	0°C	15	200		V/mV
	ap.moa.io.i				70°C	15	140		
					25°C	65	91		
CMRR	Common-mode rejection ratio	0	V _{IC} = V _{ICR} min		0°C	60	91		dB
					70°C	60	92		
					25°C	70	93		
ksvr	Supply-voltage rejection ratio	(ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	92		dB
					70°C	60	94		
			V- 05V	V 0.5.V	25°C		420	1120	
IDD	Supply current (four amplifier	rs)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V$,	0°C		500	1280	μΑ
					70°C		340	880	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CON	TEST CONDITIONS		TLC27M4C TLC27M4AC TLC27M4BC TLC27M9C			UNIT
						MIN	TYP	MAX	
		TLC27M4C	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLC2/M4C	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	
		TLC27M4AC	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	mV
VIO	Input offset voltage	TLC2/W4AC	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	
٧IO	input onset voltage	TLC27M4BC	V _O = 1.4 V,	V _{IC} = 0,	25°C		260	2000	
		TEO27W4BO	$R_S = 50 \Omega$,	R _L = 100 kΩ	Full range			3000	μV
		TLC27M9C	$V_0 = 1.4 V$	$V_{IC} = 0$,	25°C		220	1200	μν
			$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			1900	
αΛΙΟ	Average temperature co offset voltage	efficient of input	8		25°C to 70°C		2.1		μV/°C
l. o	Input offset surrent (see	Note 4)	Va - F V	V:0 - 5 V	25°C		0.1		n 1
liO	Input offset current (see	Note 4)	V _O = 5 V,	$V_{IC} = 5 V$	70°C		7	300	рA
1	Input bigg gurrant (age N	uloto 4)	V- EV	\\\- = 5 \\\.	25°C		0.7		20
^I IB	Input bias current (see N	Note 4)	$V_O = 5 V$,	$V_{IC} = 5 V$	70°C		50	600	pА
	Common-mode input voltage range			-	25°C	-0.2 to 9	-0.3 to 9.2		٧
VICR	(see Note 5)	::			Full range	-0.2 to 8.5			V
					25°C	. 8	8.7		
۷он	High-level output voltage	e .	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	0°C	7.8	8.7] v
					70°C	7.8	8.7		
					25°C		0	50	
VOL	Low-level output voltage	•	$V_{ID} = -100 \text{ mV},$	IOL = 0	0°C		0	50	mV
					70°C		0	50	
					25°C	25	275		
AVD	Large-signal differential amplification	voltage	$V_0 = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	0°C	15	320		V/mV
	amplification				70°C	15	230		
					25°C	65	94		
CMRR	Common-mode rejection	n ratio	V _{IC} = V _{ICR} min	V.	0°C	60	94		dB
					70°C	60	94		
					25°C	70	93		
ksvr	Supply-voltage rejection	ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	0°C	60	92		dB
					70°C	60	94		
					25°C		570	1200	1
lDD	Supply current (four amp	plifiers)	V _O = 5 V, No load	$V_{IC} = 5 V$	0°C		690	1600	μΑ
					70°C		440	1120	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

,	PARAMETER		TEST CONDITIONS		TAT	TI TI TI TI	UNIT		
		,	·			MIN	TYP	MAX	
		TLC27M4I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		1202/10141	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			13	mV
		TLC27M4AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	""
V _{IO}	Input offset voltage	TEOZ/WI4AI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			6.5	
٧IO	input onset voltage	TLC27M4BI	V _O = 1.4 V,	V _{IC} = 0,	25°C		250	2000	
		TEO27W4DI	$R_S = 50 \Omega$,	R _L = 100 kΩ	Full range			3000	μV
		TLC27M9I	V _O = 1.4 V,	V _{IC} = 0,	25°C		210	900	μν
		TEO27W91	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			2000	
ανιο	Average temperature coeffice offset voltage	cient of input			25°C to 85°C		1.7		μV/°C
l. a	Input offset surrent (see Ne	:- 4)	V- 05V	V 0.5.V	25°C		0.1		
liO	Input offset current (see No	le 4)	$V_0 = 2.5 \text{ V},$	V _{IC} = 2.5 V	85°C		24	1000	pΑ
1	Innut biog surrent /cos Note	4)	V- 05V	V 0.5.V	25°C		0.6		- 4
lВ	Input bias current (see Note	(4)	$V_{O} = 2.5 \text{ V},$	V _{IC} = 2.5 V	85°C		200	2000	pΑ
						-0.2	-0.3		
					25°C	to	to		٧
Vice	Common-mode input voltage range (see Note 5)					4	4.2		
					Full range	-0.2 to			v
					runtange	3.5			
	,		İ		25°C	3.2	3.9		
Vон	High-level output voltage		V _{ID} = 100 mV,	R _L = 100 kΩ	-40°C	3	3.9		v
011				_	85°C	3	4		
·				<u> </u>	25°C		0	50	
Vol	Low-level output voltage		V _{ID} = -100 mV,	I _{OL} = 0	-40°C		0	50	m∨
			"	OL.	85°C		0	-50	
	·	·			25°C	25	170		
AVD	Large-signal differential volt	age	$V_{O} = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	-40°C	15	270		V/mV
	amplification		-		85°C	15	130		ĺ
					25°C	65	91		
CMRR	Common-mode rejection ra	tio	V _{IC} = V _{ICB} min		-40°C	60	90		dB
,			.5 .5"		85°C	60	90		
	A second				25°C	70	93		
ksvr	Supply-voltage rejection rati	ο (Δν _{DD} /Δνια)	V _{DD} = 5 V to 10 V,	V _O = 1.4 V	-40°C	60	91		dB
				-	85°C	60	94		
					25°C		420	1120	1-
lDD	Supply current (four amplific	ers)	V _O = 2.5 V, V ₀	$V_{IC} = 2.5 V$,	-40°C	-	630	1600	
		upply current (four amplifiers)		.5	L	<u> </u>			

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CONI	DITIONS	T _A †	TL TL	UNIT		
				**		MIN	C27M4 C27M4 C27M4 C27M4 C27M4 C27M9 C27M9 TYP MAX		
		TLC27M4I	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
		TLG2/W41	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			13	mV
		TLC27M4AI	V _O = 1.4 V,	V _{IC} = 0,	25°C		0.9	5	1111
V _{IO}	Input offset voltage	TLO2/WHAI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			7	
100	input onset voitage	TLC27M4BI	V _O = 1.4 V,	$V_{IC} = 0$,	25°C		260	2000	
		TEO27W4BI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3500	μV
	•	TLC27M9I	V _O = 1.4 V,	V _{IC} = 0,	25°C		220	1200	μν
		TEGZ/M91	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			2900	
αΛΙΟ	Average temperature coeffice offset voltage	ient of input			25°C to 85°C		2.1		μV/°C
		4)	V 5.V	.,	25°C		0.1		,
lio	Input offset current (see Not	e 4)	$V_{O} = 5 V$,	$V_{IC} = 5 V$	85°C		26	1000	pΑ
	1 .1.1.		.,,		25°C		0.7		
lВ	Input bias current (see Note	4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	85°C		220	2000	рA
	_				25°C	-0.2 to 9	to		٧
VICR	Common mode input voltage (see Note 5)	e range		,	Full range	-0.2 to 8.5			٧
					25°C	8	8.7		
V _{OH}	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	-40°C	7.8	8.7		\
					85°C	7.8	8.7		
					25°C		0	50	
VOL	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	-40°C		0	50	mV
					85°C		0	50	
					25°C	25	275		
AVD	Large-signal differential volta	age	$V_0 = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	-40°C	15	390		V/mV
	amplification				85°C	15	220		
					25°C	65	94		
CMRR	Common-mode rejection rat	io	V _{IC} = V _{ICR} min		-40°C	60	93		dB
					85°C	60	94		1
					25°C	70	93		
ksvr	Supply-voltage rejection ratio	ο (Δν _{DD} /Δν _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	-40°C	60	91		dB
					85°C	60	94		
			V 5 V	V - 5V	25°C		570	1200	
I _{DD}	DD Supply current (four amplifie		V _O = 5 V, No load	$V_{IC} = 5 V$	-40°C		900	1800	μΑ
			1		85°C		410	1040	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.



^{5.} This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	,	TEST CONE	DITIONS	T _A †		C27M4N C27M9N		UNIT
			·			MIN	TYP	MAX	
		TLC27M4M	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	mV
V. 0	Input offset voltage	TEGZ/W4W	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	HIV
V _{IO}	input onset voltage	TLC27M9M	V _O = 1.4 V,	V _{IC} = 0,	25°C		210	900	μV
		1 LOZ/IVISIVI	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			3750	μν
αΛΙΟ	Average temperature coefficie offset voltage	nt of input			25°C to 125°C		1.7		μV/°C
1	Input offset current (see Note	4)	V- 05V	V 0.5.V	25°C		0.1		pΑ
IO	input onset current (see Note	4)	$V_{O} = 2.5 \text{ V},$	V _{IC} = 2.5 V	125°C		1.4	15	nA
1	Input his august (see Note 4	`	V- 05V	V 0.5.V	25°C		0.6		pА
IB	Input bias current (see Note 4)	$V_0 = 2.5 \text{ V},$	$V_{IC} = 2.5 V$	125°C		9	35	nA
	Common-mode input voltage	range			25°C	0 to 4	-0.3 to 4.2		٧
VICR	(see Note 5)			Full range	0 to 3.5	,		٧	
					25°C	3.2	3.9		
V_{OH}	High-level output voltage		V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	−55°C	3	3.9		_ v
					125°C	3	4		
					25°C		0	50	
V_{OL}	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	−55°C		0	50	mV	
					125°C		0	50	
					25°C	25	170		
A_{VD}	Large-signal differential voltage amplification	е	$V_O = 0.25 \text{ V to 2 V},$	$R_L = 100 \text{ k}\Omega$	−55°C	15	290		V/mV
	ampimoadon				125°C	15	120		
					25°C	65	91		
CMRR	Common-mode rejection ratio		V _{IC} = V _{ICR} min		−55°C	60	89		dB
			·		125°C	60	91		
					25°C	70	93		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	91		dB
	49				125°C	60	94		
			V _O = 2.5 V, V No load	V _{IC} = 2.5 V,	25°C		420	1120	μА
I_{DD}	Supply current (four amplifier	s)			−55°C		680	1760	
					125°C		280	720	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics at specified free-air temperature, V_{DD} = 10 V (unless otherwise noted)

	PARAMETER		TEST CO	NDITIONS	T _A †		.C27M4I .C27M9I		UNIT
					_ ^	MIN	TYP	MAX	
		TI COZNAMA	V _O = 1.4 V,	V _{IC} = 0,	25°C		1.1	10	
V -		TLC27M4M	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			12	mV
VIO	Input offset voltage	TLC27M9M	V _O = 1.4 V,	V _{IC} = 0,	25°C		220	1200	
		TEG2/W9W	$R_S = 50 \Omega$,	$R_L = 100 \text{ k}\Omega$	Full range			4300	μV
αVIO	Average temperature coeffi offset voltage	cient of input			25°C to 125°C		2.1		μV/°C
1	lanut effect suivient (e.e. No	4- 4\	V- 5V	V- 5.V	25°C		0.1		pА
lo	Input offset current (see No	te 4)	$V_0 = 5 V$,	$V_{IC} = 5 V$	125°C		1.8	15	nA
	land bir a sum of the Nick	. 4)	V 5V	.,	25°C		0.7		pΑ
lΒ	Input bias current (see Note	9 4)	$V_{O} = 5 V,$	$V_{IC} = 5 V$	125°C		10	35	nA
IVICD	Common-mode input voltag	ge range			25°C	0 to 9	-0.3 to 9.2		٧
	(see Note 5)				Full range	0 to 8.5			٧
					25°C	8	8.7		
Vон	High-level output voltage		$V_{ID} = 100 \text{ mV},$	$R_L = 100 \text{ k}\Omega$	−55°C	7.8	8.6		V
					125°C	7.8	8.8		
					25°C		0	50	
v_{OL}	Low-level output voltage		$V_{ID} = -100 \text{ mV},$	$I_{OL} = 0$	−55°C		0	50	mV
			`		125°C		0	50	
					25°C	25	275		
A_{VD}	Large-signal differential volt amplification	age	$V_O = 1 \text{ V to 6 V},$	$R_L = 100 \text{ k}\Omega$	−55°C	15	420		V/mV
	атринсацоп		,		125°C	15	190		1
					25°C	65	94		
CMRR	Common-mode rejection ra	tio	V _{IC} = V _{ICR} min		−55°C	60	93		dB
					125°C	60	93		1
	0 1 11 11 11				25°C	70	93		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$		$V_{DD} = 5 \text{ V to } 10 \text{ V},$	$V_0 = 1.4 \text{ V}$	−55°C	60	91		dB
	(A.DD/ATIO)				125°C	60	94		
			V- 5.V	V F.V	25°C		570	1200	
lDD	Supply current (four amplifiers)		V _O = 5 V, No load	$V_{IC} = 5 V$	−55°C		980	2000	μΑ
					125°C		360	960	

†Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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electrical characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

	DADAMETED	TEST CONI	NTIONE	TLC27M4Y			UNIT
	PARAMETER	IEST CONL	DITIONS	MIN	TYP	MAX	UNII
VIO	Input offset voltage	$V_{O} = 1.4 \text{ V},$ $R_{S} = 50 \Omega,$	$V_{IC} = 0$, $R_L = 100 \text{ k}\Omega$		1.1	10	mV
ανιο	Temperature coefficient of input offset voltage	T _A = 25°C to 70°C			1.7		μV/°C
IIO	Input offset current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.1		pΑ
I _{IB}	Input bias current (see Note 4)	V _O = 2.5 V,	V _{IC} = 2.5 V		0.6		pΑ
V _{ICR}	Common-mode input voltage range (see Note 5)			-0.2 to 4	-0.3 to 4.2		٧
Vон	High-level output voltage	V _{ID} = 100 mV,	$R_L = 100 \text{ k}\Omega$	3.2	3.9		٧
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	IOL = 0		0	50	mV
AVD	Large-signal differential voltage amplification	$V_O = 0.25 \text{ V to 2 V},$	R _L = 100 kΩ	25	170		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	91		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	70	93		dB
lDD	Supply current (four amplifiers)	V _O = 2.5 V, No load	$V_{IC} = 2.5 V,$		420	1120	μА

electrical characteristics, V_{DD} = 10 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEST CON	DITIONS	TL	.C27M4\	4	UNIT
	PARAMETER	TEST CONI	DITIONS	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage	$V_O = 1.4 \text{ V},$ $R_S = 50 \Omega,$	$V_{IC} = 0$, $R_L = 100 \text{ k}\Omega$		1.1	10	mV
ανιο	Temperature coefficient of input offset voltage	T _A = 25°C to 70°C			2.1		μV/°C
lio	Input offset current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.1		pА
^I IB	Input bias current (see Note 4)	V _O = 5 V,	V _{IC} = 5 V		0.7		pА
VICR	Common-mode input voltage range (see Note 5)			-0.2 to 9	-0.3 to 9.2		٧
Vон	High-level output voltage	V _{ID} = 100 mV,	R _L = 100 kΩ	. 8	8.7		V
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$	I _{OL} = 0		0	50	mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 6 V,	R _L = 100 kΩ	25	275		V/mV
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min		65	94		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 5 \text{ V to } 10 \text{ V},$	V _O = 1.4 V	70	93		dB
IDD	Supply current (four amplifiers)	V _O = 5 V, No load	V _{IC} = 5 V,		570	1200	μА

NOTES:4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

^{5.} This range also applies to each input individually.

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operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

PARAMETER		TEST CONDITIONS		TA	TLC27M4C TLC27M4AC TLC27M4BC TLC27M9C			UNIT	
					MIN	TYP	MAX		
				25°C		0.43			
SR		$R_L = 100 \Omega$, $C_L = 20 pF$, See Figure 1	V _{IPP} = 1 V	0°C		0.46			
	Slow rate at unity gain			70°C		0.36		V/uc	
	Slew rate at unity gain			25°C	0.40			V/μs	
			V _{IPP} = 2.5 V	0°C		0.43			
				70°C		0.34			
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$	25°C		32		nV/√Hz	
	dia dia dia dia dia dia dia dia dia dia	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1	25°C		55			
ВОМ	Maximum output-swing bandwidth			0°C		60		kHz	
	•		See rigule i	70°C		50			
	- Control of the Cont			25°C		525			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF_{r}$	0°C		610		kHz	
		See rigure 3		70°C		400			
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,		25°C		40°			
				0°C	41°				
		ο _L = 20 μ,	Coc i iguio o	70°C		39°			

operating characteristics at specified free-air temperature, $V_{\mbox{DD}}$ = 10 V

PARAMETER		TEST	TEST CONDITIONS		TLC27M4C TLC27M4AC TLC27M4BC TLC27M9C			UNIT	
	Slew rate at unity gain Equivalent input noise voltage				MIN	TYP	MAX		
				25°C		0.62			
		R _L = 100 Ω, C _L = 20 pF, See Figure 1	V _{IPP} = 1 V	0°C		0.67			
SR	Slow rate at unity gain			70°C		0.51		V/μs	
	Siew rate at unity gain			25°C		0.56		V/μS	
			V _{IPP} = 5.5 V	0°C		0.61			
				70°C		0.46			
٧n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz	
				25°C		35			
Вом	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,		0°C		40		kHz	
				70°C		30			
				25°C		635			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	0°C		710		kHz	
		Oee rigule 3		70°C		510			
				25°C		43°			
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	0°C		44°			
		OL = 25 pr,	CCC / Iguie o	70°C		42°			

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

PARAMETER		TEST	TEST CONDITIONS		TLC27M4I TLC27M4AI TLC27M4BI TLC27M9I			UNIT	
					MIN	TYP	MAX		
	V			25°C		0.43			
			V _{IPP} = 1 V	-40°C		0.51			
SR	Slew rate at unity gain	$R_L = 100 \Omega$, $C_L = 20 pF$, See Figure 1		85°C		0.35		V/μs	
	Siew rate at unity gain			25°C		0.40		ν/μ5	
			V _{IPP} = 2.5 V	-40°C		0.48			
				85°C		0.32			
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz	
		1	C _L = 20 pF, See Figure 1	25°C		55			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,		-40°C		75		kHz	
		TIL = 100 K22,		85°C		45			
				25°C		525			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	-40°C		770		kHz	
		Gee rigule 3		85°C		370			
φm		1		25°C		40°			
	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	-40°C		43°			
		OL = 20 pi ,	Gee i igule 3	85°C		38°			

operating characteristics at specified free-air temperature, $V_{DD} = 10 \text{ V}$

	PARAMETER	TEST CONDITIONS		TA	TLC27M4I TLC27M4AI TLC27M4BI TLC27M9I			UNIT	
V _n			<u> </u>	MIN	TYP	MAX			
i		$R_L = 100 \Omega$, $C_L = 20 pF$, See Figure 1		25°C		0.62			
SR			V _{IPP} = 1 V	-40°C		0.77			
	Clauserate at units gain			85°C		0.47		V/μs	
	Slew rate at unity gain			25°C		0.56			
			V _{IPP} = 5.5 V	-40°C		0.70			
				85°C		0.44			
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz	
			C _L = 20 pF, See Figure 1	25°C		35			
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,		-40°C		45		kHz	
				85°C		25			
				25°C		635			
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	-40°C		880		kHz	
		See Figure 3		85°C		480			
				25°C		43°			
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	-40°C		46°			
"		ο <u>Γ</u> = 20 μι,	Coo riguio o	85°C		41°			

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

	PARAMETER	TEST CO	ONDITIONS	TA		TLC27M4M TLC27M9M		
					TLC27M9W MIN TYP MAX 0.43 0.54 0.29 0.40 0.50 0.28 32 55 80 40 525 850 330 40°			
				25°C		0.43		
SR		R _L = 100 Ω,		−55°C		0.54		
	Slew rate at unity gain			125°C		0.29		V/μs
	Siew rate at unity gain	C _L = 20 pF, See Figure 1	V _{IPP} = 2.5 V	25°C		0.40		ν/μδ
				−55°C		0.50		
				125°C		0.28		
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√ Hz
	Maximum output-swing bandwidth		C _L = 20 pF, See Figure 1	25°C		55		
ВОМ		$V_O = V_{OH}$, $R_I = 100 \text{ k}\Omega$,		−55°C		80		kHz
		11(= 100 K22,		125°C		40		
				25°C		525		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	−55°C		850		kHz
		oce rigule o		125°C		330		
		V _I = 10 mV, C _L = 20 pF,	, D	25°C		40°		
φ _m	Phase margin		f = B ₁ , See Figure 3	−55°C		44°		
				125°C		36°		

operating characteristics at specified free-air temperature, V_{DD} = 10 V

	PARAMETER	TEST	TEST CONDITIONS		TLC27M4M TLC27M9M			UNIT
				TA TA	1	MIN TYP MAX		
				25°C		0.62		
SR			V _{IPP} = 1 V	−55°C		0.81		
	Slow rate at unity gain	R _L = 100 Ω,		125°C		0.38		V/μs
	Slew rate at unity gain	C _L = 20 pF, See Figure 1		25°C		0.56		ν/μ5
		gara .	V _{IPP} = 5.5 V	−55°C		0.73		
				125°C		0.35		
v _n	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,	25°C		32		nV/√Hz
	Maximum output-swing bandwidth			25°C		35		
ВОМ			C _L = 20 pF, See Figure 1	−55°C		50		kHz
			Gee rigure r	125°C		20		
				25°C		635		
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	$C_L = 20 pF$,	−55°C		960		kHz
		See rigule 3		125°C		440		
		1, ,,	, 5	25°C		43°		
φ _m	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3	−55°C		47°		
,		SE = 25 pr,	ccc , iguic o	125°C		39°		

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operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST	TEST CONDITIONS				UNIT
	PARAMETER	, lesi	TEST CONDITIONS			MAX	UNII
SR	Slew rate at unity gain	$R_L = 100 \text{ k}\Omega$	V _{IPP} = 1 V		0.43		V/µs
3n		C _L = 20 pF, See Figure 1	V _{IPP} = 2.5 V	0.40			V/μS
٧n	Equivalent input noise voltage	f = 1 kHz See Figure 2	$R_S = 20 \Omega$		32		nV/√Hz
ВОМ	Maximum output-swing bandwidth	VO = V _{OH} , R _L = 100 kΩ,	C _L = 20 pF, See Figure 1		55		kHz
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,		525		kHz
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3		40°		

operating characteristics, V_{DD} = 10 V, T_A = 25°C

	PARAMETER	TEST OF	ONDITIONS	TL	C27M4	1	UNIT
	PARAMETER	TEST CC	MIN	TYP	MAX	UNII	
SR	Slew rate at unity gain	R _L = 100 kΩ,	V _{IPP} = 1 V		0.62		V/µs
on .	Siew rate at unity gain	C _L = 20 pF, See Figure 1	V _{IPP} = 5.5 V	0.56			ν/μs
Vn	Equivalent input noise voltage	f = 1 kHz, See Figure 2	$R_S = 20 \Omega$,		32		nV/√Hz
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 100 \text{ k}\Omega$,	C _L = 20 pF, See Figure 1		35		kHz
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 3	C _L = 20 pF,		635		kHz
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 3		43°		

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PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC27M4 and TLC27M9 are optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply versus split-supply test circuits is shown below. The use of either circuit gives the same result.

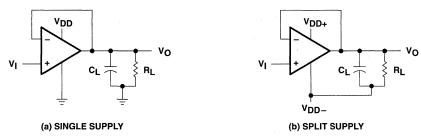


Figure 1. Unity-Gain Amplifier

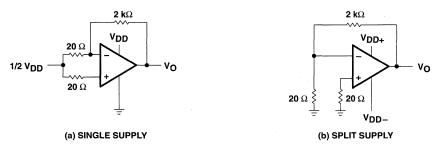


Figure 2. Noise-Test Circuit

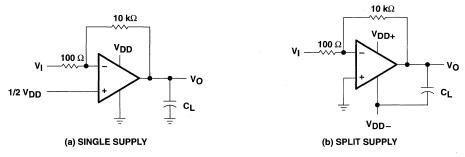


Figure 3. Gain-of-100 Inverting Amplifier

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PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC27M4 and TLC27M9 operational amplifiers, attempts to measure the input bias current can result in erroneous readings. The bias current at normal room ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 4). Leakages that would otherwise flow to the inputs are shunted away.
- 2. Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution ... many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into the test socket to obtain a correct reading; therefore, an open-socket reading is not feasible using this method.

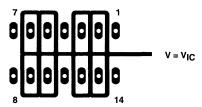


Figure 4. Isolation Metal Around Device Inputs (J and N packages)

low-level output voltage

To obtain low-supply-voltage operation, some compromise was necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to Figures 14 through 19 in the Typical Characteristics of this data sheet.

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PARAMETER MEASUREMENT INFORMATION

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance, which can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal input signal until the maximum frequency is found above which the output contains significant distortion. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 1. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 5). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.



Figure 5. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices and require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced supply levels and lower temperatures.

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	6, 7
αVIO	Temperature coefficient of input offset voltage	Distribution	8, 9
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	10, 11 12 13
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	14, 15 16 17 18, 19
AVD	Differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	20 21 32, 33
IIB	Input bias current	vs Free-air temperature	22
lo l	Input offset current	vs Free-air temperature	. 22
VIC	Common-mode input voltage	vs Supply voltage	23
lDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	29
В1	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	30 31
	Phase shift	vs Frequency	32, 33
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	34 35 36
٧n	Equivalent input noise voltage	vs Frequency	37

DISTRIBUTION OF TLC27M4 INPUT OFFSET VOLTAGE 60 612 Amplifiers Tested From 6 Wafer Lots $V_{DD} = 5 V$ T_A = 25°C 50 N Package Percentage of Units - % 40 30 20 10 0 -5 -4 -3 -2 -1 0 VIO - Input Offset Voltage - mV

Figure 6

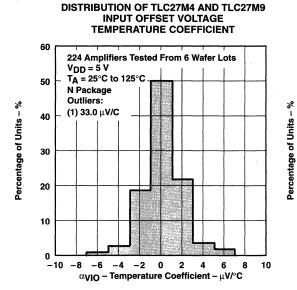


Figure 8

DISTRIBUTION OF TLC27M4 INPUT OFFSET VOLTAGE

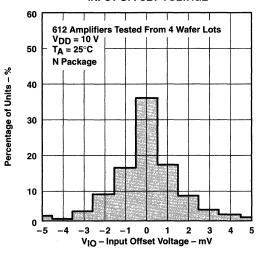


Figure 7

DISTRIBUTION OF TLC27M4 AND TLC27M9 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

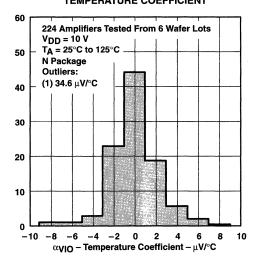


Figure 9

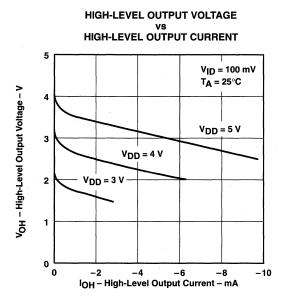


Figure 10

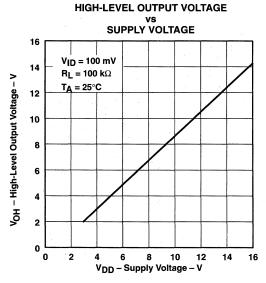
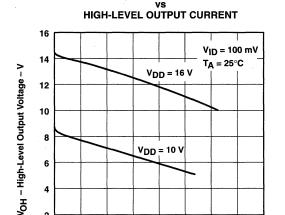


Figure 12



HIGH-LEVEL OUTPUT VOLTAGE

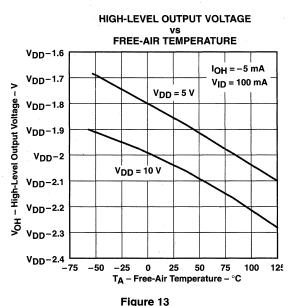
Figure 11

-10 -15 -20 -25 -30 -35

IOH - High-Level Output Current - mA

2

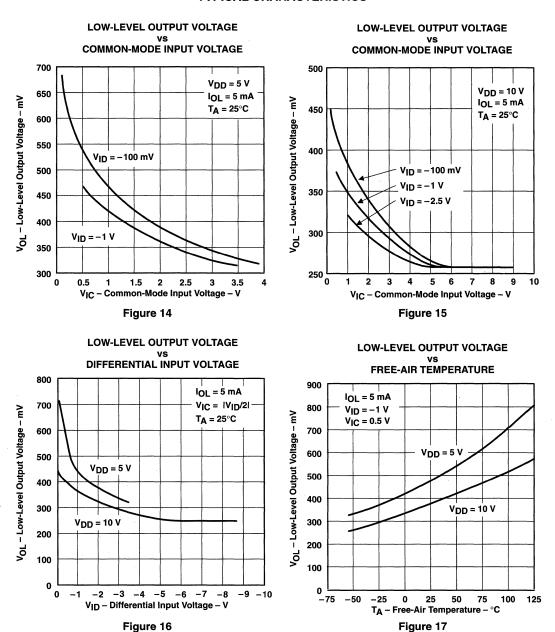
0



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

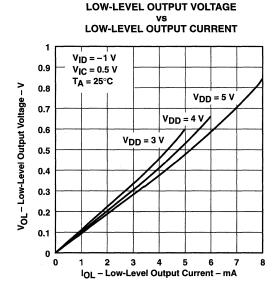


TYPICAL CHARACTERISTICS[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





LOW-LEVEL OUTPUT VOLTAGE

vs

LOW-LEVEL OUTPUT CURRENT

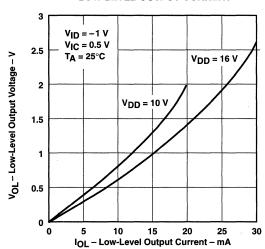
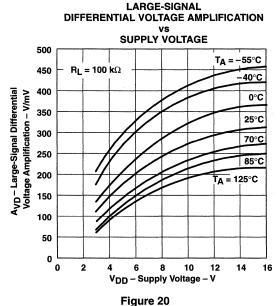


Figure 18

Figure 19



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION

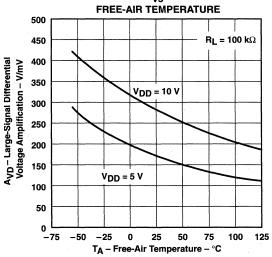


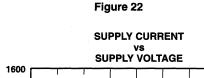
Figure 21

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

INPUT BIAS CURRENT AND INPUT OFFSET CURRENT **FREE-AIR TEMPERATURE** 10000 IIB and IIO - Input Bias and Offset Currents - pA $V_{DD} = 10 V$ VIC = 5 V See Note A 1000 ΙB 100 10 1 0.1 25 45 65 85 105 125

NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

- Free-Air Temperature - °C



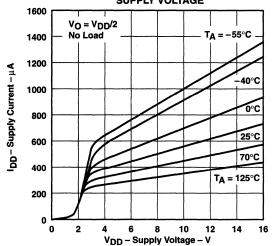


Figure 24

COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT

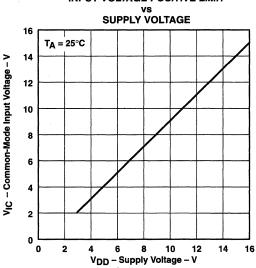


Figure 23

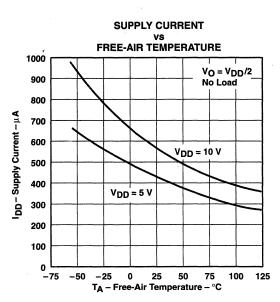


Figure 25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

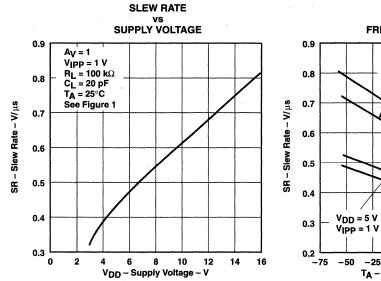
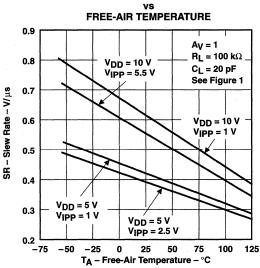


Figure 26



SLEW RATE

Figure 27

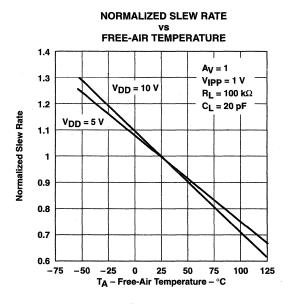


Figure 28

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE

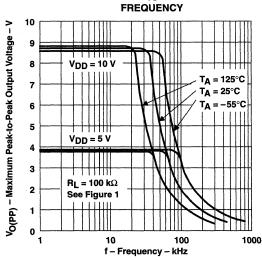
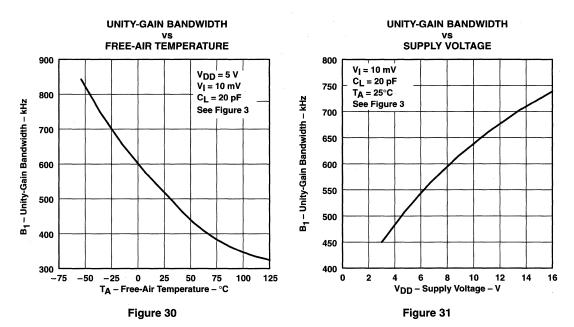


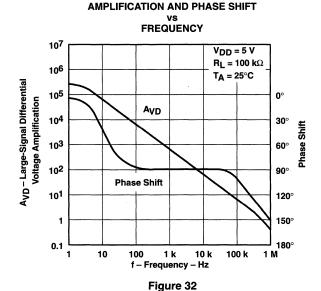
Figure 29

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





LARGE-SIGNAL DIFFERENTIAL VOLTAGE



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

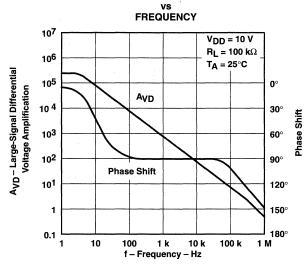
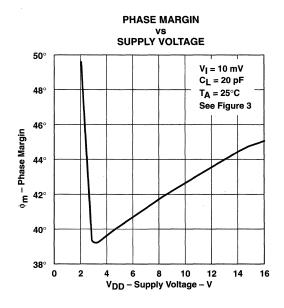


Figure 33



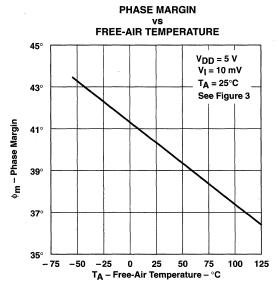


Figure 34

Figure 35

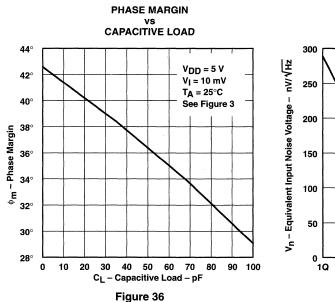
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS



EQUIVALENT INPUT NOISE VOLTAGE
VS
FREQUENCY

300

VDD = 5 V
RS = 20 Ω
TA = 25°C
See Figure 2

100
100
100
1000
1000

Figure 37

APPLICATION INFORMATION

single-supply operation

While the TLC27M4 and TLC27M9 perform well using dual power supplies (also called balanced or split supplies), the design is optimized for single-supply operation. This design includes an input common-mode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 3 V (C-suffix types), thus allowing operation with supply levels commonly available for TTL and HCMOS; however, for maximum dynamic range, 16-V single-supply operation is recommended.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. A resistive voltage divider is usually sufficient to establish this reference level (see Figure 38). The low input bias current of the TLC27M4 and TLC27M9 permits the use of very large resistive values to implement the voltage divider, thus minimizing power consumption.

The TLC27M4 and TLC27M9 work well in conjunction with digital logic; however, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- Power the linear devices from separate bypassed supply lines (see Figure 39); otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate; however, high-frequency applications may require RC decoupling.

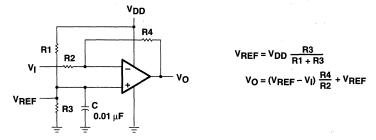


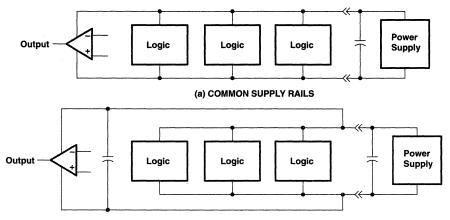
Figure 38. Inverting Amplifier With Voltage Reference

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APPLICATION INFORMATION

single-supply operation (continued)



(b) SEPARATE BYPASSED SUPPLY RAILS (preferred)

Figure 39. Common Versus Separate Supply Rails

input characteristics

The TLC27M4 and TLC27M9 are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. Note that the lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD}-1$ V at $T_A=25^{\circ}$ C and at $V_{DD}-1.5$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design gives the TLC27M4 and TLC27M9 very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is highly influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low bias current requirements, the TLC27M4 and TLC27M9 are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 4 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 40).

Unused amplifiers should be connected as unity-gain followers to avoid possible oscillation.

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC27M4 and TLC27M9 result in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than $50\,\mathrm{k}\Omega$, since bipolar devices exhibit greater noise currents.



APPLICATION INFORMATION

noise performance (continued)

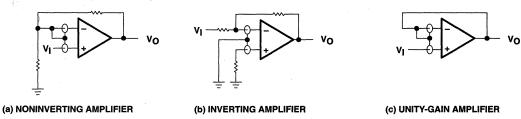


Figure 40. Guard-Ring Schemes

output characteristics

The output stage of the TLC27M4 and TLC27M9 is designed to sink and source relatively high amounts of current (see typical characteristics). If the output is subjected to a short-circuit condition, this high current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

All operating characteristics of the TLC27M4 and TLC27M9 were measured using a 20-pF load. The devices drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 41). In many cases, adding a small amount of resistance in series with the load capacitance alleviates the problem.

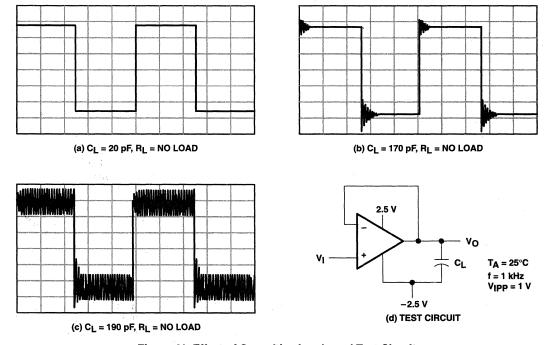


Figure 41. Effect of Capacitive Loads and Test Circuit

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APPLICATION INFORMATION

output characteristics (continued)

Although the TLC27M4 and TLC27M9 possess excellent high-level output voltage and current capability, methods for boosting this capability are available, if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 42). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor N4 (see equivalent schematic) must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately 60Ω and 180Ω , depending on how hard the op amp input is driven. With very low values of Rp. a voltage offset from 0 V at the output occurs. Second, pullup resistor Rp acts as a drain load to N4 and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

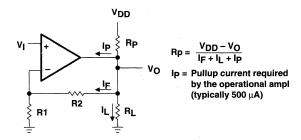


Figure 42. Resistive Pullup to Increase VOH

Figure 43. Compensation for Input Capacitance

feedback

Operational amplifier circuits nearly always employ feedback, and since feedback is the first prerequisite for oscillation, some caution is appropriate. Most oscillation problems result from driving capacitive loads (discussed previously) and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 43). The value of this capacitor is optimized empirically.

electrostatic discharge protection

The TLC27M4 and TLC27M9 incorporate an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature-dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC27M4 and TLC27M9 inputs and outputs were designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltage should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.



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latch-up (continued)

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

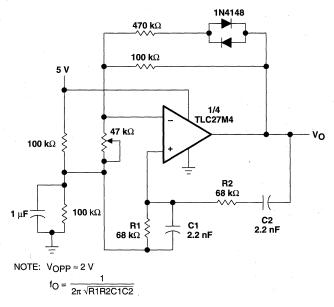


Figure 44. Wien Oscillator

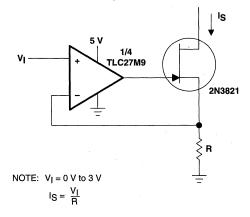
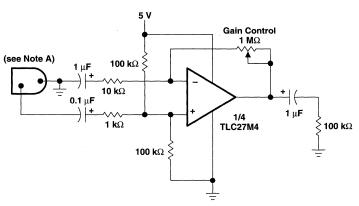


Figure 45. Precision Low-Current Sink

TLC27M4, TLC27M4A, TLC27M4B, TLC27M4Y, TLC27M9 LinCMOS™ PRECISION QUAD OPERATIONAL AMPLIFIERS

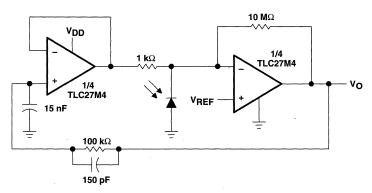
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NOTE A: Low to medium impedance dynamic mike

Figure 46. Microphone Preamplifier

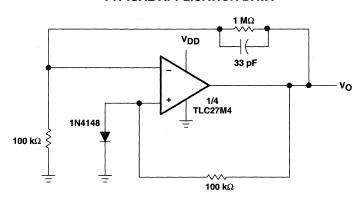


NOTE: $V_{DD} = 4 \text{ V to } 15 \text{ V}$ $V_{REF} = 0 \text{ V to } V_{DD} - 2 \text{ V}$

Figure 47. Photo-Diode Amplifier With Ambient Light Rejection

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TYPICAL APPLICATION DATA



NOTE: $V_{DD} = 8 \text{ V to } 16 \text{ V}$ $V_{O} = 5 \text{ V}$, 10 mA

Figure 48. Low-Power Voltage Regulator

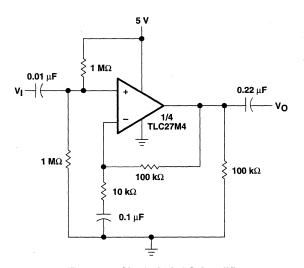


Figure 49. Single-Rail AC Amplifier

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ µPOWER PRECISION OPERATIONAL AMPLIFIERS

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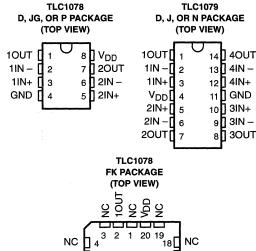
- Power Dissipation as Low as 10 μW Typ Per **Amplifier**
- Operates on a Single Silver-Oxide Watch Battery, V_{DD} = 1.4 V Min
- V_{IO} . . . 450 μ V/850 μ V Max in DIP and Small-Outline Package (TLC1078/79)
- Input Offset Voltage Drift . . . 0.1 µV/Month Typ, Including the First 30 Days
- High-impedance LinCMOS™ Inputs $I_{IR} = 0.6 pA Typ$
- High Open-Loop Gain . . . 800 000 Typ
- Output Drive Capability > 20 mA
- Slew Rate . . . 47 V/ms Typ
- Common-Mode Input Voltage Range **Extends Below the Negative Rail**
- **Output Voltage Range Includes Negative**
- On-Chip ESD-Protection Circuitry
- **Small-Outline Package Option Also** Available in Tape and Reel

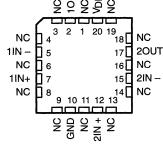
description

The TLC107x operational amplifiers offer ultralow offset voltage, high gain, 110-kHz bandwidth, 47-V/ms slew rate, and just 150-μW power dissipation per amplifier.

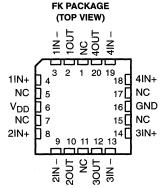
With a supply voltage of 1.4 V, common-mode input to the negative rail, and output swing to the negative rail, the TLC107xC is an ideal solution for low-voltage battery-operated systems. The 20-mA output drive capability means that the TLC107x can easily drive small resistive and large capacitive loads when needed, while maintaining ultra-low standby power dissipation.

Since this device is functionally compatible as well as pin compatible with the TLC27L2/4 and TLC27L7/9, the TLC107x easily upgrades existing designs that can benefit from its improved performance.





TLC1079



NC - No internal connection

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ μPOWER PRECISION OPERATIONAL AMPLIFIERS

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description (continued)

The TLC107x incorporates internal ESD-protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-PRF-38535, Method 3015.2; however, care should be exercised when handling these devices as exposure to ESD may result in degradation of the device parametric performance. The TLC107x design also inhibits latch-up of the device inputs and outputs even with surge currents as large 100 mA.

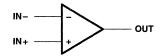
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C. The wide range of packaging options includes small-outline and chip-carrier versions for high-density system applications.

AVAILABLE OPTIONS

	PACKAGED DEVICES									
TĄ	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (N)	PLASTIC DIP (P)	FORM [‡] (Y)			
0°C to 70°C	TLC1078CD TLC1079CD				TLC1079CN	TLC1078CP	TLC1078Y TLC1079Y			
-40°C to 85°C	TLC1078ID TLC1079ID	_		_	TLC1079IN	TLC1078IP	_			
-55°C to 125°C	TLC1078MD TLC1079MD	TLC1078MFK TLC1079MFK	TLC1079MJ	TLC1078MJG	TLC1079MN	TLC1078MP	_			

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC1078CDR).

symbol (each amplifier)

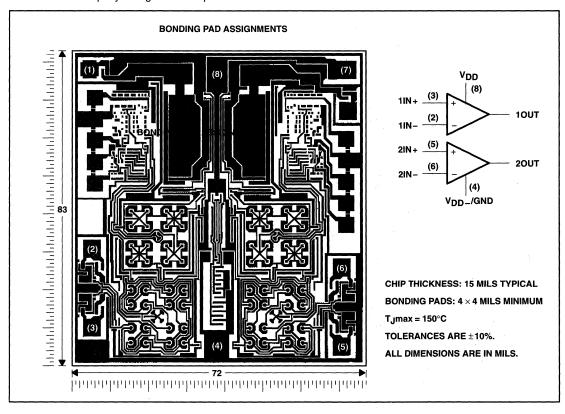


[‡]Chip forms are tested 25°C only.

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TLC1087Y chip information

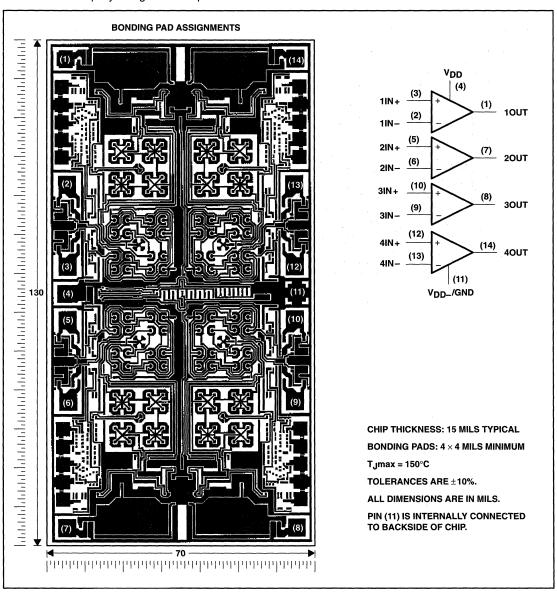
This chip, when properly assembled, displays characteristics similar to the TLC1078C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips can be mounted with conductive epoxy or a gold-silicon preform.



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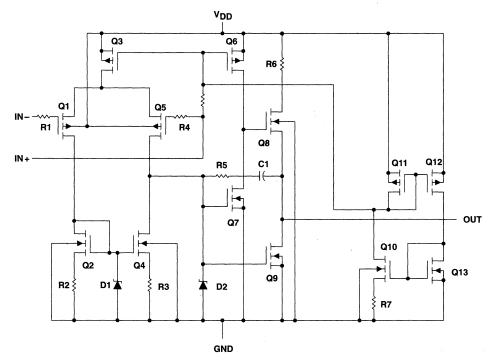
TLC1079Y chip information

This chip, when properly assembled, display characteristics similar to the TLC1079C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips can be mounted with conductive epoxy or a gold-silicon preform.



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equivalent schematic (each amplifier)



ACTUAL DEV	ICE COMPONEI	NT COUNT
COMPONENT	TLC1078	TLC1079
Transistors	38	76
Resistors	16	32
Diodes	12	24
Capacitors	2	4

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ μPOWER PRECISION OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	18 V
Differential input voltage, V _{ID} (see Note 2)	±V _{DD}
Input voltage range, V _I (any input)	
Input current, I _I (each input)	± 5 mA
Output current, IO (each output)	
Total current into V _{DD} (see Note 3)	45 mA
Duration of short-circuit at (or below) T _A = 25°C (see Note 3)	unlimited
Continuous total power dissipation	see Dissipation Rating Table
Operating free-air temperature range, T _A : C suffix	0°C to 70°C
I suffix	–40°C to 85°C
M suffix	–55°C to 125°C
Storage temperature range	65°C to 150°C
Case temperature for 60 seconds: FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	9 260°C
Lead temperature 1.6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

- 2. Differential voltages are at IN+ with respect to IN-.
- The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation ratings are not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	230 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

					I SUFFIX		M SUFFIX	
		MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD}		1.4	16	3	16	4	16	٧
Common-mode input voltage, V _{IC}	V _{DD} = 5 V	-0.2	4	-0.2	4	0	4	
Common-mode input voltage, vIC	V _{DD} = 10 V	-0.2	9	-0.2	9	0	9	V
Operating free-air temperature, T _A		0	70	-40	85	-55	125	°C

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOSTM μPOWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

electrical characteristics at specified free-air temperature

		TEST				TLC1	078C				
	PARAMETER	CONDITIONS	TAT	V	DD = 5	٧	V	DD = 10	٧	UNIT	
		CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX		
V	land Anti-Anti-Anti-Anti-Anti-Anti-Anti-Anti-	VO = 1.4 V,	25°C		160	450		180	600		
VIO	Input offset voltage	$R_S \approx 50 \Omega$	Full range			800			950	μV	
αΛΙΟ	Temperature coefficient of input offset voltage	$V_{IC} = 0,$ $R_I = 1 M\Omega$	25°C to 70°C		1.1			1		μV/°C	
1	Input offset surrent (see Note 4)		25°C		0.1			0.1			
lio	Input offset current (see Note 4)	$V_{O} = V_{DD} / 2$,	70°C		7	300		7	300	рA	
1	Input bias current (see Note 4)	$V_{IC} = V_{DD}/2$	25°C		0.6			0.7		20	
IB	input bias current (see Note 4)		70°C		40	600		50	600	рA	
V	Common-mode input voltage		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		٧	
VICR	range (see Note 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			٧	
			25°C	3.2	4.1		8.2	8.9			
VOH	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	0°C	3.2	4.1		8.2	8.9		V	
		110-11032	70°C	3.2	4.2		8.2	8.9			
	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OL} = 0$	25°C		0	25		0	25		
VOL			0°C		0	25		0	25	mV	
			70°C		0	25		0	25		
			25°C	250	525		500	850			
AVD	Large-signal differential voltage amplification	R_L = 1 $MΩ$, See Note 6	0°C	250	680		500	1010		V/mV	
	ampinioation	000 14010 0	70°C	200	380		350	660			
			25°C	70	95		75	97			
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	0°C	70	95		75	97		dB	
			70°C	70	95		75	97			
			25°C	75	98		75	98			
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _O = 1.4 V	0°C	75	98		75	98		dB	
			70°C	75	98		75	98		1	
		$V_O = V_{DD}/2$	25°C		20	34		29	46		
lDD	Supply current (two amplifiers)	$V_{IC} = V_{DD}/2$	0°C		24	42		36	66	⊣ '	
		No load	70°C	T	16	28		22	40		

†Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.
6. At V_{DD} = 5 V. V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

TLC1078, TLC1078Y, TLC1079, TLC1079Y LincMoSTM μ POWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

electrical characteristics at specified free-air temperature

						TLC1	079C			
	PARAMETER	TEST CONDITIONS	TAT	V	DD = 5 \	1	V	OD = 10	V	UNIT
		ĺ		MIN	TYP	MAX	MIN	TYP	MAX	
	land a ffeet college		25°C		190	850		200	1150	
VIO	Input offset voltage	V _O = 1.4 V, V _{IC} = 0,	Full range			1200			1500	μV
αVIO	Temperature coefficient of input offset voltage	$R_S = 50 \Omega$, $R_I = 1 M\Omega$	25°C to 70°C		1.1			1		μV/°C
li o	Input offset current		25°C		0.1			0.1		рA
lo	(see Note 4)	$V_O = V_{DD}/2$	70°C		7	300		7	300	PΑ
lin	Input bias current	$V_{IC} = V_{DD}/2$	25°C		0.6			0.7		pА
IB	(see Note 4)	·	70°C		40	600		50	600	PA
V: 0.5	Common mode input		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		٧
VICR	voltage range (see Note 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			٧
			25°C	3.2	4.1		8.2	8.9		
Vон	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_{I} = 1 \text{ M}\Omega$	0°C	3.2	4.1		8.2	8.9		V
		11 - 1 10122	70°C	3.2	4.2		8.2	8.9		
			25°C		0	25		0	25	
VOL	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OI} = 0$	0°C		0	25		0	25	mV
	'	I OL = 0	70°C		0	25		0	25	
			25°C	250	525		500	850		
AVD	Large-signal differential voltage amplification	$R_L = 1 M\Omega$, See Note 6	0°C	250	700		500	1010		V/mV
			70°C	200	380		350	660		
			25°C	70	95		75	97		
CMRR	Common mode rejection ratio	V _{IC} = V _{ICR} min	0°C	70	95		75	97		dB
	rado		70°C	70	95		75	97		
	0	V 5.V4-40.V	25°C	75	98		75	98		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V, V _O = 1.4 V	0°C	75	98		75	98		dB
	(DD,IO)	.0	70°C	75	98		75	98		
-	Supply current (four	V- V/0	25°C		40	68		57	92	4
IDD	amplifiers)	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	0°C		48	84		72	132	
		10 00 = 7 11 7 11	70°C		31	56		44	80	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At V_{DD} = 5 V, V_{O} = 0.25 V to 2 V; at V_{DD} = 10 V, V_{O} = 1 V to 6 V.

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOSTM μPOWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

operating characteristics at specified free-air temperature

		TEST CONDITIONS			TLC1078C									
	PARAMETER			TA	V _{DD} = 5 V			٧c	D = 10	٧	UNIT			
					MIN	TYP	MAX	MIN	TYP	MAX				
				25°C		32			47					
SR	Slew rate at unity gain		CL = 20 pF, , See Figure 1		$R_L = 1 M\Omega$, $C_L = 20 pF$,	0°C		35			51		V/ms	
1		VI(PP) ~ 1 V,		70°C		27			38					
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	25°C		68			68		nV/√Hz			
		C _L = 20 pF,	See Figure 2	25°C		85			110					
B ₁	Unity-gain bandwidth			C _L = 20 pF, See Figure 2	0°C		100			125		kHz		
l				70°C		65			90					
		C _L = 20 pF,	C _L = 20 pF, See Figure 2				25°C		34°			38°		
φm	Phase margin at unity gain			See Figure 2	0°C		36°			40°				
ĺ			-	70°C		30°			34°					

operating characteristics at specified free-air temperature

							TLC1	079C				
l	PARAMETER	TEST CO	TEST CONDITIONS		V _{DD} = 5 V			٧	D = 10	V	UNIT	
					MIN	TYP	MAX	MIN	TYP	MAX		
				25°C		32			47			
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	Cլ = 20 pF, See Figure 1	0°C		35			51		V/ms	
		(PP) •,	See rigure r	70°C		27			38			
٧n	Equivalent input noise voltage	f = 1 kHz,	R _S = 20 Ω	25°C		68			68		nV/√Hz	
			pF, See Figure 2	25°C		85			110			
B ₁	Unity-gain bandwidth	C _L = 20 pF,		0°C		100			125		kHz	
				70°C		65			90			
				25°C		34°			38°			
φm	Phase margin at unity gain	C _L = 20 pF, See Figure	See Figure 2	See Figure 2	0°C		36°			40°		
				70°C		30°			34°			

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ µPOWER PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature

						TLC1	10781			
	PARAMETER	TEST	T _A †	\ \	DD = 5 \	/	٧	DD = 10	٧	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
\/	land offer to the co		25°C		160	450		180	600	
VIO	Input offset voltage	$V_0 = 1.4 \text{ V},$ $R_S = 50 \Omega,$	Full range			950			1100	μV
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_I = 1 M\Omega$	25°C to 85°C		1.1			1		μV/°C
l	Input offset current		25°C		0.1	7		0.1		^
ΙΟ	(see Note 4)	$V_O = V_{DD}/2$	85°C		24	1000		26	1000	рA
1	Innuit bigg gurrant (one Note 4)	$V_{IC} = V_{DD}/2$	25°C		0.6	•		0.7		
lВ	Input bias current (see Note 4)	`	85°C		200	2000		220	2000	рA
V	Common-mode input voltage		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		· V
VICR	range (see Note 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			٧
			25°C	3.2	4.1		8.2	8.9		
Vон	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_{I} = 1 \text{ M}\Omega$	-40°C	3.2	4.1		8.2	8.9		٧
		INC = 1 IVIS2	85°C	3.2	4.2		8.2	8.9		
	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0	25°C		0	25		0	25	mV
v_{OL}			-40°C		0	25		0	25	
			85°C		0	25		0	25	
			25°C	250	525		500	850		
A_{VD}	Large-signal differential voltage amplification	$R_L = 1 M\Omega$, See Note 6	-40°C	250	900		500	1550		V/mV
	amplification	See Note 6	85°C	150	300		250	585		1
	,		25°C	70	95		75	97		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	-40°C	70	95		75	97		dB
			85°C	70	95		75	97		
			25°C	75	98		75	98		
ksvr	Supply-voltage rejection ratio (ΔVDD/ΔVIO)	V _O = 1.4 V	-40°C	75	98		75	98		dB
	(AADD/AAIO)		85°C	75	98		75	98		
		$V_{O} = V_{DD}/2$	25°C		20	34		29	46	
IDD	Supply current (two amplifiers)	$V_{IC} = V_{DD}/2$	-40°C		31	54		50	86	μА
		No load	85°C		15	26		20	36	

† Full range is -40°C to 80°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOSTM μPOWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

electrical characteristics at specified free-air temperature

						TLC1	0791			
	PARAMETER	TEST CONDITIONS	T _A †	V	DD = 5 \	′	V	DD = 10 '	٧	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
\/	Innut offert veltors		25°C		190	850		200	1150	\/
VIO	Input offset voltage	$V_O = 1.4 \text{ V}, V_{IC} = 0,$	Full range			1350			1650	μV
αVIO	Temperature coefficient of input offset voltage	$R_S = 50 \Omega$, $R_I = 1 M\Omega$	25°C to 85°C		1.1			1		μV/°C
li o	Input offset current		25°C		0.1			0.1		рA
110	(see Note 4)	$V_O = V_{DD}/2$	85°C		24	1000		26	1000	рA
Iв	Input bias current	$V_{IC} = V_{DD}/2$	25°C		0.6			0.7		pA
אוי	(see Note 4)		85°C		200	2000		220	2000	РΑ
Vion	Common-mode input voltage range		25°C	-0.2 to 4	-0.3 to 4.2		-0.2 to 9	-0.3 to 9.2		>
VICR	(see Note 5)		Full range	-0.2 to 3.5			-0.2 to 8.5			٧
			25°C	3.2	4.1		8.2	8.9		
V_{OH}	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_{I} = 1 \text{ M}\Omega$	-40°C	3.2	4.1		8.2	8.9		V
	· · · · · · · · · · · · · · · · · · ·	11[- 1 1/152	85°C	3,2	4.2		8.2	8.9		
	Low-level output voltage		25°C		0	25		0	25	
v_{OL}		V _{ID} = -100 mV, I _{OL} = 0	-40°C		0	25		0	25	mV
		10L = 0	85°C		0	25		0	25	
			25°C	250	525		500	850		
AVD	Large-signal differential voltage amplification	$R_L = 1 M\Omega$, See Note 6	-40°C	250	900		500	1550		V/mV
	voltago arripinioadori		85°C	150	330		250	585		
			25°C	70	95		75	97		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	-40°C	70	95		75	97		dB
	rojoonon tano		85°C	70	95	· ·	75	97		
	O	5.44.40.4	25°C	75	98		75	98		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V, V _O = 1.4 V	-40°C	75	98		75	98		dB
			85°C	75	98		75	98		
	Supply ourrent	Vo - V / 2	25°C		40	68		57	92	
lDD	Supply current (four amplifiers)	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	-40°C		62	108		98	172	μΑ
	(/	10 000 3, 110 100 100	85°C		29	52		40	72	

† Full range is -40°C to 85°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At V_{DD} = 5 V, V_{O} = 0.25 V to 2 V; at V_{DD} = 10 V, V_{O} = 1 V to 6 V.

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ µPOWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

operating characteristics at specified free-air temperature

		TEST CONDITIONS									
1	PARAMETER			TA	V _{DD} = 5 V			V _{DD} = 10 V			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		32			47		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	CL = 20 pF, See Figure 1	-40°C		39			59	V/ms	
l		VI(PP) = 1 V,	Gee i igule i	85°C	25			34			
Vn	Equivalent input noise voltage	f = 1 kHz,	R _S = 20 Ω	25°C		68		68			nV/√Hz
		C _L = 20 pF,	See Figure 2	25°C		85			110		
B ₁	Unity-gain bandwidth			-40°C		130			155		
				85°C		55			80		
	,	C _L = 20 pF,	See Figure 2	25°C		34°			38°	· ·	
φm	Phase margin at unity gain			-40°C		38°			40°		
				85°C		28°			32°		

operating characteristics at specified free-air temperature

1	PARAMETER	TEST CO	TA	V _{DD} = 5 V			V _{DD} = 10 V			UNIT					
				MIN	TYP	MAX	MIN TYP		MAX						
				25°C		32			47						
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $V_{I(PP)} = 1 V$,		-40°C		39			59		V/ms				
			See rigule r	85°C	25			34							
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	25°C		68		68		nV/√Hz					
		C _L = 20 pF,	See Figure 2	25°C		85			110						
B ₁	Unity-gain bandwidth			-40°C	130 155					kHz					
		1		85°C		55			80						
		C _L = 20 pF,						25°C		34°			38°		
φm	Phase margin at unity gain		See Figure 2	-40°C		38°			42°						
				85°C		28°			32°						

TLC1078, TLC1078Y, TLC1079, TLC1079Y LinCMOS™ μPOWER PRECISION OPERATIONAL AMPLIFIERS SLOS179 - FEBRUARY 1997

electrical characteristics at specified operating free-air temperature

						TLC1	078M			
	PARAMETER	TEST	T _A †	V	DD = 5 \	7	V	DD = 10	v	UNIT
		CONDITIONS		MIN	TYP	MAX	MIN	TYP	MAX	
\/		V _O = 1.4 V,	25°C		160	450		180	600	μV
V _{IO}	Input offset voltage	V _{IC} = 0,	Full range			1250			1400	μν
αVIO	Temperature coefficient of input offset voltage	$R_S = 50 \Omega$, $R_L = 1 M\Omega$	25°C to 125°C		1.4			1.4		μV/°C
1	Input offset current		25°C		0.1			0.1		pА
110	(see Note 4)	$V_O = V_{DD}/2$	125°C		1.4	15		1.8	15	nA
l	Input bias current	$V_{IC} = V_{DD}/2$	25°C		0.6			0.7		pΑ
IB	(see Note 4)		125°C		9	35		10	35	nA
VICR	Common-mode input		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		٧
VICH	voltage range (see Note 5)		Full range	0 to 3.5			0 to 8.5			٧
	High-level output voltage		25°C	3.2	4.1		8.2	8.9		
Vон		$V_{ID} = 100 \text{ mV},$ $R_I = 1 \text{ M}\Omega$	−55°C	3.2	4.1		8.2	8.8		V
		11[-11022	125°C	3.2	4.2		8.2	9		
	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 0	25°C		0	25		0	25	mV
VOL			−55°C		0	25		0	25	
			125°C		0	25		0	25	
	1 1 196	2 4440	25°C	250	525		500	850		
AVD	Large-signal differential voltage amplification	R _L = 1 MΩ , See Note 6	−55°C	250	950		500	1750		V/mV
	ronago ampimoadon	000 11010 0	125°C	35	200		75	380		
,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			25°C	70	95		75	97		
CMRR	Common-mode rejection ratio	VIC = VICRmin	−55°C	70	95		75	97		dB
			125°C	70	85		75	91		
,			25°C	75	98		75	98		
ksvr	Supply-voltage rejection ratio (ΔVDD/ΔVIO)	V _O = 1.4 V	−55°C	70	98		70	98		dB
	(7 A DID 17 A IO)		125°C	70	98		70	98		
		V _O = V _{DD} / 2,	25°C		20	34		29	46	
IDD	Supply current (two amplifiers)	$V_{IC} = V_{DD}/2$	−55°C		35	60		56	96	μΑ
	/	No load	125°C		14	24		18	30	1

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.

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electrical characteristics at specified free-air temperature

						TLC1	079M			
	PARAMETER	TEST CONDITIONS	TA [†]	V	DD = 5 \	,	V	DD = 10	٧	UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
			25°C		190	850		200	1150	.,
VIO	Input offset voltage	V _O = 1.4 V, V _{IC} = 0,	Full range	<u> </u>	***************************************	1600			1900	μV
αVIO	Temperature coefficient of input offset voltage	$R_S = 50 \Omega$, $R_I = 1 M\Omega$	25°C to 125°C		1.4			1.4		μV/°C
	Input offset current		25°C		0.1			0.1		pΑ
lo '	(see Note 4)	V _O = V _{DD} /2,	125°C		1.4	15		1.8	15	nA
	Input bias current	V _{IC} = V _{DD} /2	25°C		0.6			0.7		pΑ
lB.	(see Note 4)		125°C		9	35		10	35	nA
	Common mode input		25°C	0 to 4	-0.3 to 4.2		0 to 9	-0.3 to 9.2		٧
VICR	voltage range (see Note 5)		Full range	0 to 3.5			0 to 8.5			٧
			25°C	3.2	4.1		8.2	8.9		
۷он	High-level output voltage	$V_{ID} = 100 \text{ mV},$ $R_{I} = 1 \text{ M}\Omega$	-55°C	3.2	4.1		8.2	8.9		V
			125°C	3.2	4.2		8.2	9		
			25°C		0	25		0	25	
V_{OL}	Low-level output voltage	$V_{ID} = -100 \text{ mV},$ $I_{OI} = 0$	−55°C		0	25		0	25	mV
		IOL = 0	125°C		0	25		0	25	
			25°C	250	525		500	850		
AVD	Large-signal differential voltage amplification	$R_L = 1 M\Omega$, See Note 6	−55°C	250	950		500	1750		V/mV
	voltage amplification		125°C	35	200		75	380		
			25°C	70	95		75	97		
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min	−55°C	70	95		75	97		dB
	i i		125°C	70	85		75	91		
			25°C	75	98		75	98		
ksvr	Supply voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 5 V to 10 V, V _O = 1.4 V	−55°C	70	98		70	98		dB
		10	125°C	70	98		70	98		
	Commission and	V- V /0	25°C		40	68		57	92	
DD	Supply current (four amplifiers)	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	−55°C		69	120		111	192	μΑ
	/ annipilitato/	,	125°C		27	48		35	60	

† Full range is -55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

6. At $V_{DD} = 5 \text{ V}$, $V_{O} = 0.25 \text{ V}$ to 2 V; at $V_{DD} = 10 \text{ V}$, $V_{O} = 1 \text{ V}$ to 6 V.

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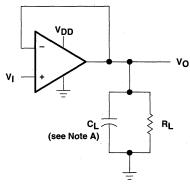
operating characteristics at specified free-air temperature

		TEST CONDITIONS		TA											
Ì	PARAMETER				V _{DD} = 5 V			V _{DD} = 10 V			UNIT				
				MIN	TYP	MAX	MIN	TYP	MAX						
		D 4440	0 00 5	25°C		32			47						
SR	Slew rate at unity gain	$R_L = 1 M\Omega$, $V_{VDD} = 1 V$	C _L = 20 pF, See Figure 1	−55°C		41			63		V/ms				
İ		VI(PP) = 1 V,	oce i igule i	125°C		20		27							
٧n	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	25°C	i	68			68		nV/√Hz				
	Unity-gain bandwidth	C _L = 20 pF,	See Figure 2	25°C		85			110						
B ₁				−55°C		140		165			kHz				
ļ				125°C		45			70						
		C _L = 20 pF,						25°C		34°			38°		
φm	Phase margin at unity gain		See Figure 2	−55°C		39°			43°						
ļ				125°C		25°			29°						

operating characteristics at specified free-air temperature

		TEST CONDITIONS		TA							
1	PARAMETER				V _{DD} = 5 V			V _{DD} = 10 V			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
				25°C		32			47		
SR	Slew rate at unity gain	$R_L = 1 M\Omega$,	C _L = 20 pF, See Figure 1	−55°C		41			63		V/ms
		V(PP) = VV	See rigure r	125°C		20			27		
Vn	Equivalent input noise voltage	f = 1 kHz,	$R_S = 20 \Omega$	25°C		68			68		nV/√Hz
			See Figure 2	25°C		85			110		
Ь.	Unity agin bandwidth			−55°C		140			165		
B ₁	Unity-gain bandwidth	C _L = 20 pF,		125°C		45			70		kHz
				25°C		34°			38°		KΠZ
	Dhana marain at unity asin	C: 00 = E	0 F: 0	−55°C		39°			43°		
φm	Phase margin at unity gain	$C_L = 20 pF$,	See Figure 2	125°C		25°			29°		

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew-Rate Test Circuit

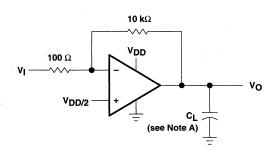


Figure 2. Unity-Gain Bandwidth and **Phase-Margin Test Circuit**

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TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
ανιο	Temperature coefficient of input offset voltage	Distribution	3-6
l _{IB}	Input bias current	vs Free-air temperature	7
lιο	Input offset current	vs Free-air temperature	7
VIС	Common-mode input voltage	vs Supply voltage	8
Vон	High-level output voltage	vs High-level output current vs Supply voltage vs Free-air temperature	9, 10 11 12
V _{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	13, 14 15 16 17, 18
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	19 20 21, 22
Vом	Maximum peak output voltage	vs Frequency	23
lDD	Supply current	vs Supply voltage vs Free-air temperature	24 25
SR	Slew rate	vs Supply voltage vs Free-air temperature	26 27
	Normalized slew rate	vs Free-air temperature	28
Vn	Equivalent input noise voltage	vs Frequency	29
В1	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	30 31
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Capacitance load	32 33 34
	Phase shift	vs Frequency	21, 22

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC1078 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

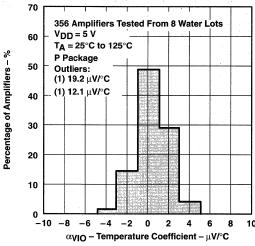


Figure 3

DISTRIBUTION OF TLC1079 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

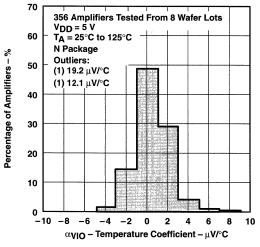


Figure 5

DISTRIBUTION OF TLC1078 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

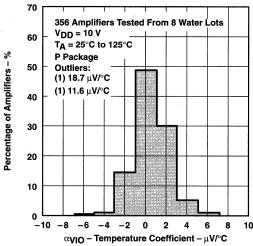


Figure 4

DISTRIBUTION OF TLC1079 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

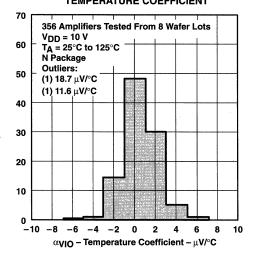
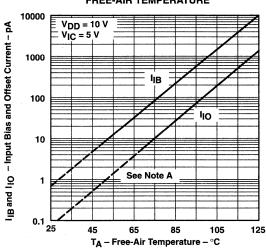


Figure 6

Percentage of Amplifiers – %

TYPICAL CHARACTERISTICS

INPUT BIAS AND OFFSET CURRENT† vs FREE-AIR TEMPERATURE



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 7

HIGH-LEVEL OUTPUT VOLTAGE^{†‡} vs HIGH-LEVEL OUTPUT CURRENT

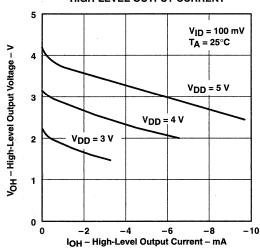


Figure 9

COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT vs

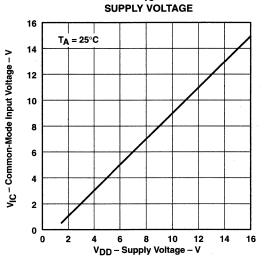
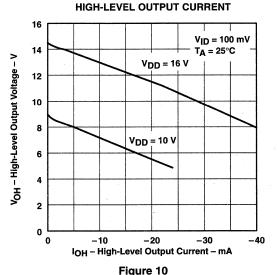


Figure 8

HIGH-LEVEL OUTPUT VOLTAGE vs

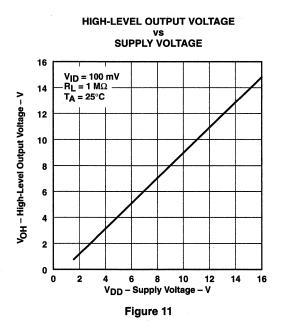


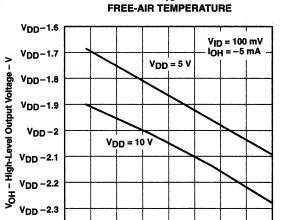
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. † The V_{DD} = 3 V curve does not apply to the TLC107xM.

TYPICAL CHARACTERISTICS

V_{DD} -2.4 -75

-50 -25





HIGH-LEVEL OUTPUT VOLTAGE†

Figure 12

0

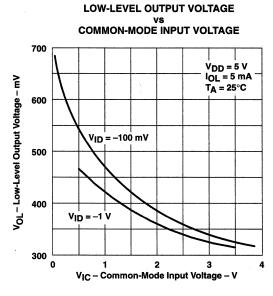


Figure 13

LOW-LEVEL OUTPUT VOLTAGE **COMMON-MODE INPUT VOLTAGE**

25

TA - Free-Air Temperature - °C

50 75 100 125

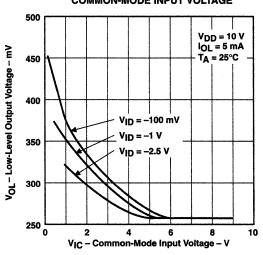
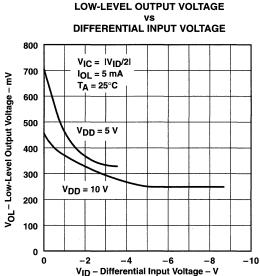


Figure 14

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



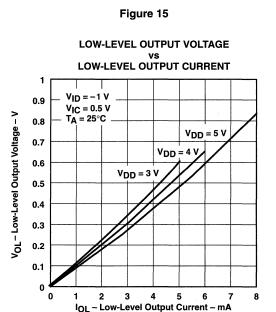


Figure 17

LOW-LEVEL OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE

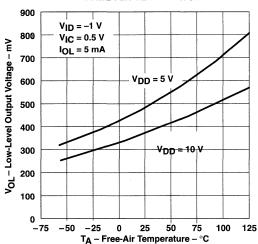


Figure 16

LOW-LEVEL OUTPUT VOLTAGE

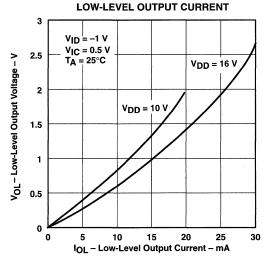
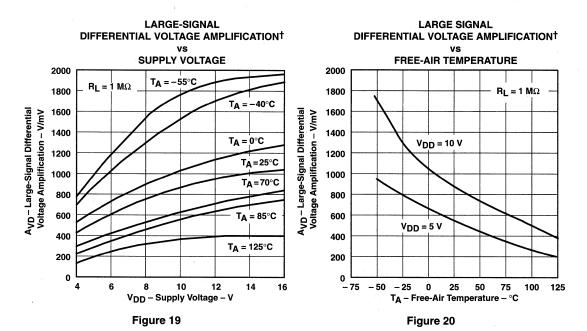


Figure 18

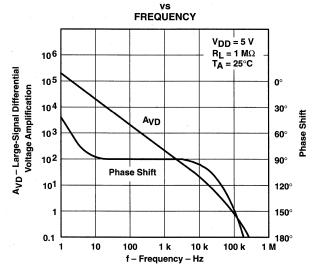
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 21

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

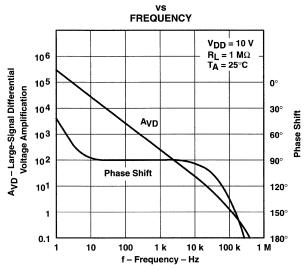
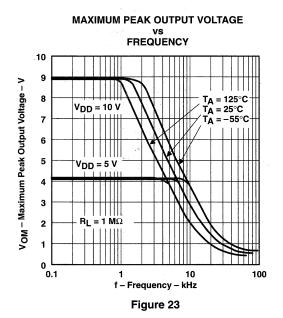
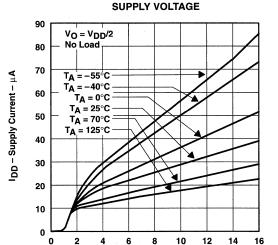


Figure 22





V_{DD} - Supply Voltage - V

Figure 24

SUPPLY CURRENT[†]

vs

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS

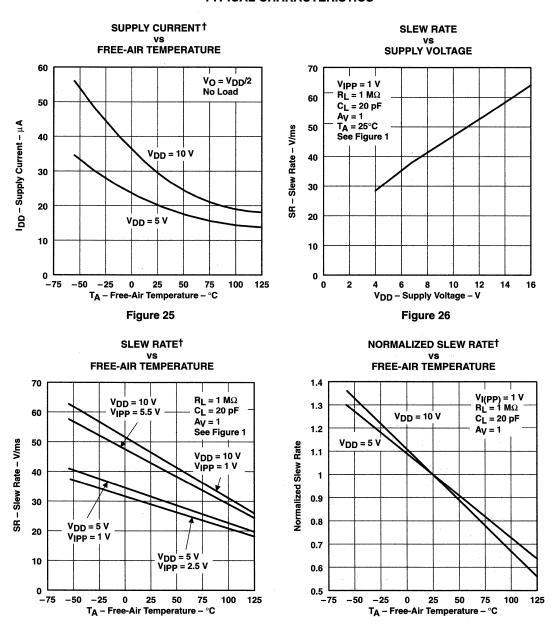


Figure 28

Figure 27



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 32

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TYPICAL CHARACTERISTICS

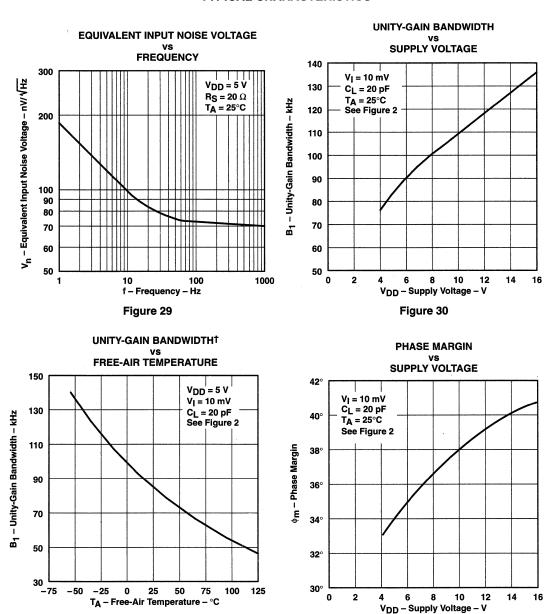
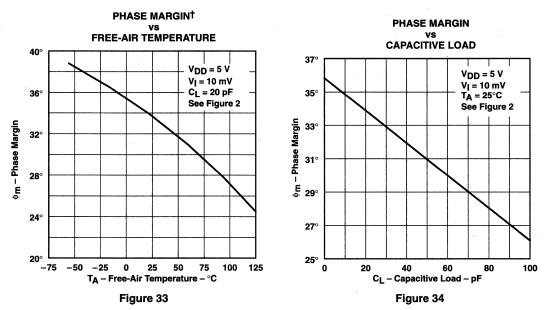


Figure 31



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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- B Grade Is 100% Tested for Noise 30 nV/√Hz Max at f = 10 Hz 12 nV/√Hz Max at f = 1 kHz
- Low Input Offset Voltage . . . 500 μV Max
- Excellent Offset Voltage Stability
 With Temperature . . . 0.5 μV/°C Typ
- Rail-to-Rail Output Swing

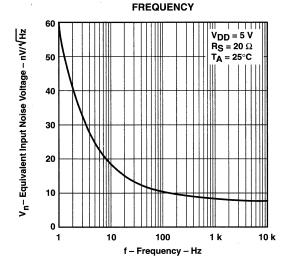
description

The TLC220x, TLC220xA, TLC220xB, and TLC220xY are precision, low-noise operational amplifiers using Texas Instruments Advanced LinCMOS™ process. These devices combine the noise performance of the lowest-noise JFET amplifiers with the dc precision available previously only in bipolar amplifiers. The Advanced LinCMOS™ process uses silicon-gate technology to obtain input offset voltage stability with temperature and time that far exceeds that obtainable using metal-gate technology. In addition, this technology makes possible input impedance levels that meet or exceed levels offered by top-gate JFET and expensive dielectric-isolated devices.

The combination of excellent dc and noise performance with a common-mode input voltage range that includes the negative rail makes these devices an ideal choice for high-impedance, low-level signal-conditioning applications in either single-supply or split-supply configurations.

- Low Input Bias Current
 1 pA Typ at T_A = 25°C
- Common-Mode Input Voltage Range Includes the Negative Rail
- Fully Specified For Both Single-Supply and Split-Supply Operation

TYPICAL EQUIVALENT INPUT NOISE VOLTAGE vs



The device inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up. In addition, internal ESD-protection circuits prevent functional failures at voltages up to 2000 V as tested under MIL-PRF-38535, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in degradation of the parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

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TLC2201 AVAILABLE OPTIONS

		V	V		PACKAGE	DEVICES		CHIP
TA	V _{IO} max AT 25°C	V _n max f = 10 Hz AT 25°C	V _n max f = 1 kHz AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	FORM‡ (Y)
0°C to 70°C	200 μV 200 μV 500 μV	35 nV/√Hz 30 nV/√Hz —	15 nV/√Hz 12 nV/√Hz —	TLC2201ACD TLC2201BCD TLC2201CD	_		TLC2201ACP TLC2201BCP TLC2201CP	TLC2201Y
-40°C to 85°C	200 μV 200 μV 500 μV	35 nV/√Hz 30 nV/√Hz —	15 nV/√Hz 12 nV/√Hz —	TLC2201AID TLC2201BID TLC2201ID	_		TLC2201AIP TLC2201BIP TLC2201IP	_
-55°C to 125°C	200 μV 200 μV 500 μV	35 nV/√Hz 30 nV/√Hz —	15 nV/√Hz 12 nV/√Hz —	TLC2201AMD TLC2201BMD TLC2201MD	TLC2201AMFK TLC2201BMFK TLC2201MFK	TLC2201AMJG TLC2201BMJG TLC2201MJG	TLC2201AMP TLC2201BMP TLC2201MP	

[†] The D packages are available taped and reeled. Add R suffix to device type (e.g. TLC220xBCDR).

TLC2202 AVAILABLE OPTIONS

					PACKAGEI	D DEVICES	<u> </u>	0.115
TA	V _{IO} max AT 25°C	V _n max f = 10 Hz AT 25°C	V _n max f = 1 kHz AT 25°C	SMALL OUTLINE† (D)	OUTLINE† CARRIER		PLASTIC DIP (P)	CHIP FORM [‡] (Y)
0°C to 70°C	500 μV 500 μV 1 mV	30 nV/√Hz 35 nV/√Hz —	12 nV/√Hz 15 nV/√Hz —	TLC2202BCD TLC2202ACD TLC2202CD		<u>-</u>	TLC2202BCP TLC2202ACP TLC2202CP	TLC2202Y
-40°C to 85°C	500 μV 500 μV 1 mV	30 nV/√Hz 35 nV/√Hz —	12 nV/√Hz 15 nV/√Hz —	TLC2202BID TLC2202AID TLC2202ID	_ _ _	_ _ _	TLC2202BIP TLC2202AIP TLC2202IP	_
-55°C to 125°C	500 μV 500 μV 1 mV	30 nV/√ Hz 35 nV/√ Hz —	12 nV/√Hz 15 nV/√Hz —	TLC2202BMD TLC2202AMD TLC2202MD	TLC2202BMFK TLG2202AMFK TLC2202MFK	TLC2202BMJG TLC2202AMJG TLC2202MJG	TLC2202BMP TLC2202AMP TLC2202MP	_

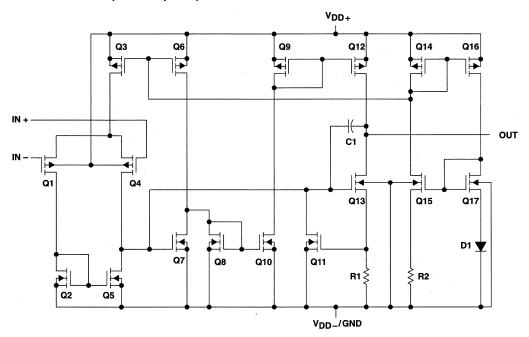
[†] The D packages are available taped and reeled. Add R suffix to device type (e.g. TLC220xBCDR). ‡ Chip forms are tested at 25°C only.

[‡] Chip forms are tested at 25°C only.

TLC2202 TLC2201 TLC2202 D. JG. OR P PACKAGE JG OR P PACKAGE **D PACKAGE** (TOP VIEW) (TOP VIEW) (TOP VIEW) 14 NC 8 NC 8 V_{DD+} NC NC [10UT [NC[] 2 13 NC IN− **1** 2 7 V_{DD+} 1IN-[2 7 1 20UT 10UT[] 3 IN+ **[**] 3 6 OUT 1IN+[]3 6 2IN-12 V_{DD+} V_{DD}_/GND ∄ V_{DD}_/GND ∏ 1IN-[] 4 11 20UT 5 NC 5 2IN+ 1IN+[10 2IN-V_{DD}_/GND 6 9 2IN+ 8] NC TLC2201 FK PACKAGE (TOP VIEW) TLC2202 FK PACKAGE (TOP VIEW) NC 10UT 2222 2 G NC NC 3 2 1 20 19 NC | 18∏ NC 5 IN-17 V_{DD+} 17 20UT 1IN-NC 6 NC 16 NC 6 1IN+ 7 16**∏** NC IN+ OUT Π7 15П 15 2IN-NC NC 14 10 11 12 13 NC 18 14**☐** NC 9 10 11 12 13 O O O O NC THE VDD

NC - No internal connection

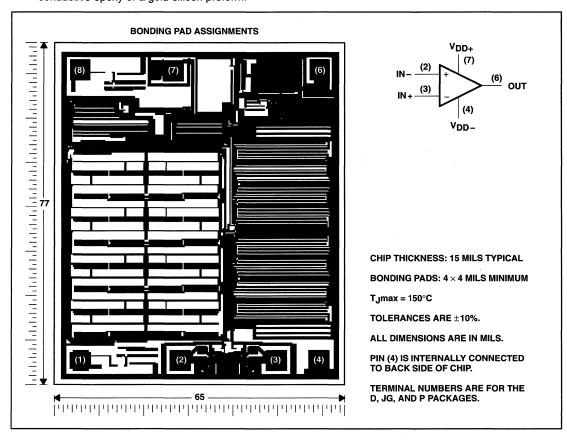
equivalent schematic (each amplifier)



ACTUAL DEV	ACTUAL DEVICE COMPONENT COUNT										
COMPONENT	TLC2201	TLC2202									
Transistors	17	34									
Resistors	2	2									
Diodes	1	4									
Capacitors	1	2									

TLC2201Y chip information

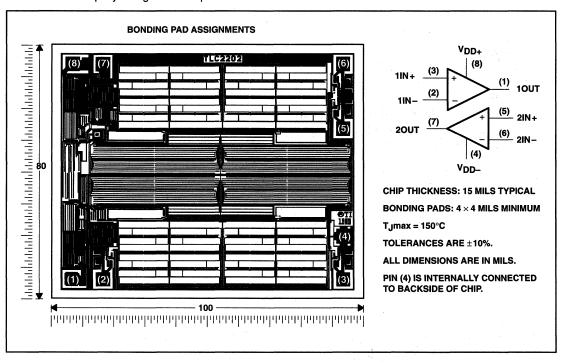
This chip, when properly assembled, displays characteristics similar to the TLC2201C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding path. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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TLC2202Y chip formation

This chip, when properly assembled, displays characteristics similar to the TLC2202C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+} (see Note 1)	8 V
Supply voltage, V _{DD}	8 V
Differential input voltage, V _{ID} (see Note 2)	±16 V
Input voltage, V _I (any input)	
Input current, I _I (each input)	±5 mA
Output current, IO (each output)	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T_A : C suffix	
I suffix	–40°C to 85°C
M suffix	–55°C to 125°C
Storage temperature range	65°C to 150°C
Case temperature for 60 seconds: FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P page	ckage 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	•

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values except differential voltages are with respect to the midpoint between VDD+ and VDD-.
 - 2. Differential voltages are at IN+ with respect to IN-.
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating in not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

	С	SUFFIX	15	SUFFIX	M SUFFIX		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	ONII
Supply voltage, V _{DD} ±	±2.3	±8	±2.3	±8	±2.3	±8	٧
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} -2.3	V _{DD} _	V _{DD+} -2.3	V _{DD} -	V _{DD+} -2.3	٧
Operating free-air temperature, TA	0	70	-40	85	-55	125	°C

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TLC2201C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED		DITIONS	_ +	T	LC22010	2	UNIT	
	PARAMETER	TEST CON	DITIONS	T _A †	MIN	TYP	MAX	UNII	
Via	Input offset voltage			25°C		100	500	μV	
VIO	input onset voltage			Full range			600	μν	
αVIO	Temperature coefficient of input offset voltage			Full range		0.5		μV/°C	
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.001	0.005	μV/mo	
lio	Input offset current	VIC = 0,	ng = 30 12	25°C		0.5		рA	
liO	input onset current			Full range			100	PΑ	
I _{IB}	Input bias current			25°C		1		рA	
'IB	input bias current			Full range			100	PΛ	
VICR	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	-5 to 2.7			v	
W.	Marian and the same and the sam			25°C	4.7	4.8		v	
VOM+	Maximum positive peak output voltage swing	D: 1010		Full range	4.7			<u> </u>	
Vou	Maximum negative peak output voltage swing	R _L = 10 kΩ		25°C	-4.7	-4.9		V	
V _{OM} -	waximum negative peak output voltage swing			Full range	-4.7				
		$V_0 = \pm 4 \text{ V},$	$R_I = 500 \text{ k}\Omega$	25°C	400	560			
AVD	Large-signal differential voltage amplification	VO = ±4 V,	11[= 300 kgz	Full range	300			V/mV	
/\vD	Large signal differential voltage arripinication	$V_O = \pm 4 \text{ V},$	$R_I = 10 \text{ k}\Omega$	25°C	90	100		Ville	
		VO = ± + V,	11L = 10 K22	Full range	70				
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,	Full range	85			dB	
kove	Supply voltage rejection ratio (AVI =/AVI =)	V== +0.3 V +		25°C	90	110		dB	
ksvr	Supply voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD\pm} = \pm 2.3 \text{ V to } \pm 8 \text{ V}$		Full range	85			uВ	
Inn	Supply current	$V_{\Omega} = 0$, No load		25°C		1.1	1.5	mA	
IDD	очррну синени	V _O = 0,	INO IDAU	Full range			1.5	111/4	

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

DADAMETED	TEST COMPITIONS	T. +	TL	C2201C		UNIT
PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	UNIT
Class rate at units rain	$V_O = \pm 2.3 \text{ V}, R_L = 10 \text{ k}\Omega,$	25°C	2	2.7		V/us
Siew rate at unity gain	C _L = 100 pF	Full range	1.5	5 18 8	V/μs	
Equippolant input poins voltage	f = 10 Hz	25°C		18		->4/1
Equivalent input noise voltage	f = 1 kHz	25°C	8		nV/√Hz	
Dools to mode assistated in the size of the size	f = 0.1 to 1 Hz	25°C		0.5		
reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μν
Equivalent input noise current		25°C		0.6		fA/√Hz
Gain-bandwidth product		25°C		1.9		MHz
Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°		
	Gain-bandwidth product	Slew rate at unity gain	Slew rate at unity gain	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Slew rate at unity gain	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

† Full range is 0°C to 70°C.



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TLC2201C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEOT 00	NDITIONS	- +	TL	C2201/	AC .	TL	C2201	ВС		
	PARAMETER	IESI CO	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
\/.o	Input offset voltage			25°C		80	200		80	200		
VIO	Input offset voltage			Full range			300			300	μV	
αΛΙΟ	Temperature coefficient of input offset voltage			Full range		0.5			0.5		μV/°C	
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.001	0.005		0.001	0.005	μV/mo	
l.o	Input offset current			25°C		0.5			0.5		рA	
ΙΟ	input onset current			Full range			100			100	pΑ	
l _{IB}	Input bias current			25°C		1			1		рA	
אוי	input bias current			Full range			100			100	pΑ	
V _{ICR}	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	-5 to 2.7			-5 to 2.7			٧	
V _{OM+}	Maximum positive peak output				4.7	4.8		4.7	4.8		V	
VOM+	voltage swing	R _I = 10 kΩ		Full range	4.7			4.7			1 '	
V _{OM} -	Maximum negative peak output	NL = 10 K22		25°C	-4.7	-4.9		-4.7	-4.9		v	
VOM-	voltage swing			Full range	-4.7			-4.7			V	
		Vo = +4 V	$R_1 = 500 \text{ k}\Omega$	25°C	400	560		400	560			
AVD	Large-signal differential voltage	VO = ± + v,	11L = 300 K22	Full range	300			300			V/mV	
~VD	amplification	Vo = +4 V	$R_I = 10 \text{ k}\Omega$	25°C	90	100		90	100		V/111V	
		VO = ± + v,	11[- 10 K32	Full range	70			70				
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} r	min,	25°C	90	115		90	115		dB	
		$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	85			85			uD.	
ksvr	Supply voltage rejection ratio	Vpp + = +2	3 V to +8 V	25°C	. 90	110		90	110		dB	
ovH	(ΔV _{DD±} /ΔV _{IO})	* DD ± - ±2.	$V_{DD\pm} = \pm 2.3 \text{ V to } \pm 8 \text{ V}$		85			85			uD	
IDD	Supply current	V _O = 0, No load		25°C		1.1	1.5		1.1	1.5	1.5 mA	
-טט	Cappy carron	10 = 0,		Full range			1.5			1.5		

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

PARAMETER		TEST CONDITIONS	- +	TLC2201AC			TL	C2210E	BC .		
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	$V_0 = \pm 2.3 \text{ V}, R_L = 10 \text{ k}\Omega,$	25°C	2	2.7		2	2.7		V/μs	
51	Siew rate at unity gain	C _L = 100 pF	Full range	1.5			1.5			ν/μδ	
v _n	Equivalent input noise volt-	f = 10 Hz	25°C		18	35		18	30	->4//	
	age (see Note 5)	f = 1 kHz	25°C		8	15		8	12	nV/√Hz	
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		μ۷	
VN(PP)	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7			
In	Equivalent input noise current	1	25°C		0.6			0.6		fA/√Hz	
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz	
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°			48°			

† Full range is 0°C to 70°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2201C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	TEOT COMP	UTIONO	- +	TI	C22010	2	UNIT	
	PARAMETER	TEST COND	ITIONS	TA [†]	MIN	TYP	MAX	UNII	
V. a	Input offset voltege			25°C		100	500	μV	
V _{IO}	Input offset voltage			Full range			600	μν	
ανιο	Temperature coefficient of input offset voltage	1		Full range		0.5		μV/°C	
	Input offset voltage long-term drift (see Note 4)],, ,	D- 500	25°C		0.001	0.005	μV/mo	
1	Innut offeet surrent	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.5		- 1	
ΙΟ	Input offset current	:	;	Full range			100	pΑ	
L	land bin a summa			25°C		1		^	
lВ	Input bias current			Full range			100	pΑ	
					0				
VICR	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	to 2.7			V	
.,		D. 1010		25°C	4.7	4.8		V	
VOH	Maximum high-level output voltage	$R_L = 10 \text{ k}\Omega$		Full range	4.7			ľ	
.,				25°C		0	50	.,	
VOL	Maximum low-level output voltage	IO = 0		Full range			50	mV	
		$V_{O} = 1 \text{ V to 4 V},$		25°C	150	315			
۸	Louis simple differential values as amplification	$R_L = 500 \text{ k}\Omega$		Full range	100			V/mV	
AVD	Large-signal differential voltage amplification	$V_{O} = 1 \text{ V to 4 V},$		25°C	25	55		V/IIIV	
		$R_L = 10 \text{ k}\Omega$		Full range	15				
CMRR	Common mode valenties vetic	V _{IC} = V _{ICB} min,	V _O = 0,	25°C	90	110		٩D	
CIVINN	Common-mode rejection ratio	$R_S = 50 \Omega$		Full range	85			dB	
kove	Supply voltage rejection ratio (AV) = (AV) =	V== 46 V to 10	2 \/	25°C	90	110		dB	
ksvr	Supply voltage rejection ratio $(\Delta V_{DD\pm}/\Delta V_{IO})$	V _{DD} = 4.6 V to 16 V		Full range	85			uБ	
la a	Supply gurrent	Va - 2 5 V	No load	25°C		1	1.5	m A	
IDD	Supply current	$V_{O} = 2.5 \text{ V},$	INO IDAU	Full range			1.5	mA	

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201C operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CONDITIONS	- +	TL	C2201C	;	UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	V _O = 0.5 V to 2.5 V,	25°C	1.8	2.5		V/µs
J Sh	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.3			V/μS
V	Equivalent input noise voltage	f = 10 Hz	25°C		18		->4//
Vn	Equivalent input noise voltage	f = 1 kHz	25°C		8		nV/√Hz
V	Dook to pook assistated input point valence	f = 0.1 to 1 Hz	25°C		0.5		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μV
In	Equivalent input noise current		25°C		0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.8		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		45°		

† Full range is 0°C to 70°C.

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TLC2201C electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEGT CONDITIONS	-+	TL	C2201	VC.	TL	.C2201E	3C	
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage		25°C		80	200		80	200	μV
VIO			Full range			300			300	μν
ανιο	Temperature coefficient of input offset voltage		Full range		0.5		1	0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.001	0.005		0.001	0.005	μV/mo
lio	Input offset current	1	25°C		0.5			0.5		рA
10]	Full range			100			100	PA
Iв	Input bias current		25°C		1			1		рA
מוי	mpat bias carrent		Full range			100			100	PA
V _{ICR}	Common-mode input voltage range	$R_S = 50 \Omega$	Full range	0 to 2.7			0 to 2.7			v
Vон	Maximum high-level output	$R_I = 10 \text{ k}\Omega$	25°C	4.7	4.8		4.7	4.8		v
VOH	voltage	11L = 10 K32	Full range	4.7			4.7			· ·
VOL	Maximum low-level output	IO = 0	25°C		0	50		0	50	mV
VOL.	voltage	10 - 0	Full range			50			50	
		$V_0 = 1 V \text{ to } 4 V,$	25°C	150	315		150	315		l
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$	Full range	100			100			V/mV
/ VD	voltage amplification	$V_0 = 1 \text{ V to 4 V},$	25°C	25	55		25	55		V/////
	<u> </u>	R _L = 10 kΩ	Full range	15			15			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$	25°C	90	110		90	110		dB
J.,,, a. ($V_O = 0$, $R_S = 50 \Omega$	Full range	85			85			
ksvr	Supply voltage rejection ratio	V _{DD} = 4.6 V to 16 V	25°C	90	110		90	110		dB
ייסעוו	(ΔV _{DD±} /ΔV _{IO})	100 = 4.0 V to 10 V	Full range	85			85			45
I _{DD}	Supply current	V _O = 2.5 V, No load	25°C		1	1.5		1	1.5	mA
יטט.	Capp., odnone	1 0 = 2.0 V, 140 10au	Full range	1		1.5			1.5	''''

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201C operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CONDITIONS	- +	TL	C2201A	C	TL	C2210E	C	
	PARAMETER	TEST CONDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V _O = 0.5 V to 2.5 V,	25°C	1.8	2.5		1.8	2.5		V/us
J.	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.3			1.3			ν/μδ
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
Vn	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	nv/vHz
Varian	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product		25°C		1.8			1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		45°			45°		

† Full range is 0°C to 70°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2202C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	PARAMETER	TECT C	CONDITIONS	T. +	Т	LC22020	:	UNIT
	PARAMETER	IESIC	CHDITIONS	TΑ [†]	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		100	1000	μV
VIO	input onset voitage	V 0	$R_S = 50 \Omega$	Full range			1150	μν
ανιο	Temperature coefficient of input offset voltage	V _{IC} = 0,	ng = 50 12	Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.001	0.005	μV/mo
	langut offeet europa			25°C		0.5		
ΙO	Input offset current	\/- 0	D- 50.0	Full range			100	1
1	land bigs summer	$V_{IC} = 0$, $R_S = 50 \Omega$		25°C		1		рA
lΒ	Input bias current			Full range			100	
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			٧
				25°C	4.7	4.8		
VOM+	Maximum positive peak output voltage swing			Full range	4.7			v
		$R_L = 10 \text{ k}\Omega$		25°C	-4.7	-4.9		
VOM-	Maximum negative peak output voltage swing			Full range	-4.7			V
			B 500 l-0	25°C	300	560		
Δ	l avec cional differential college and life ation	$V_0 = \pm 4 V$	$R_L = 500 \text{ k}\Omega$	Full range	200			\//\/
AVD	Large-signal differential voltage amplification	V 1437	B 401:0	25°C	50	100		V/mV
		$V_O = \pm 4 V$	$R_L = 10 \text{ k}\Omega$	Full range	25			
CMDD	Comment was a street water	$V_{O} = 0$,	V _{IC} = V _{ICB} min,	25°C	80	115		dB
CMRR	Common-mode rejection ratio	$R_S = 50 \Omega$, , , , ,	Full range	80			aв
ka=	Cumply voltage rejection ratio (AVI (AVI)	V 10	2.1/+0.1-0.1/	25°C	80	110		٩D
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD\pm} = \pm 2.3$	3 V 10 ±8 V	Full range	80			dB
1	Cumply current	V- 0	Noteed	25°C		1.8	2.7	^
IDD	Supply current	V _O = 0,	No load	Full range			2.7	mA

[†] Full range is 0°C to 70°C.

TLC2202C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	DADAMETED	TEGT GOL	IDITIONS	- +	TL	C22020	;	LINUT
	PARAMETER	TEST CON	IDITIONS	T _A †	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = \pm 2.3 V$,	$R_L = 10 \text{ k}\Omega$,	25°C	1.8	2.7		V/µs
OIT	olew rate at unity gain	C _L = 100 pF		Full range	1.3			ν /μ5
V _n	Equivalent input noise voltage	f = 10 Hz		25°C		18		nV/√Hz
٧n	Equivalent input hoise voltage	f = 1 kHz		25°C		8		ΠV/∀HZ
Varian	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		25°C		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		0.7		μν
In	Equivalent input noise current			25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	25°C		48°		

[†] Full range is 0°C to 70°C.



NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEST OF	NDITIONS	T. †	TL	C2202/	AC .	TL	C2202E	3C	UNIT
	PARAMETER	I IESI CO	INDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		80	500		80	500	μV
*10				Full range			650			650	μν
αVIO	Temperature coefficient of input offset voltage	V _{IC} = 0,	$R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.001	0.005		0.001	0.005	μV/mo
Iю	Input offset current			25°C		0.5			0.5		рA
טוי	mput onset current	V _{IC} = 0,	$R_S = 50 \Omega$	Full range			100			100	PΛ
lıB	Input bias current	1 VIC = 0,	118 = 30 22	25°C		1			1		рA
цВ	mpat blas current			Full range			100			100	PΛ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	-5 to 2.7			-5 to 2.7			٧
V	Maximum positive peak			25°C	4.7	4.8		4.7	4.8		V
V _{OM+}	output voltage swing	$R_1 = 10 \text{ k}\Omega$		Full range	4.7			4.7			V
V _{OM} -	Maximum negative peak	111 - 10 132		25°C	-4.7	-4.9		-4.7	-4.9		V
*OIVI-	output voltage swing			Full range	-4.7			-4.7			·
		Vo = +4 V.	$R_I = 500 \text{ k}\Omega$	25°C	300	560		300	560		
AVD	Large-signal differential	-0 - 1 1		Full range	200			200			V/mV
VD	voltage amplification	VO = +4 V.	$R_{I} = 10 \text{ k}\Omega$	25°C	50	100		50	100		
				Full range	25			25			
CMRR	Common-mode rejection ratio	VIC = VICR		25°C	80	115		80	115		dB
		$V_{O} = 0,$	$R_S = 50 \Omega$	Full range	80			80			
ksvr	Supply-voltage rejection ratio	$V_{DD+} = \pm 2.3$	3 V to ±8 V	25°C	80	110		80	110		dB
5011	(ΔV _{DD±} /ΔV _{IO})	JU:		Full range	80			80			
lpp	Supply current	$V_{O} = 0$	No load	25°C		1.8	2.7		1.8	2.7	mA
50		1		Full range			2.7			2.7	

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CONDITIONS	T. †	TL	C2202/	C	TL	C2202E	C	UNIT
	PARAMETER	I EST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
CD.	Olavi vata at inciti sacia	$V_0 = \pm 2.3 \text{ V},$	25°C	1.8	2.7		1.8	2.7		Miss
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.3			1.3			V/μs
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
V _n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	nv/√Hz
VALCED	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV
VN(PP)	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°			48°		

† Full range is 0°C to 70°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TLC2202C electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS	T.+	Т	LC22020	3	UNIT
	PARAMETER	TEST CONDITIONS	TA [†]	MIN	TYP	MAX	UNII
\/	Innut offeet veltege		25°C		100	1000	μV
VIO	Input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			1150	μν
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005	μV/mo
lio	Input offset current		Full range			100	
lın	Input bias current	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		1		pА
IB	input bias current		Full range			100	
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			٧
V	Maximum high-level output voltage	R _I = 10 kΩ	25°C	4.7	4.8		V
VOH	waximum nign-ievel output voitage	U[= 10 K75	Full range	4.7			V
VOL	Maximum low-level output voltage	IO = 0	25°C		0	50	mV
VOL	waximum low-level output voltage	10 = 0	Full range			50	1110
		V _O =1 V to 4 V,	25°C	150	315		
Λ.σ	Large-signal differential voltage amplification	$R_L = 500 \text{ k}\Omega$	Full range	100			V/mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V////V
		$R_L = 10 \text{ k}\Omega$	Full range	15			
CMRR	Common-mode rejection ratio	$V_O = 0$, $V_{IC} = V_{ICR}min$,	25°C	75	110		dB
CIVILL	Common-mode rejection ratio	$R_S = 50 \Omega$	Full range	75			ub
kova	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	V _{DD} = 4.6 V to 16 V	25°C	80	110		dB
ksvr	anbhiλ-voirade relection tario (ανDD∓\ανIO)	VDD= 4.0 V to 16 V	Full range	80			L ub
loo	Supply current	V∩ = 0. No load	25°C		1.7	2.6	mA
DD	Supply current	$V_O = 0$, No load	Full range			2.6] ""A

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202C operating characteristics at specified free-air temperature, V_{DD} = 5 V

	DADAMETED	TEST CON	IDITIONS	T _A †	TLC2202C			LINUT
	PARAMETER	TEST CON	DITIONS		MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = 0.5 \text{ V to } 2.5$	5 V,	25°C	1.6	2.5		V/μs
J Sh	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	Full range	1.1			ν/μ5
Vn	Equivalent input noise voltage	f = 10 Hz		25°C		18		nV/√Hz
vn	Equivalent input noise voltage	f = 1 kHz		25°C		8		IIV/VIIZ
Vivon	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		25°C		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		0.7		μν
In	Equivalent input noise current			25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	25°C		47°		

[†] Full range is 0°C to 70°C.



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TLC2202C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	TƠ	TL	C2202/	AC .	TL	.C2202E	3C	UNIT
	PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	ONIT
VIO	Input offset voltage		25°C		80	500		80	500	μV
10			Full range			650			650	٠.
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005		0.001	0.005	μV/mo
l _{IO}	Input offset current		25°C		0.5			0.5		рA
Q	input onset current	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			100			100	p/s
lв	Input bias current	110 - 0, 115 - 50 22	25°C		1			1		pА
В	mput bigs current		Full range			100			100	p/\
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			0 to 2.7			V
Vou	Maximum high-level	$R_i = 10 \text{ k}\Omega$	25°C	4.7	4.8		4.7	4.8		V
VOH	output voltage		Full range	4.7			4.7			,
VOL	Maximum low-level	I _O = 0	25°C		0	50		0	50	mV
· OL	output voltage	1.0 = 0	Full range			50			50	
		$V_0 = 1 \text{ V to 4 V},$	25°C	150	315		150	315		
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$	Full range	100			100			V/mV
1.40	voltage amplification	$V_0 = 1 \text{ V to 4 V},$	25°C	25	55		25	55		.,
		$R_L = 10 \text{ k}\Omega$	Full range	15			15			
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min,	25°C	75	110		75	110		dB
		$V_O = 0$, $R_S = 50 \Omega$	Full range	75			75			
ksvr	Supply-voltage rejection ratio	V _{DD} = 4.6 V to 16 V	25°C	80	110		80	110		dB
	(ΔV _{DD±} /ΔV _{IO})		Full range	80			80			
IDD	Supply current	V _O = 2.5 V, No load	25°C		1.7	2.6		1.7	2.6	mA
			Full range			2.6			2.6	

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202C operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CONDITIONS	- .+	TL	C2202/	C	TL	C2202E	C	UNIT	
	PARAMETER	I EST CONDITIONS	TA [†]	MIN	TYP	MAX	MIN	TYP	MAX	UNII	
CD	Olavo vata at ovrito asim	V _O = 0.5 V to 2.5 V,	25°C	1.6	2.5		1.6	2.5		1////-	
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.1			1.1			V/μs	
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz	
Vn	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	nv/vnz	
Vivinn	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV	
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν	
I _n	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz	
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz	
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		47°			47°			

† Full range is 0°C to 70°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TLC2201I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ±5 V (unless otherwise noted)

	DIDAMETED :		OVERTIONS.	_ +	T	LC2201	ı	
	PARAMETER	l lesi c	ONDITIONS	T _A †	MIN	TYP	MAX	UNIT
Vio	Input offset voltage			25°C		100	500	μV
VIO	input onset voltage			Full range			650	μν
ανιο	Temperature coefficient of input offset voltage			Full range		0.5	, .	μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.001	0.005	μV/mo
li o	Input offset current	VIC = 0,	HS = 30 32	25°C		0.5		pА
10	input onset current			Full range			150	PΑ
Iв	Input bias current			25°C		1		рA
'IB	input bias current			Full range			150	PΑ
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			٧
t				25°C	4.7	4.8		
VOM+	Maximum positive peak output voltage swing	, 1010		Full range	4.7			V
V	Maximum no gotivo neek sutnut voltogo suina	$R_L = 10 \text{ k}\Omega$		25°C	-4.7	-4.9		V
VOM-	Maximum negative peak output voltage swing			Full range	-4.7			V
		V _O = ±4 V,	$R_{\rm I} = 500 \text{k}\Omega$	25°C	400	560		
AVD	Large-signal differential voltage amplification	VO = ±4 V,	TIL = 300 K22	Full range	250			V/mV
^VD	Large-signal differential voltage amplification	Vo = +4 V	$R_I = 10 \text{ k}\Omega$	25°C	90	100		V/111V
		VO = ±4 V,	TIL = 10 K22	Full range	65			
CMRR	Common-mode rejection ratio	VIC = VICR	nin,	25°C	90	115		dB
Civil II I		$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	85			ub
ksvr	Supply voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	$V_{DD+} = \pm 2.3$	3 V to +8 V	25°C	90	110		dB
ovn		100± - ±2.0		Full range	85			45
IDD	Supply current	V _O = 0,	No load	25°C		1.1	1.5	mA
טט.	Supply Sulfolit	1.0_0,	, , , , , , , , , , , , , , , , , , , ,	Full range			1.5	

[†] Full range is -40°C to 85°C.

TLC2201I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

DADAMETED	TEST CONDITIONS	T. +	T	LC22011		UNIT
PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	UNIT
Claurate at unity gain	$V_{O} = \pm 2.3 \text{ V}, R_{L} = 10 \text{ k}\Omega,$	25°C	2	2.7		V/µs
Siew rate at unity gain	C _L = 100 pF	Full range	1.4			V/μS
Equivalent input poice veltage	f = 10 Hz	25°C		18		nV/√Hz
Equivalent input noise voltage	f = 1 kHz	25°C		8		nv/√HZ
Pools to pools aguivalent input poins valtage	f = 0.1 to 1 Hz	25°C		0.5		μV
reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μν
Equivalent input noise current		25°C		0.6		fA/√Hz
Gain-bandwidth product		25°C		1.9		MHz
Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°		
	Gain-bandwidth product	Slew rate at unity gain	Slew rate at unity gain $ \begin{array}{c} V_O = \pm 2.3 \ \text{V}, \\ C_L = 100 \ \text{pF} \end{array} \begin{array}{c} 25^{\circ}\text{C} \\ \text{Full range} \end{array} $ Equivalent input noise voltage $ \begin{array}{c} f = 10 \ \text{Hz} \\ f = 10 \ \text{Hz} \end{array} \begin{array}{c} 25^{\circ}\text{C} \\ \text{Full range} \end{array} $ Peak-to-peak equivalent input noise voltage $ \begin{array}{c} f = 10 \ \text{Hz} \\ f = 0.1 \ \text{to} \ 1 \ \text{Hz} \\ f = 0.1 \ \text{to} \ 10 \ \text{Hz} \end{array} \begin{array}{c} 25^{\circ}\text{C} \\ \text{Equivalent input noise current} \end{array} $ Equivalent input noise current $ \begin{array}{c} f = 10 \ \text{kHz}, \\ C_L = 100 \ \text{pF} \end{array} \begin{array}{c} R_L = 10 \ \text{k}\Omega, \\ 25^{\circ}\text{C} \\ \end{array} $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$Slew \ rate \ at \ unity \ gain $

[†] Full range is -40°C to 85°C.



NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25 °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201I electrical characteristics at specified free-air temperature, $V_{DD\pm}=\pm 5~V$ (unless otherwise noted)

<u> </u>	DADAMETED	aaus		_ 4	TL	C2201	AI	TI	C2210	ВІ	
	PARAMETER	TEST COND	ITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
Via	Input offset voltage			25°C		80	200		80	200	μV
VIO	input onset voltage			Full range			350			350	μν
ανιο	Temperature coefficient of input offset voltage			Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, R ₅	ς = 50 Ω	25°C		0.001	0.005		0.001	0.005	μV/mo
lio.	Input offset current			25°C		0.5			0.5		рA
10	input onset current			Full range			150			150	PΛ
lıв	Input bias current			25°C		1			1		pА
'iB	Input bias current			Full range			150			150	PΛ
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			-5 to 2.7			V
V	Maximum positive peak output			25°C	4.7	4.8		4.7	4.8		٧
V _{OM+}	voltage swing	R _I = 10 kΩ		Full range	4.7			4.7			•
VOM-	Maximum negative peak output	11[- 10 132		25°C	-4.7	-4.9		-4.7	-4.9		V
VOM-	voltage swing			Full range	-4.7			-4.7			•
		V _O = ±4 V, R _I	- 500 kO	25°C	400	560		400	560		
AVD	Large-signal differential voltage			Full range	250			250			V/mV
7.00	amplification	V _O = ±4 V, R _I	= 10 kO	25°C	90	100		90	100		•/•
		* 0-±+ * , ⊓	10 1022	Full range	65			65			
CMBB	Common-mode rejection ratio	VIC = VICRmin,	,	25°C	90	115		90	115		dB
0111111		$V_O = 0$, Re	$S = 50 \Omega$	Full range	85			85			40
ksvr	Supply voltage rejection ratio		25°C	90	110		90	110		dB	
-SVA	(ΔV _{DD±} /ΔV _{IO})	$V_{DD \pm} = \pm 2.3 \text{ V to } \pm 8^{\circ}$		Full range	85			85		_	
lDD	Supply current	V _O = 0, No	oload	25°C		1.1	1.5		1.1	1.5	mA
-00				Full range			1.5			1.5	

† Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150 °C extrapolated to T_A = 25°C using the Arrhenius equation assuming an activation energy of 0.96 eV.

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TLC2201I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CONDITIONS	- +	TL	C2201	Al	TL	.C2210I	31	UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
SR	Clay rate at unity sain	$V_0 = \pm 2.3 V$,	25°C	2	2.7		2	2.7		Who
SH	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.4			1.4			V/µs
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
V _n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	110/1112
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μV
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°			48°		

[†] Full range is -40°C to 85°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2201I electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS	_ +	T	LC2201	1	UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNII
V	Input offeet voltage		25°C		100	500	μV
VIO	Input offset voltage		Full range			650	μν
ανιο	Temperature coefficient of input offset voltage		Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V . 0 D . 500	25°C		0.001	0.005	μV/mo
	land offer a comment	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.5		- 4
IЮ	Input offset current		Full range			150	pА
1	lanut bigg gurrant		25°C		1		
lв	Input bias current	,	Full range			150	pΑ
				0			
VICR	Common-mode input voltage range	$R_S = 50 \Omega$	Full range	to 2.7			V
.,			25°C	4.7	4.8		.,
VOH	Maximum high-level output voltage	R _L = 10 kΩ	Full range	4.7			V
.,	M. Carlotte and the second		25°C		0	50	
VOL	Maximum low-level output voltage	IO = 0	Full range			50	mV
		V _O = 1 V to 4 V,	25°C	150	315		
۸	Lorge cianal differential voltage emplification	R _L = 500 kΩ	Full range	100			V/mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V/mv
}		R _L = 10 kΩ	Full range	15			
CMRR	Common mode valenties votic	V _{IC} = V _{ICR} min,	25°C	90	110		dB
CIVINA	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	Full range	85			uБ
ka	Cumply valtage rejection ratio (AV = - /AV =)	V 46V to 16V	25°C	90	110		dB
ksvr	Supply voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD} = 4.6 V to 16 V	Full range	85			uB
	Cupply gurrent	V- 05V No lood	25°C		1	1.5	m A
IDD	Supply current	$V_O = 2.5 \text{ V}$, No load	Full range			1.5	mA

† Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CONDITIONS	T - +	Т	LC2201I		UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.8	2.5		V/µs
on .	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$,, $C_L = 100 \text{ pF}$	Full range	1.2			V/μS
V	Equivalent input noise voltage	f = 10 Hz	25°C		18		nV/√Hz
V _n	Equivalent input hoise voltage	f = 1 kHz	25°C		8		NV/∀⊓Z
V	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input hoise voitage	f = 0.1 to 10 Hz	25°C		0.7		μν
In	Equivalent input noise current		25°C		0.6		fA/√Hz
	Gain-bandwidth product	$ f = 10 \text{ kHz}, \qquad R_L = 10 \text{ k}\Omega, $ $ C_L = 100 \text{ pF} $	25°C		1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		45°		

†Full range is -40°C to 85°C.

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TLC2201I electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEGT COMPLETIONS		TL	C2201	Al	TI	LC2201	ВІ	
	PARAMETER	TEST CONDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
ViO	Input offset voltage		25°C		80	200		80	200	μА
٧١٥			Full range			350			350	μΛ
αVIO	Temperature coefficient of input offset voltage		Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.001	0.005		0.001	0.005	μV/mo
lio	Input offset current		25°C		0.5			0.5		pA
10	input onset current		Full range			150			150	PΛ
lв	Input bias current		25°C		1			1		pA
'ID			Full range			150			150	pr
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			0 to 2.7			٧
	Maximum high-level output	D 4010	25°C	4.7	4.8		4.7	4.8		.,
VOH	voltage	$R_L = 10 \text{ k}\Omega$	Full range	4.7			4.7			
Voi	Maximum low-level output	IO = 0	25°C		0	50		0	50	mV
VOL	voltage	10=0	Full range			50			50	1110
		V _O = 1 V to 4 V,	25°C	150	315		150	315		
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$	Full range	100			100			V/mV
, vD	voltage amplification	$V_0 = 1 \text{ V to 4 V},$	25°C	25	55		25	55		•////
		$R_L = 10 \text{ k}\Omega$	Full range	15			15			
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min,	25°C	90	110		90	110		dB
		$V_O = 0$, $R_S = 50 \Omega$	Full range	85			85			
ksvr	Supply voltage rejection ratio	V _{DD} = 4.6 V to 16 V	25°C	90	110		90	110		dΒ
	(ΔV _{DD±} /ΔV _{IO})		Full range	85			85			
lDD	Supply current	V _O = 2.5 V, No load	25°C		1	1.5		1	1.5	mA
00	y O = 2.5 v, No load	Full range	1		1.5			1.5	1	

† Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CONDITIONS	- +	TL	.C2201	ΑI	TL	.C2210	31	
	PARAMETER	TEST CONDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.8	2.5		1.8	2.5		V/μs
Sh.	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.2			1.2			V/μS
V	Equivalent input noise	f = 10 Hz	25°C		18	35		18	30	-V/6/11=
V _n	voltage (see Note 5)	f = 1 kHz	25°C		8	15		8	12 nV/√Hz	nv/vnz
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV
VN(PP)	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$ f = 10 \text{ kHz}, \qquad \text{R}_L = 10 \text{ k}\Omega, \\ \text{C}_L = 100 \text{ pF} $	25°C		1.8	,		1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ p}$	25°C		45°			45°		

[†] Full range is -40°C to 85°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2202I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEGT	CANDITIONS	+.+	Т	LC2202I		UNIT
	PARAMETER	IESIC	CONDITIONS	T _A †	MIN	TYP	MAX	UNII
V.o	Input offset voltage			25°C		100	1000	μV
VIO	input oliset voltage	V:= 0	$R_S = 50 \Omega$	Full range			1200	μ ν
αVIO	Temperature coefficient of input offset voltage	VIC = 0,	HS = 50 22	Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)			25°C		0.001	0.005	μV/mo
lio	Input offset current			Full range			150	
l.o.	Input bias current	$V_{IC} = 0$,	$R_S = 50 \Omega$	25°C		1		pА
ΙΒ	input bias current			Full range			150	
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			٧
V _{OM+}	Maximum positive peak output voltage swing			25°C	4.7	4.8		
VOM+	waximum positive peak output voitage swing	R _I = 10 kΩ		Full range	4.7			٧
V _{OM} _	Maximum negative peak output voltage swing	111 - 10 K22		25°C	-4.7	-4.9		
VOIVI-	waximum negative peak output voltage swing			Full range	-4.7			٧
		V _O = ± 4 V,	$R_I = 500 \text{ k}\Omega$	25°C	300	560		
AVD	Large-signal differential voltage amplification	VO = ± + v,	11[= 500 K22	Full range	150			V/mV
~VD	Large-signal differential voltage amplification	VO = ± 4 V,	$R_I = 10 \text{ k}\Omega$	25°C	50	100		V/111V
		VO = ± 4 V,	11[= 10 K22	Full range	25			
CMRR	Common-mode rejection ratio	$V_{O} = 0$,	V _{IC} = V _{ICR} min,	25°C	80	115		dB
Own in	Common-mode rejection ratio	$R_S = 50 \Omega$		Full range	80			GD
ksvr	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	$V_{DD} = \pm 2.3 \text{ V to } \pm 8 \text{ V}$		25°C	80	110		dB
"SVH				Full range	80			GD.
lpp	Supply current	Vo = 0	No load	25°C		1.8	2.7	mA
טטי	Cuppiy Current	$V_O = 0$, No load	NO IOAU	Full range			2.7	1117

[†]Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202I operating characteristics at specified free-air temperature, $V_{DD+} = \pm 5 \text{ V}$

	DADAMETED	TEGT 001	IDITIONS	T _A †	TLC2202I			LINUT
	PARAMETER	IEST CON	TEST CONDITIONS			TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	$R_L = 10 \text{ k}\Omega$	25°C	1.8	2.7		V/µs
JN .	Siew rate at unity gain	C _L = 100 pF	_	Full range	1.2			ν/μδ
V	Equivalent input noise voltage	f = 10 Hz		25°C		18		nV/√Hz
V _n	Equivalent input hoise voltage	f = 1 kHz		25°C		8		nv/vnz
V	Dook to neek as involent input paige valters	f = 0.1 to 1 Hz		25°C		0.5		/
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		0.7		μV
In	Equivalent input noise current			25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	25°C		48°		

[†] Full range is -40°C to 85°C.



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TLC2202I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	D. D. A. L. L. T. T. T. T. T. T. T. T. T. T. T. T. T.		T _ +	TL	C2202	Al	TI	LC2202	BI	·
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage		25°C		80	500		80	500	μV
VIO			Full range			700			700	μν
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)]	25°C		0.001	0.005		0.001	0.005	μV/mo
lio	Input offset current		25°C		0.5			0.5		рA
ΙΟ	input onset current	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			150			150	
Iв	Input bias current	7 410 = 0, 118 = 30 22	25°C		1			1		pА
чв	input blas current		Full range			150			150	PΛ
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω	Full range	-5 to 2.7			-5 to 2.7			v
· · · ·	Maximum positive peak		25°C	4.7	4.8		4.7	4.8		v
V _{OM+}	output voltage swing	$R_{\rm I} = 10 \rm k\Omega$	Full range	4.7			4.7			1 °
V _{OM} -	Maximum negative peak	- IU K22	25°C	-4.7	-4.9		-4.7	-4.9		V
*OM-	output voltage swing		Full range	-4.7			-4.7			l
		$V_O = \pm 4 V$,	25°C	300	560		300	560		
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$	Full range	150			150			V/mV
, vD	voltage amplification	$V_O = \pm 4 V$,	25°C	50	100		50	100		
		R _L = 10 kΩ	Full range	25			25			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$	25°C	80	115		80	115		dB
		$V_O = 0$, $R_S = 50 \Omega$	Full range	80			80			
ksvr	Supply-voltage rejection ratio	V _{DD+} ±2.3 V to ±8 V	25°C	80	110		80	110		dB
OVIT	(ΔV _{DD±} /ΔV _{IO})	VDD± ±2.3 V t0 ±8 V	Full range	80			80			
IDD	Supply current	$V_{O} = 0$, No load	25°C		1.8	2.7		1.8	2.7	mA
	11 2	VO = 0, No load	Full range			2.7			2.7	

† Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V

	PARAMETER	TEST COMPLETIONS	 +	TL	.C2202	Al	TL	C2202	31	LINUT
	PARAMETER	TEST CONDITIONS	TA [†]	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
CD.	Olassa at societa acia	$V_0 = \pm 2.3 \text{ V, R}_L = 10 \text{ k}\Omega$	25°C	1.8	2.7		1.8	2.7		\//
SR	Slew rate at unity gain	C _L = 100 pF	Full range	1.2			1.2			V/μs
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
v _n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	IIV/VM2
Varion	Peak-to-peak equivalent	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV
VN(PP)	input noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	$R_{I} = 10 \text{ k}\Omega, C_{I} = 100 \text{ pF}$	25°C		48°			48°		

† Full range is -40°C to 85°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TLC2202l electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST SOUDITIONS	- +	T	LC2202	ı	UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	P MAX 0 1000 1200 5 1 0.005 150 1 150 8 0 50 5	UNIT
V	Innut effect veltere		25°C		100	1000	
VIO	Input offset voltage	V 0 Pa 50 O	Full range			1200	μV
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005	μV/mo
lo	Input offset current		Full range			150	
lin	Input bias current	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		1		pА
lΒ	mput bias current		Full range			150	
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to			V
				2.7			
Vон	Maximum high-level output voltage	$R_{I} = 10 \text{ k}\Omega$	25°C	4.7	4.8		v
VOH	waxiifum fiigh-level output voitage	H[= 10 K22	Full range	4.7			
VOL	Maximum low-level output voltage	IO = 0	25°C		0	50	mV
VOL	waximum low-level output voltage	10 = 0	Full range			- 50	1110
		V _O =1 V to 4 V,	25°C	150	315		
AVD	Large-signal differential voltage amplification	$R_L = 500 \text{ k}\Omega$	Full range	100			V/mV
~VU	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V////V
		R _L = 10 kΩ	Full range	15			
CMRR	Common-mode rejection ratio	VO = 0, VIC = VICRmin,	25°C	75	110		dB
CIVILLE	Common-mode rejection ratio	$R_S = 50 \Omega$	Full range	75			ub
kovr	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	V _{DD} = 4.6 V to 16 V	25°C	80	110		dB
ksvr	Supply voltage rejection ratio (2 vDD±/2 v IO)	VDD- +.0 V to 10 V	Full range	80			ub
loo	Supply current	V _O = 2.5 V, No load	25°C		1.7	2.6	mA
IDD		VO = 2.5 V, NO load	Full range			2.6	IIIA

[†] Full range is -40°C to 85°C.

TLC2202I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	DADAMETED	TEST COMPLETIONS	T. +	T	LC22021		
	PARAMETER	TEST CONDITIONS	TA [†]	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.6	2.5		V/µs
31	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1			ν/μ5
V	Equivalent input noise voltage	f = 10 Hz	25°C		18		nV/√Hz
Vn	Equivalent input noise voltage	f = 1 kHz	25°C		8		nv/√Hz
Verre	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μν
In	Equivalent input noise current	· · · · · · · · · · · · · · · · · · ·	25°C		0.6		fA/√Hz
	Gain-bandwidth product		25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		47°		

[†]Full range is -40°C to 85°C.



NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202I electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS	T. +	TI	C2202	Al	TI	C2202	BI	UNIT
ĺ	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage		25°C		80	500		80	500	μV
10	mpar onser voltage	j	Full range			700			700	μν
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005		0.001	0.005	μV/mo
10	Input offset current		25°C		0.5			0.5		рA
טוי	input onset current	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			150			150	рΑ
Iв	Input bias current	1 10 = 0, 115 = 30 22	25°C		1			1		pA
IIB	mput bias current		Full range			150			150	PΛ
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			0 to 2.7			٧
VOH	Maximum high-level output	$R_{l} = 10 \text{ k}\Omega$	25°C	4.7	4.8		4.7	4.8		V
VOH	voltage	I I = 10 K22	Full range	4.7			4.7			v
VOL	Maximum low-level output	I _O = 0	25°C		0	50		0	50	mV
· OL	voltage	1.0 - 0	Full range			50			50	1111
		$V_0 = 1 \text{ V to 4 V},$	25°C	150	315		150	315		
AVD	Large-signal differential	R _L ≈ 500 kΩ	Full range	100			100			V/mV
7.40	voltage amplification	$V_O = 1 V \text{ to } 4 V$	25°C	25	55		25	55		•/•
		R _L ≈ 10 kΩ	Full range	15			15			
CMRR	Common-mode rejection ratio	V _{IC} = V _{ICR} min,	25°C	75	110		75	110		dB
		$V_O = 0$, $R_S = 50 \Omega$	Full range	75			75			
ksvr	Supply-voltage rejection ratio	V _{DD} = 4.6 V to 16 V	25°C	80	110		80	110		dB
-571	(ΔV _{DD±} /ΔV _{IO})	100	Full range	80			80			
I _{DD}	Supply current	$V_{O} = 2.5 \text{ V}$, No load	25°C		1.7	2.6		1.7	2.6	mA
+=	···	L	Full range	L		2.6			2.6	

† Full range is -40°C to 85°C

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

{	PARAMETER	TEST CONDITIONS	T. †	TL	C2202	Al	TL	C2202	31	UNIT
L	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	וואט
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.6	2.5		1.6	2.5		V/us
Jon J	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1			1			V/μS
v _n	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
V n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	IIV/VIIZ
V _{N(PP)}	Peak-to-peak equivalent	f = 0.1 to 1 Hz	25°C		0.5			0.5		μV
VN(PP)	input noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μν
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9	,		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		47°			47°		

† Full range is -40°C to 85°C

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.



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TLC2201M electrical characteristics at specified free-air temperature, $V_{DD\,\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED		ONDITIONS	_ +	Т	TLC2201M		
	PARAMETER	IESIC	ONDITIONS	T _A †	MIN	TYP	MAX	UNIT
· · · · · · · · · · · · · · · · · · ·	lament officet welltone			25°C		100	500	/
VIO	Input offset voltage			Full range			700	μV
αVIO	Temperature coefficient of input offset voltage			Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	1,4 0	D- 50.0	25°C		0.001	0.005	μV/mo
1	land affect account	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.5		
ΙΟ	Input offset current			Full range			500	pΑ
1	Innut his a surrent			25°C		1		4
lΒ	Input bias current	,		Full range			500	pΑ
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			٧
				25°C	4.7	4.8		
V _{OM+}	Maximum positive peak output voltage swing			Full range	4.7	4.0		V
		R _L = 10 kΩ		25°C	-4.7	-4.9		
VOM-	Maximum negative peak output voltage swing			Full range	-4.7	7.0		٧
				25°C	400	560		
		$V_0 = \pm 4 V$	$R_L = 500 \text{ k}\Omega$	Full range	200			
AVD	Large-signal differential voltage amplification			25°C	90	100		V/mV
		$V_O = \pm 4 V$	$R_L = 10 \text{ k}\Omega$	Full range	45			
		VIC = VICR	nin,	25°C	90	115		
CMRR	Common-mode rejection ratio	V _O = 0,	$R_S = 50 \Omega$	Full range	85			dB
г.	Our book and a standard of the		21/1-101/	25°C	90	110		.ip
ksvr	Supply voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.3$	S V to ±8 V	Full range	85			dB
I	Completed	\\- 0	No local	25°C		1.1	1.5	4
IDD	Supply current	$V_{O} = 0$,	No load	Full range			1.5	mA

[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	DADAMETED	TEST COMPLETIONS	- +	TL	C2201N		UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	$V_O = \pm 2.3 \text{ V}, R_L = 10 \text{ k}\Omega,$	25°C	2	2.7		V/μs
on .	Siew rate at unity gain	C _L = 100 pF	Full range	1.3			V/μS
V	Equivalent input noise voltage	f = 10 Hz	25°C		18		nV/√Hz
Vn	Equivalent input noise voltage	f = 1 kHz	25°C		8		nv/√Hz
V	Dook to peak aguivalent input paige veltage	f = 0.1 to 1 Hz	25°C		0.5		
VN(PP)	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μV
In	Equivalent input noise current		25°C		0.6		fA/√Hz
	Gain-bandwidth product		25°C		1.9		MHz
φm	Phase margin	R _L = 10 kΩ, C _L = 100 pF	25°C		48°		

[†] Full range is -55°C to 125°C.



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TLC2201M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEOT 001	IDITIONIO	- +	TL	C2201A	M	TL	C2210B	М	
	PARAMETER	TEST CON	IDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		80	200		80	200	μV
۷۱٥	input onset voltage			Full range			400			400	μν
αVIO	Temperature coefficient of input offset voltage			Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C	-	0.001	0.005		0.001	0.005	μV/mo
lio	Input offset current			25°C		0.5			0.5		рA
ΙO	input onset current			Full range			500			500	PΛ
lin.	Input bias current			25°C		1			1		рA
ΙΒ	input bias current			Full range			500			500	PΑ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	-5 to 2.7			~5 to 2.7			٧
V	Maximum positive peak			25°C	4.7	4.8		4.7	4.8		V
V _{OM+}	output voltage swing	$R_{\rm I} = 10 \rm k\Omega$		Full range	4.7			4.7			V
V	Maximum negative peak	JUL = 10 KZ2		25°C	-4.7	-4.9		-4.7	-4.9		V
V _{OM} -	output voltage swing			Full range	-4.7			-4.7			٧
		$V_0 = \pm 4 V$,		25°C	400	560		400	560		
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$		Full range	200			200			V/mV
700	voltage amplification	$V_0 = \pm 4 V$,		25°C	90	100		90	100		V////V
		$R_L = 10 \text{ k}\Omega$		Full range	45			45			
CMRR	Common-mode rejection	VIC = VICRM	in,	25°C	90	115		90	115		dB
CIVILL	ratio	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	85			85			GD.
ksvr	Supply voltage rejection	$V_{DD} + = \pm 2.3$	1 V to +8 V	25°C	90	110		90	110		dB
"SVH	ratio (ΔV _{DD±} /ΔV _{IO})	*UU ± - ±2.0	, v 10 ± 0 v	Full range	85			85			u.D
l _{DD}	Supply current	V _O = 0,	No load	25°C		1.1	1.5		1.1	1.5	mA
-טט	Cappy current	.0 = 0,	140 1000	Full range			1.5			1.5	111/5

[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observable through 168 hours of operating life test at $T_A = 150$ °C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST	T.+	TL	C2201A	М	TL	C2201B	M	
	PARAMETER	CONDITIONS	ONDITIONS TAT MIN		TYP	MAX	MIN	TYP	MAX	UNIT
00	01	Vo = ±2.3 V,	25°C	2	2.7		2	2.7		\//
SR	Slew rate at unity gain	R _L = 10 kΩ, C _L = 100 pF	Full range	1.3			1.3			V/μs
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	nV/√Hz
V _n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	nv/vHz
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μV
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9	-	MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		48°			48°		

† Full range is -55°C to 125°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2201M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	- +	Т	LC2201	М	UNIT
	PARAMEIER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNIT
VIO	Input offset voltage		25°C		100	500	μV
۷IO	input onset voltage		Full range			700	μν
αVIO	Temperature coefficient of input offset voltage		Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V- 0 D- 500	25°C		0.001	0.005*	μV/mo
l. a	Input offeet ourrent	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.5		
ΙΟ	Input offset current		Full range			500	pA
1	land bigg summer		25°C		1		- 1
lΒ	Input bias current		Full range			500	рA
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			٧
.,			25°C	4.7	4.8		.,
VOH	Maximum high-level output voltage	$R_L = 10 \text{ k}\Omega$	Full range	4.7			V
	, A		25°C		0	50	
VOL	Maximum low-level output voltage	IO = 0	Full range			50	mV
		V _O = 1 V to 4 V,	25°C	150	315		
A	Laura aireal differential valtage amplification	$R_L = 500 \text{ k}\Omega$	Full range	75			V/mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V/mv
		$R_L = 10 \text{ k}\Omega$	Full range	10			
CMDD	Common mode valenties vatio	V _{IC} = V _{ICR} min,	25°C	90	110		٩D
CMRR	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	Full range	85	,		dB
les	Complementation write (AV = - (AV =)	V 46V4546V	25°C	90	110		dB
ksvr	Supply voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	V _{DD} = 4.6 V to 16 V	Full range	85			uВ
	0	V OF V No lead	25°C		1	1.5	4
IDD	Supply current	$V_O = 2.5 \text{ V}$, No load	Full range			1.5	mA

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

TLC2201M operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

DADAMETED	TEST COMPLETIONS	T - +	TLC2201M			
PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	UNIT
Slaw rate at unity sain	V _O = 0.5 V to 2.5 V,	25°C	1.8	2.5		V/µs
Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.1			V/μS
Equivalent input poice voltage	f = 10 Hz	25°C		18		nV/√Hz
Equivalent input hoise voltage	f = 1 kHz	25°C		8		nv/√Hz
Book to peak aguivalent input poins valtage	f = 0.1 to 1 Hz	25°C		0.5		
reak-to-peak equivalent input hoise voltage	f = 0.1 to 10 Hz	25°C		0.7		μV
Equivalent input noise current		25°C		0.6		fA/√Hz
Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.8		MHz
Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		45°		
	Gain-bandwidth product	Slew rate at unity gain $ \begin{array}{c} V_{O} = 0.5 \text{ V to } 2.5 \text{ V,} \\ R_{L} = 10 \text{ k}\Omega, C_{L} = 100 \text{ pF} \\ \end{array} $ Equivalent input noise voltage $ \begin{array}{c} f = 10 \text{ Hz} \\ f = 1 \text{ kHz} \\ \end{array} $ Peak-to-peak equivalent input noise voltage $ \begin{array}{c} f = 0.1 \text{ to } 1 \text{ Hz} \\ \hline f = 0.1 \text{ to } 10 \text{ Hz} \\ \end{array} $ Equivalent input noise current $ \begin{array}{c} f = 10 \text{ kHz,} \\ C_{L} = 100 \text{ pF} \end{array} $ $R_{L} = 10 \text{ k}\Omega, $	Slew rate at unity gain	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	PARAMETER TEST CONDITIONS TAT MIN TYP Slew rate at unity gain $V_O = 0.5 \text{ V to } 2.5 \text{ V,}$ 25°C 1.8 2.5 Equivalent input noise voltage f = 10 kΩ, C _L = 100 pF Full range 1.1 Equivalent input noise voltage f = 10 kHz 25°C 8 Peak-to-peak equivalent input noise voltage f = 0.1 to 1 Hz 25°C 0.5 f = 0.1 to 10 Hz 25°C 0.7 Equivalent input noise current 25°C 0.6 Gain-bandwidth product f = 10 kHz, CL = 100 pF RL = 10 kΩ, CL = 100 pF 25°C 1.8	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

[†] Full range is -55°C to 125°C.

[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2201M electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS	- +	TL	C2201A	M	TL	.C2210B	М	<u>-</u>
	PARAMETER	TEST CONDITIONS	TA [†]	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage		25°C		80	200		80	200	μV
۷۱٥	input onset voltage		Full range			400			400	μν
αVIO	Temperature coefficient of input offset voltage		Full range	ļ	0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.001	0.005		0.001	0.005	μV/mo
lio	Input offset current		25°C		0.5			0.5		рА
טוי	Input onset current		Full range			500			500	РΑ
IIB	Input bias current		25°C		1			1		рA
שוי	input bias current		Full range			500			500	PΛ
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			0 to 2.7			٧
V	Maximum high-level output	D. 1010	25°C	4.7	4.8		4.7	4.8		v
VOH	voltage	$R_L = 10 \text{ k}\Omega$	Full range	4.7			4.7			v
VOL	Maximum low-level output	I _O = 0	25°C		0	50		0	50	ν
VOL	voltage	10-0	Full range			50			50	•
		V _O = 1 V to 4 V,	25°C	150	315		150	315		
AVD	Large-signal differential	R _L = 500 kΩ	Full range	75			75			V/mV
י מסי	voltage amplification	V _O = 1 V to 4 V,	25°C	25	- 55		25	55		V/111V
		$R_L = 10 \text{ k}\Omega$	Full range	10			10			
CMRR	Common-mode rejection	V _{IC} = V _{ICR} min,	25°C	90	110		90	110		dB
Civil ii i	ratio	$V_O = 0$, $R_S = 50 \Omega$	Full range	85			85			u.b
ksvr	Supply voltage rejection	V _{DD} = 4.6 V to 16 V	25°C	90	110		90	110		dB
"SVR	ratio (ΔV _{DD±} /ΔV _{IO})	100 = 4.0 V to 10 V	Full range	85			85			
¹ DD	Supply current	V _O = 2.5 V, No load	25°C		1.1	1.5		1.1	1.5	mA
יטט.	- Cappiy current	10 - 2.0 t, No load	Full range			1.5			1.5	

† Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observable through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201M operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CONDITIONS	T. +	TL	C2201A	М	TL	C2201B	M	
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.8	2.5	-	1.8	2.5		V/ue
5 n	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.1			1.1		V/μs	
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35		18	30	->4/15
V _n	(see Note 5)	f = 1 kHz	25°C		8	15		8	12	nV/√Hz
	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μV
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.8			1.8		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		45°			45°		

† Full range is -55°C to 125°C.

NOTE 5: This parameter is tested on a sample basis for the TLC2201A and on all devices for the TLC2201B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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TLC2202M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

DADAMPTED	TEST CONDITIONS	- +	Т	LC2202	M ·	UNIT
PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	UNII
Input offset voltage		25°C		100	1000	μV
Input onset voltage	V 0 Po - 50 O	Full range			1250	μν
Temperature coefficient of input offset voltage	VIC = 0, HS = 50 72	Full range		0.5		μV/°C
Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005*	μV/mo
Input offset current		Full range			500	
Input bigs ourrent	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		1		рA
input bias current		Full range			500	
			-5			
Common-mode input voltage range	$R_S = 50 \Omega$	Full range				٧
		2500		4.0		
Maximum positive peak output voltage swing				4.0		v
	$R_L = 10 \text{ k}\Omega$			4.0		\ \
Maximum negative peak output voltage swing				-4.5		V
				560		<u> </u>
				300		
Large-signal differential voltage amplification				100		V/mV
				100		
				115		
Common-mode rejection ratio						dB
	1.0 -5			110		
Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	V _{DD} = ±2.3 V to ±8 V			110		dB
		<u> </u>		1.8	27	
Supply current	$V_O = 0$, No load			1.0		mA
	Input offset voltage long-term drift (see Note 4) Input offset current Input offset current Common-mode input voltage range Maximum positive peak output voltage swing Maximum negative peak output voltage swing Large-signal differential voltage amplification Common-mode rejection ratio Supply-voltage rejection ratio (ΔVDD±/ΔVIO)	Input offset voltage Temperature coefficient of input offset voltage Input offset voltage long-term drift (see Note 4) Input offset current Input bias current Common-mode input voltage range Maximum positive peak output voltage swing Maximum negative peak output voltage swing Large-signal differential voltage amplification Vo = 1 V to 4 V, RL = 500 kΩ Vo = 1 V to 4 V, RL = 10 kΩ Common-mode rejection ratio Vo = 0, VIC = VICRmin, RS = 50 Ω Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$) VDD= ± 2.3 V to ± 8 V	$ \begin{array}{c} \text{Input offset voltage} \\ \text{Temperature coefficient of input offset voltage} \\ \text{Input offset voltage long-term drift (see Note 4)} \\ \text{Input offset current} \\ \text{Input bias current} \\ \text{Full range} \\ \text{Eull range} \\ \text{25°C} \\ \text{Full range} \\ \text{Full range} \\ \text{Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)} \\ \text{ViC} = 0, R_S = 50 \ \Omega \\ \text{Full range} \\ \text{Full range} \\ \text{Full range} \\ \text{Full range} \\ \text{Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)} \\ \text{ViC} = 0, R_S = 50 \ \Omega \\ \text{Full range} \\ Full range$	TEST CONDITIONS TAT MIN Input offset voltage 25°C Temperature coefficient of input offset voltage Full range Input offset voltage long-term drift (see Note 4) 25°C Input offset current VIC = 0, RS = 50 Ω Full range Input bias current VIC = 0, RS = 50 Ω Full range Common-mode input voltage range RS = 50 Ω Full range Maximum positive peak output voltage swing Full range 4.7 Maximum negative peak output voltage swing RL = 10 kΩ 25°C 4.7 Full range 4.7 VO = 1 V to 4 V, RL = 500 kΩ Full range 100 VO = 1 V to 4 V, RL = 10 kΩ Full range 100 VO = 1 V to 4 V, RL = 10 kΩ Full range 25°C 50 Full range 25°C 50 Full range 25°C 50 Full range 25°C 80 Full range 25°C 80 Full range 80 Supply-voltage rejection ratio (ΔVDD±/ΔVIO) VDD=±2.3 V to ±8 V Full range 80	Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset current Input bias current	Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset voltage Input offset current Input offset current Input offset current Input bias current VIC = 0,

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

TLC2202M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm5~V$

	DADAMETED	TEOT 001	DITIONS	- .+	TL	.C2202N	1	
	PARAMETER	TEST CONDITIONS		T _A †	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	$R_L = 10 \text{ k}\Omega$,	25°C	1.8	2.7		V/µs
JN.	Siew rate at unity gain	C _L = 100 pF		Full range	1.1			V /μS
Vn	Equivalent input noise voltage	f = 10 Hz		25°C		18		nV/√Hz
٧n	Equivalent input noise voltage	f = 1 kHz		25°C		8		nv/vnz
Verren	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		25°C		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		0.7		μν
In	Equivalent input noise current			25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	25°C		48°		

[†] Full range is -55°C to 125°C.



[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202M electrical characteristics at specified free-air temperature, $V_{DD\pm}=\pm 5~V$ (unless otherwise noted)

	DADAMETED	TEST CONDITIONS TAT	TL	C2202	M	TL	.C2202E	BM	UNIT	
	PARAMETER	TEST CONDITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
VIO	Input offset voltage		25°C		80	500		80	500	μV
VIO	Input onset voltage		Full range			750			750	μν
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005*		0.001	0.005*	μV/mo
lio	Input offset current		25°C		0.5			0.5		рA
ַט	input onset current	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			500			500	PΛ
lв	Input bias current	10 - 0, 115 - 30 32	25°C		1			1		pА
שוי	input bias current		Full range			500			500	pΛ
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	-5 to 2.7			-5 to 2.7			V
V	Maximum positive peak		25°C	4.7	4.8		4.7	4.8		V
VOM+	output voltage swing	R _L = 10 kΩ	Full range	4.7			4.7			٧
V _{OM} -	Maximum negative peak	HE = 10 K22	25°C	-4.7	-4.9		-4.7	-4.9		V
VOM−	output voltage swing	,	Full range	-4.7			-4.7			
		$V_O = \pm 4 V$,	25°C	300	560		300	560		
AVD	Large-signal differential	$R_L = 500 \text{ k}\Omega$	Full range	100			100			V/mV
AVD	voltage amplification	$V_O = \pm 4 V$,	25°C	50	100		50	100		V/IIIV
		$R_L = 10 \text{ k}\Omega$	Full range	25			25			
CMRR	Common-mode rejection	$V_O = 0$, $V_{IC} = V_{ICR}min$,	25°C	80	115		80	115		dB
O.W.I. C.	ratio	$R_S = 50 \Omega$	Full range	80			80			u.b
ksvr	Supply-voltage rejection	$V_{DD+} = \pm 2.3 \text{ V to } \pm 8 \text{ V}$	25°C	80	110		80	110		dB
SVH	ratio (ΔV _{DD±} /ΔV _{IO})	-DDE-12:0 (10 10 (Full range	80			80			
IDD	Supply current	V _O = 0, No load	25°C		1.8	2.7		1.8	2.7	mA
טט.		1	Full range			2.7			2.7	

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	DADAMETED	TEST CONDITIONS	- +	TL	C2202A	М	TLC2202BM			
_	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
0.0		$V_0 = \pm 2.3 \text{ V},$	25°C	1.8	2.7		1.8	2.7		Ţ.,,
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	1.1			1.1			V/µs
.,	Equivalent input noise voltage	f = 10 Hz	25°C		18	35*		18	30*	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
V _n	(see Note 5)	f = 1 kHz	25°C		8	15*		8	12*	nV/√Hz
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μV
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°			48°		

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[†] Full range is -55°C to 125°C.

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TLC2202M electrical characteristics at specified free-air temperatures, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	TEST COMPLETIONS	- +	Т	LC2202	М	LINUT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNIT
V	Innut offeet veltere		25°C		100	1000	
VIO	Input offset voltage	V 0 D- 50.0	Full range			1250	μV
ανιο	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005*	μV/mo
110	Input offset current		Full range			500	
lin	Input bias current	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		1		рA
lΒ	input bias current		Full range			500	
VICR	Common-mode input voltage range	R _S = 50 Ω	Full range	0 to 2.7			٧
V	Maximum high lavel output voltage	D. 1040	25°C	4.7	4.8		V
VOH	Maximum high-level output voltage	$R_L = 10 \text{ k}\Omega$	Full range	4.7			v
Voi	Maximum low-level output voltage	IO = 0	25°C		0	50	mV
VOL	waximum low-level output voltage	10 = 0	Full range			50	IIIV
		V _O = 1 V to 4 V,	25°C	150	315		
A	Large-signal differential voltage amplification	$R_L = 500 \text{ k}\Omega$	Full range	75			V/mV
AVD	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V/IIIV
		$R_L = 10 \text{ k}\Omega$	Full range	10			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, $R_S = 50 \Omega$	25°C	75	110		dB
CIVILL	Common-mode rejection ratio	AIC = AICHIIIIII, LIZ = 20.75	Full range	75			uБ
kovo	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	V _{DD} = 4.6 V to 16 V	25°C	80	110		dB
ksvr	and the second state of th	VDD = 4.0 V to 10 V	Full range	80			GD
loo	Supply current	V _O = 2.5 V, No load	25°C		1.7	2.6	mA
DD	очрріў счітені	VO = 2.5 V, NO load	Full range			2.6	111/4

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

TLC2202M operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CO.	NDITIONS	T. †	TL	C2202N	Λ	UNIT
	PARAWEIER	TEST CO	NDITIONS	TA [†]	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.$	5 V,	25°C	1.6	2.5		V/µs
Jon L	Siew rate at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF	Full range	0.9			ν/μ5
V	Equivalent input noise voltage	f = 10 Hz		25°C		18		nV/√ Hz
V _n	Equivalent input noise voltage	f = 1 kHz		25°C		8		nv/√Hz
	Pools to needs equivalent input point voltage	f ≈ 0.1 to 1 Hz		25°C		0.5		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		0.7		μV
In	Equivalent input noise current			25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		1.9		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ,	C _L = 100 pF	25°C		47°		

[†] Full range is -55°C to 125°C.

[†] Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	- +	TL	.C2202	M	TL	C2202E	вМ	
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage		25°C		80	500		80	500	μV
VIO	input onset voltage		Full range			750			750	μν
αVIO	Temperature coefficient of input offset voltage	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.001	0.005*		0.001	0.005*	μV/mo
lιο	Input offset current		25°C		0.5			0.5		рA
ilO	mput oliset current	$V_{IC} = 0$, $R_S = 50 \Omega$	Full range			500			500	PΑ
I _{IB}	Input bias current	$A \cap A \cap A \cap A \cap A \cap A \cap A \cap A \cap A \cap A \cap$	25°C		1			1		рA
цВ	input bias current		Full range			500			500	PΑ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$	Full range	0 to 2.7			0 to 2.7			٧
	Maximum high-level output		25°C	4.7	4.8		4.7	4.8		v
VOH	voltage	$R_L = 10 \text{ k}\Omega$	Full range	4.7			4.7			\ \
Voi	Maximum low-level output	10 - 0	25°C		0	50		0	50	mV
VOL	voltage	IO = 0	Full range			50			50	IIIV
		V _O = 1 V to 4 V,	25°C	150	315		150	315		
AVD	Large-signal differential	R _L = 500 kΩ	Full range	75			75			V/mV
^VD	voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		25	55		V/IIIV
		$R_L = 10 \text{ k}\Omega$	Full range	10			10			
CMRR	Common-mode rejection	$V_O = 0$, $V_{IC} = V_{ICR}$ min,	25°C	75	110		75	110		dB
JIVII ICI	ratio	$R_S = 50 \Omega$	Full range	75			75			GD.
ksvr	Supply-voltage rejection	V _{DD} = 4.6 V to 16 V	25°C	80	110		80	110		dB
ovH	ratio (ΔV _{DD±} /ΔV _{IO})	- 4.0 V 10 10 V	Full range	80			80			
1DD	Supply current	$V_{O} = 2.5 \text{ V}$, No load	25°C		1.7	2.6		1.7	2.6	mA
		1.0 2.0 1, 110.000	Full range			2.6			2.6	

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

[†] Full range is -55°C to 125°C

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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TLC2202M operating characteristics at specified free-air temperature, V_{DD} = 5 V

	DADAMETED	TEST COMPLETONS		TL	C2202A	M	TL	C2202B	M	·
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
0.0	0	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.6	2.5		1.6	2.5		.,,
SR	Slew rate at unity gain	R_L = 10 kΩ, C_L = 100 pF	Full range	0.9			1.1			V/µs
,,	Equivalent input noise voltage	f = 10 Hz	25°C		18	35*		18	30*) // [II
Vn	n (see Note 5)	f = 1 kHz	25°C		8	15*		8	12*	nV/√Hz
.,	Peak-to-peak equivalent input	f = 0.1 to 1 Hz	25°C		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz	25°C		0.7			0.7		μV
In	Equivalent input noise current		25°C		0.6			0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		47°			47°		

^{*}On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

NOTE 5: This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

[†] Full range is -55°C to 125°C

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TLC2201Y electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CON	NTIONS	TL	.C2201Y	,	UNIT
	PARAMETER	MIN T		TYP	MAX	UNII	
VIO	Input offset voltage				100		μV
	Input offset voltage long-term drift (see Note 4)] _{V-2} 0	$R_S = 50 \Omega$		0.001		μV/mo
10	Input offset current	V _{IC} = 0,	ng = 50 12		0.5		pА
I _{IB}	Input bias current				1		pΑ
Vон	Maximum high-level output voltage	$R_L = 10 \text{ k}\Omega$			4.8		٧
VOL	Maximum low-level output voltage	IO = 0			0		mV
Δ	Large-signal differential voltage amplification	$V_0 = 1 \text{ V to 4 V},$	$R_L = 500 \Omega$		55		V/mV
AVD	Large-signal differential voltage amplification	$V_0 = 1 \text{ V to 4 V},$	R _L = 10 Ω		55		V/IIIV
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,		110		dB
ksvr	Supply voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD} = 4.6 to 16	/		110		dB
IDD	Supply current per amplifier	V _O = 2.5 V,	No load		1		mA

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2201Y operating characteristics at V_{DD \pm} = \pm 5 V, T_A = 25°C

	PARAMETER	TECT	CONDITIONS		TL	C2201Y	'	UNIT
	PANAMETER	IESI	CONDITIONS		MIN	TYP	MAX	UNII
SR	Positive slew rate at unity gain	$V_0 = \pm 0.5 \text{ to } 2.5 \text{ V},$	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF		2.5		V/μs
.,	Equivalent input noise voltage	f = 10 Hz				18		nV/√ Hz
Vn	Equivalent input noise voltage	f = 1 kHz				8		nv/√Hz
V	Peak-to-peak equivalent input noise	f = 0.1 to 1 Hz				0.5		μV
VN(PP)	voltage	f = 0.1 to 10 Hz				0.7		μν
In	Equivalent input noise current					0.6	*	pA/√Hz
	Gain-bandwidth product	f = 10 kHz,	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF		1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF			48°		

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TLC2202Y electrical characteristics, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEST CONI	DITIONO	TL	C2202\	′	
	PARAMETER	I EST CONL	DITIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage				100		μV
	Input offset voltage long-term drift (see Note 4)],,_ 0	$R_S = 50 \Omega$		0.001		μV/mo
Iю	Input offset current	V _{IC} = 0,		0.5		pА	
lв	Input bias current			1		pА	
VOH	Maximum high-level output voltage	R _L = 10 kΩ			4.8		٧
VOL	Maximum low-level output voltage	IO = 0			0		mV
۸	Large signal differential voltage emplification	V _O = 1 V to 4 V,	R _L = 500 Ω		315		V/mV
AVD	Large-signal differential voltage amplification	$V_0 = 1 \text{ V to 4 V},$	R _L = 10 Ω		55		V/IIIV
CMRR	Common-mode rejection ratio	VO = 0, VICRmin,	$R_S = 50 \Omega$		110		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DCC} /ΔV _{IO})	V _{DD} = 4.6 to 16 V			110		dB
lDD	Supply current	V _O = 2.5 V,	No load		1.7		mA

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2202Y operating characteristics at V_{DD} = 5 V, T_A = 25°C

	DADAMETED	TEST 00	NOTIONS	TL	.C2202\	<i>'</i>	
	PARAMETER	TEST CO	NDITIONS	MIN	MIN TYP MAX		UNIT
SR	Positive slew rate at unity gain	V _O = 0.5 V to 2.5 C _L = 100 pF	V, $R_L = 10 \text{ k}\Omega$,		2.5		V/μs
, , , , , , , , , , , , , , , , , , ,	Equivalent input noise voltage	f = 10 Hz			18		nV/√Hz
V _n	Equivalent input noise voltage	f = 10 kHz		8		nv/√Hz	
\/	Dock to work assistation time to cine walters	f = 0.1 to 1 Hz			0.5		μV
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz			0.7		μν
In	Equivalent input noise current				0.6		pA/√Hz
B ₁	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	R _L = 10 kΩ,		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$,	C _L = 100 pF		47°		

PARAMETER MEASUREMENT INFORMATION

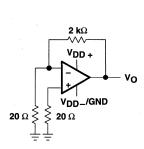
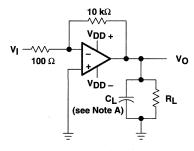
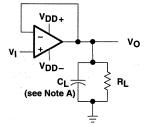


Figure 1. Noise-Voltage Test Circuit



NOTE A: Ci includes fixture capacitance.

Figure 2. Phase-Margin Test Circuit



NOTE A: CL includes fixture capacitance.

Figure 3. Slew-Rate Test Circuit

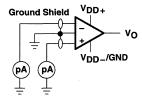


Figure 4. Input-Bias and Offset-Current Test Circuit

typical values

Typical values presented in this data sheet represent the median (50% point) of device parametric performance.

input bias and offset current

At the picoamp bias current level of the TLC220x, TLC220xA, and TLC220xB, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted in the socket, and a second test measuring both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

noise

Texas Instruments offers automated production noise testing to meet individual application requirements. Noise voltage at f = 10 Hz and f = 1 kHz is 100% tested on every TLC2201B device, while lot sample testing is performed on the TLC220xA. For other noise requirements, please contact the factory.



TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	5, 6
I _{IB}	Input bias current	vs Common-mode input voltage vs Free-air temperature	7 8
V _{ОМ}	Maximum peak output voltage	vs Output current vs Free-air temperature	9 10
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	11
Vон	High-level output voltage	vs Frequency vs High-level output current vs Free-air temperature	12 13 14
VOL	Low-level output voltage	vs Low-level output current vs Free-air temperature	15 16
AVD	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	17 18
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	19 20
CMRR	Common-mode rejection ratio	vs Frequency	21
IDD	Supply current	vs Supply voltage vs Free-air temperature	22 23, 24
	Pulse response	Small signal Large signal	25, 26 27, 28
SR	Slew rate	vs Supply voltage vs Free-air temperature	29 - 30
	Noise voltage (referred to input)	0.1 to 1 Hz 0.1 to 10 Hz	31 32
	Gain-bandwidth product	vs Supply voltage vs Free-air temperature	33, 34 35
φm	Phase margin	vs Supply voltage vs Free-air temperature	36, 37 38, 39
	Phase shift	vs Frequency	17

TYPICAL CHARACTERISTICS

Percentage of Units - %

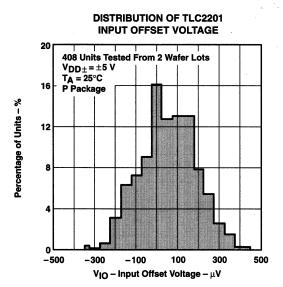
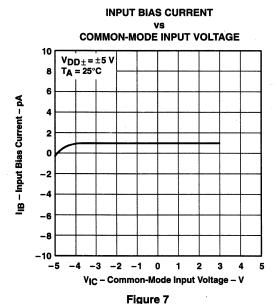


Figure 5



TLC2202 DISTRIBUTION OF INPUT OFFSET VOLTAGE

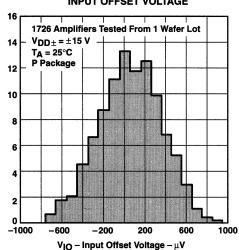
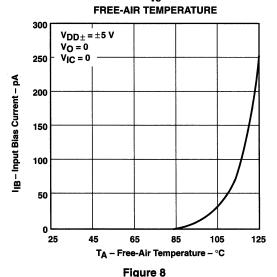


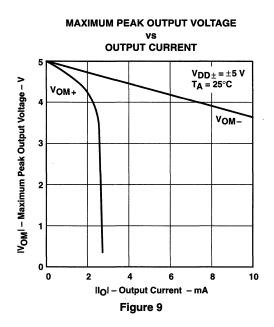
Figure 6

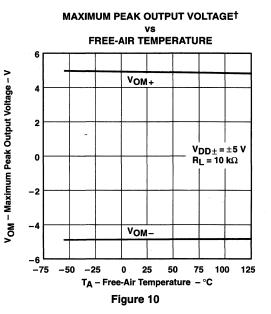
INPUT BIAS CURRENT†

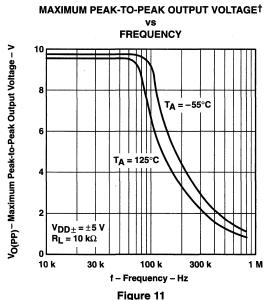


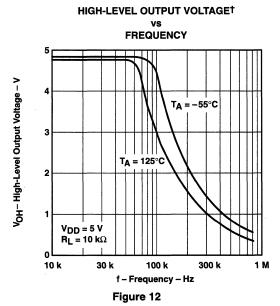
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



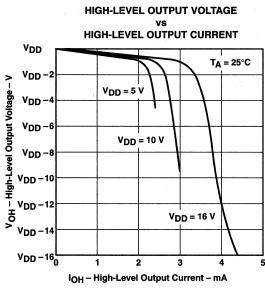


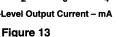




† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS





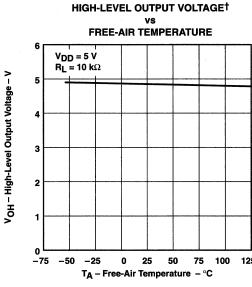
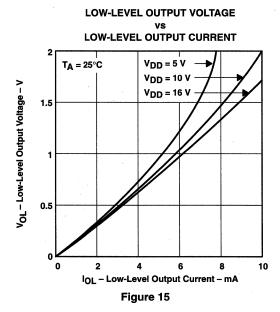
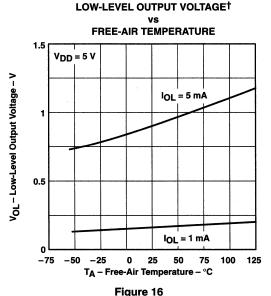


Figure 14





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

LARGE-SIGNAL DIFFERENTIAL VOLTAGE

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TYPICAL CHARACTERISTICS

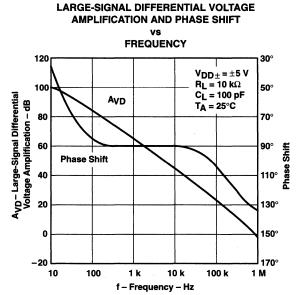


Figure 17

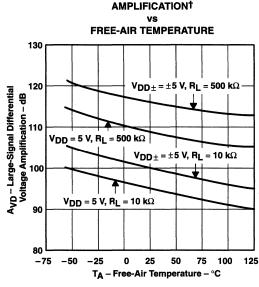
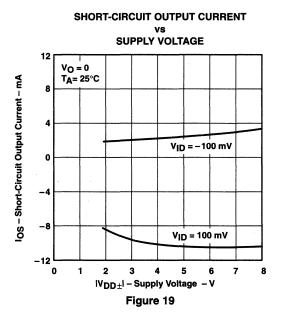
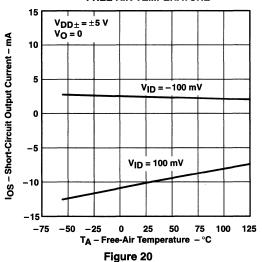


Figure 18



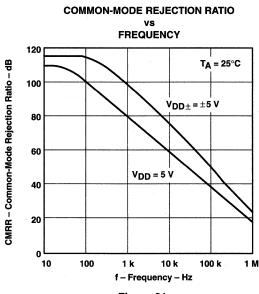
SHORT-CIRCUIT OUTPUT CURRENT[†] VS FREE-AIR TEMPERATURE



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



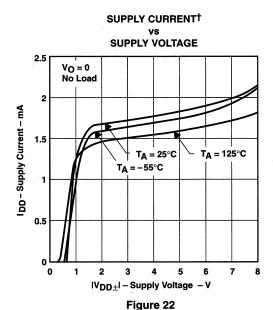
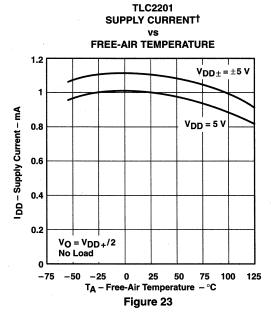
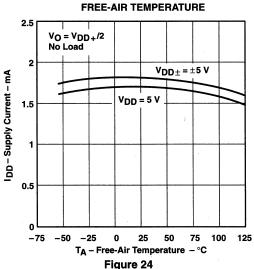


Figure 21



TLC2202 SUPPLY CURRENT[†]



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



Figure 28

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TYPICAL CHARACTERISTICS

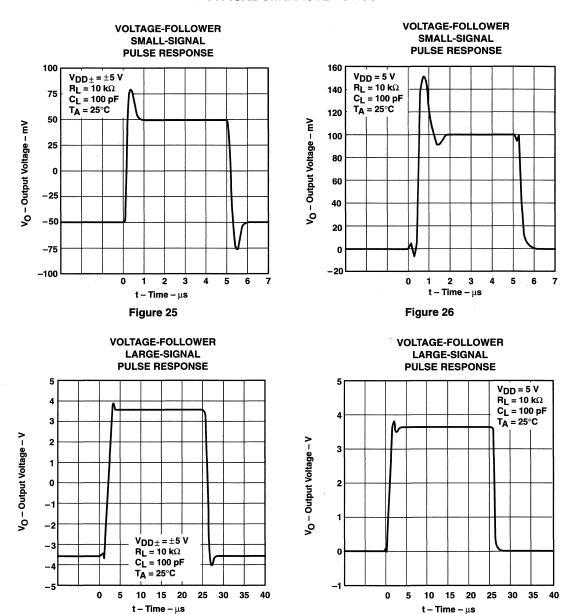
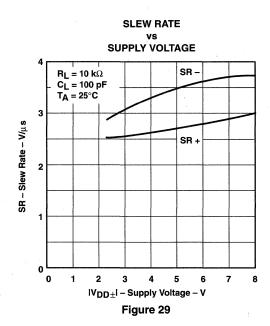
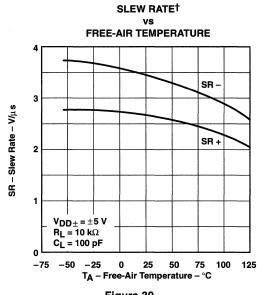


Figure 27

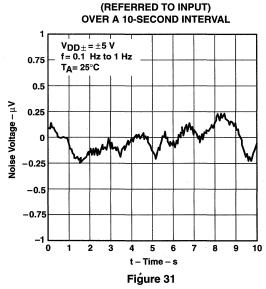
TYPICAL CHARACTERISTICS

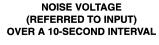


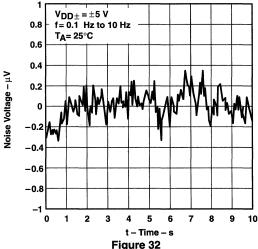


NOISE VOLTAGE



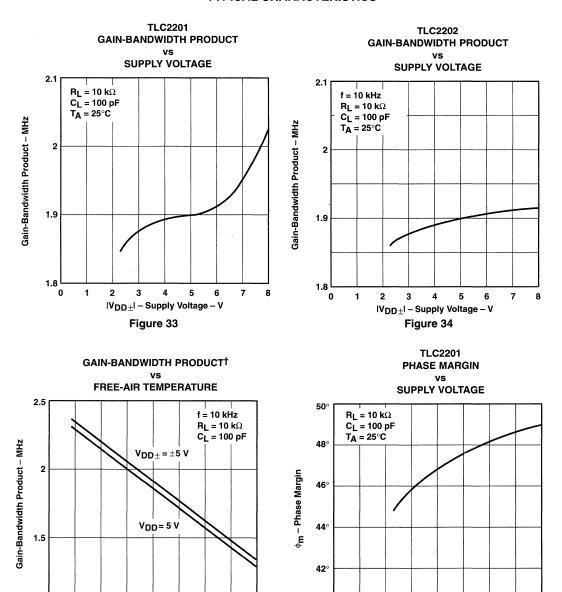






[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



75 100

-75 -50 -25

0 25 50

TA - Free-Air Temperature - °C

Figure 35



40°

0

1

2

3

4

IVDD+I - Supply Voltage - V

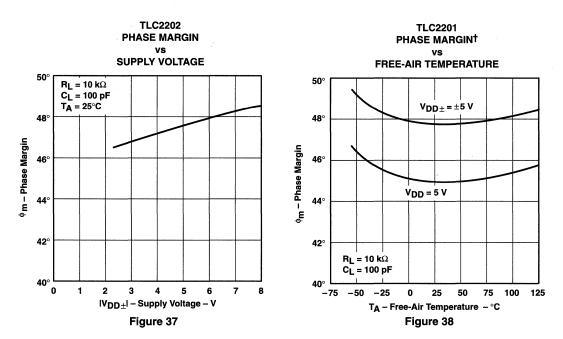
Figure 36

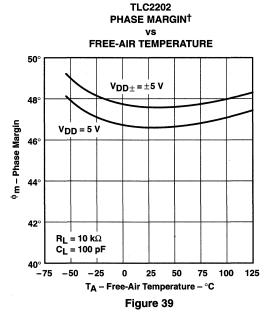
8

7

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



APPLICATION INFORMATION

latch-up avoidance

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC220x, TLC220xA, and TLC220xB inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up; however, techniques reducing the chance of latch-up should be used whenever possible. Internal protection diodes should not be forward biased in normal operation. Applied input and output voltages should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

electrostatic discharge protection

These devices use internal ESD-protection circuits that prevent functional failures at voltages at or below 2000 V. Care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 40 were generated using the TLC220x typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

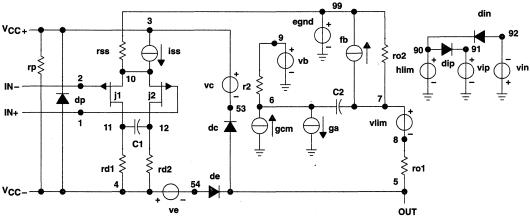
NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

PSpice and Parts are trademarks of MicroSim Corporation.



APPLICATION INFORMATION

macromodel information (continued)



```
.subckt TLC220x 1 2 3 4 5
                                                                 10 dc 135.0E-6
                                                         iss
                                                              3
                                                              2
                                                                 0
                                                                     .5E-12
                                                         iio
                                                              88
 c1
      1
          12 8.51E-12
                                                         i1
                                                                 0
                                                                    1E-21
 c2
             50.00E-12
                                                              11
                                                                 89
                                                                    10 jx
                                                         j1
 cpsr 85
         86 79.6E-9
                                                                 80 10 jx
                                                         i2
                                                              12
 dcm+ 81
          82 dx
                                                         r2
                                                              6
                                                                 9
                                                                     100.0E3
 dcm- 83
          81 dx
                                                         rcm
                                                              84
                                                                 81
                                                                    1k
 dс
          53 dx
                                                         rn1
                                                              88
                                                                 0 1500
      54
 de
          5
             dx
                                                         ro1
                                                              8
                                                                 5
                                                                     188
 dlp 90
                                                                 99 187
          91
            dx
                                                         ro2
                                                              7
 dln 92
         90 dx
                                                             10
                                                                 99 1.481E6
                                                         rss
 đр
                                                         vad
                                                              60
                                                                 4
                                                                     -.3v
      4
          3
             dx
                                                                 99 2.2
 ecmr 84
         99
             (2,99) 1
                                                              82
                                                         vcm+
 egnd 99
         0
             poly(2) (3,0) (4,0) 0 .5 .5
                                                         vcm- 83
                                                                 99
                                                                    -4.5
             poly(1) (3,4) -200E-6 20E-6
 epsr 85
                                                              9
                                                                     dc 0
          0
                                                         vb
                                                                 0
             poly(1) (88,0) 100E-6 1
 ense 89
                                                                 53 dc .9
         2
                                                              3
                                                         VC
 fb
      7
          99 poly(6) vb vc ve vlp vln
                                                                     dc .8
                                                         ve
                                                              54
                                                                 4
  vpsr 0
              895.9E3 -90E3 90E3 90E3 -90E3 895E3
                                                         vlim 7
                                                                 8
                                                                     dc 0
     6
             11 12 314.2E-6
                                                         vlp 91
                                                                0
                                                                    dc 2.8
 ga
 gcm 0
                                                                 92 dc 2.8
                                                         vln 0
          6
             10 99 1.295E-9
 gpsr 85
         86
             (85,86) 100E-6
                                                         vpsr 0
                                                                 86 dc 0
 grd1 60 11 (60,11) 3.141E-4
                                                       .model dx d(is=800.0E-18)
 grd2 60
         12 (60,12) 3.141E-4
                                                       .model jx pjf(is=500.0E-15 beta=1.462E-3
 hlim 90 0 vlim 1k
                                                       + vto=-.155 kf=1E-17)
 hcmr 80 1
             poly(2) vcm+ vcm- 0 1E2 1E2
                                                       .endsx
 irp 3
             965E-6
```

Figure 40. Boyle Macromodel and Subcircuit

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- **Output Swing includes Both Supply Rails**
- Low Noise . . . 19 nV/ \sqrt{Hz} Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ

description

- Fully Specified for Both Single-Supply and Split-Supply Operation
- Very Low Power . . . 35 μ A Per Channel Typ

The TLC2252 and TLC2254 are dual and quadruple operational amplifiers from Texas

Instruments. Both devices exhibit rail-to-rail

output performance for increased dynamic range

in single- or split-supply applications. The TLC225x family consumes only 35 µA of supply current per channel. This micropower operation

makes them good choices for battery-powered applications. The noise performance has been

dramatically improved over previous generations of CMOS amplifiers. Looking at Figure 1, the TLC225x has a noise level of 19 nV/ \sqrt{Hz} at 1kHz:

four times lower than competitive micropower

- Common-Mode Input Voltage Range **Includes Negative Rail**
- **Low Input Offset Voltage** 850 μ V Max at T_{Δ} = 25°C (TLC225xA)
- Macromodel Included
- Performance Upgrades for the TS27L2/L4 and TLC27L2/L4

EQUIVALENT INPUT NOISE VOLTAGE

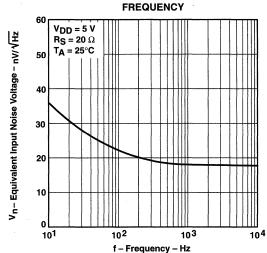


Figure 1

solutions. The TLC225x amplifiers, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the

rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC225xA family is available and has a maximum input offset voltage of 850 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage ranges, see the TLV2432 and TLV2442 devices. If the design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

TLC225x, TLC225xA, TLC225xY Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS SLOS176 – FEBRUARY 1997

TLC2252 AVAILABLE OPTIONS

TA		PACKAGED DEVICES						
	V _{IO} max AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP‡ (PW)	CERAMIC FLATPACK (U)	CHIP FORM§ (Y)
0°C to 70°C	1500 μV	TLC2252CD	_		TLC2252CP	TLC2252CPWLE	_	
-40°C to 85°C	850 μV 1500 μV	TLC2252AID TLC2252ID	_		TLC2252AIP TLC2252IP	TLC2252AIPWLE —	_	TLC2252Y
-55°C to 125°C	850 μV 1500 μV	<u> </u>	TLC2252AMFK TLC2252MFK	TLC2252AMJG TLC2252MJG			TLC2252AMU TLC2252MU	

[†] The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2262CDR).

TLC2254 AVAILABLE OPTIONS

		PACKAGED DEVICES							
. T _A	V _{IO} max AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP‡ (PW)	CERAMIC FLATPACK (W)	CHIP FORM [§] (Y)	
0°C to 70°C	1500 μV	TLC2254CD			TLC2254CN	TLC2254CPWLE	_	TLC2254Y	
-40°C to 125°C	850 μV 1500 μV	TLC2254AID TLC2254ID			TLC2254AIN TLC2254IN	TLC2254AIPWLE		_	
−55°C to 125°C	850 μV 1500 μV		TLC2254AMFK TLC2254MFK	TLC2254AMJ TLC2254MJ	_	_	TLC2254AMW TLC2254MW	_	

The D packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2254CDR).

[‡] The PW package is available only left-ended taped and reeled.

[§] Chip forms are tested at 25°C only.

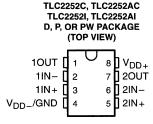
[‡] The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

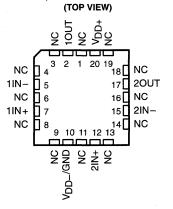
[§] Chip forms are tested at 25°C only.

TLC225x, TLC225xA, TLC225xY Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS

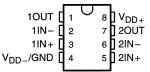
TLC2252M, TLC2252AM . . . FK PACKAGE

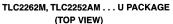
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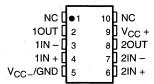




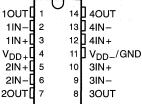
TLC2252M, TLC2252AM . . . JG PACKAGE (TOP VIEW)



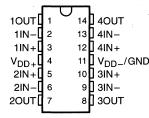




TLC2254C, TLC2254AC TLC2254I, TLC2254AI D, N, OR PW PACKAGE (TOP VIEW)



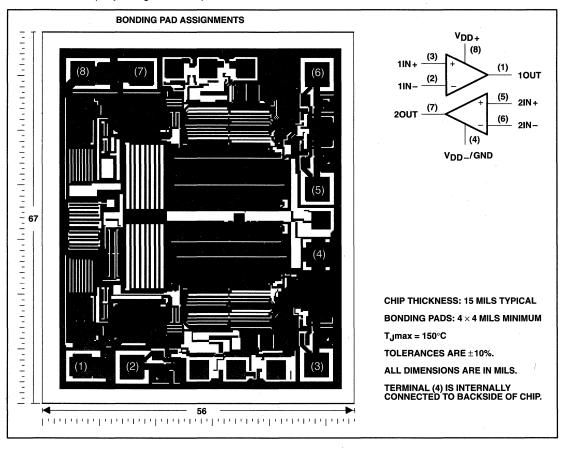
TLC2254M, TLC2254AM J OR W PACKAGE (TOP VIEW)



TLC2254M, TLC2254AM **FK PACKAGE** (TOP VIEW) 11N -10UT NC 40UT 2 1 20 19 1IN+ 4IN+ 17 NC NC **1** 5 V_{CC+} 16 V_{CC}_/GND 15 NC NC 2IN+ ηв 14**☐** 3IN+ 10 11 12 13 2IN -20UT

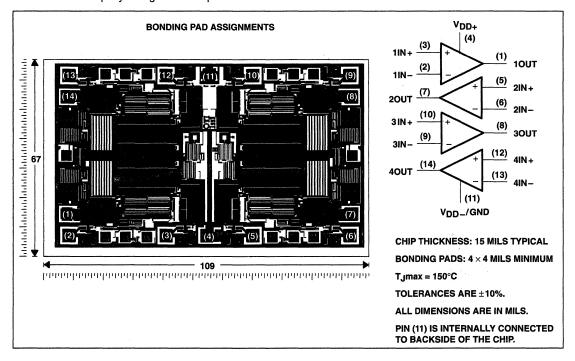
TLC2252Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2252C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.

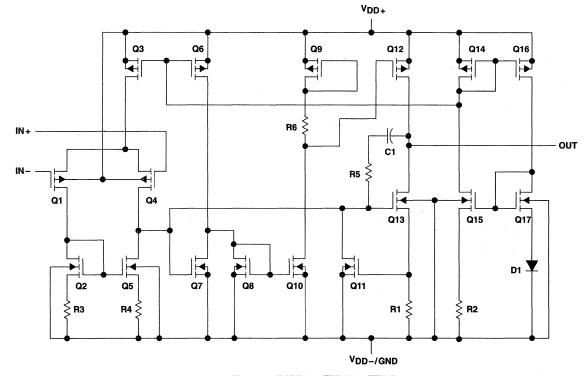


TLC2254Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2254C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. The chip may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic (each amplifier)



TLC225x, TLC225xA, TLC225xY
Advanced LinCMOSTM RAIL-TO-RAIL
VERY LOW-POWER OPERATIONAL AMPLIFIERS
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ACTUAL DEVICE COMPONENT COUNT								
COMPONENT TLC2252 TLC2254								
Transistors	38	76						
Resistors	30	56						
Diodes	9	18						
Capacitors	3	6						

[†] Includes both amplifiers and all ESD, bias, and trim circuitry

TLC225x, TLC225xA, TLC225xY Advanced LinCMOS™ RAIL-TO-RAIL **VERY LOW-POWER OPERATIONAL AMPLIFIERS**

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage Vpp (see Note 1)	8 V
Supply voltage, V _{DD+} (see Note 1)	0 \/
Differential input voltage, V _{ID} (see Note 2)	
Input voltage, V _I (any input, see Note 1)	±8 V
Input current, I ₁ (each input)	±5 mA
Output current, I _O	±50 mA
Total current into V _{DD+}	±50 mA
Total current out of V _{DD}	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A : C suffix	0°C to 70°C
l suffix	40°C to 85°C
	55°C to 125°C
Storage temperature range, T _{stg}	65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VDD+ and VDD-.

- 2. Differential voltages are at IN+ with respect to IN-. Excessive current flows when input is brought below V_{DD} = 0.3 V.
- 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	724 mW	5.8 mW/°C	464 mW	377 mW	_
D-14	950 mW	7.6 mW/°C	608 mW	450 mW	_
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	275 mW
N	1150 mW	9.2 mW/°C	736 mW	736 mW	_
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	_
PW-8	525 mW	4.2 mW/°C	336 mW	273 mW	_
PW-14	700 mW	5.6 mW/°C	448 mW	448 mW	_
υ	700 mW	5.5 mW/°C	246 mW	330 mW	150 mW
w	700 mW	5.5 mW/°C	246 mW	330 mW	150 mW

recommended operating conditions

	С	C SUFFIX		I SUFFIX		M SUFFIX	
	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.2	±8	±2.2	±8	±2.2	±8	٧
Input voltage range, V _I	V _{DD} _	V _{DD+} -1.5	V_{DD-}	V _{DD+} -1.5	V_{DD-}	V _{DD+} -1.5	٧
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} -1.5	V _{DD} _	V _{DD+} -1.5	V_{DD-}	V _{DD+} -1.5	٧
Operating free-air temperature, TA	0	70	-40	85	-55	125	°C



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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

:	PARAMETER	TEST CO	NDITIONS	+ +	Т	C22520)	11117
	PARAMETER	lesi co	MUITIONS	TAT	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		200	1500	μV
VIO				Full range			1750	μν
αΛΙΟ	Temperature coefficient of input offset voltage			25°C to 70°C		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ $V_{O} = 0,$	$V_{DD} \pm = \pm 2.5 \text{ V},$ $R_S = 50 \Omega$	25°C		0.003		μV/mo
l.o	Input offeet current	VO = 0,	ng = 50 22	25°C		0.5		n 1
ΙΟ	Input offset current			Full range			100	рA
lin	Input bias current			25°C		1		рA
IB	mput bias current			Full range			100	рΑ
Vion	Common-mode input voltage range	Po = 50 O	\/\c\ < 5 m\/	25°C	0 to 4	-0.3 to 4.2		V
VICR	Common-mode input voitage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	Full range	0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.98		
Vou	High-level output voltage	l _{OH} = -75 μA	*	25°C	4.9	4.94		v
VOH	riigh-level output voitage	ΙΟΗ = -75 μΑ		Full range	4.8			ľ
		$I_{OH} = -150 \mu A$ 25°C 4.8 4		4.88				
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01		
		V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15	
		VIC = 2.5 V,		Full range			0.15	
v_{OL}	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 1 mA	25°C		0.2	0.3	V
		10 = 2.0 t,		Full range			0.3	
		V _{IC} = 2.5 V,	$I_{OI} = 4 \text{ mA}$	25°C		0.7	1	
		10 2.0 1,		Full range			1.2	
		V _{IC} = 2.5 V,	R _L = 100 kΩ [‡]	25°C	100	350		
AVD	Large-signal differential voltage amplification	$V_0 = 1 \text{ V to 4 V}$		Full range	10			V/mV
		_	$R_L = 1 M\Omega^{\ddagger}$	25°C		1700		
^r id	Differential input resistance			25°C		1012		Ω
r _{ic}	Common-mode input resistance			25°C		1012		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	$V_0 = 2.5 V$,	25°C Full range	70 70	83		dB
		V _{DD} = 4.4 V to	16 V	25°C	80	95		
ksvr	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{IC} = V_{DD}/2$,	No load	Full range	80			dB
IDD	Supply current	$V_{O} = 2.5 \text{ V},$	No load	25°C		70	125	μА
		$V_O = 2.5 \text{ V}$, No load		Full range	<u> </u>		150	<u> </u>

[†] Full range is 0°C to 70°C.



[‡] Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^{\circ}C$ extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}}$ = 5 V

	DADAMETED	TEST COND	ITIONS	- +	TI	_C2252C	;	UNIT
	PARAMETER	TEST COND	ITIONS	T _A †	MIN	TYP	MAX	UNII
		4574-0575	100 lot	25°C	0.07	0.12		
SR	Slew rate at unity gain	V _O = 1.5 V to 3.5 V, R C _L = 100 pF [‡]	L = 100 K22+,	Full range	0.05		•	V/μs
V	Equivalent input noise voltage	f = 10 Hz		25°C		36		->4/10=
Vn	Equivalent input noise voltage	f = 1 kHz		25°C		19		nV/√Hz
V	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz		25°C	0.7			μV
VN(PP)	reak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.1		μν
In	Equivalent input noise current			25°C		0.6		fA√Hz
THD + N	Total harmonic distortion plus noise	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$ f = 10 kHz,	A _V = 1	25°C		0.2%		
THD + N	Total Harmonic distortion plus Hoise	$R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25 0		1%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF [‡]	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 V$, $R_{L} = 50 \text{ k}\Omega^{\ddagger}$,	A _V = 1, C _L = 100 pF [‡]	25°C		30		kHz
φm	Phase margin at unity gain	$R_{I} = 50 \text{ k}\Omega^{\ddagger}$	C _I = 100 pF [‡]	25°C		63°		
	Gain margin	U[= 00 k22+,	CL = 100 pr+	25°C		15		dB

[†] Full range is 0°C to 70°C. ‡ Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	PARAMETER	TEST CO	NDITIONS	T. 1	T	LC2252C	;	LINUT
	FARAMETER	1231 00		TA [†]	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		200	1500	μV
V10	input onset voltage			Full range			1750	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_{O} = 0$,	25°C		0.003		μV/mo
li a	Input offset surrent	7115 - 30 32		25°C		0.5		
ΙΟ	Input offset current			Full range			100	pA
lun	Input bigg ourrent	1		25°C		1		nΛ
IB	Input bias current			Full range			100	рA
Vion	Common mode input voltage range	V _{IO} ≤5 mV,	Po - 50 O	25°C	-5 to 4	-5.3 to 4.2		٧
VICR	Common-mode input voltage range	INDY SOMM,	ng = 50 sz	Full range	-5 to 3.5			V
		$I_{O} = -20 \mu A$	_	25°C		4.98		,
V _{OM+}	Maximum positive peak output voltage	I _O = -100 μA		25°C	4.9	4.93		V
VOIVI+	maximum poolivo pour output voitago	ΙΟ - 100 μπ	_	Full range	4.7			·
		I _O = -200 μA		25°C	4.8	4.86		
		$V_{IC} = 0$,	IO = 50 μA	25°C		-4.99		
		V _{IC} = 0,	l _O = 500 μA	25°C	-4.85	-4.91		
		-10		Full range	-4.85			
∨ом–	Maximum negative peak output voltage	V _{IC} = 0,	I _O = 1 mA	25°C	-4.7	-4.8		V
		-10		Full range	-4.7			
		V _{IC} = 0,	$I_O = 4 \text{ mA}$	25°C	-4	-4.3		
		1.0	,	Full range	-3.8			
			R _L = 100 kΩ	25°C	45	650		
AVD	Large-signal differential voltage amplification	$V_0 = \pm 4 \text{ V}$	ŀ	Full range	10			V/mV
			$R_L = 1 M\Omega$	25°C		3000		
rid	Differential input resistance			25°C		1012		Ω
ric	Common-mode input resistance		en	25°C		1012		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8		pF
z _O	Closed-loop output impedance	f = 25 kHz,	Ay = 10	25°C		190		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = -5 V \text{ to } 2$	2.7 V,	25°C	75	88		dB
		V _O = 0,	$R_S = 50 \Omega$	Full range	75			
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD\pm} = 2.2 V$		25°C	80	95		dB
-5411		V _{IC} = 0,	No load	Full range	80			
lDD	Supply current	V _O = 0,	No load	25°C		80	125	μА
טטי		1.0 = 3,		Full range	<u> </u>		150	ļ.,,

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CO	NDITIONS	- +	-	TLC22520	;	UNIT
	PARAMETER	IESI CO	NUTTONS	TAT	MIN	TYP	MAX	UNII
		V- +10V	D. 100 kg	25°C	0.07	0.12		
SR	Slew rate at unity gain	$V_O = \pm 1.9 \text{ V},$ $C_L = 100 \text{ pF}$	$R_L = 100 \text{ k}\Omega$,	Full range	0.05			V/μs
V	Equivalent input paige valtage	f = 10 Hz		25°C		38		-14/11-
V _n	Equivalent input noise voltage	f = 1 kHz		25°C		19		nV/√Hz
V	Dook to peak aguivalent input paige valtage	f = 0.1 Hz to 1 Hz	:	25°C		0.8		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 H	lz	25°C		1.1		μV
In	Equivalent input noise current			25°C		0.6		fA√Hz
THD + N	Total harmonic distortion pulse duration	$V_0 = \pm 2.3 \text{ V},$ f = 10 kHz,	A _V = 1	25°C		0.2%		
וו + טחו	total narmonic distortion pulse duration	$R_L = 50 \text{ k}\Omega$	A _V = 10	25.0		1%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21		MHz
вом	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		14		kHz
φm	Phase margin at unity gain	D. 50 kg	C: 100 pF	25°C		63°		
	Gain margin	$R_L = 50 \text{ k}\Omega$,	C _L = 100 pF	25°C		15		dB

[†] Full range is 0°C to 70°C.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	T. +	Ti	LC22540	;	UNIT
	FARAMETER	1231 00		T _A †	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		200	1500	μV
VIO	mput onset voitage			Full range			1750	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$V_{DD\pm} = \pm 2.5 \text{ V},$ $R_S = 50 \Omega$	25°C		0.003		μV/mo
lio	Input offset current	\ \(\) = 0,	HS = 30 75	25°C		0.5		рA
10	input oliset current			Full range			100	ÞΑ
1	Input bigg gurrent	1		25°C		1		
IB	Input bias current			Full range			100	pΑ
V	Common mode insult vallence vance	D- 50.0	116-1251	25°C	0 to 4	-0.3 to 4.2		٧
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _O ≤ 5 mV	Full range	0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.98		
VOH	High-level output voltage	Jan - 75 uA	1	25°C	4.9	4.94		v
VOH	riigii-level output voltage	IOH = -75 μA IOH = -150 μA		Full range	4.8			٧
				25°C	4.8	4.88		
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01		
		V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15	
		V ₁ C = 2.5 V,	10L = 300 μΑ	Full range			0.15	
VOL	Low-level output voltage	V _{IC} = 2.5 V,	IOL = 1 mA	25°C		0.2	0.3	٧
		V ₁ C = 2.5 v,	10L = 1111A	Full range			0.3	
		V _{IC} = 2.5 V,	IOL = 4 mA	25°C		0.7	1	
		V ₁ C = 2.5 V,	10L = 4111A	Full range			1.2	
		V 05V	R _L = 100 kه	25°C	100	350		
AVD	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $V_{O} = 1 \text{ V to 4 V}$	11L = 100 K22+	Full range	10			V/mV
			$R_L = 1 M\Omega^{\ddagger}$	25°C		1700		
ri(d)	Differential input resistance			25°C		1012		Ω
r _{i(c)}	Common-mode input resistance			25°C		1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200		Ω
	Common mode valention valie	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	83		40
CIVINA	Common-mode rejection ratio	$R_S = 50 \Omega$		Full range	70			dB
kove	Supply voltage rejection ratio (AV-= /AV-=)	V _{DD} = 4.4 V to	16 V,	25°C	80	95		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			uв
Inn	Supply current (four amplifiers)	V _O = 2.5 V,	No load	25°C		140	250	μА
IDD	Supply current (lour amplifiers)	VO = 2.5 V,	INO IDAU	Full range			300	μΑ.

[†] Full range is 0°C to 70°C.



[‡] Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at TA = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

	DADAMETED	TEST COND	NTIONE	- +	TL	C22540	;	UNIT
	PARAMETER	TEST COND	JIIONS	T _A †	MIN	TYP	MAX	UNII
SR	Slew rate at unity gain	V _O = 1.4 V to 2.6 V	$R_L = 100 \text{ k}\Omega^{\ddagger}$,	25°C	0.07	0.12		V/µs
on	Siew rate at unity gain	C _L = 100 pF [‡]		Full range	0.05			V/μS
V	Equivalent input poins valtage	f = 10 Hz		25°C		36		
Vn	Equivalent input noise voltage	f = 1 kHz		25°C		19		nV/√Hz
V	Peak-to-peak equivalent input noise	f = 0.1 Hz to 1 Hz		25°C	0.7			/
VN(PP)	voltage	f = 0.1 Hz to 10 Hz		25°C		1.1		μV
In	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$ f = 10 kHz,	A _V = 1	25°C		0.2%		
THD + N	Total flamfortic distortion plus floise	$R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	23 0		1%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		30		kHz
φm	Phase margin at unity gain	$R_{I} = 50 \text{ k}\Omega^{\ddagger}$	C _I = 100 pF‡	25°C		63°		
	Gain margin	7 PL = 50 K22+,	OL = 100 pr+	25°C		15		dB

[†] Full range is 0°C to 70°C.

[‡] Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	PARAMETER	TEST CO	ONDITIONS	T. +	Т	LC22540	;	LIMIT
	PARAWIE I ER	1231 00		T _A †	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		200	1500	μV
VIO		_		Full range			1750	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_O = 0$,	25°C		0.003		μV/mo
lio.	Input offset current	7 ng = 30 12		25°C		0.5		- nΛ
lo ol	input onset current			Full range			100	pΑ
lum	Input bias current			25°C		1		рA
IB	input bias current			Full range			100	PΛ
V	Common mode involvelle as a series	N - 1-55	D- 50.0	25°C	-5 to 4	-5.3 to 4.2		,,
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	HS = 50 72	Full range	-5 to 3.5		,	V
		I _O = -20 μA		25°C		4.98		
V	Maximum positive poets autout valtore	1- 1001		25°C	4.9	4.93		v
VOM+	Maximum positive peak output voltage	I _O = -100 μA		Full range	4.7			V
		$I_{O} = -200 \mu$ A	\	25°C	4.8	4.86		
	·	V _{IC} = 0,	l _O = 50 μA	25°C		-4.99		
		V 0	I- F00 A	25°C	-4.85	-4.91		
		$V_{IC} = 0$,	ΙΟ = 500 μΑ	Full range	-4.85			
V _{OM} -	Maximum negative peak output voltage	V 0	la 1 mA	25°C	-4.7	-4.8		٧
		$V_{IC} = 0,$	I _O = 1 mA	Full range	-4.7			
		V _{IC} = 0,	lo - 4 m4	25°C	-4	-4.3		
		VIC = 0,	I _O = 4 mA	Full range	-3.8			
			R _L = 100 kΩ	25°C	40	150		
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 4 V$	H_ = 100 K32	Full range	10			V/mV
			$R_L = 1 M\Omega$	25°C		3000		
^r i(d)	Differential input resistance			25°C		1012		Ω
ri(c)	Common-mode input resistance			25°C		1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	Ay = 10	25°C		190		Ω
	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to}$ $V_{O} = 0$,	2.7 V, R _S = 50 Ω	25°C Full range	75 75	88		dB
		V _{DD±} = ±2.		25°C	80	95		
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{IC} = 0,	No load	Full range	80			dB
lDD	Supply current (four amplifiers)	V _O = 0,	No load	25°C		160	250	μА
				Full range			300	

[†] Full range is 0°C to 70°C.



NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^{\circ}C$ extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~\text{V}$

	DADAMETED	TEST CON	UDITIONS	- +	TL	C22540	;	UNIT
	PARAMETER	TEST COM	NUTTONS	TAT	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_0 = \pm 1.9 V$,	R _L = 100 kΩ,	25°C	0.07	0.12		V/μs
J Sh	Siew rate at unity gain	C _L = 100 pF		Full range	0.05			ν /μ5
V	Equivalent input noise voltage	f = 10 Hz		25°C	-	38		nV/√ Hz
V _n	Equivalent input noise voltage	f = 1 kHz		25°C	1:			nv/vHz
Verran	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 1 Hz	Z	25°C		0.8		\/
V _{N(PP)}	reak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 H	łz	25°C		1.1		μV
In	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	$V_0 = \pm 2.3 \text{ V},$ f = 20 kHz,	Ay = 1	25°C		0.2%		
L IIID + N	Total Harmonic distortion plus hoise	$R_L = 50 \text{ k}\Omega$	A _V = 10	25 0		1%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		14		kHz
φm	Phase margin at unity gain	B 50 kO	C _I = 100 pF	25°C		63°		
	Gain margin	$R_L = 50 \text{ k}\Omega$,	CL = 100 pr	25°C		15		dB

[†] Full range is 0°C to 70°C.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONE	- +	T	LC2252	ı	TI	_C2252A	VI.	
	PANAMETER	TEST CON	IDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		200	1500		200	850	μV
۷۱٥	input onset voltage			Full range			1750			1000	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 85°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{IC} = 0,$	$V_O = 0$, $R_S = 50 \Omega$	25°C		0.003			0.003		μV/mo
10	Input offset current			25°C		0.5			0.5		pA
10				Full range			1000			1000	ρ, ι
lв	Input bias current			25°C		1			1		рA
10				Full range			1000			1000	Ρ, .
Vion	Common-mode input	$R_S = 50 \Omega$,	Wo 1/5 mV	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		v
VICR	voltage range	ng = 50 12,	V _{IO} ≤5 mV	Full range	0 to 3.5			0 to 3.5			v
		I _{OH} = -20 μA		25°C		4.98			4.98		
v	High-level output	- 75 A		25°C	4.9	4.94		4.9	4.94		.,
VOH	voltage	I _{OH} = -75 μA		Full range	4.8			4.8			٧
		$I_{OH} = -150 \mu A$		25°C	4.8	4.88		4.8	4.88	1	
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
		V 05V	1 F00 A	25°C		0.09	0.15		0.09	0.15	
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA	Full range			0.15			0.15	٧
	Tollago	V _{IC} = 2.5 V,	I _{OL} = 4 mA	25°C		8.0	1		0.7	1	
		V ₁ C = 2.5 V,	IOL - + IIIA	Full range			1.2			1.2	
	Large-signal differential	V _{IC} = 2.5 V,	R _L = 100 kه	25°C	100	350		100	350		
A_{VD}	voltage amplification	$V_0 = 1 \text{ V to 4 V}$		Full range	10			10			V/mV
			$R_L = 1 M\Omega^{\ddagger}$	25°C		1700			1700		
rid	Differential input resistance			25°C		1012			1012		Ω
ric	Common-mode input resistance			25°C		1012			1012		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200			200		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	$V_0 = 2.5 \text{ V},$	25°C Full range	70 70	83		70 70	83		dB
	Supply-voltage	1		25°C	80	95		80	95		<u> </u>
ksvr	rejection ratio	V _{DD} = 4.4 V to				90			90,		dB
	(ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			
IDD	Supply current	V _O = 2.5 V,	No load	25°C		70	125		70	125	μА
-טט		1 - 0 - 2.5 v,	110 1000	Full range			150			150	μΑ

[†] Full range is – 40°C to 125°C.



[‡] Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150$ °C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	ARAMETER	TEST COND	ITIONS	_ +	Т.	LC2252		TL	.C2252A	.I	
P.	ARAMEIER	1EST COND	IIIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	$V_O = 1.5 \text{ V to } 3.5 \text{ V},$ $R_L = 100 \text{ k}\Omega^{\ddagger},$		25°C	0.07	0.12		0.07	0.12		
SR	gain	C _L = 100 k22+,		Full range	0.05			0.05			V/μs
V	Equivalent input	f = 10 Hz		25°C		36			36		nV/√Hz
Vn	noise voltage	f = 1 kHz		25°C		19			19		nv/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7		0.7			
VN(PP)	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.1			1.1		μV
In	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
THD + N	Total harmonic distortion plus	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$ f = 10 kHz,	A _V = 1	25°C		0.2%			0.2%		
I HD + N	noise	$R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	250		1%			1%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2			0.2		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 50 \text{ k}\Omega^{\ddagger}$,	$A_V = 1$, $R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		30			30		kHz
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF‡	25°C		63°			63°		
	Gain margin			25°C		15			15		dB

[†] Full range is – 40°C to 125°C. ‡ Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEST CO	NDITIONS	-+	Т	LC2252		TI	C2252A	.I	11117
	PARAMETER	1EST CC	SNOTTIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
Via	Input offset voltage			25°C		200	1500		200	850	μV
V _{IO}	mput onset voltage			Full range			1750			1000	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 85°C		0.5		:	0.5		μV/°C
	Input offset voltage long- term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	$V_O = 0$,	25°C		0.003			0.003		μV/mo
		1		25°C		0.5			0.5		
ΙO	Input offset current		•	Full range			1000		. , , , , , , , , , , , , , , , , , , ,	1000	рA
1.	I	1		25°C		1			1		4
lΒ	Input bias current			Fuli range			1000			1000	pΑ
V _{ICR}	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	25°C	-5 to 4 -5	-5.3 to 4.2		-5 to 4 -5	-5.3 to 4.2		٧
				Full range	to 3.5			to 3.5	-		
		I _O = -20 μA		25°C		4.98			4.98		
Vou	Maximum positive peak	l _O = -100 μ	\	25°C	4.9	4.93		4.9	4.93		v
V _{OM+}	output voltage	ΙΟ = - 100 μ	`	Full range	4.7			4.7			·
		ΙΟ = -200 μ	4	25°C	4.8	4.86		4.8	4.86		
		$V_{IC} = 0$,	IO = 50 μA	25°C		-4.99			-4.99		
	ľ	V _{IC} = 0,	l _O = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91		
V_{OM-}	peak output voltage	VIC = 0,	10 = 300 μΑ	Full range	-4.85			-4.85			٧
	F	V _{IC} = 0,	$I_0 = 4 \text{ mA}$	25°C	-4	-4.3		-4	-4.3		
		VIC = 0,	10 = 4111A	Full range	-3.8			-3.8			
			R _L = 50 kΩ	25°C	40	150		40	150		
A_{VD}	Large-signal differential voltage amplification	$V_0 = \pm 4 V$	11[= 50 K22	Full range	10			10			V/mV
			$R_L = 1 M\Omega$	25°C		3000			3000		
^r id	Differential input resistance			25°C		1012			1012		Ω
r _{ic}	Common-mode input resistance		=======================================	25°C		1012			10 ¹²		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		190			190		Ω
CMDC	Common-mode	V _{IC} = −5 V t	o 2.7 V,	25°C	75	88		75	88		
CMRR	rejection ratio	V _O = 0,	$R_S = 50 \Omega$	Full range	75			75			dB
1	Supply-voltage rejection	V _{DD} = 4.4 \	' to 16 V,	25°C	80	95		80	95		-10
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{IC} = V_{DD}/2$		Full range	80			80			dB
I	Cupali aumort	V- 05V	No loo-l	25°C		80	125		80	125	
םם ^ו	Supply current	$V_0 = 2.5 V$,	NO IOAG	Full range			150			150	μA

[†] Full range is - 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150$ °C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~\text{V}$

	DADAMETED	TEST 00	UDITIONS	_ +	Т	LC2252	ı	TL	.C2252A	VI	UNIT
	PARAMETER	I EST CO	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
		$V_{O} = \pm 1.9 \text{ V},$	D. 100 kg	25°C	0.07	0.12		0.07	0.12		
SR	Slew rate at unity gain	C _L = 100 pF	H_ = 100 ks2,	Full range	0.05			0.05			V/μs
V	Equivalent input noise	f = 10 Hz		25°C		38			38		->4/5
V _n	voltage	f = 1 kHz		25°C		19			19		nV/√Hz
Veren	Peak-to-peak equivalent	f = 0.1 Hz to 1	Hz	25°C		0.8			0.8		\/
V _{N(PP)}	input noise voltage	f = 0.1 Hz to 10) Hz	25°C		1.1			1.1		μV
In	Equivalent input noise current			25°C	,	0.6			0.6		fA√Hz
TUD . N	Total harmonic distortion	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	0500		0.2%			0.2%		
THD + N	plus noise	$R_L = 50 \text{ k}\Omega$, f = 10 kHz	Ay = 10	25°C		1%			1%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21			0.21		MHz
Вом	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ N}$ R _L = 50 k Ω ,	/,A _V = 1, C _L = 100 pF	25°C		14			14		kHz
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega$,	C _L = 100 pF	25°C		63°			63°		
	Gain margin			25°C		15			15		dB

[†] Full range is -40°C to 125°C.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS	- +	Т	LC2254	ı	TI	_C2254A	VI	
	PANAMETEN	1EST CON	IDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
ViO	Input offset voltage			25°C		200	1500		200	850	μV
VIO	input onset voltage			Full range			1750			1000	μν
αVIO	Temperature coefficient of input offset voltage	V _{DD±} = ±2.5 V,		25°C to 125°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ $V_{O} = 0,$ $R_{S} = 50 \Omega$		25°C		0.003			0.003		μV/mo
lio	Input offset current			25°C		0.5			0.5		pA
10				Full range			1000			1000	p
I _{IB}	Input bias current	1		25°C		1			1		pA
				Full range			1000			1000	
	O-manus manda limud			25°C	to 4	-0.3 to 4.2		to 4	-0.3 to 4.2		
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	$ V_{IO} \le 5 \text{ mV}$		0	4.2		0	4.2		٧
	voltago rango			Full range	to			to			
					3.5			3.5			
		I _{OH} = -20 μA		25°C		4.98			4.98		
Vон	High-level output	I _{OH} = -75 μA		25°C	4.9	4.94		4.9	4.94		V
VOH	voltage	IOH = -75 μA		Full range	4.8			4.8			, v
		IOH = -150 μA		25°C	4.8	4.88		4.8	4.88		
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Low-level output	$V_{1C} = 2.5 \text{ V},$	lOI = 500 μA	25°C		0.09	0.15		0.09	0.15	!
VOL	voltage	10 =10 1,		Full range			0.15			0.15	V
	-	V _{IC} = 2.5 V,	$I_{Ol} = 4 \text{ mA}$	25°C		0.8	1		0.7	1	
		110	-OL	Full range			1.2			1.2	
	Large-signal	V _{IC} = 2.5 V,	R _I = 100 kΩ [‡]	25°C	100	350		100	350		
AVD	differential	V _O = 1 V to 4 V		Full range	10			10			V/mV
	voltage amplification		$R_L = 1 M\Omega^{\ddagger}$	25°C		1700			1700		
^r i(d)	Differential input resistance			25°C		1012			1012		Ω
r _{i(c)}	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200			200		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	V _O = 2.5 V,	25°C Full range	70 70	83		70 70	83		dB
·	Supply-voltage	-		25°C	80	95		80	95		
ksvr	rejection ratio (ΔVDD/ΔVIO)	$V_{DD} = 4.4 \text{ V to}$ $V_{IC} = V_{DD}/2$,	16 V, No load	Full range	80			80			dB
	Supply current	V. 05.V	NI- II	25°C		140	250		140	250	
DD	(four amplifiers)	$V_0 = 2.5 V$,	No load	Full range			300			300	μΑ

[†] Full range is - 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡] Referenced to 2.5 V

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	ADAMETED	TEST SOUD	ITIONIC	- +	Т	LC2254		TL	.C2254A	7	UNIT
P	ARAMETER	TEST COND	IIIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at unity	V _O = 1.4 V to 2.6 V,		25°C	0.07	0.12		0.07	0.12		
SR	gain	$R_L = 100 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$		Full range	0.05			0.05			V/μs
V	Equivalent input	f = 10 Hz		25°C		36			36		-V//II-
V _n	noise voltage	f = 1 kHz		25°C		19			19		nV/√Hz
	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.1			1.1		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.2%			0.2%		
IND+N	distortion plus noise	f = 20 kHz, $R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25 0		1%			1%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2			0.2		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 V,$ $R_{L} = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		30			30		kHz
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF‡	25°C		63°			63°		
	Gain margin	1		25°C		15			15		dB

[†] Full range is – 40°C to 125°C. ‡ Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CO	ONDITIONS	T.+	1	LC2254		TI	_C2254A	MAX 850 1000	11411-
	PANAMETEN	TEST CC	DINDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		200	1500		200	850	μV
VIO .	input onset voltage			Full range			1750			1000	μV
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	V _O = 0,	25°C		0.003			0.003		μV/mo
		1		25°C		0.5			0.5		
lio	Input offset current			Full range			1000			1000	pΑ
l	land the land account			25°C		1			1		
IB	Input bias current			Full range			1000			1000	рA
V:	Common-mode input	Pa - 50 0	11/1-1-/F m1/	25°C	-5 to 4	-5.3 to 4.2		−5 to 4	-5.3 to 4.2		V
VICR	voltage range	HS = 50 12,	V _{1O} ≤5 mV	Full range	-5 to 3.5			-5 to 3.5			V
		$I_0 = -20 \mu A$		25°C		4.98			4.98		
	Maximum positive peak	100	A	25°C	4.9	4.93		4.9	4.93		.,
V _{OM+}	output voltage	$I_0 = -100 \mu$	А	Full range	4.7			4.7			٧
		$I_{O} = -200 \mu$	A	25°C	4.8	4.86		4.8	4.86		
		V _{IC} = 0,	l _O = 50 μA	25°C		-4.99			-4.99		
			I - 500 · A	25°C	-4.85	-4.91		-4.85	-4.91		
V _{OM} _	Maximum negative peak output voltage	$V_{IC} = 0$,	I _O = 500 μA	Full range	-4.85			-4.85			٧
	output voltage	V 0	In 1 m 1	25°C	-4	-4.3		-4	-4.3		
	,	$V_{IC} = 0,$	I _O = 4 mA	Full range	-3.8			-3.8			
			R _L = 100 kΩ	25°C	40	150		40	150		
A_{VD}	Large-signal differential voltage amplification	$V_0 = \pm 4 V$	HE = 100 K22	Full range	10			10			V/m\
			R _L = 1 MΩ	25°C		3000			3000		
^r i(d)	Differential input resistance			25°C		1012			1012		Ω
ri(c)	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		190			190		Ω
CMDD	Common-mode rejection	V _{IC} = -5 V	to 2.7 V,	25°C	75	88		75	88		dB
CMRR	ratio	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	75			75			aB
kov-	Supply-voltage rejection		2 V to ±8 V,	25°C	80	95		80	95		dB
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	VIC = VDD/	2, No load	Full range	80			80			ub
loo.	Supply current	V0 = 0	No load	25°C		160	250		160	250	.,,
DD	(four amplifiers)	$V_O = 0$,	INO IOAU	Full range			300			300	μΑ

[†] Full range is - 40°C to 125°C.



NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~\text{V}$

	DADAMETED	TEST SON	DITIONS	_ +	T	LC2254		TL	.C2254A	Al .	
	PARAMETER	TEST CON	DITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
		V= - +1 0 V	R _L = 100 kΩ,	25°C	0.07	0.12		0.07	0.12		,
SR	Slew rate at unity gain	$V_O = \pm 1.9 \text{ V,}$ $C_L = 100 \text{ pF}$	M_ = 100 ks2,	Full range	0.05			0.05			V/μs
V	Equivalent input noise	f = 10 Hz		25°C		38			38		-14/15-
V _n	voltage	f = 1 kHz		25°C		19			19		nV/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C	,	0.8			0.8		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 H	İz	25°C		1.1			1.1		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	25°C		0.2%			0.2%		
IND + N	distortion plus noise	$R_L = 50 \text{ k}\Omega$, f = 20 kHz	A _V = 10	25.0		1%			1%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21			0.21		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		14			14		kHz
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega$	C _L = 100 pF	25°C		63°			63°		
	Gain margin			25°C		15			15		dB

[†] Full range is -40°C to 125°C.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

-	DADAMETED	TEST CON	DITIONS	- +	TL	-C22521	VI	TL	C2252A	М	
	PARAMETER	IESI CONI	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V	lour de effect ve la co			25°C		200	1500		200	850	
VIO	Input offset voltage			Full range			1750			1000	μV
ανιο	Temperature coefficient of input offset voltage			25°C to 125°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{DD±} = ±2.5 V, V _O = 0,	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.003			0.003		μV/mo
lio	Input offset current			25°C		0.5			0.5		pА
10	- Input onoct duriont			Full range			500			500	ρ, ,
lв	Input bias current			25°C		1			1		pΑ
'IB				Full range			500			500	PA
	Common-mode input			25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	0 to 3.5			0 to 3.5			V
		IOH = -20 μA		25°C		4.98			4.98		
V	High-level output			25°C	4.9	4.94		4.9	4.94		
VOH	voltage	IOH = -75 μA		Full range	4.8			4.8			٧
		1 _{OH} = -150 μA		25°C	4.8	4.88		4.8	4.88		
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Lan tarretaria	V 0.5.V	Jan. 500 A	25°C		0.09	0.15		0.09	0.15	
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA	Full range			0.15			0.15	٧
	vollago	V _{IC} = 2.5 V,	lo: - 4 m4	25°C		8.0	1		0.7	1	
		VIC = 2.5 V,	I _{OL} = 4 mA	Full range			1.2			1.2	
	Large-signal differential	V:0 - 2 5 V	R _L = 100 kΩ [‡]	25°C	100	350		100	350		
AVD	voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V		Full range	10			10			V/mV
		.0	$R_L = 1 M\Omega^{\ddagger}$	25°C		1700			1700		
^r id	Differential input resistance			25°C		1012			1012		Ω
r _{ic}	Common-mode input resistance			25°C		1012			1012		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	f = 10 kHz,	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200			200		Ω
CMRR	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$	V _O = 2.5 V,	25°C	70	83		70	83		dB
OWINK	rejection ratio	$R_S = 50 \Omega$		Full range	70			70			uБ
ksvr	Supply-voltage rejection ratio	V _{DD} = 4.4 V to 16 V _{IC} = V _{DD} /2,	3 V, No load	25°C	80	95		80	95	····	dB
	(ΔV _{DD} /ΔV _{IO})	*IC - *DD/2,	140 load	Full range	80			80			
lDD	Supply current	V _O = 2.5 V,	No load	25°C		70	125		70	125	μΑ
טט				Full range	<u> </u>		150			150	,

[†] Full range is - 55°C to 125°C.



[‡] Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

_	ADAMETED	TEGT COMP	TIONO	_ +	TL	.C2252	Л	TL	C2252A	М	11117
P.	ARAMETER	TEST COND	HONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	V _O = 0.5 V to 3.5 V,		25°C	0.07	0.12		0.07	0.12		
SR	gain	$R_L = 100 \text{ k}\Omega^{\ddagger}$	$C_L = 100 \text{ pF}^{\ddagger}$	Full range	0.05			0.05			V/μs
W	Equivalent input	f = 10 Hz		25°C		36			36		nV/√Hz
V _n	noise voltage	f = 1 kHz		25°C		19			19		nv/vHz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		V
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.1			1.1		μV
In	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
THD + N	Total harmonic	V _O = 0.5 V to 2.5 V,	A _V = 1	25°C		0.2%			0.2%		
IND+N	distortion plus noise	f = 10 kHz, $R_L = 50$ k Ω^{\ddagger}	A _V = 10	25 0		1%			1%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF [‡]	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2			0.2		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 V,$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF [‡]	25°C		30			30		kHz
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF [‡]	25°C		63°			63°		
	Gain margin			25°C		15			15		dB

[†] Full range is – 55°C to 125°C.

[‡] Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ±5 V (unless otherwise noted)

						<u> </u>					
	PARAMETER	TEST CO	ONDITIONS	T _A †		_C2252N			C2252A		UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO}	Input offset voltage			25°C		200	1500		200	850	μV
-10		1		Full range			1750			1000	μ.
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		0.5			0.5	,	μV/°C
	Input offset voltage long- term drift (see Note 4)	$V_{IC} = 0,$ R _S = 50 Ω	$V_O = 0$,	25°C		0.003			0.003		μV/mo
l				25°C		0.5			0.5		^
lo lo	Input offset current			Full range			500			500	pА
l	Innut his a surrent			25°C		1			1		Λ
lВ	Input bias current			Full range			500			500	pА
\\	Common-mode input	D- 500	N/- 1 < 5 m)/	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		٧
VICR	voltage range	HS = 50 12,	V _{IO} ≤5 mV	Full range	-5 to 3.5	-		-5 to 3.5			V
		$I_0 = -20 \mu A$		25°C		4.98			4.98		
M	Maximum positive peak	100		25°C	4.9	4.93		4.9	4.93		v
VOM+	output voltage	$I_{O} = -100 \mu$	4	Full range	4.7			4.7			V
		I _O = -200 μ/	A	25°C	4.8	4.86		4.8	4.86		
		V _{IC} = 0,	l _O = 50 μA	25°C		-4.99			-4.99		
		V:0 - 0	In 500 A	25°C	-4.85	-4.91		-4.85	-4.91		
V _{OM} -	Maximum negative peak output voltage	V _{IC} = 0,	I _O = 500 μA	Full range	-4.85			-4.85			٧
	pour output voltago	V _{IC} = 0,	IO = 4 mA	25°C	-4	-4.3		-4	-4.3		
		V ₁ C = 0,	10 = 41114	Full range	-3.8			-3.8			
	I awar airmal differential		R _L = 100 kΩ	25°C	40	150		40	150		
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 4 V$	11[= 100 K32	Full range	10			10			V/mV
			R _L = 1 MΩ	25°C		3000			3000		
^r id	Differential input resistance			25°C		10 ¹²			1012	,	Ω
^r ic	Common-mode input resistance			25°C		1012			1012		Ω
c _{ic}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		190			190		Ω
OMBB	Common-mode	V _{IC} = -5 V t	o 2.7 V,	25°C	75	88		75	88		JIP.
CMRR	rejection ratio	V _O = 0,	$R_S = 50 \Omega$	Full range	75			75			dB
k	Supply-voltage rejection	V _{DD} = ±2.2	V to ±8 V,	25°C	80	95		80	95		٩D
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{IC} = 0$,	No load	Full range	80			80			dB
Inn	Supply current	Vo = 2.5.V	No load	25°C		80	125		80	125	μА
IDD	Supply current	$V_0 = 2.5 V$,	NO IOAU	Full range			150			150	μΑ

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



operating characteristics at specified free-air temperature, $V_{\mbox{\scriptsize DD}\pm}$ = $\pm 5~\mbox{\scriptsize V}$

	DADAMETED	TEST COM	DITIONS	- +	TL	.C2252I	VI	TL	C2252A	М	114117
	PARAMETER	TEST CON	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
		V= +2.V	$R_I = 100 \text{ k}\Omega$	25°C	0.07	0.12		0.07	0.12		
SR	Slew rate at unity gain	$V_O = \pm 2 \text{ V},$ $C_L = 100 \text{ pF}$	n[= 100 ksz,	Full range	0.05			0.05			V/μs
V	Equivalent input noise	f = 10 Hz		25°C		38			38		-14/11
Vn	voltage	f = 1 kHz		25°C		19			19		nV/√Hz
V	Peak-to-peak equivalent	f = 0.1 Hz to 1 H	z	25°C		0.8			0.8		
VN(PP)	input noise voltage	f = 0.1 Hz to 10 l	-lz	25°C		1.1			1.1		μV
ın	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
TUD N	Total harmonic distortion	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	0500		0.2%			0.2%		
THD + N	plus noise	$R_L = 50 \text{ k}\Omega$, f = 10 kHz	A _V = 10	25°C		1%			1%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21			0.21		MHz
Вом	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		14			14		kHz
φm	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C		63°			63°		
	Gain margin	1		25°C		15			15		dB

[†] Full range is -55°C to 125°C.

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	- +	T	LC22541	VI .	TL	.C2254A	М	LINUT
	PANAMETEN	TEST CON	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO} :	Input offset voltage			25°C		200	1500		200	850	μV
۷Ю	input onset voltage		•	Full range			1750			1000	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, R _S = 50 Ω	25°C		0.003			0.003		μV/mo
lo lo	Input offset current			25°C		0.5			0.5		рA
-10				125°C			500			500	
lв	Input bias current			25°C		1			1		pA
יוני				125°C			500			500	P
.,	Common-mode input			25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		.,
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	0 to 3.5			0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.98			4.98		
Vall	High-level output	Jan 75 11 A		25°C	4.9	4.94		4.9	4.94		v
VOH	voltage	I _{OH} = -75 μA		Full range	4.8			4.8			V
		I _{OH} = -150 μA		25°C	4.8	4.88		4.8	4.88		
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Low-level output	V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
V_{OL}	voltage	VIC - 2.5 V,		Full range			0.15			0.15	٧
	· ·	V _{IC} = 2.5 V,	IOL = 4 mA	25°C		0.8	1		0.7	1	
	1	1,0 =,		Full range			1.2			1.2	
	Large-signal	V _{IC} = 2.5 V,	$R_I = 100 \text{ k}\Omega^{\ddagger}$	25°C	100	350		100	350		
AVD	differential	V _O = 1 V to 4 V		Full range	10			10			V/mV
	voltage amplification		$R_L = 1 M\Omega^{\ddagger}$	25°C		1700			1700		
ri(d)	Differential input resistance			25°C		1012			1012		Ω
ri(c)	Common-mode input resistance			25°C		1012			1012		Ω
ci(c)	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		200			200		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	$V_{O} = 2.5 \text{ V},$	25°C Full range	70 70	83		70 70	83		dB
	Supply-voltage	V _{DD} = 4.4 V to 1	6 V	25°C	80	95		80	95		
ksvr	rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			dB
IDD	Supply current	V _O = 2.5 V,	No load	25°C		140	250		140	250	μΑ
-00	(four amplifiers)	1.0 = 2.0 4,		Full range			300			300	L "'

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡] Referenced to 2.5 V

operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	ADAMETED	TEOT COUR	TLC2254M TLC2254AM		MAX	LIAUT					
P	ARAMETER	TEST COND	IIIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	$V_0 = 0.5 \text{ V to } 3.5 \text{ V},$		25°C	0.07	0.12		0.07	0.12		
SR	gain	$R_L = 100 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$		Full range	0.05			0.05			V/μs
V	Equivalent input	f = 10 Hz		25°C		36			36		->4/5
V _n	noise voltage	f = 1 kHz		25°C		19			19		nV/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.1			1.1		μV
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.2%			0.2%		ĺ
ו + טחו	distortion plus noise	f = 20 kHz, $R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25.0		1%			1%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.2			0.2		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 50 \text{ k}\Omega^{\ddagger}$,	A _V = 1, C _L = 100 pF [‡]	25°C		30			30		kHz
φm	Phase margin at unity gain	RL = 50 kه,	C _L = 100 pF‡	25°C		63°			63°		
	Gain margin]	•	25°C		15			15		dB

[†] Full range is - 55°C to 125°C.

[‡] Referenced to 2.5 V

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	TAT	Т	LC2254N	/	TL	C2254AI	M	UNIT
	PANAMETEN	1231 00	MDITIONS	'A'	MiN	TYP	MAX	MIN	TYP	MAX	UNII
V:-	Input offset voltage			25°C		200	1500		200	850	μV
VIO	input onset voltage			Full range			1750			1000	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 125°C		0.5			0.5		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	$V_O = 0$,	25°C		0.003			0.003		μV/mo
1	Innut offeet gurrent			25°C		0.5			0.5		
ΙO	Input offset current			125°C			500			500	pА
t	In a set bina a summer.	1		25°C		1			1		- 4
IB	Input bias current			125°C			500			500	рA
VICR	Common-mode input	Rs = 50 Ω.	V _{IO} ≤5 mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		٧
TION	voltage range			Full range	-5 to 3.5			-5 to 3.5			-
		$I_{O} = -20 \mu A$		25°C		4.98			4.98		
V _{OM+}	Maximum positive peak	l _O = -100 μ	Α	25°C	4.9	4.93		4.9	4.93		v
· OWI+	output voltage			Full range	4.7			4.7			
		$I_0 = -200 \mu$	Α	25°C	4.8	4.86		4.8	4.86		
		V _{IC} = 0,	I _O = 50 μA	25°C		-4.99			-4.99		
	Maximum negative peak	V _{IC} = 0,	ΙΟ = 500 μΑ	25°C	-4.85	-4.91		-4.85	-4.91		
VOM-	output voltage	10 - 0,		Full range	-4.85			-4.85			V
	. •	V _{IC} = 0,	I _O = 4 mA	25°C	-4	-4.3		-4	-4.3		
		1,0 " ",		Full range	-3.8			-3.8			
	Large-signal differential		R _L = 100 kΩ	25°C	40	150		40	150		
AVD	voltage amplification	$V_O = \pm 4 V$		Full range	10			10			V/mV
			$R_L = 1 M\Omega$	25°C		3000			3000		
r _{i(d)}	Differential input resistance			25°C		1012			1012		Ω
^r i(c)	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 25 kHz,	A _V = 10	25°C		190	_		190		Ω
CMDD	Common-mode rejection	V _{IC} = -5 V	o 2.7 V,	25°C	75	88		75	88		4D
CMRR	ratio	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	75			75			dB
ka	Supply-voltage rejection	V _{DD±} = ±2	2 V to ±8 V,	25°C	80	95		80	95		dB
ksvr	ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	VIC = VDD/	2, No load	Full range	80			80			ab
l	Supply current	V= -0	Nolood	25°C		160	250		160	250	^
ססי	(four amplifiers)	$V_O = 0$,	No load	Full range			300			300	μА

† Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CON	DITIONS	- +	TL	.C22541	VI	TL	C2254A	М	UNIT
	PARAMETER	I EST CON	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
		V _O = ±2 V,	$R_{l} = 100 \text{ k}\Omega$	25°C	0.07	0.12		0.07	0.12		
SR	Slew rate at unity gain	$C_L = 100 \text{ pF}$	n_ = 100 ksz,	Full range	0.05			0.05			V/µs
V	Equivalent input noise	f = 10 Hz		25°C		38			38		
Vn	voltage	f = 1 kHz		25°C		19			19		nV/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz	:	25°C		0.8			0.8		/
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 H	lz	25°C		1.1			1.1		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√ Hz
THD + N	Total harmonic	V _O = ±2.3 V,	A _V = 1	25°C		0.2%			0.2%		
IND+N	distortion plus noise	R _L = 50 kΩ, f = 20 kHz	A _V = 10	25°C		1%			1%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.21			0.21		MHz
ВОМ	Maximum output-swing bandwidth	V _O (PP) = 4.6 V, R _L = 50 kΩ,	A _V = 1, C _L = 100 pF	25°C		14			14		kHz
фm	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C		63°			63°		
	Gain margin]]	25°C		15			15		dB

[†] Full range is -55°C to 125°C.

electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TECT CON	TEST COMPITIONS		TLC2252Y				
		IESI CON	TEST CONDITIONS			MAX	UNIT		
V _{IO}	Input offset voltage				200		μV		
lo lo	Input offset current	$V_{IC} = 0,$ $V_{O} = 0,$	$V_{DD\pm} = \pm 2.5 \text{ V},$ R _S = 50 Ω		0.5		pА		
lΒ	Input bias current	VO = 0,	115 - 50 22		1		рA		
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω		-0.3 to 4.2	-	٧		
		I _{OH} = -20 μA			4.98				
V_{OH}	High-level output voltage	I _{OH} = -75 μA			4.94		v		
		I _{OH} = -150 μA			4.88				
	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 50 μA		0.01				
V_{OL}		$V_{IC} = 2.5 \text{ V},$	I _{OL} = 500 μA		0.09		٧		
		V _{IC} = 2.5 V,	I _{OL} = 4 mA		0.8				
	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 100 kΩ [†]		350	V/r	Man		
AVD			$R_L = 1 M\Omega^{\dagger}$		1700		V/mV		
rid	Differential input resistance				1012		Ω		
ric	Common-mode input resistance				1012		Ω		
c _{ic}	Common-mode input capacitance	f = 10 kHz			8		pF		
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10		200		Ω		
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 2.7 V, V_{O} = 2.5 V, R_{S} = 50 Ω			83		dB		
kSVR	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, No load	V_{DD} = 4.4 V to 16 V, V_{IC} = $V_{DD}/2$, No load		95		dB		
IDD	Supply current	V _O = 2.5 V,	No load		70		μΑ		

[†] Referenced to 2.5 V

electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_{A} = $25^{\circ}C$ (unless otherwise noted)

DADAMETED		TECT CONDI	TLC2252Y					
	PARAMETER	TEST CONDIT	MIN	TYP	MAX	UNIT		
V _{IO}	Input offset voltage				200		μV	
lio	Input offset current	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_O = 0$,		0.5		pА	
lв	Input bias current	115 - 30 22			1		pА	
V _{ICR}	Common-mode input voltage range	V _{IO} ≤5 mV,	$R_S = 50 \Omega$		-5.3 to 4.2		٧	
		I _O = -20 μA			4.99			
V _{OM+}	Maximum positive peak output voltage	$I_{O} = -100 \mu\text{A}$			4.93		V	
		I _O = -200 μA			4.86			
	Maximum negative peak output voltage	V _{IC} = 0,	I _{OL} = 50 μA		-4.99			
V_{OM-}		V _{IC} = 0,	I _{OL} = 500 μA		-4.91		٧	
		$V_{IC} = 0$,	I _{OL} = 4 mA		-4.1			
^	Large-signal differential voltage amplification	V _O = ±4 V	$R_L = 100 \text{ k}\Omega$		150		V/mV	
AVD			$R_L = 1 M\Omega$		3000		V/IIIV	
rid	Differential input resistance				1012		Ω	
ric	Common-mode input resistance				1012		Ω	
Cic	Common-mode input capacitance	f = 10 kHz			8		pF	
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10		190		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,		88		dB	
ksvr	Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm}$ = ±2.2 V to ±8 V, No load	V _{IC} = 0,		95		dB	
lDD	Supply current	$V_{O} = 0$,	No load		80		μА	

electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

DADAMETED			- CONDITIONS		TLC2254Y		<i>'</i>		
	PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT	
V _{IO}	Input offset voltage					200		μV	
l _{IO}	Input offset current	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_{\text{DD}\pm} = \pm 2.5 \text{ V},$	$V_{O} = 0$,		0.5		pА	
lв	Input bias current	- NS = 50 12				1		pА	
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω	,		-0.3 to 4.2		٧	
		I _{OH} = -20 μA				4.98			
Vон	High-level output voltage	I _{OH} = -75 μA				4.94		٧	
		I _{OH} = -150 μA				4.88		ĺ	
	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 50 μA			0.01		v	
v_{OL}		V _{IC} = 2.5 V,	I _{OL} = 500 μA			0.09			
		V _{IC} = 2.5 V,	I _{OL} = 4 mA			0.8			
	Large-signal differential	V _{IC} = 2.5 V,	$R_L = 100 \text{ k}\Omega^{\dagger}$			350) //>/	
AVD	voltage amplification	V _O = 1 V to 4 V	$R_L = 1 M\Omega^{\dagger}$			1700		V/mV	
ri(d)	Differential input resistance					1012		Ω	
ri(c)	Common-mode input resistance					1012		Ω	
Ci(c)	Common-mode input capacitance	f = 10 kHz				8		pF	
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10			200		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$	V _O = 2.5 V,	R _S = 50 Ω		83		dB	
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _{DD} = 4.4 V to 16 V,	V _{IC} = V _{DD} /2,	No load		95		dB	
l _{DD}	Supply current (four amplifiers)	V _O = 2.5 V,	No load			140		μΑ	

[†] Referenced to 2.5 V

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electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_A = $25^{\circ}C$ (unless otherwise noted)

PARAMETER		TECT OF	ONDITIONS		TLC2254Y			·		
		TEST CONDITIONS			MIN	TYP	MAX	UNIT		
V _{IO}	Input offset voltage					200		μV		
10	Input offset current	V _{IC} = 0,	$R_S = 50 \Omega$	V _O = 0,		0.5		pА		
lв	Input bias current					1		pА		
V _{ICR}	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω			-5.3 to 4.2		٧		
		I _O = -20 μA				4.99				
V _{OM+}	Maximum positive peak output voltage	I _O = -100 μA	$I_{O} = -100 \mu\text{A}$			4.93	- 1	V		
		I _O = -200 μA				4.86				
	Maximum negative peak output voltage	V _{IC} = 0,	I _{OL} = 50 μA			-4.99				
V _{OM}		V _{IC} = 0,	I _{OL} = 500 μA			-4.91		V		
		V _{IC} = 0,	I _{OL} = 4 mA			-4.1				
Λ	Large-signal differential voltage amplification	V _O = ±4 V	$R_L = 100 \text{ k}\Omega$)		150		V/mV		
AVD		VO = ±4 V	$R_L = 1 M\Omega$			3000		v/mv		
ri(d)	Differential input resistance					1012		Ω		
ri(c)	Common-mode input resistance					1012		Ω		
c _{i(c)}	Common-mode input capacitance	f = 10 kHz				8		pF		
z _o	Closed-loop output impedance	f = 25 kHz,	A _V = 10			190		Ω		
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$	V _O = 0,	R _S = 50 Ω		88		dB		
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD\pm}/\Delta V_{IO})$	$V_{DD\pm} = \pm 2.2 \text{ V to } \pm 8 \text{ V,}$	V _{IC} = 0,	No load		95		dB		
lDD	Supply current (four amplifiers)	V _O = 0,	No load			160		μΑ		

TYPICAL CHARACTERISTICS

Table of Graphs

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ksvr	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	34, 35 36
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TYPICAL CHARACTERISTICS

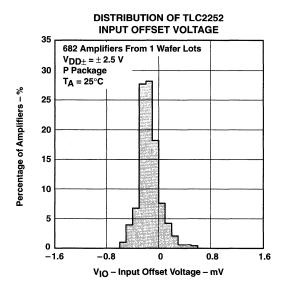


Figure 2

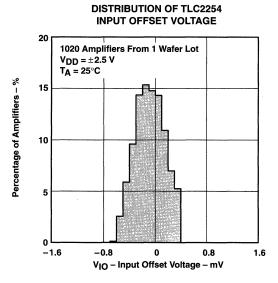


Figure 4

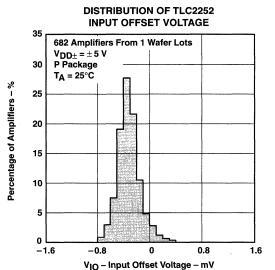


Figure 3

DISTRIBUTION OF TLC2254

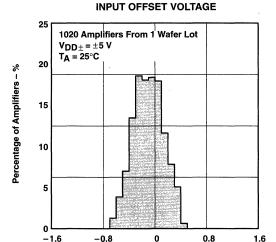
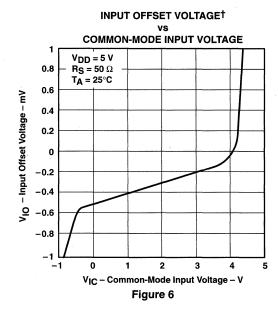
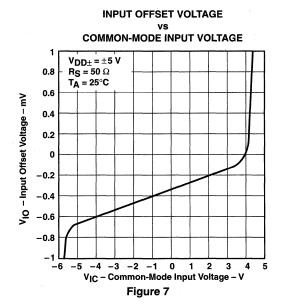


Figure 5

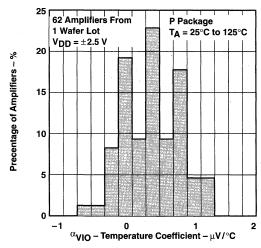
V_{IO} - Input Offset Voltage - mV

TYPICAL CHARACTERISTICS





DISTRIBUTION OF TLC2252 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT



DISTRIBUTION OF TLC2252 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

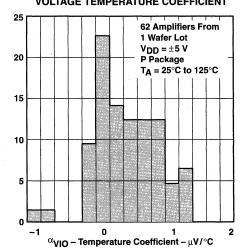


Figure 9

Figure 8



Percentage of Amplifiers - %

[†] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

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TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC2254 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT 25 **62 Amplifiers From** 1 Wafer Lot $V_{DD\pm} = \pm 2.5 V$ 20 P Package Percentage of Amplifiers – % T_A = 25°C to 125°C 15 10 5 -2 αVIO - Temperature Coefficient of Input Offset Voltage - μV/°C

Figure 10

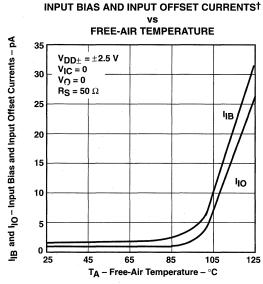
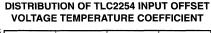


Figure 12



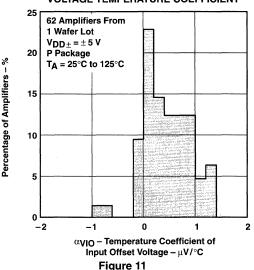


Figure 11

INPUT VOLTAGE RANGE vs SUPPLY VOLTAGE

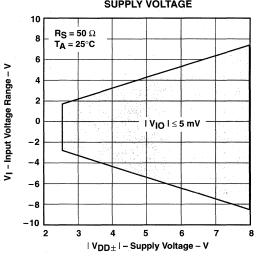
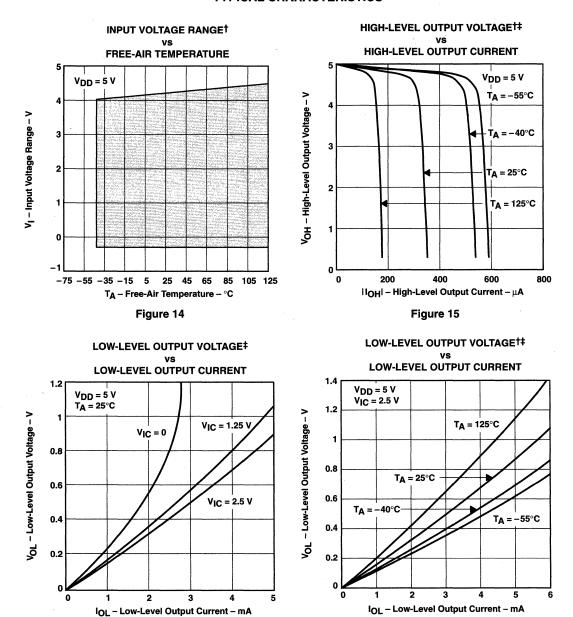


Figure 13

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 17

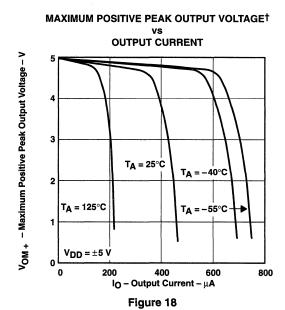
Figure 16



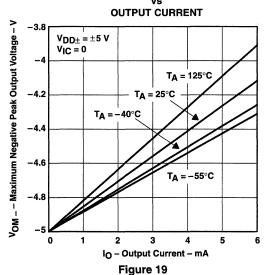
[‡] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.

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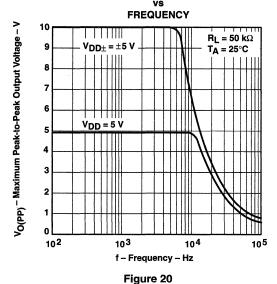
TYPICAL CHARACTERISTICS



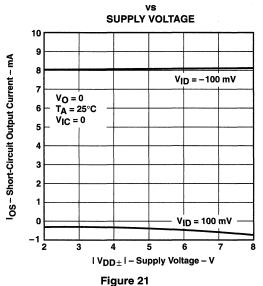
MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE†



MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE‡



SHORT-CIRCUIT OUTPUT CURRENT



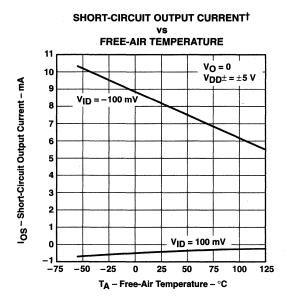
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.



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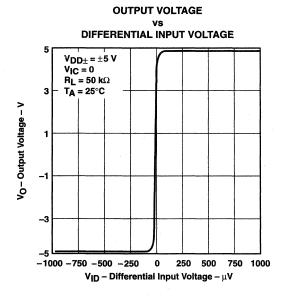
TYPICAL CHARACTERISTICS



OUTPUT VOLTAGE‡ **DIFFERENTIAL INPUT VOLTAGE** $V_{DD} = 5 V$ $R_L = 50 \text{ k}\Omega$ VIC = 2.5 V T_A = 25°C Vo-Output Voltage - V -1000 -750 -500 -250 0 250 500 750 1000 V_{ID} - Differential Input Voltage - μV

Figure 22

Figure 23



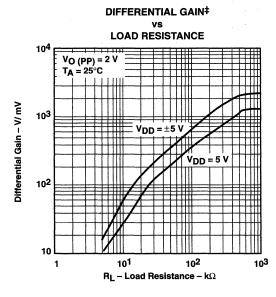


Figure 24

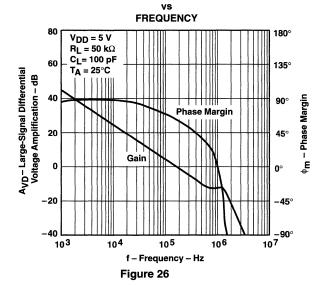
Figure 25

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where VDD = 5 V, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN[†]



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

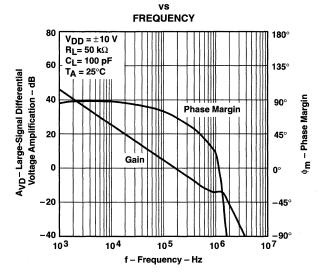
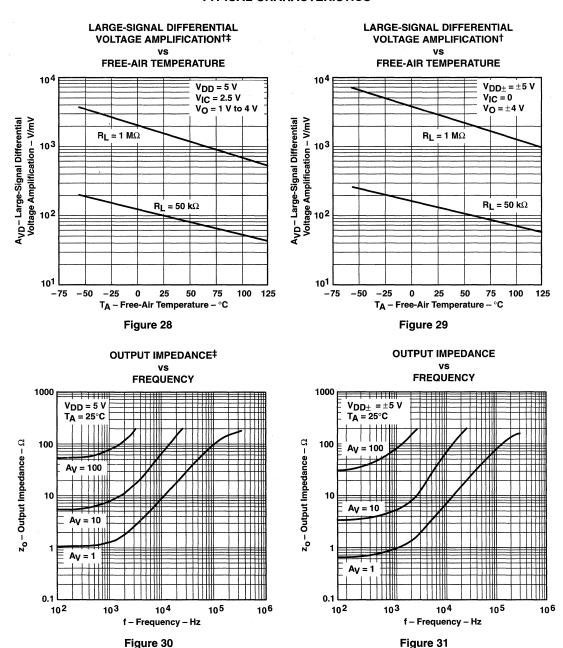


Figure 27

† For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.



TYPICAL CHARACTERISTICS

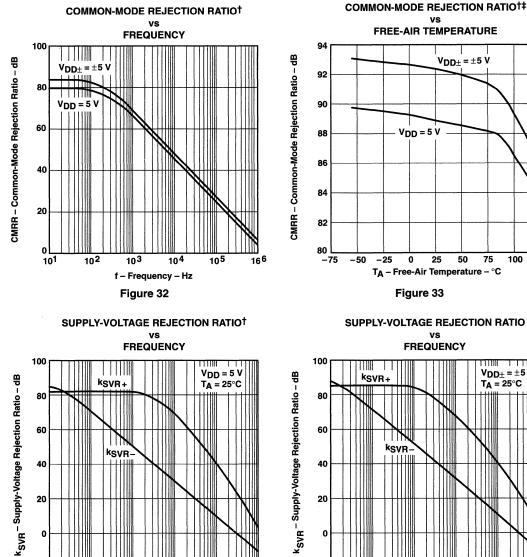


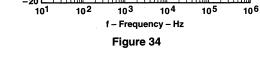
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

V_{DD±} = ±5 V

TYPICAL CHARACTERISTICS



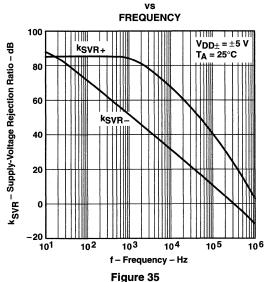


ksvR

60

40

20



25 50

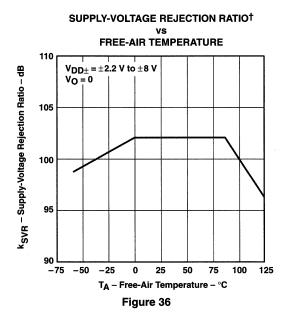
[‡] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

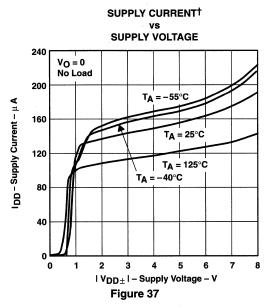


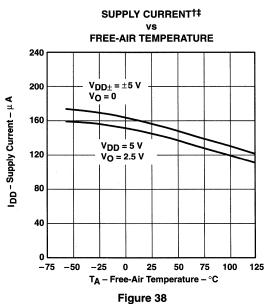
125

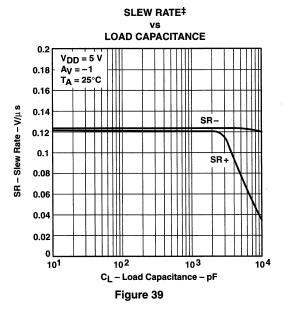
 $[\]dagger$ For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS









[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.



 $V_{DD} = 5 V$

 $R_L = 50 \text{ k}\Omega$

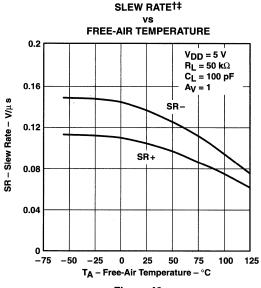
C_L = 100 pF

0 10 20 30

Vo - Output Voltage - V

90 100

TYPICAL CHARACTERISTICS

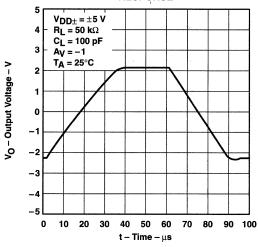


INVERTING LARGE-SIGNAL PULSE RESPONSE‡

Figure 40

Figure 41





VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE[‡]

50 60

t - Time - μs

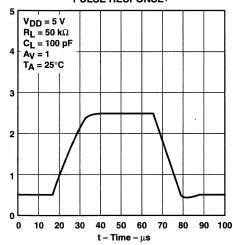


Figure 43

Figure 42



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE $V_{DD\pm} = \pm 5 \text{ V}$ $R_L = 50 \text{ k}\Omega$ CL = 100 pF A_V = 1 T_A = 25°C V_O - Output Voltage - V -1 -2 -3 -4 0 10 20 30 40 50 60 70 80 90 100

t – Time – μs Figure 44

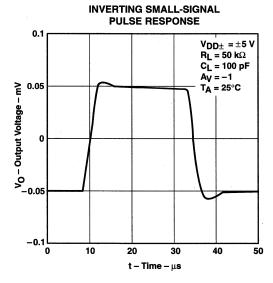


Figure 46

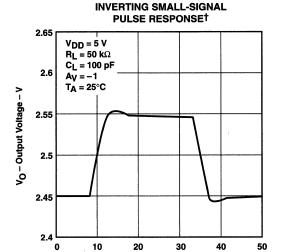


Figure 45

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE†

t – Time – μs

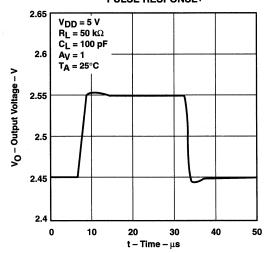


Figure 47

[†] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.



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TYPICAL CHARACTERISTICS

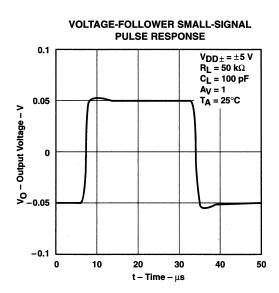
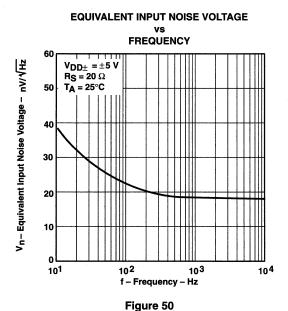


Figure 48



† For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.

EQUIVALENT INPUT NOISE VOLTAGE†

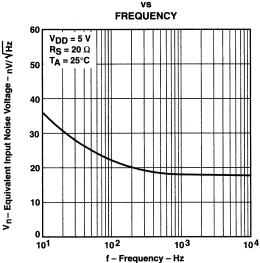


Figure 49

EQUIVALENT INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD[†]

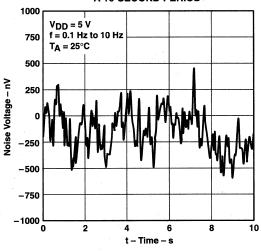


Figure 51



TYPICAL CHARACTERISTICS

INTEGRATED NOISE VOLTAGE vs **FREQUENCY** Calculated Using Ideal Pass-Band Filter Low Frequency = 1 Hz T_A = 25°C Integrated Noise Voltage - µV 0.1 103 101 102 104 105 f - Frequency - Hz Figure 52

TOTAL HARMONIC DISTORTION PLUS NOISE[†]

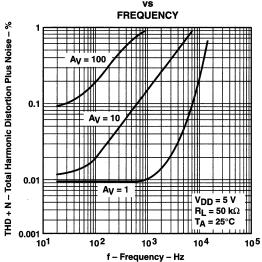
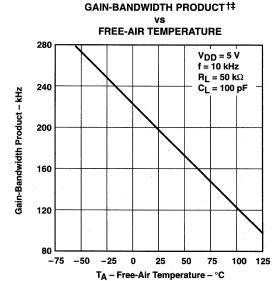
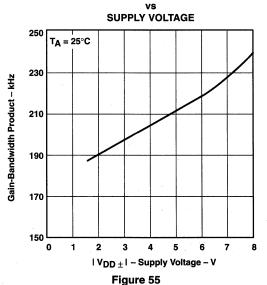


Figure 53



GAIN-BANDWIDTH PRODUCT



[†] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

Figure 54

Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS

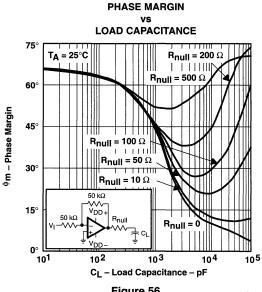


Figure 56

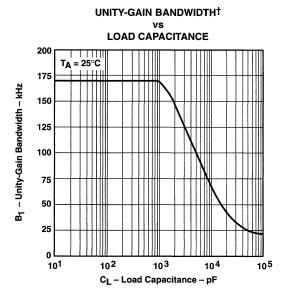
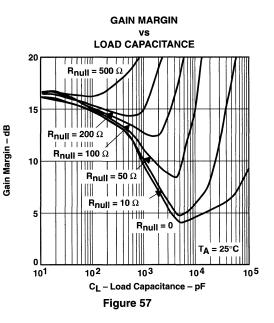


Figure 58



OVERESTIMATION OF PHASE MARGIN[†]

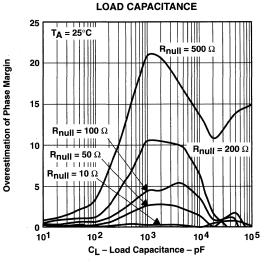


Figure 59

[†] See application information

APPLICATION INFORMATION

driving large capacitive loads

The TLC225x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 56 and Figure 57 illustrate its ability to drive loads up to 1000 pF while maintaining good gain and phase margins (R_{null} = 0).

A smaller series resistor (R_{null}) at the output of the device (see Figure 60) improves the gain and phase margins when driving large capacitive loads. Figure 56 and Figure 57 show the effects of adding series resistances of 10 Ω , 50 Ω , 100 Ω , 200 Ω , and 500 Ω . The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second is that it reduces the frequency of the pole associated with the output load in the transfer function.

The zero introduced to the transfer function is equal to the series resistance times the load capacitance. To calculate the improvement in phase margin, equation 1 can be used.

$$\Delta \phi_{m1} = \tan^{-1} \left(2 \times \pi \times \text{UGBW} \times R_{\text{null}} \times C_{\text{L}} \right)$$
 (1)

where:

 $\Delta \phi_{m1}$ = improvement in phase margin

UGBW = unity-gain bandwidth frequency

R_{null} = output series resistance

C_I = load capacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 58). To use equation 1, UGBW must be approximated from Figure 58.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 59. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin.

Using Figure 60, with equation 1 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitance loads.

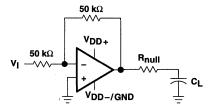


Figure 60. Series-Resistance Circuit

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APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim $Parts^{TM}$, the model generation software used with Microsim $PSpice^{TM}$. The Boyle macromodel (see Note 5) and subcircuit in Figure 61 are generated using the TLC225x typical electrical and operating characteristics at $T_A = 25^{\circ}C$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

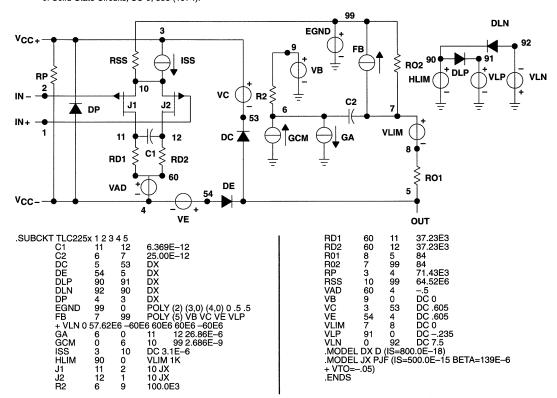


Figure 61. Boyle Macromodel and Subcircuit

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- Output Swing includes Both Supply Rails
- Low Noise . . . 12 nV/ $\sqrt{\text{Hz}}$ Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Low Power . . . 500 μA Max

description

The TLC2262 and TLC2264 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC226x family offers a compromise between the micropower TLC225x and the ac performance of the TLC227x. It has low supply current for battery-powered applications, while still having adequate ac performance for applications that demand it. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Figure 1 depicts the low level of noise voltage for this CMOS amplifier, which has only 200 µA (typ) of supply current per amplifier.

The TLC226x, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, these devices work well in hand-held monitoring and remote-sensing

- Common-Mode Input Voltage Range Includes Negative Rail
- Low Input Offset Voltage
 950 μV Max at T_A = 25°C (TLC2262A)
- Macromodel Included
- Performance Upgrade for the TS27M2/M4 and TLC27M2/M4

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

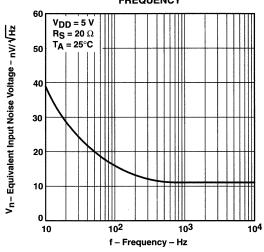


Figure 1

applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC226xA family is available and has a maximum input offset voltage of 950 μ V. This family is fully characterized at 5 V and ± 5 V.

The TLC2262/4 also makes great upgrades to the TLC27M2/L4 or TS27M2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442. If your design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

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TLC2262 AVAILABLE OPTIONS

				PACKAGE	D DEVICES			CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)	CERAMIC FLATPACK (U)	FORM (Y)
0°C to 70°C	2.5 mV	TLC2262CD			TLC2262CP	TLC2262CPWLE	- , .	
-40°C to 125°C	950 μV 2.5 mV	TLC2262AID TLC2262ID			TLC2262AIP TLC2262IP	TLC2262AIPWLE		TLC2262Y
-55°C to 125°C	950 μV 2.5 mV	_	TLC2262AMFK TLC2262MFK	TLC2262AMJG TLC2262MJG	_		TLC2262AMU TLC2262MU	

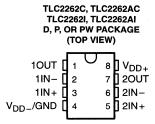
The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2262CDR). The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

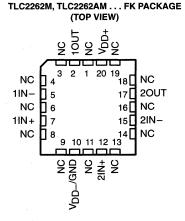
TLC2264 AVAILABLE OPTIONS

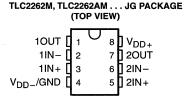
				PACKAGE	D DEVICES			CHIP
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP (PW)	CERAMIC FLATPACK (W)	FORM (Y)
0°C to 70°C	2.5 mV	TLC2264CD		_	TLC2264CN	TLC2264CPWLE	_	
-40°C to 125°C	950 μV 2.5 mV	TLC2264AID TLC2264ID	_		TLC2264AIN TLC2264IN	TLC2264AIPWLE —		TLC2262Y
−55°C to 125°C	950 μV 2.5 mV		TLC2264AMFK TLC2264MFK	TLC2264AMJ TLC2264MJ	_	_	TLC2264AMW TLC2264MW	

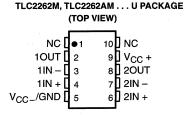
The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2264CDR). The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

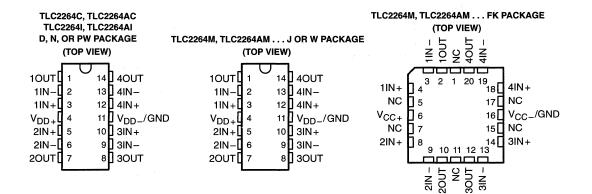
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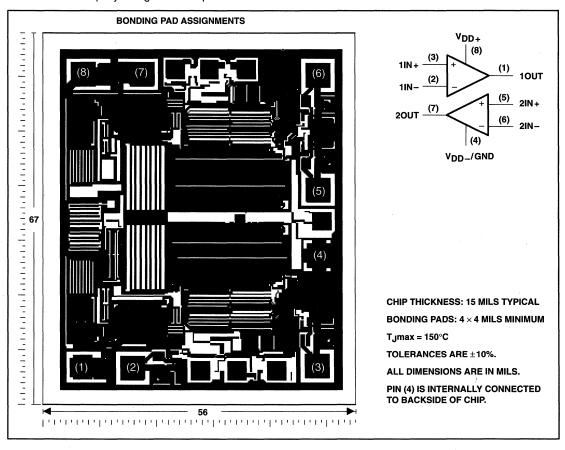




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TLC2262Y chip information

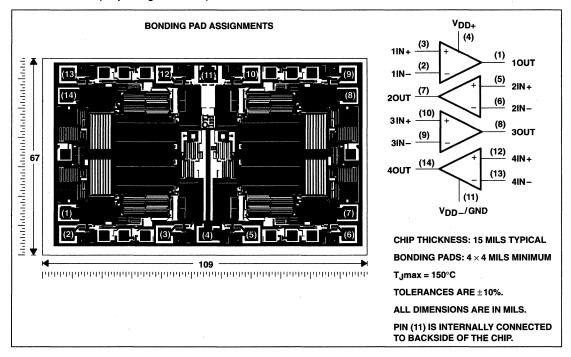
This chip, when properly assembled, displays characteristics similar to the TLC2262C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.



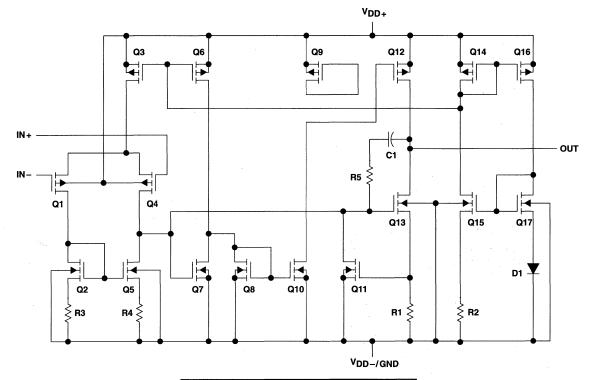
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TLC2264Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2264C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic (each amplifier)



ACTUAL DEVI	CE COMPONENT	COUNT
COMPONENT	TLC2262	TLC2264
Transistors	38	76
Resistors	28	56
Diodes	9	18
Capacitors	3	6

Tincludes both amplifiers and all ESD, bias, and trim circuitry

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+} (see Note 1)		8 V 8 V
		±16 V
		V _{DD} – 0.3 V to V _{DD+}
Input current, I _I (each input)		±5 mÅ
Output current, IO		±50 mA
Total current into V _{DD+}		±50 mA
Total current out of V _{DD}		±50 mA
Duration of short-circuit current at (or belo	w) 25°C (see Note 3)	unlimited
Continuous total dissipation		See Dissipation Rating Table
Operating free-air temperature range, TA:	C suffix	0°C to 70°C
	I suffix	–40°C to 125°C
	M suffix	
Storage temperature range, T _{stg}		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) fron	n case for 10 seconds:	D, N, P, and PW packages 260°C
		J, JG, U, and W packages 300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{DD+} and V_{DD-} .
 - 2. Differential voltages are at IN+ with respect to IN-. Excessive current flows if input is brought below V_{DD} 0.3 V.
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	230 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW
PW-8	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW
PW-14	700 mW	5.6 mW/°C	448 mW	364 mW	140 mW
U	700 mW	5.5 mW/°C	452 mW	370 mW	150 mW
w	700 mW	5.5 mW/°C	452 mW	370 mW	150 mW

recommended operating conditions

	C SUFFIX		15	SUFFIX	M	UNIT	
	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.2	±8	±2.2	±8	±2.2	±8	٧
Input voltage range, V _I	V _{DD} _	V _{DD+} -1.5	V _{DD} _	V _{DD+} –1.5	V_{DD-}	V _{DD+} –1.5	٧
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} -1.5	V _{DD} _	V _{DD+} –1.5	V _{DD} _	V _{DD+} -1.5	٧
Operating free-air temperature, TA	0	70	-40	125	-55	125	°C



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TLC2262C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	T _A †	TI	LC22620		UNIT
	PARAMETER	TEST CO	NDITIONS	'A'	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		300	2500	μV
VIO	input onset voltage			Full range			3000	μν
αΝΙΟ	Temperature coefficient of input offset voltage			25°C to 70°C		2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ $V_{O} = 0,$	$V_{DD} \pm = \pm 2.5 \text{ V},$ R _S = 50 \Omega	25°C		0.003		μV/mo
l	Input offset current			25°C		0.5		pА
lo lo	input onset current			Full range			100	PΑ
lin	Input bias current			25°C		1		pA
IB	input bias current			Full range			100	PΑ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	25°C	0 to 4	-0.3 to 4.2		V
VICH	Common-mode input voltage range	ng = 50 sz,	IAIO I ZO IIIA	Full range	0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99		
		I _{OH} = -100 μA		25°C	4.85	4.94		
VOH	High-level output voltage	ΙΟΗ = - 100 μΑ		Full range	4.82			V
		I _{OH} = -400 μA		25°C	4.70	4.85		
		ΙΟΗ = -400 μΑ		Full range	4.60			
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01		
		V _{IC} = 2.5 V,	lOI = 500 μA	25°C		0.09	0.15	V
		VIC = 2.5 V,		Full range			0.15	
v_{OL}	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 1 mA	25°C		0.2	0.3	
			10L = 1111A	Full range			0.3	
		V _{IC} = 2.5 V,	la. 1m1	25°C		0.7	1	
		V ₁ C = 2.5 V,	I _{OL} = 4 mA	Full range			1.2	
			D. FOROT	25°C	80	170		
A_{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	$R_L = 50 \text{ k}\Omega^{\ddagger}$	Full range	55	,,,,,,,,		V/mV
			$R_L = 1 M\Omega^{\ddagger}$	25°C		550		
ri(d)	Differential input resistance		4	25°C		1012		Ω
ri(c)	Common-mode input resistance		·	25°C		1012		Ω
Ci(c)	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	Ay = 10	25°C		240		Ω
CMPD	0	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	83		-10
CMRR	Common-mode rejection ratio			Full range	70			dΒ
kova	Supply voltage rejection ratio (AVI = /AVI =)	V _{DD} = 4.4 V to	16 V,	25°C	80	95		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			
los	Supply current	Vo = 2 5 V	No load	25°C		400	500	μА
DD	Supply current	$V_0 = 2.5 \text{ V},$	INO IOAU	Full range		•	500	μΑ

[†]Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2262C operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TECT CONDI	TIONO	- +	TLC2262C			UNIT
	PARAMETER	TEST CONDI	TIONS	T _A †	MIN	TYP	MAX	I UNII
SR	Slew rate at unity gain	$V_O = 1.5 \text{ V to } 3.5 \text{ V},$	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C	0.35	0.55		V/μs
JN	Siew rate at unity gain	C _L = 100 pF [‡]		Full range	0.3			ν /μδ
V	Equivalent input noise voltage	f = 10 Hz		25°C		40		nV/√Hz
v _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		
V	Peak-to-peak equivalent input noise	f = 0.1 Hz to 1 Hz		25°C		0.7		
VN(PP)	voltage	f = 0.1 Hz to 10 Hz		25°C		1.3		μV
In	Equivalent input noise current			25°C		0.6		fA√Hz
THD + N	Total harmonic distortion plus noise	V _O = 0.5 V to 2.5 V, f = 20 kHz.	A _V = 1	25°C		0.017%		
IND + N	rotal flatmonic distortion plus hoise	$R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25 0		0.03%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.71		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 V,$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	Ay = 1, C _L = 100 pF [‡]	25°C		185		kHz
	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4		
ts	Getting time	$R_L = 50 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	230		14.1		μs
φm	Phase margin at unity gain	B. Foliat C. 100		25°C		56°		
	Gain margin	$R_L = 50 \text{ k}\Omega^{\ddagger,}$	C _L = 100 pF‡	25°C		11		dB

[†] Full range is 0°C to 70°C. ‡ Referenced to 2.5 V

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TLC2262C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	D.D		NOTIONO		T	C22620	;	T
	PARAMETER	TEST CO	NDITIONS	TAT	MIN	TYP	MAX	UNIT
Via	Input offset voltage			25°C		300	2500	μV
VIO	Input offset voltage			Full range			3000	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 70°C		2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_O = 0$,	25°C		0.003		μV/mo
lio	Input offset current	715 - 30 12		25°C		0.5		рA
lio	input onset current			Full range			100	PΛ
lim	Input bias current			25°C		1		pA
lΒ	input bias current		-	Full range			100	pΑ
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	Po = 50 O	25°C	-5 to 4	-5.3 to 4.2		٧
VICH	Common mode input voilage range	[V]O1 30 mV,		Full range	-5 to 3.5			•
		$I_{O} = -20 \mu A$		25°C		4.99		
		I _O = -100 μA		25°C	4.85	4.94		
V _{OM+}	Maximum positive peak output voltage	10=-100 μΑ		Full range	4.82			V
		I _O = -400 μA		25°C	4.7	4.85		
		10 = -400 μΑ		Full range	4.6			
		$V_{IC} = 0$,	I _O = 50 μA	25°C		-4.99		
		V _{IC} = 0,	I _O = 500 μA	25°C	-4.85	-4.91		V
	Maximum negative peak output voltage	VIC = 0,		Full range	-4.85			
V _{OM} -		V _{IC} = 0,	IO = 1 mA	25°C	-4.7	-4.8		
			10 - 1111A	Full range	-4.7			
		V _{IC} = 0,	IO = 4 mA	25°C	-4	-4.3		
		V ₁ C = 0,		Full range	-3.8			
			R _L = 50 kΩ	25°C	80	200		
AVD	Large-signal differential voltage amplification	$V_O = \pm 4 V$	112 - 00 1122	Full range	55			V/mV
			$R_L = 1 M\Omega$	25°C		1000		
^r i(d)	Differential input resistance			25°C		1012		Ω
r _{i(c)}	Common-mode input resistance			25°C		1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		220		Ω
CMBB	Common-mode rejection ratio	V _{IC} = −5 V to	2.7 V,	25°C	75	88		dB
OWI IN	Common mode rejection ratio			Full range	75			ub.
ksvr	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	$V_{DD\pm} = 2.2 \text{ V to } \pm 8 \text{ V},$		25°C	80	95		dB
איסיי		V _{IC} = 0,	No load	Full range	80			GD.
IDD	Supply current	V _O = 0 V,	No load	25°C		425	500	μА
-טט	Supply Surroll			Full range			500	μ

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150$ °C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2262C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	DADAMETED	TEST CONDIT	IONIC	- +			UNIT	
	PARAMETER	TEST CONDIT	IONS	TAT	MIN	TYP	MAX	UNII
		V- 140V	D FOLO	25°C	0.35	0.55		
SR	Slew rate at unity gain	$V_O = \pm 1.9 \text{ V},$ $C_L = 100 \text{ pF}$	$R_L = 50 \text{ k}\Omega$,	Full range	0.3			V/μs
V	Facilitation to the same valtered	f = 10 Hz		25°C		43		
v _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		nV/√Hz
Varion	Peak-to-peak equivalent input noise	f = 0.1 Hz to 1 Hz		25°C		0.8		μV
V _{N(PP)}	voltage	f = 0.1 Hz to 10 Hz		25°C		1.3		μν
In	Equivalent input noise current			25°C		0.6		fA√Hz
THD + N	Total harmonic distortion pulse duration	V _O = ±2.3 V, f = 20 kHz,	A _V = 1	`25°C		0.014%		
THU + N	Total harmonic distortion pulse duration	$R_L = 50 \text{ k}\Omega$	A _V = 10	250		0.024%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73		MHz
Вом	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_{L} = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		85		kHz
ŧ	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1		ue
t _s	Setting time	$R_L = 50 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	230		16.5		μs
φm	Phase margin at unity gain	B 50 kO	C 100 pE	25°C		57°		
	Gain margin	$R_L = 50 \text{ k}\Omega$	C _L = 100 pF	25°C		11		dB

[†]Full range is 0°C to 70°C.

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TLC2264C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	TEST 601	IDITIONS	- +	T	LC22640	;	LINUT
	PARAMETER	TEST COI	NDITIONS	T _A †	MIN	TYP	MAX	UNIT
Via	Input offset voltage			25°C		300	2500	μV
VIO	input onset voitage			Full range			3000	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$V_{DD\pm} = \pm 2.5 \text{ V},$	25°C		0.003		μV/mo
	la de Maria	$V_O = 0$,	$R_S = 50 \Omega$	25°C		0.5		
ΙΟ	Input offset current			Full range		,	100	рA
1	I and big a summer	1		25°C		1		- 4
lВ	Input bias current			Full range			100	pΑ
	0	B 50.0		25°C	0 to 4	-0.3 to 4.2		.,
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	Full range	0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99		
		100		25°C	4.85	4.94		
Vон	High-level output voltage	IOH = -100 μA		Full range	4.82			v
		100		25°C	4.70	4.85		
		I _{OH} = -400 μA		Full range	4.60			
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01		
		V:0 - 2 5 V	lo: 500 A	25°C		0.09	0.15	
	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA	Full range			0.15	
VOL		V _{IC} = 2.5 V,	la. 1 mA	25°C		0.2	0.3	V
		VIC = 2.5 V,	I _{OL} = 1 mA	Full range			0.3	
		V _{IC} = 2.5 V,	la. – 4 m4	25°C		0.7	1	
		VIC = 2.5 V,	I _{OL} = 4 mA	Full range			1.2	
			$R_1 = 50 \text{ k}\Omega^{\ddagger}$	25°C	80	170		
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $V_{O} = 1 \text{ V to 4 V}$	HE = 50 K22+	Full range	55			V/mV
		1.0	$R_L = 1 M\Omega^{\ddagger}$	25°C		550		
ri(d)	Differential input resistance			25°C		1012		Ω
ri(c)	Common-mode input resistance	,		25°C		1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		240		Ω
CMDD	Common mode rejection votice	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	83		٩D
CIVIRR	Common-mode rejection ratio	R _S = 50 Ω		Full range	70			dB
kovo	Supply voltage rejection ratio (AVI) = (AVI) =	V _{DD} = 4.4 V to 16 V,		25°C	80	95		4D
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			dB
Inn	Supply current (four amplifiers)	V _O = 2.5 V,	No load	25°C		0.8	1	mA
DD	Supply current (four amplifiers)	V() = 2.5 V,	NO IDAU	Full range			1] ""

[†] Full range is 0°C to 70°C.

NOTE 4. Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^{\circ}C$ extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2264C operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	PARAMETER	TEST CONDI	TIONS	-+	Т	LC2264C		UNIT
	PANAMETER	1E31 CONDI	110113	T _A †	MIN	TYP	MAX	UNIT
		Vo - 1.4 V to 2.6 V	$R_1 = 50 \text{ k}\Omega^{\ddagger}$	25°C	0.35	0.55		
SR	Slew rate at unity gain	$V_O = 1.4 \text{ V to } 2.6 \text{ V},$ $C_L = 100 \text{ pF}^{\ddagger}$	nL = 50 K22+,	Full range	0.3			V/µs
V	Equivalent input noise voltage	f = 10 Hz		25°C		40		nV/√Hz
V _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		nv/√Hz
VALCED	Peak-to-peak equivalent input noise	f = 0.1 Hz to 1 Hz		25°C		0.7		μV
V _{N(PP)}	voltage	f = 0.1 Hz to 10 Hz		25°C		1.3		μν
In	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$ f = 20 kHz,	Ay = 1	25°C		0.017%		
IIID + N	Total Harmonic distortion plus hoise	$R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25 0		0.03%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF [‡]	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.71		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		185		kHz
+.	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4		ue
t _S	Getting time	$R_L = 50 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	230		14.1		μs
φm	Phase margin at unity gain	$R_1 = 50 \text{ k}\Omega^{\ddagger}$	C _I = 100 pF [‡]	25°C		56°		
	Gain margin	- 30 K221,	OL = 100 pr+	25°C		11		dB

[†]Full range is 0°C to 70°C.

[‡]Referenced to 2.5 V

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TLC2264C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	DADAMETED	T-07.00	UDITIONS	- +	T	LC22640	;	
	PARAMETER	TEST CO	NDITIONS	T _A †	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		300	2500	μV
۷O	input offset voltage			Full range			3000	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	$V_O = 0$,	25°C		0.003		μV/mo
li a	Input offset surrent	T ng = 50 12		25°C		0.5		nΛ
<u> 1</u> 0	Input offset current			Full range			100	рA
1	Input bias current	7		25°C		1		рA
□B	input bias current			Full range			100	PΑ
Vicr	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω	25°C	-5 to 4	-5.3 to 4.2		٧
VICH	Common Private input Voltage range	INIO 1 23 mv,	ng = 30 sz	Full range	-5 to 3.5			•
		$I_{O} = -20 \mu\text{A}$		25°C		4.99		
		I _O = -100 μA		25°C	4.85	4.94		
V _{OM+}	Maximum positive peak output voltage	10 = - 100 μΑ		Full range	4.82			٧
		ΙΟ = -400 μΑ		25°C	4.7	4.85		
				Full range	4.6			
		$V_{IC} = 0$,	I _O = 50 μA	25°C		-4.99		
		$V_{IC} = 0$,	ΙΟ = 500 μΑ	25°C	-4.85	-4.91		ľ
		VIC = 0,	10 = 000 prv	Full range	-4.85			
VOM-	Maximum negative peak output voltage	$V_{IC} = 0$	I _O = 1 mA	25°C	-4.7	-4.8		٧
	* K	V ₁ C = 0,		Full range	-4.7			
		$V_{IC} = 0$,	I _O = 4 mA	25°C	-4	-4.3		
		10 - 0,	.0 = 111171	Full range	-3.8			
			R _L = 50 kΩ	25°C	80	200		
AVD	Large-signal differential voltage amplification	$V_O = \pm 4 V$	110 - 00 102	Full range	55			V/mV
			$R_L = 1 M\Omega$	25°C		1000		
^r i(d)	Differential input resistance			25°C		1012		Ω
ri(c)	Common-mode input resistance			25°C		1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8		рF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		220		Ω
CMDD	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2$.7 V,	25°C	75	88		dB
OWITH	Common-mode rejection ratio	V _O = 0,	$R_S = 50 \Omega$	Full range	75			ub
kove	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	V _{DD±} = ±2.2 \	/ to ±8 V,	25°C	80	95		dB
ksvr	- σαρριγ-voltage rejection ratio (ΔνDD±/ΔνIO)	V _{IC} = 0,	No load	Full range	80			ub
I _{DD}	Supply current (four amplifiers)	V _O = 0,	No load	25°C Full range		0.85	1	mA
		_i		190	L			L

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2264C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CONDIT	IONO		Т	LC2264C		UNIT
	PARAMETER	TEST CONDIT	IONS	TAT	MIN	TYP	MAX	UNII
		V- 14.0V	D. FAIO	25°C	0.35	0.55		
SR	Slew rate at unity gain	$V_O = \pm 1.9 \text{ V},$ $C_L = 100 \text{ pF}$	$R_L = 50 \text{ k}\Omega$,	Full range	0.3			V/μs
	Facility leading the same and the same	f = 10 Hz		25°C		43		
Vn	Equivalent input noise voltage	f = 1 kHz		25°C		12		nV/√Hz
Verme	Peak-to-peak equivalent input noise	f = 0.1 Hz to 1 Hz		25°C		0.8		
V _{N(PP)}	voltage	f = 0.1 Hz to 10 Hz		25°C		1.3		μV
In	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	V _O = ± 2.3 V, f = 20 kHz,	A _V = 1	25°C		0.014%		
1110+11	rotal Harmonic distortion plus noise	$R_L = 50 \text{ k}\Omega$	A _V = 10	23 0		0.024%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	Ay = 1, C _L = 100 pF	25°C		70		kHz
	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1		ue.
t _S	Setting time	$R_L = 50 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	23 0		16.5		μs
φm	Phase margin at unity gain	$R_1 = 50 \text{ k}\Omega$	C _I = 100 pF	25°C		57°		
	Gain margin	7 nL = 50 ksz,	OL = 100 pr	25°C		11		dB

[†] Full range is 0°C to 70°C.

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TLC2262I electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	T _Δ †	Т	LC2262	!!	TL	_C2262/	AI .	UNIT
	FANAMETER	1231 001	DITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		300	2500		300	950	μV
VIO	input oliset voltage	}		Full range			3000			1500	μν
αγιο	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.003			0.003		μV/mo
lo	Input offset current			25°C		0.5			0.5		pА
		4		Full range			500			500	
lв	Input bias current			25°C		1	500		1	500	pА
				Full range			500			500	
V	Common-mode input	Bo - 50 O	\\\ <e m\\<="" td=""><td>25°C</td><td>0 to 4</td><td>-0.3 to 4.2</td><td></td><td>0 to 4</td><td>-0.3 to 4.2</td><td></td><td>٧</td></e>	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		٧
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	0 to 3.5			0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99			4.99		
				25°C	4.85	4.94		4.85	4.94		
Vон	High-level output voltage	IOH = -100 μA		Full range	4.82			4.82			٧
				25°C	4.7	4.85		4.7	4.85		
		IOH = -400 μA		Full range	4.5			4.5			
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
				25°C		0.09	0.15		0.09	0.15	
V_{OL}	Low-level output voltage	$V_{IC} = 2.5 V,$	I _{OL} = 500 μA	Full range			0.15			0.15	٧
		V 05V		25°C		0.8	1		0.7	1	
		V _{IC} = 2.5 V,	IOL = 4 mA	Full range			1.2			1.2	
	1		D. FOLIOT	25°C	80	100		80	170		
A_{VD}	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	$R_L = 50 \text{ k}\Omega^{\ddagger}$	Full range	50			50			V/mV
	voltage amplification	10-10-0	$R_L = 1 M\Omega^{\ddagger}$	25°C		550			550		
r _{i(d)}	Differential input resistance			25°C		1012			10 ¹²		Ω
^r i(c)	Common-mode input resistance			25°C		1012			1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		240			240		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	$V_0 = 2.5 V$,	25°C Full range	70 70	83		70 70	83		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{DD} = 4.4 \text{ V to 1}$	6 V, No load	25°C	80	95		80	95		dB
		$V_{IC} = V_{DD}/2$,	140 loau	Full range	80	400		80	100	F00	
מסו	Supply current	$V_0 = 2.5 V$	No load	25°C	ļ	400	500		400	500	μΑ
		1		Full range	L		500	<u> </u>		500	

[†] Full range is – 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2262I operating characteristics at specified free-air temperature, V_{DD} = 5 V

-	ARAMETER	TEST COND	TIONS	- +		TLC2262	:1	7	LC2262	AI	UNIT
	ANAMETER	TEST CONDI	IIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Claurate at unity	Va 15 V to 2 5 V	D. Fakot	25°C	0.35	0.55		0.35	0.55		
SR	Slew rate at unity gain	$V_O = 1.5 \text{ V to } 3.5 \text{ V,}$ $C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	Full range	0.25			0.25			V/μs
Vn	Equivalent input	f = 10 Hz		25°C		40			40		nV/√Hz
٧n	noise voltage	f = 1 kHz		25°C		12			12		nv/√Hz
Varion	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		μV
V _{N(PP)}	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μν
In	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
TUD . N	Total harmonic	V _O = 0.5 V to 2.5 V,	A _V = 1	0500		0.017%			0.017%		
THD + N	distortion plus noise	$f = 20 \text{ kHz},$ $R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25°C		0.03%			0.03%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF [‡]	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.82			0.82	,	MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF [‡]	25°C		185			185		kHz
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4			6.4		μs
rs	Settling time	$R_L = 50 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	23 0		14.1			14.1		μο
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF‡	25°C		56°			56°		
	Gain margin	1		25°C		11			11		dB

[†] Full range is - 40°C to 125°C.

[‡] Referenced to 2.5 V

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TLC2262I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	TAT		LC2262		TI	LC2262A	J.	UNIT
	PANAMETER	TEST CO	NDITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		300	2500		300	950	μV
۷IO	input onset voltage			Full range			3000			1500	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°0
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	V _O = 0,	25°C		0.003			0.003		μV/m
lo	Input offset current			25°C		0.5			0.5		ρA
10		1		Full range			500			500	P
Iв	Input bias current			25°C		1			1		ρA
·ID		<u> </u>		Full range			500			500	ρ,,
VICR	Common-mode input	Bo = 50 O	V _{IO} ≤5 mV	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2	-	v
TICH	voltage range	113 - 00 12,	14101 301114	Full range	-5 to 3.5			-5 to 3.5	,		·
		$I_{O} = -20 \mu A$		25°C		4.99			4.99		
		1004		25°C	4.85	4.94		4.85	4.94		
Vом+	Maximum positive peak output voltage	$I_{O} = -100 \mu A$		Full range	4.82			4.82			٧
	output voltage	I - 400 A		25°C	4.7	4.85		4.7	4.85		
		I _O = -400 μA		Full range	4.5			4.5			
		V _{IC} = 0,	I _O = 50 μA	25°C		-4.99			-4.99		
		V 0	I- 500 A	25°C	-4.85	-4.91		-4.85	-4.91		
VOM-	Maximum negative peak output voltage	V _{IC} = 0,	$I_O = 500 \mu\text{A}$	Full range	-4.85			-4.85			٧
	output voltage	V:- 0	l- 4A	25°C	-4	-4.3		-4	-4.3		
		V _{IC} = 0,	$I_O = 4 \text{ mA}$	Full range	-3.8			-3.8			
		_	D: 50 kg	25°C	80	200		80	200		
A_{VD}	Large-signal differential voltage amplification	V _O = ±4 V	$R_L = 50 \text{ k}\Omega$	Full range	50			50			V/m
	voltage amplification		$R_L = 1 M\Omega$	25°C		1000			1000		
^r i(d)	Differential input resistance			25°C		10 ¹²			10 ¹²		Ω
ri(c)	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	Ay = 10	25°C		220			220		Ω
CMRR	Common-mode	V _{IC} = -5 V to	2.7 V,	25°C	75	88		75	88		dB
CIVIDI	rejection ratio	$V_O = 0$,	$R_S = 50 \Omega$	Full range	75			75			ub
	Supply-voltage rejection	V _{DD} = 4.4 V	to 16 V,	25°C	80	95		80	95		٦,٠
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{IC} = V_{DD}/2$		Full range	80			80			dB
l	Complexessment	V- 05V	Nalaad	25°C	,	425	500		425	500	
dם ^ו	Supply current	$V_0 = 2.5 V$	NO IOAG	Full range			500			500	μΑ

[†] Full range is - 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2262I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	ARAMETER	TEST CONDITI	ONE	- .+		TLC2262	1	Т	LC2262/	AI .	UNIT
P	AHAMEIEH	TEST CONDITI	ONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	V _O = ±1.9 V,	R _I = 50 kΩ,	25°C	0.35	0.55		0.35	0.55		
SR	gain	C _L = 100 pF	112 00 1123	Full range	0.25			0.25			V/μs
V _n	Equivalent input	f = 10 Hz		25°C		43			43		nV/√Hz
٧n	noise voltage	f ≈ 1 kHz		25°C		12			12		NV/VH2
VALCED	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		0.8			0.8		μV
V _{N(PP)}	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μν
I _n	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
THD + N	Total harmonic	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	25°C		0.014%			0.014%		
IND+N	distortion plus noise	$R_L = 50 \text{ k}\Omega$, f = 20 kHz	A _V = 10	25°C		0.024%			0.024%		
	Gain-bandwidth product	f ≃10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73			0.73		MHz
ВОМ	Maximum output-swing bandwidth	V _{O(PP)} = 4.6 V, R _L = 50 kΩ,	A _V = 1, C _L = 100 pF	25°C		85			85		kHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1			7.1		μs
'S	Obtaing affic	R _L = 50 kΩ, C _L = 100 pF	To 0.01%	230		16.5			16.5		μο
φm	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C		57°			57°		
	Gain margin	1		25°C		11			11		dB

[†] Full range is -40°C to 125°C.

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TLC2264I electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	- .+	Т	LC2264	1	TL	.C2264/	AI	UNIT
	PANAMETER	TEST CON	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage	}		25°C		300	2500		300	950	μV
-10				Full range			3000			1500	μ·
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, R _S = 50 Ω	25°C		0.003	,		0.003		μV/mo
1.0	Input offeet ourrent			25°C		0.5	,		0.5		
lo ol	Input offset current			Full range			500			500	рA
l _{IB}	Input bias current			25°C		1			1		pΑ
סוי	mput biao ourront			Full range			500			500	P''.
	Common-mode input			25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	0 to			0 to			٧
				· · · · · · · · · · · · · ·	3.5			3.5			
		I _{OH} = -20 μA		25°C		4.99			4.99		
	I link lavel autout	100		25°C	4.85	4.94		4.85	4.94		
VOH	High-level output voltage	IOH = -100 μA		Full range	4.82			4.82			٧
	vollago	l _{OH} = -400 μA		25°C	4.7	4.85		4.7	4.85		
		ЮН = -400 иА		Full range	4.5			4.5			
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Low-level output	V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
VOL	voltage	1,0 === 1,		Full range			0.15			0.15	٧
		V _{IC} = 2.5 V,	IOL = 4 mA	25°C		0.8	1		0.7	1	
		10	T	Full range			1.2			1.2	
	Large-signal differential	V _{IC} = 2.5 V,	$R_L = 50 \text{ k}\Omega^{\ddagger}$	25°C	80	100		80	170		
AVD	voltage amplification	V _O = 1 V to 4 V	- d Mot	Full range	50			50			V/mV
r _{i(d)}	Differential input		$R_L = 1 M\Omega^{\ddagger}$	25°C		550 10 ¹²			550 10 ¹²		Ω
ι(α)	resistance	ļ									
ri(c)	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		рF
z _O	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		240			240		Ω
01400	Common-mode	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	83		70	83		
CMRR	rejection ratio	$R_S = 50 \Omega$	_	Full range	70			70			dB
1.	Supply-voltage	V _{DD} = 4.4 V to 1	6 V,	25°C	80	95		80	95		
ksvr	rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			dB
lon	Supply current	V _O = 2.5 V,	No load	25°C		0.8	1		0.8	1	mA
DD	(four amplifiers)	VO = 2.5 V,	INU IUAU	Full range			1			1.] "'^

[†] Full range is – 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2264I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

D.4	DAMETER	TEST SOUD	TIONO		Т	LC2264I		TI	_C2264A		UNIT
PA	ARAMETER	TEST CONDI	IIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at unity	V- 14V4-00V	D. sakot	25°C	0.35	0.55		0.35	0.55		
SR	gain	$V_O = 1.4 \text{ V to } 2.6 \text{ V},$ $C_L = 100 \text{ pF}^{\ddagger}$	HL = 50 K22+,	Full range	0.25			0.25			V/μs
V	Equivalent input	f = 10 Hz		25°C		40			40		nV/√Hz
V _n	noise voltage	f = 1 kHz		25°C		12			12		nv/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.017%			0.017%		
THD + N	distortion plus noise	f = 20 kHz, R _L = 50 kΩ [‡]	A _V = 10	25°C		0.03%			0.03%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_{L} = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.71			0.71		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF [‡]	25°C		185			185		kHz
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4			6.4		us
'S	octaing arise	$R_L = 50 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	25 0		14.1			14.1		μο
φm	Phase margin at unity gain	RL = 50 kΩ [‡] ,	C _L = 100 pF [‡]	25°C		56°			56°		
	Gain margin] -		25°C		11			11		dB

[†] Full range is – 40°C to 125°C.

[‡] Referenced to 2.5 V

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TLC2264I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ±5 V (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	TAT	Т	LC2264	<u> </u>	TI	LC2264A	d .	UNIT
	PARAMETER	I ESI CO	MUITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	ONII
V	Innut offeet veltage		,	25°C		300	2500		300	950	/
V _{IO}	Input offset voltage			Full range			3000			1500	μV
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, R _S = 50 Ω	V _O = 0,	25°C		0.003			0.003		μV/mo
lio	Input offset current	1		25°C		0.5			0.5		pА
10	Input onset ourrent	1		Full range			500			500	P
lв	Input bias current			25°C		1			1		рA
-10				Full range			500			500	
V. 0 =	Common-mode input	Bo - 50 O	1\(\alpha \left\)	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		V
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	-5 to 3.5			5 to 3.5			V
		$I_0 = -20 \mu A$		25°C		4.99			4.99		
	Mandage and the same to	100 4		25°C	4.85	4.94		4.85	4.94		
V _{OM+}	Maximum positive peak output voltage	I _O = -100 μA		Full range	4.82			4.82			V
	output voltage	ΙΟ = -400 μΑ		. 25°C	4.7	4.85		4.7	4.85		
	······································	10 = -400 μλ	·	Full range	4.5			4.5			
		V _{IC} = 0,	IO = 50 μA	25°C		-4.99			-4.99		
	Maximum negative peak	V _{IC} = 0,	ΙΟ = 500 μΑ	25°C	-4.85	-4.91		-4.85	-4.91		
VOM-	output voltage	1,0		Full range	-4.85			-4.85			٧
		V _{IC} = 0,	$I_O = 4 \text{ mA}$	25°C	-4	-4.3		-4	-4.3		
		10	, <u> </u>	Full range	-3.8			-3.8			
A	Large-signal differential	V	$R_L = 50 \text{ k}\Omega$	25°C	80	200		80	200)//\/
AVD	voltage amplification	$V_O = \pm 4 V$	D: 1MO	Full range 25°C	50	1000		50	1000		V/mV
r _{i(d)}	Differential input resistance		$R_L = 1 M\Omega$	25°C		1012			1012		Ω
ri(c)	Common-mode input resistance			25°C		1012			1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,		25°C		220			220		Ω
CMRR	Common-mode	$V_{IC} = -5 V to$	2.7 V,	25°C	75	88		75	88		dΒ
J (1 1	rejection ratio	$V_{O} = 0$,		Full range	75			75			45
ksvr	Supply-voltage rejection	$V_{DD\pm} = \pm 2.2$		25°C	80	95		80	95		dB
5VN	ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	V _{IC} =V _{DD} /2,	No load	Full range	80			80			
lDD	Supply current	$V_{O} = 0$	No load	25°C		0.85	1		0.85	1	mA
	(four amplifiers)	L		Full range	L		1	<u> </u>		1	l

[†] Full range is – 40°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2264I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

D.	RAMETER	TEST CONDIT	IONO	_ +		TLC2264		7	LC2264A	J	UNIT
PF	KHAIVIE I EK	TEST CONDIT	IONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Class rate at smits	V- 140V	D. 50 kO	25°C	0.35	0.55		0.35	0.55		
SR	Slew rate at unity gain	$V_O = \pm 1.9 \text{ V},$ $C_L = 100 \text{ pF}$	$R_L = 50 \text{ k}\Omega$,	Full range	0.25			0.25			V/μs
	Equivalent input	f = 10 Hz		25°C		43			43		nV/√Hz
Vn	noise voltage	f = 1 kHz		25°C		12			12		nv/√Hz
Vivi	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.8			0.8		μV
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μν
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	25°C		0.014%			0.014%		
א + טחו	distortion plus noise	$R_L = 50 \text{ k}\Omega,$ f = 20 kHz	A _V = 10	25-0		0.024%			0.024%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73			0.73		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		70			70		kHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1			7.1		μs
'S	Setting time	R _L = 50 kΩ, C _L = 100 pF	To 0.01%	250		16.5			16.5		μэ
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega$	C _L = 100 pF	25°C		57°			57°		
	Gain margin			25°C		11			11		dB

[†] Full range is -40°C to 125°C.

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TLC2262M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	TEST COL	DITIONS	- +	TI	.C2262I	VI	TL	.C2262A	M	
	PARAMETER	TEST CON	IDITIONS	TA†	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
\/\o	Input offset voltage			25°C		300	2500		300	950	μV
VIO	Input offset voltage			Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage			Full range		5	-		5		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$		25°C		0.003			0.003		μV/m
lio.	Input offset current]		25°C		0.5			0.5		pА
10	input onset current			125°C			500			500	PΑ
l _{IB}	Input bias current			25°C		1			- 1		рA
'IB				125°C			500			500	pA
Vion	Common-mode input	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		v
ViCR	voltage range	ng = 50 sz,	IAIO I ≥2 IIIA	Full range	0 to 3.5			0 to 3.5			v
		IOH = -20 μA		25°C		4.99			4.99		
	I the board and and	100		25°C	4.85	4.94		4.85	4.94		
Vон	High-level output voltage	IOH = -100 μA		Full range	4.82			4.82			٧
	voltage	100		25°C	4.7	4.85		4.7	4.85		
		I _{OH} = -400 μA		Full range	4.5			4.5			
		$V_{IC} = 2.5 V$,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Lour lovel autout	V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
VOL	Low-level output voltage	VIC = 2.5 V,	IOL = 300 μA	Full range			0.15			0.15	٧
	vollago	V _{IC} = 2.5 V,	I _{OL} = 4 mA	25°C		8.0	1		0.7	1	
		VIC = 2.5 V,	IOL = 4 IIIA	Full range			1.2			1.2	
	Large-signal differential	V _{IC} = 2.5 V,	$R_1 = 50 \text{ k}\Omega^{\ddagger}$	25°C	80	100		80	170		
AVD	voltage amplification	$V_0 = 1 \text{ V to 4 V}$	11[= 50 ks21	Full range	50			50			V/m
		.0	$R_L = 1 M\Omega^{\ddagger}$	25°C		550			550		
^r i(d)	Differential input resistance			25°C		1012			1012		Ω
r _{i(c)}	Common-mode input resistance			25°C		1012			1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		240			240		Ω
CMRR	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$	$V_0 = 2.5 V$,	25°C	70	83		70	83		dB
CIVII III	rejection ratio	$R_S = 50 \Omega$		Full range	70			70			ub
kovo	Supply-voltage rejection	$V_{DD} = 4.4 \text{ V to } 1$		25°C	80	95		80	95		dB
ksvr	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			ub
Inn	Supply current	V _O = 2.5 V,	No load	25°C		400	500		400	500	μА
DD	oupply outlett	VO - 2.5 V,	110 1000	Full range			500			500	^{μΑ}

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2262M operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

				Ι.	Т 7	LC2262	M	TL	C2262A	М	
Р	ARAMETER	TEST CONDI	TIONS	TA [†]	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	0	V 05W 05W	5 -51 ot	25°C	0.35	0.55		0.35	0.55		
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 3.5 \text{ V,}$ $C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	Full range	0.25			0.25			V/μs
.,	Equivalent input	f = 10 Hz		25°C		40			40		
v _n	noise voltage	f = 1 kHz		25°C		12			12		nV/√Hz
	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.7			0.7		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μV
In	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
THD + N	Total harmonic	V _O = 0.5 V to 2.5 V,	A _V = 1	25°C		0.017%			0.017%		
וחט + א	distortion plus noise	f = 20 kHz, $R_L = 50 \text{ k}\Omega^{\ddagger}$	A _V = 10	25.0		0.03%			0.03%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.82			0.82		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_{L} = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF [‡]	25°C		185			185		kHz
ts	Settling time	A _V = -1, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4			6.4		μs
'S	Octaing affic	$R_L = 50 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	250		14.1			14.1		μэ
φm	Phase margin at unity gain	R _L = 50 kΩ [‡] ,	C _L = 100 pF‡	25°C	,	56°			56°		
	Gain margin			25°C		11			11		dB

[†] Full range is – 55°C to 125°C. ‡ Referenced to 2.5 V

TLC2262M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST	NDITIONS	T.+	TI	_C2262N	Л	TL	C2262A	М	
	PARAMETER	IESI CC	MUITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		300	2500		300	950	μV
VIO	input onset voltage			Full range			3000			1500	μν
ανιο	Temperature coefficient of input offset voltage			Full range		5			5		μV/°C
	Input offset voltage long- term drift (see Note 4)	$V_{IC} = 0,$ R _S = 50 Ω	V _O = 0,	25°C		0.003		,	0.003		μV/mo
I	In most offerst assessment]		25°C		0.5			0.5		рA
lo Io	Input offset current			125°C			500			500	PΑ
lin.	Input bias current			25°C		1			1		рA
^I IB	input bias current			125°C			500			500	PΑ
Vion	Common-mode input	R _S = 50 Ω,	V _{IO} ≤ 5 mV	25°C	-5 to 4	-5.3 to 4.2	,	-5 to 4	-5.3 to 4.2		v
VICR	voltage range	ng = 50 sz,	IAIO LZ 2 IIIA	Full range	–5 to 3.5			-5 to 3.5			V
		$I_O = -20 \mu A$		25°C		4.99			4.99		
		lo = 100 u/		25°C	4.85	4.94		4.85	4.94		
V _{OM+}	Maximum positive peak output voltage	$I_O = -100 \mu$		Full range	4.82			4.82			٧
	· Carpar Conago	Ι _Ο = -400 μΑ		25°C	4.7	4.85		4.7	4.85		
		10 = -400 μ/		Full range	4.5			4.5			
		$V_{IC} = 0$,	I _O = 50 μA	25°C		-4.99			-4.99		
	Maximum pagativa pagk	V _{IC} = 0,	IO = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91		
VOM-	Maximum negative peak output voltage	10 - 0,		Full range	-4.85			-4.85			٧
		V _{IC} = 0,	IO = 4 mA	25°C	-4	-4.3		-4	-4.3		
~~*****		110 - 0,		Full range	-3.8			-3.8			
	Large-signal differential		R _L = 50 kΩ	25°C	80	200		80	200		
A_{VD}	voltage amplification	$V_O = \pm 4 V$		Full range	50			50			V/mV
			$R_L = 1 M\Omega$	25°C		1000			1000		
ri(d)	Differential input resistance			25°C		1012			1012		Ω
^r i(c)	Common-mode input resistance			25°C		10 ¹²			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		220			220		Ω
CMRR	Common-mode	V _{IC} = −5 V to	2.7 V,	25°C	75	88		75	88		dB
CIVINA	rejection ratio	$V_O = 0$,		Full range	75			75			uв
kovr	Supply-voltage rejection	VDD = 4.4 V 10 10 V,	25°C	80	95		80	95		dB	
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})		Full range	80			80			L ub	
Inn	Supply current	Vo = 0	No load	25°C		425	500		425	500	μА
IDD	очрріў очнопі	10-0,	O = 0, No load Full ra	Full range			500			500	"^

† Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at TA = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2262M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

-	ARAMETER	TEST CONDITIONS		-+	1	LC2262	М	TI	LC2262A	M	UNIT
Pi	AKAMETEK	TEST CONDITI	ONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at unity	Vo -+2.V	D. FOLO	25°C	0.35	0.55		0.35	0.55		
SR	gain	V _O = ±2 V, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	Full range	0.25			0.25			V/μs
V	Equivalent input	f = 10 Hz		25°C		43			43		
V _n	noise voltage	f = 1 kHz		25°C		12			12		nV/√Hz
Variant	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.8			0.8		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
THD + N	Total harmonic	$V_0 = \pm 2.3 \text{ V},$	A _V = 1	25°C		0.014%			0.014%		
IND+N	distortion plus noise	$R_L = 50 \text{ k}\Omega,$ f = 20 kHz	A _V = 10	25.0		0.024%			0.024%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73			0.73		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		85			85		kHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1			7.1		μs
'S	County time	$R_L = 50 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	25 0		16.5			16.5		μο
φm	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C		57°			57°		
	Gain margin			25°C		11			11		dB

[†] Full range is –55°C to 125°C.

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TLC2264M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	T. +	TI	_C2264I	M	TL	C2264A	M	UNIT
	TANAMETEN	1231 001		T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
VIO	Input offset voltage			25°C		300	2500		300	950	μV
10	Temperature coefficient	ļ		Full range			3000			1500	
αNIO	of input offset voltage			Full range		2			2		μV/°C
	Input offset voltage long- term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, R _S = 50 Ω	25°C		0.003			0.003		μV/mo
lio	Input offset current			25°C		0.5			0.5		pA
110	Input onset current			125°C			500			500	PΑ
I _{IB}	Input bias current			25°C		1			1		pΑ
.ID	par blas sarront			125°C			500			500	P/ \
				25°C	0	-0.3		0 to	-0.3		
	Common-mode input			25 0	to 4	to 4.2		4	to 4.2		
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV		0			0			٧
				Full range	to			to			
	·				3.5			3.5			
		I _{OH} = -20 μA		25°C		4.99			4.99		
	High-level output	I _{OH} = -100 μA		25°C	4.85	4.94		4.85	4.94		
VOH	voltage	- 100 μ/1		Full range	4.82			4.82			V
	· ·	ΙΟΗ = -400 μΑ		25°C	4.7	4.85		4.7	4.85		
		- 100 μ/ι		Full range	4.5			4.5			
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
	Low-level output	V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
VOL	voltage	1,0 = 0,		Full range			0.15			0.15	V
	•	V _{IC} = 2.5 V,	I _{OL} = 4 mA	25°C		0.8	1		0.7	1	
		110 = 2.10 1,		Full range			1.2			1.2	
	Large-signal differential	V _{IC} = 2.5 V,	R _L = 50 kه	25°C	80	100		80	170		
AVD	voltage amplification	V _O = 1 V to 4 V	_	Full range	50			50			V/mV
			$R_L = 1 M\Omega^{\ddagger}$	25°C		550			550		
^r i(d)	Differential input resistance			25°C		10 ¹²			1012		Ω
r _{i(c)}	Common-mode input resistance			25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _O	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		240			240		Ω
OMBE	Common-mode	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	83		70	83		
CMRR	rejection ratio	$R_S = 50 \Omega$		Full range	70			70			dB
	Supply-voltage	V _{DD} = 4.4 V to 1	6 V	25°C	80	95		80	95		
ksvr	rejection ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$	No load	Full range	80			80			dB
				25°C	-	0.8	1		0.8	1	
IDD	Supply current (four amplifiers)	$V_0 = 2.5 V$	No load	Full range		0.0	1		0.0	<u>'</u>	mA
<u> </u>	nge is - 55°C to 125°C	L		I un range	L			L			L

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

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TLC2264M operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

	1 7 00										
DA	DAMETED	TEST SOUR	TIONO		TI	LC2264N	l	TL	.C2264AN	Λ	UNIT
PA	RAMETER	TEST CONDI	HONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Class make alternibe	V- 05V4-05V	5	25°C	0.35	0.55		0.35	0.55		
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 3.5 \text{ V,}$ $C_L = 100 \text{ pF}^{\ddagger}$	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	Full range	0.25			0.25			V/μs
V	Equivalent input	f = 10 Hz		25°C		40			40		->4/5
Vn	noise voltage	f = 1 kHz		25°C		12			12		nV/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz	0.1 Hz to 1 Hz			0.7			0.7		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
THD + N	Total harmonic	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.017%			0.017%		
IUD + M	distortion plus noise	f = 20 kHz, R _L = 50 kΩ [‡]	A _V = 10	25°C		0.03%			0.03%		
	Gain-bandwidth product	f = 50 kHz, C _L = 100 pF‡	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	25°C		0.71			0.71		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 50 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		185			185		kHz
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		6.4			6.4		μs
°5		$R_L = 50 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	25 0		14.1		,	14.1		μο
φm	Phase margin at unity gain	$R_L = 50 \text{ k}\Omega^{\ddagger}$,	C _L = 100 pF [‡]	25°C		56°			56°		-
	Gain margin			25°C		11			11		dB

[†] Full range is – 55°C to 125°C. ‡ Referenced to 2.5 V

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TLC2264M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CON	IDITIONS	_ +	TLC2264M		TLC2264AM			UNIT	
	PARAMETER	IESI CON	DITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V	Innut offset valtage			25°C		300	2500		300	950	μV
VIO	Input offset voltage			Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage		1	Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	V _O = 0,	25°C		0.003			0.003		μV/mo
	1			25°C		0.5			0.5		
liO	Input offset current			125°C			500		-	500	pΑ
	I	1		25°C		1			1		
lВ	Input bias current			125°C			500		***************************************	500	pΑ
VICR	Common-mode input	$R_S = 50 \Omega$,		25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		v
·ich	voltage range	V _{IO} ≤5 mV		Full range	-5 to 3.5			-5 to 3.5			
		$I_O = -20 \mu A$		25°C		4.99			4.99		
	Maximum positive peak	ΙΟ = -100 μΑ		25°C	4.85	4.94		4.85	4.94		
VOM+	output voltage			Full range	4.82			4.82			٧
		ΙΟ = -400 μΑ		25°C	4.7	4.85		4.7	4.85		
				Full range	4.5			4.5			
		V _{IC} = 0,	l _O = 50 μA	25°C		-4.99			-4.99		
	Maximum negative peak	V _{IC} = 0,	ΙΟ = 500 μΑ	25°C	-4.85	-4.91		-4.85	-4.91		
V _{OM} ~	output voltage			Full range	-4.85			-4.85			\
		V _{IC} = 0,	IO = 4 mA	25°C	-4	-4.3		-4	-4.3		
		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		Full range	-3.8			-3.8			
	Large-signal differential		$R_I = 50 \text{ k}\Omega$	25°C	80	200		80	200		
AVD	voltage amplification	V _O = ±4 V		Full range	50			50			V/mV
			$R_L = 1 M\Omega$	25°C		1000			1000		
^r i(d)	Differential input resistance			25°C		1012			1012		Ω
^r i(c)	Common-mode input resistance	·		25°C		1012			1012		Ω
c _{i(c)}	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10	25°C		220			220		Ω
CMRR	Common-mode	$V_{IC} = -5 \text{ V to } 2$	2.7 V,	25°C	75	88		75	88		dB
OWINA	rejection ratio	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	75			75			L UB
kovo	Supply-voltage rejection	V _{DD±} = ±2.2 \	/ to ±8 V,	25°C	80	95		80	95		dB
ksvr	ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			Lub
lnn.	Supply current	Vo = 0	No load	25°C		0.85	1		0.85	1	mA
IDD	(four amplifiers)	$V_O = 0$,	NO IOAU	Full range			1			1] ""A

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2264M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

D/	ARAMETER	TECT CONDIT	IONG	_ +	Т	LC2264N	1	Т	UNIT		
PA	AHAMETER	TEST CONDIT	IONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Claw rate at unity	V- +0V	D. 5010	25°C	0.35	0.55		0.35	0.55		
SR	Slew rate at unity gain	V _O = ±2 V, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	Full range	0.25			0.25			V/μs
V	Equivalent input	f = 10 Hz		25°C		43			43		nV/√Hz
Vn	noise voltage	f = 1 kHz		25°C		12			12		nv/√HZ
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		0.8			0.8		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.3			1.3		μV
I _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
TUD . N	Total harmonic	V _O = ±2.3 V,	A _V = 1	25°C		0.014%			0.014%		
THD + N	distortion plus noise	$R_L = 50 \text{ k}\Omega,$ f = 20 kHz	A _V = 10	25°C		0.024%			0.024%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 50 \text{ k}\Omega$,	25°C		0.73			0.73		MHz
ВОМ	Maximum output- swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 50 \text{ k}\Omega,$	A _V = 1, C _L = 100 pF	25°C		70			70		kHz
t _s	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		7.1			7.1		μs
<i>'</i> 5		$R_L = 50 k\Omega$, $C_L = 100 pF$	To 0.01%	25 0		16.5			16.5		μσ
φm	Phase margin at unity gain	R _L = 50 kΩ,	C _L = 100 pF	25°C		57°			57°		
	Gain margin			25°C		11			11		dB

[†] Full range is –55°C to 125°C.

TLC2262Y electrical characteristics at V_{DD} = 5 V, T_{A} = 25°C (unless otherwise noted)

	DADAMETED	TEGT	CONDITIONS		TL	_C2262\	1	
	PARAMETER	IEST	CONDITIONS		MIN	TYP	MAX	UNIT
VIO	Input offset voltage					300		μV
lio	Input offset current	$V_{IC} = 0,$ $V_{O} = 0,$	$V_{DD\pm} = \pm 2.5 \text{ V}$ Rs = 50 Ω	^{/,}		0.5		pA
Iв	Input bias current	1 v 0 = 0,	NS = 30 12			1		pА
V _{ICR}	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω			-0.3 to 4.2		٧
	·	I _{OH} = -20 μA				4.99		
Vон	High-level output voltage	I _{OH} = -100 μA				4.94		V
		I _{OH} = -400 μA				4.85		
	· · · · · · · · · · · · · · · · · · ·	$V_{IC} = 2.5 V$,	I _{OL} = 50 μA			0.01		
VOL	Low-level output voltage	$V_{IC} = 2.5 V$,	I _{OL} = 500 μA			0.09		V
		V _{IC} = 2.5 V,	$I_{OL} = 4 \text{ mA}$			0.8		
۸. ۳	Large-signal differential voltage	V _{IC} = 2.5 V,	$R_L = 50 \text{ k}\Omega^{\dagger}$			170		V/mV
AVD	amplification	V _O = 1 V to 4 V	$R_L = 1 M\Omega^{\dagger}$			550		V/IIIV
ri(d)	Differential input resistance					1012		Ω
ri(c)	Common-mode input resistance					1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz				8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10			240		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	$R_S = 50 \Omega$		83		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V,	V _{IC} = V _{DD} /2,	No load		95		dB
IDD .	Supply current	V _O = 2.5 V,	No load			400		μΑ

[†] Referenced to 2.5 V

TLC2262Y electrical characteristics at $V_{DD\pm}$ = ±5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEOT 001	DITIONS	TL	.C2262\	<i>'</i>	UNIT
	PARAMETER	TEST CON	SMOILIGH	MIN	TYP	MAX	UNII
VIO	Input offset voltage				300		μV
lo	Input offset current	V _{IC} = 0, V _O = 0	$R_S = 50 \Omega$,		0.5		pΑ
lв	Input bias current	7 0 - 0	3		1		pА
V _{ICR}	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω		-5.3 to 4.2		٧
		I _O = -20 μA			4.99		
V _{OM+}	Maximum positive peak output voltage	$I_O = -100 \mu\text{A}$			4.94		V
		$I_O = -400 \mu A$			4.85		
		V _{IC} = 0,	I _{OL} = 50 μA		-4.99		
VOM-	Maximum negative peak output voltage	V _{IC} = 0,	I _{OL} = 500 μA		-4.91		V
		$V_{IC} = 0$,	I _{OL} = 4 mA		-4.1	,	·
۸	Large-signal differential voltage	V= -+4.V	$R_L = 50 \text{ k}\Omega$		200		V/mV
AVD	amplification	V _O = ±4 V	$R_L = 1 M\Omega$		1000		V/IIIV
ri(d)	Differential input resistance				1012		Ω
ri(c)	Common-mode input resistance				1012		Ω
Ci(c)	Common-mode input capacitance	f = 10 kHz			8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10		220		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$	$V_{O} = 0$, $R_{S} = 50 \Omega$		88		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD\pm}/\Delta V_{IO})$	$V_{DD\pm} = \pm 2.2 \text{ V to } \pm 8 \text{ V,}$	V _{IC} = 0, No load		95		dB
I _{DD}	Supply current	V _O = 0,	No load		425		μΑ

TLC2264Y electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEAT	CONDITIONS		TI	LC2264	1	UNIT
	PARAMETER	1591	CONDITIONS		MIN	TYP	MAX	UNIT
VIO	Input offset voltage					300		μV
lo	Input offset current	V _{IC} = 0, V _O = 0,	$V_{DD\pm} = \pm 2.5 \ N_{DD\pm} = 50 \ \Omega$	/,		0.5		pА
l _{IB}	Input bias current	7 • • • • • • • • • • • • • • • • • • •	115 - 00 11			1		pА
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω			-0.3 to 4.2		٧
		I _{OH} = -20 μA				4.99		
VOH	High-level output voltage	I _{OH} = -100 μA				4.94		٧
		I _{OH} = -400 μA				4.85		
		V _{IC} = 2.5 V,	I _{OL} = 50 μA			0.01		
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA			0.09		V
		V _{IC} = 2.5 V,	IOL = 4 mA			0.8		
	Large-signal differential voltage	V _{IC} = 2.5 V,	$R_L = 50 \text{ k}\Omega^{\dagger}$			170		V/mV
AVD	amplification	V _O = 1 V to 4 V	$R_L = 1 M\Omega^{\dagger}$			550		V/IIIV
ri(d)	Differential input resistance					1012		Ω
ri(c)	Common-mode input resistance				,	1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz				8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10			240		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	$R_S = 50 \Omega$		83		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V,	V _{IC} = V _{DD} /2,	No load		95		dB
IDD	Supply current (four amplifiers)	V _O = 2.5 V,	No load			0.8		mA

[†] Referenced to 2.5 V

TLC2264Y electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_A = 25°C (unless otherwise noted)

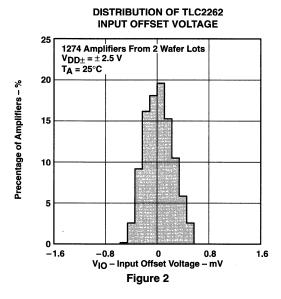
	DADAMETED	TEST 00	NDITIONS		TL	-C2264\	/	UNIT
	PARAMETER	IESI CO	NDITIONS		MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage		_			300		μV
l _{IO}	Input offset current	V _{IC} = 0, V _O = 0	$R_S = 50 \Omega$	•		0.5		рA
fιв	Input bias current	1 *0 - 0				1		pА
VICR	Common-mode input voltage range	V _{IO} ≤5 mV,	R _S = 50 Ω			-5.3 to 4.2		٧
		I _O = -20 μA				4.99		
V _{OM+}	Maximum positive peak output voltage	I _O = -100 μA				4.94		V
		I _O = -400 μA				4.85		
		V _{IC} = 0,	I _{OL} = 50 μ	A		-4.99		
VOM-	Maximum negative peak output voltage	V _{IC} = 0,	I _{OL} = 500	μΑ		-4.91		٧
		V _{IC} = 0,	I _{OL} = 4 m/	4		-4.1		
AVD	Large-signal differential voltage	V _O = ±4 V	$R_L = 50 \text{ k}\Omega$	2		200		V/mV
~VD	amplification	VO - ±4 V	$R_L = 1 M\Omega$			1000		V/111V
ri(d)	Differential input resistance				*	1012		Ω
ri(c)	Common-mode input resistance					1012		Ω
^C i(c)	Common-mode input capacitance	f = 10 kHz				8		pF
z _o	Closed-loop output impedance	f = 100 kHz,	A _V = 10			220		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$	V _O = 0,	$R_S = 50 \Omega$		88		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD\pm}/\Delta V_{IO})$	$V_{DD\pm} = \pm 2.2 \text{ V to } \pm 8 \text{ V},$	V _{IC} = 0,	No load		95		dB
lDD	Supply current (four amplifiers)	V _O = 0,	No load			0.85		mA

Table of Graphs

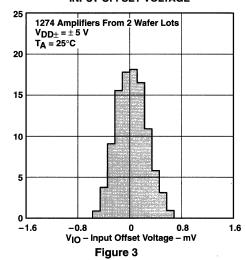
			FIGURE
V _{IO}	Input offset voltage	Distribution vs Common-mode input voltage	2 – 5 6, 7
αVIO	Input offset voltage temperature coefficient	Distribution	8 – 11
IB/IO	Input bias and input offset currents	vs Free-air temperature	12
VI	Input voltage range	vs Supply voltage vs Free-air temperature	13 14
Vон	High-level output voltage	vs High-level output current	15
VoL	Low-level output voltage	vs Low-level output current	16, 17
V _{OM+}	Maximum positive peak output voltage	vs Output current	18
V _{OM} -	Maximum negative peak output voltage	vs Output current	19
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	20
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	21 22
Vo	Output voltage	vs Differential input voltage	23, 24
	Differential gain	vs Load resistance	25
AVD	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	26, 27 28, 29
z _o	Output impedance	vs Frequency	30, 31
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	32 33
ksvr	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	34, 35 36
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v _n	Equivalent input noise voltage	vs Frequency	51, 52
	Noise voltage (referred to input)	Over a 10-second period	53
	Integrated noise voltage	vs Frequency	54
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	Gain-bandwidth product	vs Supply voltage vs Free-air temperature	56 57
φm	Phase margin	vs Frequency vs Load capacitance	26, 27 58
	Gain margin	vs Load capacitance	59
B ₁	Unity-gain bandwidth	vs Load capacitance	60
	Overestimation of phase margin	vs Load capacitance	61

TYPICAL CHARACTERISTICS

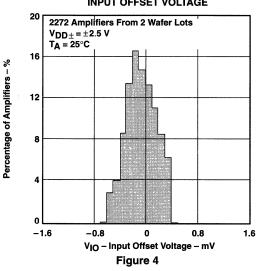
Percentage of Amplifiers – %



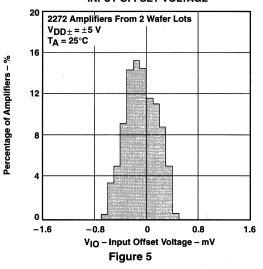
DISTRIBUTION OF TLC2262 INPUT OFFSET VOLTAGE





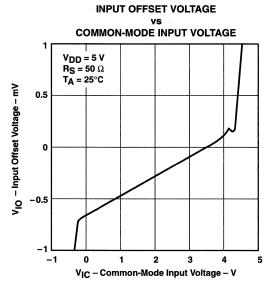


DISTRIBUTION OF TLC2264 INPUT OFFSET VOLTAGE





TYPICAL CHARACTERISTICS



† For curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V. **Figure 6**

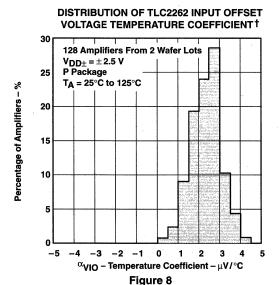
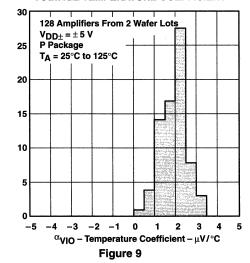


Figure 7

DISTRIBUTION OF TLC2262 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT[†]

V_{IC} - Common-Mode Input Voltage - V



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Percentage of Amplifiers – %



DISTRIBUTION OF TLC2264 INPUT OFFSET

VOLTAGE TEMPERATURE COEFFICIENT[†]

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TYPICAL CHARACTERISTICS

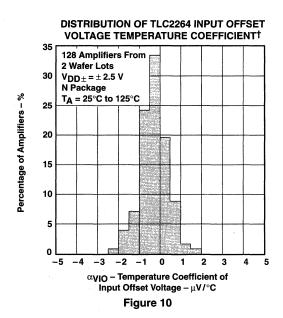
Percentage of Amplifiers – %

15

10

5

-5



30 V_{DD±=±5} V N Package T_A = 25°C to 125°C

128 Amplifiers From

2 Water Lots

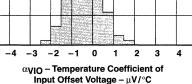


Figure 11

INPUT BIAS AND INPUT OFFSET CURRENTS†

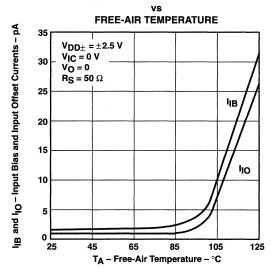


Figure 12

INPUT VOLTAGE RANGE

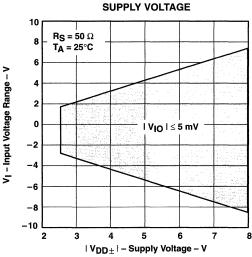
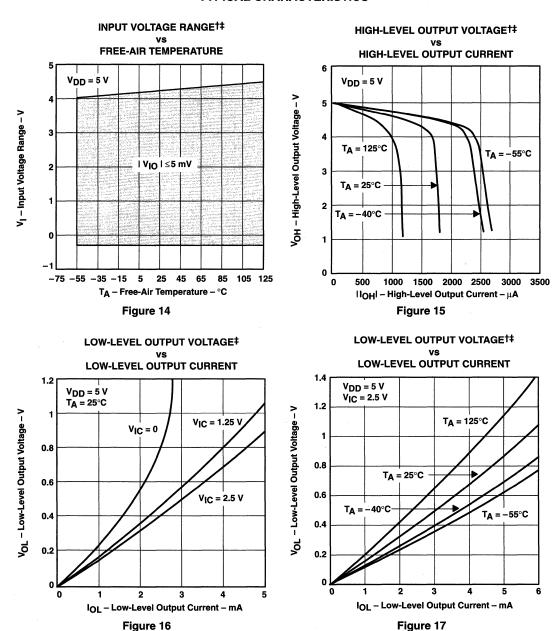


Figure 13

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

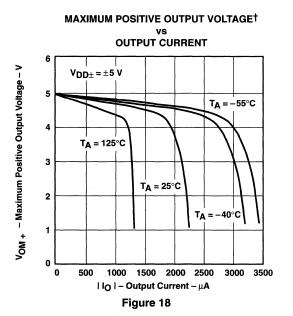




[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

[‡] For curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V.





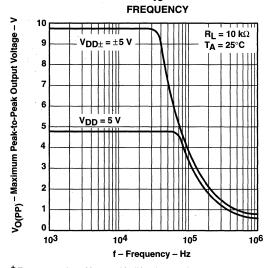
MAXIMUM NEGATIVE OUTPUT VOLTAGE[†] **OUTPUT CURRENT** -3.8 VOM _ - Maximum Negative Output Voltage - V $V_{DD\pm} = \pm 5 V$ $V_{IC} = 0$ T_A = 125°C -4.2 T_A = 25°C T_A = -40°C T_A = -55°C -4.65 6 IO - Output Current - mA

Figure 19

SHORT-CIRCUIT OUTPUT CURRENT

SUPPLY VOLTAGE

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE†‡



I_{OS} - Short-Circuit Output Current - mA 6 $V_0 = 0$ TA = 25°C 2 0 $V_{ID} = 100 \text{ mV}$ -2

 $V_{ID} = -100 \text{ mV}$

I $V_{DD\pm}$ I – Supply Voltage – V

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



12

10

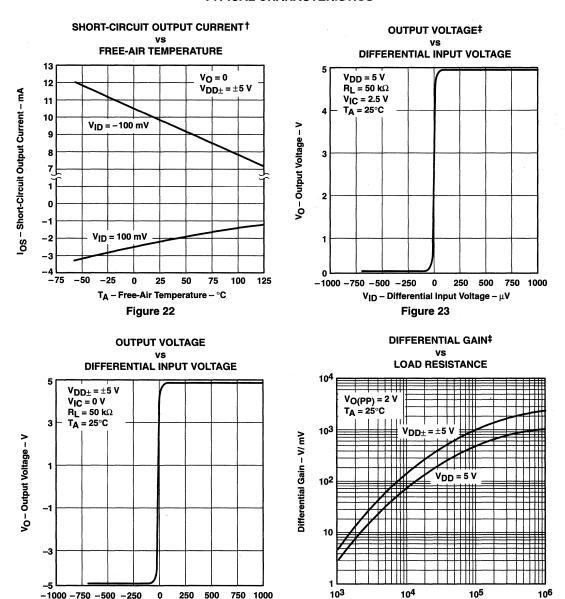
8

2

3

[‡] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V. Figure 20

Figure 21



 V_{ID} – Differential Input Voltage – μV Figure 24

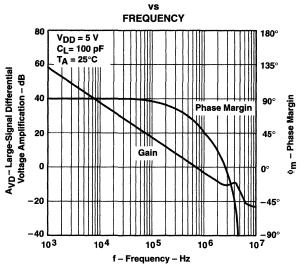
 R_L - Load Resistance - $k\Omega$

Figure 25



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. ‡ For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

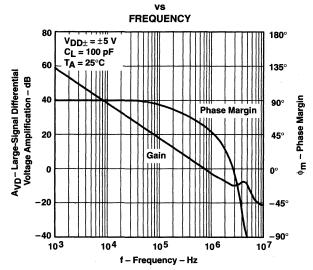
LARGE-SIGNAL DIFFERENTIAL VOLTAGE[†] AMPLIFICATION AND PHASE MARGIN



† For curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V.

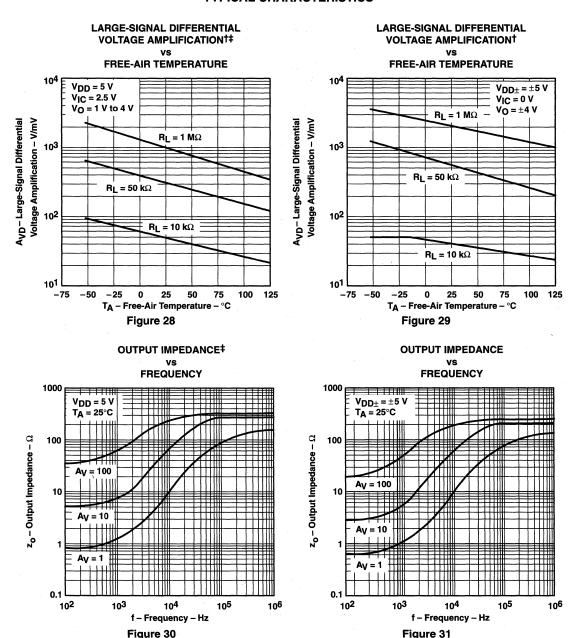
Figure 26

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN









[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

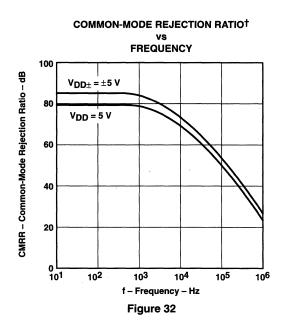
[‡] For curves where VDD = 5 V, all loads are referenced to 2.5 V.



COMMON-MODE REJECTION RATIO†‡

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TYPICAL CHARACTERISTICS



FREE-AIR TEMPERATURE

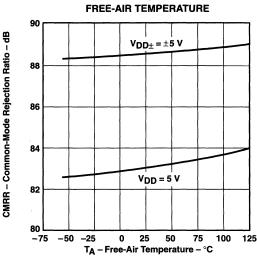
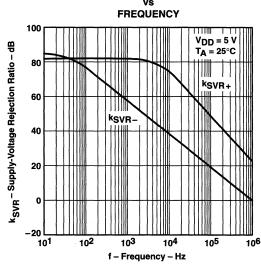
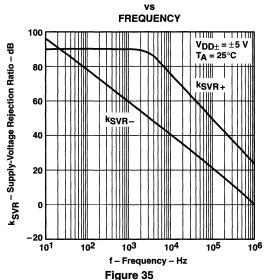


Figure 33





SUPPLY-VOLTAGE REJECTION RATIO

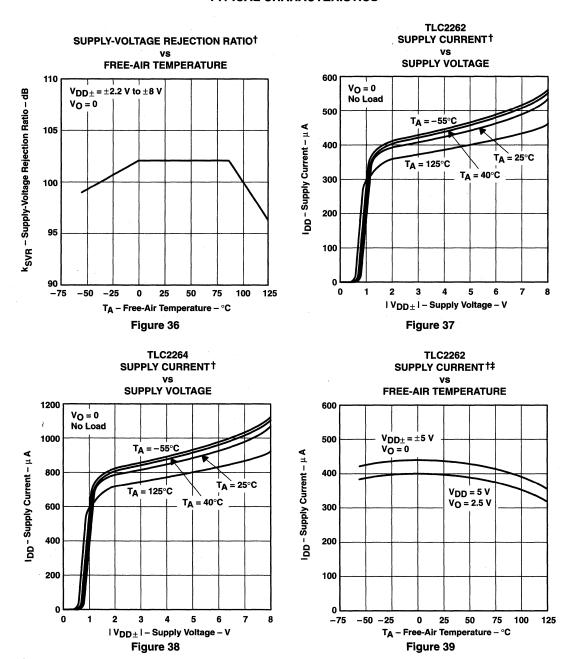


[†] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.

Figure 34

Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



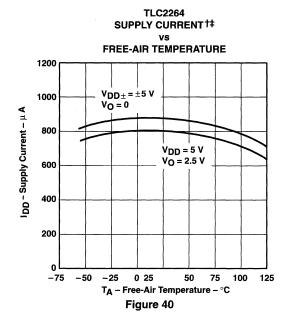


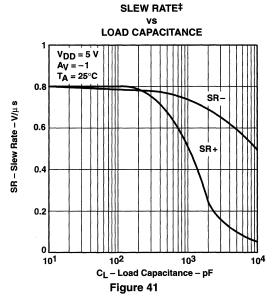
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

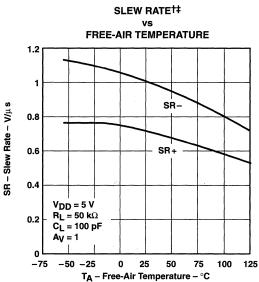
[‡] For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

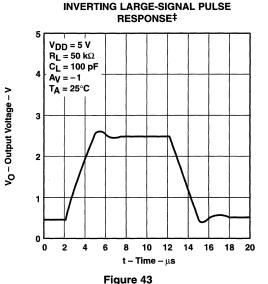


TYPICAL CHARACTERISTICS









[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

Figure 42

[‡] For curves where VDD = 5 V, all loads are referenced to 2.5 V.

INVERTING LARGE-SIGNAL PULSE RESPONSE $V_{DD\pm} = \pm 5 \text{ V}$ $R_L = 50 \text{ k}\Omega$ CL = 100 pF 3 $A_V = -1$ TA = 25°C V_O - Output Voltage - V 2 1 0 -2 -3 -4 -5 2 0 4 6 8 10 12 14 16 18 20 $t - Time - \mu s$

Figure 44

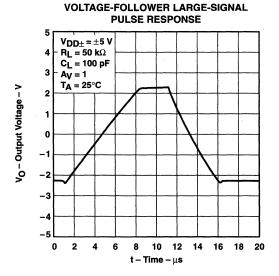


Figure 46

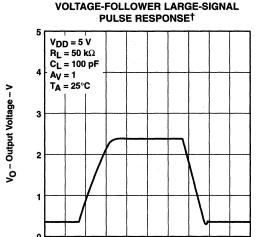


Figure 45

10 12 14 16 18

t - Time - μs

2 4 6

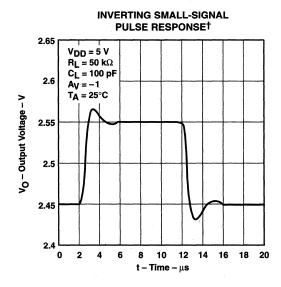


Figure 47

[†] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.



TYPICAL CHARACTERISTICS

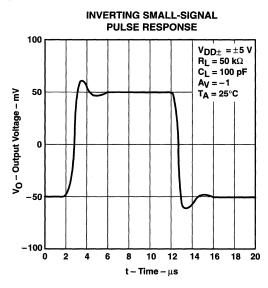


Figure 48

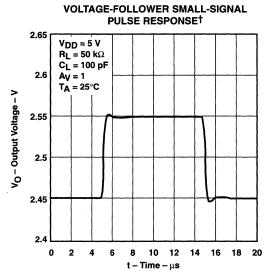


Figure 49

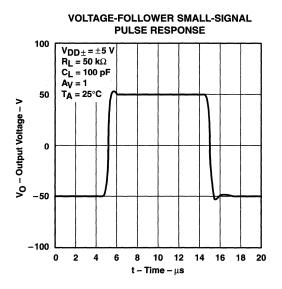


Figure 50

EQUIVALENT INPUT NOISE VOLTAGET vs FREQUENCY 60 VDD = 5 V

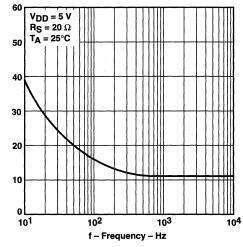


Figure 51

Vn - Equivalent Input Noise Voltage - nV/√Hz

[†] For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.

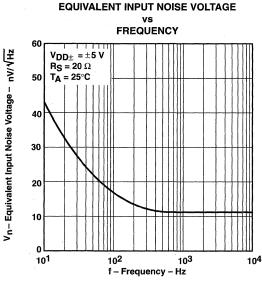


Figure 52

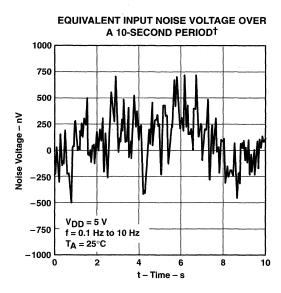


Figure 53

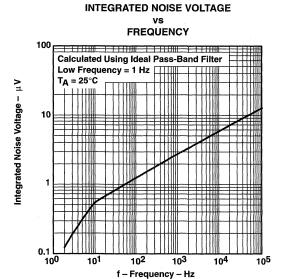


Figure 54

 \dagger For curves where $V_{DD} = 5$ V, all loads are referenced to 2.5 V.

TOTAL HARMONIC DISTORTION PLUS NOISET

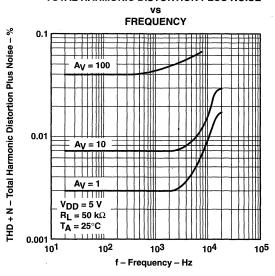
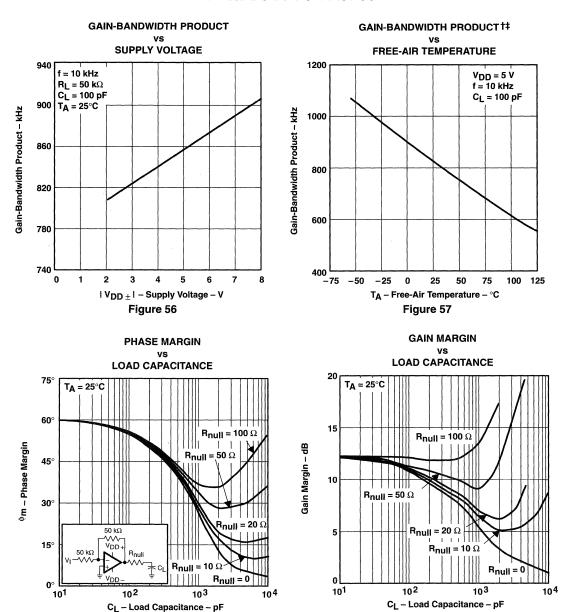


Figure 55



TYPICAL CHARACTERISTICS

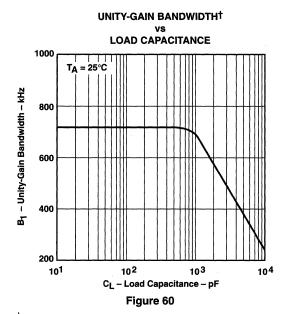


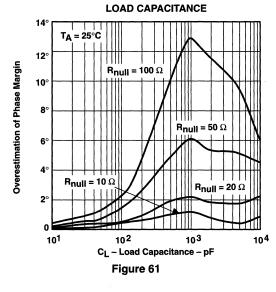
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. ‡ For curves where V_{DD} = 5 V, all loads are referenced to 2.5 V.

Figure 58



Figure 59





OVERESTIMATION OF PHASE MARGIN[†]

[†] See application information

APPLICATION INFORMATION

driving large capacitive loads

The TLC226x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 52 and Figure 53 illustrate its ability to drive loads greater than 400 pF while maintaining good gain and phase margins (R_{null} = 0).

A smaller series resistor (R_{null}) at the output of the device (see Figure 56) improves the gain and phase margins when driving large capacitive loads. Figure 52 and Figure 53 show the effects of adding series resistances of 10 Ω , 20 Ω , 50 Ω , and 100 Ω . The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second is that it reduces the frequency of the pole associated with the output load in the transfer function.

The zero introduced to the transfer function is equal to the series resistance times the load capacitance. To calculate the improvement in phase margin, equation 1 can be used.

$$\Delta\Theta_{\rm m1} = \tan^{-1} \left(2 \times \pi \times \rm UGBW \times R_{\rm null} \times C_{\rm L} \right) \tag{1}$$

where:

 $\Delta\Theta_{m1}$ = improvement in phase margin

UGBW = unity-gain bandwidth frequency

R_{null} = output series resistance

C₁ = loadcapacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 54). To use equation 1, UGBW must be approximated from Figure 54.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 55. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin. The pole associated with the load is reduced by the factor calculated in equation 2.

$$F = \frac{1}{1 + g_{\text{m}} \times R_{\text{pull}}} \tag{2}$$

where:

F = factor reducing frequency of pole

 $g_m = \text{small-signal output transconductance (typically } 4.83 \times 10^{-3} \text{ mhos})$

R_{null} = output series resistance

For the TLC226x, the pole associated with the load is typically 7 MHz with 100-pF load capacitance. This value varies inversely with C_L : at C_L = 10 pF, use 70 MHz, at C_L = 1000 pF, use 700 kHz, and so on.

Reducing the pole associated with the load introduces phase shift, thereby reducing phase margin. This results in an error in the increase in phase margin expected by considering the zero alone (equation 1). Equation 3 approximates the reduction in phase margin due to the movement of the pole associated with the load. The result of this equation can be subtracted from the result of the equation 1 to better approximate the improvement in phase margin.



APPLICATION INFORMATION

driving large capacitive loads (continued)

$$\Delta\Theta_{m2} = \tan^{-1} \left[\frac{UGBW}{(F \times P_2)} \right] - \tan^{-1} \left(\frac{UGBW}{P_2} \right)$$
 (3)

where:

 $\Delta\Theta_{m2}$ = reduction in phase margin

UGBW = unity-gain bandwidth frequency

F = factor from equation 2

 P_2 = unadjusted pole (70 MHz@10 pF, 7 MHz@100 pF, etc.)

Using these equations with Figure 54 and Figure 55 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitive loads.

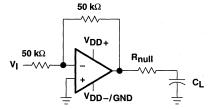


Figure 62. Series-Resistance Circuit

APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim Parts™, the model generation software used with Microsim PSpice™. The Boyle macromodel (see Note 5) and subcircuit in Figure 57 are generated using the TLC226x typical electrical and operating characteristics at $T_A = 25^{\circ}$ C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Intergrated Circuit Operational Amplifiers," IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

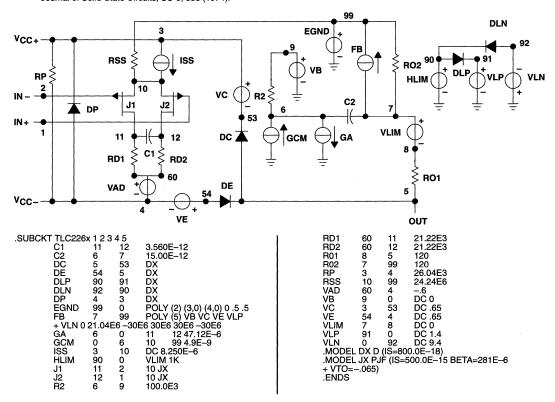


Figure 63. Boyle Macromodel and Subcircuit

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TLC227x, TLC227xA, TLC227xY Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

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- Output Swing Includes Both Supply Rails
- Low Noise . . . 9 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Common-Mode Input Voltage Range Includes Negative Rail

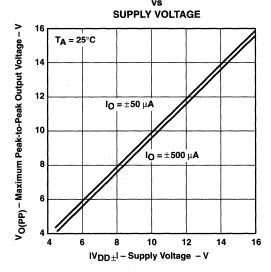
description

The TLC2272 and TLC2274 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC227x family offers 2 MHz of bandwidth and 3 V/μs of slew rate for higher speed applications. These devices offer comparable ac performance while having better noise, input offset voltage, and power dissipation than existing CMOS operational amplifiers. The TLC227x has a noise voltage of 9 nV/\Hz; two times lower than competitive solutions.

The TLC227x, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single- or split-supplies makes this family a great choice when interfacing with

- High-Gain Bandwidth . . . 2.2 MHz Typ
- High Slew Rate . . . 3.6 V/μs Typ
- Low Input Offset Voltage
 950 μV Max at T_A = 25°C
- Macromodel included
- Performance Upgrades for the TS272, TS274, TLC272, and TLC274

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE



analog-to-digital converters (ADCs). For precision applications, the TLC227xA family is available and has a maximum input offset voltage of 950 μ V. This family is fully characterized at 5 V and \pm 5 V.

The TLC2272/4 also makes great upgrades to the TLC272/4 or TS272/4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see TLV2432 and TLV2442 devices. If the design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

Advanced LinCMOS is a trademark of Texas Instruments Incorporated.

TLC227x, TLC227xA, TLC227xY Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

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TLC2272 AVAILABLE OPTIONS

,		Р	ACKAGED DEVIC	ES	
TA	V _{IO} max At 25°C	SMALL OUTLINE† (D)	PLASTIC DIP (P)	TSSOP‡ (PW)	CHIP FORM§ (Y)
0°C to 70°C	950 μV 2.5 mV	TLC2272ACD TLC2272CD	TLC2272ACP TLC2272CP	TLC2272CPWLE	TLC2272Y
-40°C to 85°C	950 μV 2.5 mV	TLC2272AID TLC2272ID	TLC2272AIP TLC2272IP		
-55°C to 125°C	950 μV 2.5 mV	TLC2272AMD TLC2272MD	TLC2272AMP TLC2272MP		

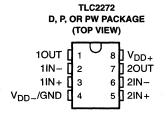
[†] The D packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2272CDR).

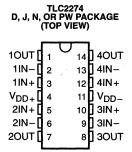
TLC2274 AVAILABLE OPTIONS

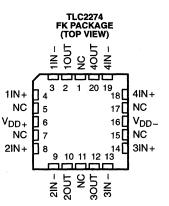
			ı	PACKAGED DEV	VICES		
TA	V _{IO} max AT 25°C	SMALL OUTLINE† (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	TSSOP [‡] (PW)	CHIP FORM§ (Y)
0°C to 70°C	950 μV 2.5 mV	TLC2274ACD TLC2274CD	_	-	TLC2274ACN TLC2274CN	TLC2274CPWLE	TLC2274Y
-40°C to 85°C	950 μV 2.5 mV	TLC2274AID TLC2274ID	<u> </u>		TLC2274AIN TLC2274IN	TLC2274IPWLE	
−55°C to 125°C	950 μV 2.5 mV	TLC2274AMD TLC2274MD	TLC2274AMFK TLC2274MFK	TLC2274AMJ TLC2274MJ	TLC2274AMN TLC2274MN		

The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2274CDR).

[§] Chips are tested at 25°C.







NC - No internal connection

[‡] The PW package is available only left-end taped and reeled.

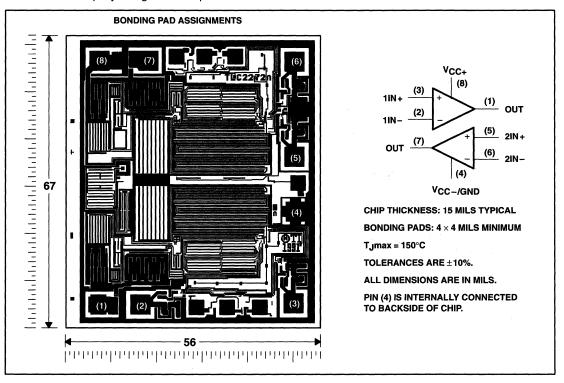
[§] Chips are tested at 25°C.

[‡]The PW package is available only left-end taped and reeled.

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TLC2272Y chip information

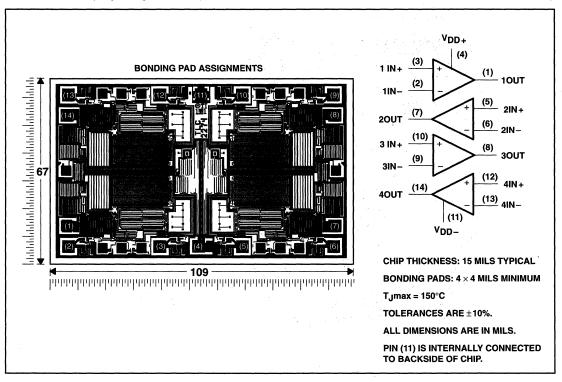
These chips, when properly assembled, display characteristics similar to the TLC2272C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



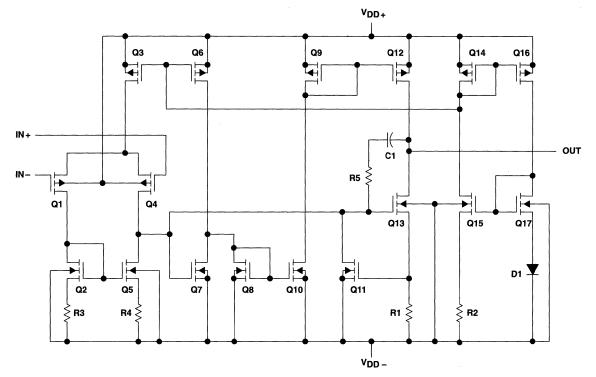
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TLC2274Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2274C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT					
COMPONENT	TLC2272	TLC2274			
Transistors	38	76			
Resistors	26	52			
Diodes	9	18			
Capacitors	3	6			

[†] Includes both amplifiers and all ESD, bias, and trim circuitry

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+} (see Note 1) Supply voltage, V _{DD-} (see Note 1) Differential input voltage, V _{ID} (see Note 2) Input voltage, V _I (any input, see Note 1) Input current, I _I (any input)	· · · · · · · · · · · · · · · · · · ·	
Output current, IO		
Total current into V _{DD+}		±50 mA
Total current out of V _{DD}		
Duration of short-circuit current at (or belo	w) 25°C (see Note 3)	unlimited
Continuous total dissipation		. See Dissipation Rating Table
Operating free-air temperature range, T _A :		
	I suffix	40°C to 85°C
	M suffix	
Storage temperature range		65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from	n case for 10 seconds: D, N, P or P	W package 260°C
Lead temperature 1,6 mm (1/16 inch) from	n case for 60 seconds: J package	300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VDD+ and VDD-..

- 2. Differential voltages are at IN+ with respect to IN -. Excessive current will flow if input is brought below VDD - 0.3 V.
- The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D-8	725 mW	5.8 mW/°C	464 mW	337 mW	145 mW
D-14	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	.1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	230 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW
PW8	525 mW	4.2 mW/°C	336 mW		<u> </u>
PW-14	700 mW	5.6 mW/°C	448 mW	364 mW	_

recommended operating conditions

	С	SUFFIX	15	SUFFIX	М	UNIT	
	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.2	±8	±2.2	±8	±2.2	±8	٧
Input voltage range, V _I	V _{DD} -	V _{DD+} -1.5	V _{DD} _	V _{DD+} –1.5	V_{DD-}	V _{DD+} -1.5	٧
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} -1.5	V _{DD} _	V _{DD+} -1.5	V_{DD-}	V _{DD+} -1.5	٧
Operating free-air temperature, TA	0	70	-40	85	-55	125	°C



TLC2272C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	T _A †	T	LC2272	С	TL	C2272A	C	UNIT
	FANAMETER	1231 00			MIN	TYP	MAX	MIN	TYP	MAX	UNII
VIO	Input offset voltage			25°C		300	2500		300	950	μV
-10				Full range			3000			1500	μ.
ανιο	Temperature coefficient of input offset voltage			25°C to 70°C		2		:	2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, V _O = 0,	$V_{DD}\pm=\pm2.5$ V, R _S = 50 Ω	25°C		0.002			0.002		μV/mo
10	Input offset current			25°C		0.5			0.5		рA
10	Input onset current	i		Full range			100			100	PΛ
lв	Input bias current	1		25°C		1			1		рA
אוי	input bias current			Full range			100			100	PΑ
VICR	Common-mode input	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V
·ICH	voltage range	11.5 = 55 12,	, ,	Full range	0 to 3.5			0 to 3.5			·
		I _{OH} = -20 μA		25°C		4.99			4.99		
	18 1 1 1 1 1 1	J 000 A		25°C	4.85	4.93		4.85	4.93		
Vон	High-level output voltage	ΙΟΗ = -200 μΑ		Full range	4.85			4.85			٧
	voltage			25°C	4.25	4.65		4.25	4.65		
		$I_{OH} = -1 \text{ mA}$		Full range	4.25			4.25			
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
	1 1 1 2 2 1	V 05V	I 500 A	25°C		0.09	0.15		0.09	0.15	
VOL	Low-level output voltage	$V_{IC} = 2.5 \text{ V},$	$I_{OL} = 500 \mu\text{A}$	Full range			0.15			0.15	٧
	vollago	V 25V	la: EmA	25°C		0.9	1.5		0.9	1.5	
		$V_{IC} = 2.5 \text{ V},$	IOL = 5 mA	Full range			1.5			1.5	
	Laure simual differential	V - 05V	$R_{\rm I} = 10 \rm k\Omega^{\ddagger}$	25°C	15	35		15	35		
AVD	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $V_{O} = 1 \text{ V to 4 V}$	HE = 10 K32+	Full range	15			15			V/mV
	vollago amplinoation	1.0-11.0	$R_L = 1 \text{ m}\Omega^{\ddagger}$	25°C		175			175		
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		10 ¹²			1012		Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $V_{O} = 2.5 \text{ V},$	R _S = 50 Ω	25°C Full range	70 70	75		70 70	75		dB
ksvr	Supply-voltage rejection	$V_{DD} = 4.4 \text{ V to}$		25°C	80	95		80	95		dB
	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	INO IOAU	Full range	80			80			
lpp	Supply current	V _O = 2.5 V,	No load	25°C	L	2.2	3		2.2	3	mA
20		L		Full range			3			3	

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

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TLC2272C operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

DADAMETED	TEST CONDITI	ONC	- +	T	LC22720	,	Т	LC2272A	С	UNIT
PARAMETER	IEST CONDITI	ONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
Slew rate at unity	V _O = 0.5 V to 2.5 V,	+	25°C	2.3	3.6		2.3	3.6		
gain	R _L = 10 kΩ∓, C _L =	= 100 pF+	Full range	1.7			1.7			V/µs
Equivalent input	f = 10 Hz		25°C		50			50		nV/√Hz
noise voltage	f = 1 kHz		25°C		. 9			9		ΠV/∀HZ
Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	$V_0 = 0.5 \text{ V to } 2.5 \text{ V}.$	A _V = 1			0.0013%			0.0013%		
	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		
alotoriton plao noto	R _L = 10 kΩ∓,	$A_{V} = 100$			0.03%			0.03%		
Gain-bandwidth product	f = 10 kHz, R _L = C _L = 100 pF [‡]	= 10 kΩ [‡] ,	25°C		2.18			2.18		MHz
Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V}, \qquad A_{V} = R_{L} = 10 \text{ k}\Omega^{\ddagger}, \qquad C_{L} = 0$	= 1, = 100 pF‡	25°C		1			1		MHz
Sattling time	A _V = -1, Step = 0.5 V to 2.5 V,	To 0.1%	25°€		1.5			1.5		μs
County unio	$R_L = 10 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	25 0		2.6			2.6		μο
Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L =	= 100 pF‡	25°C		50°			50°		
Gain margin] -	*	25°C		10			10		dB
	Equivalent input noise voltage Peak-to-peak equivalent input noise voltage Equivalent input noise current Total harmonic distortion plus noise Gain-bandwidth product Maximum output-swing bandwidth Settling time Phase margin at unity gain	Slew rate at unity gain $ \begin{array}{lll} V_O = 0.5 \ V \ to \ 2.5 \ V, \\ R_L = 10 \ k\Omega^{\ddagger}, & C_L : \\ \end{array} $ Equivalent input noise voltage $ \begin{array}{lll} f = 10 \ Hz \\ f = 1 \ kHz \\ \end{array} $ Peak-to-peak equivalent input noise voltage $ \begin{array}{lll} f = 0.1 \ Hz \ to \ 1 \ Hz \\ \hline f = 0.1 \ Hz \ to \ 10 \ Hz \\ \end{array} $ Total harmonic distortion plus noise $ \begin{array}{llll} V_O = 0.5 \ V \ to \ 2.5 \ V, \\ f = 20 \ kHz, \\ R_L = 10 \ k\Omega^{\ddagger}, & C_L : \\ \end{array} $ Gain-bandwidth $ \begin{array}{llll} f = 10 \ kHz, \\ C_L = 100 \ pF^{\ddagger} \\ \end{array} $ Maximum output-swing bandwidth $ \begin{array}{lllll} f = 10 \ k\Omega^{\ddagger}, & C_L : \\ \hline \\ Settling time & AV = -1, \\ Step = 0.5 \ V \ to \ 2.5 \ V, \\ R_L = 10 \ k\Omega^{\ddagger}, & C_L : \\ \hline \\ Phase margin at unity gain & R_L = 10 \ k\Omega^{\ddagger}, & C_L : \\ \end{array} $	Slew rate at unity gain	Slew rate at unity gain $ \begin{array}{lllllllllllllllllllllllllllllllllll$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} \text{Slew rate at unity gain} & V_{O} = 0.5 \ V \ \text{to} \ 2.5 \ V, \\ R_{L} = 10 \ \text{k} \Omega^{\ddagger}, C_{L} = 100 \ \text{pF}^{\ddagger} \\ \hline \\ Full range \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ Full range \\ \hline \\ 1.7 \\ \hline \\ \hline \\ 1.7 \\ \hline \\ \hline \\ 9 \\ \hline \\ 1.4 \\ \hline \\ 25^{\circ}C \\ \hline \\ 1.4 \\ \hline \\ 25^{\circ}C \\ \hline \\ 1.4 \\ \hline \\ 25^{\circ}C \\ \hline \\ 1.4 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline \\ 1.5 \\ \hline$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

[†] Full range is 0°C to 70°C.

[‡] Referenced to 2.5 V

TLC2272C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise specified)

	PARAMETER	TEST CO	PAOITIONS	T _A †	T	LC22720	>	TL	C2272A	C	UNIT
	PARAMETER	IEST COI	ADITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage			25°C		300	2500		300	950	μV
10		<u> </u>		Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 70°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ $R_S = 50 \Omega$	V _O = 0,	25°C		0.002			0.002		μV/m
l _{IO}	Input offset current	1		25°C		0.5			0.5		pΑ
10	Input onder outron	1		Full range			100			100	ρ, ι
lв	Input bias current			25°C		1			1		pА
·1D				Full range			100			100	ρ, .
	Common-mode input			25°C	−5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		
ViCR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	-5 to 3.5			-5 to 3.5			V
		$I_0 = -20 \mu A$		25°C		4.99			4.99		
	Maximum maaitiya maale	Jo = 200 4A		25°C	4.85	4.93		4.85	4.93		
V _{OM+}	Maximum positive peak output voltage	I _O = -200 μA		Full range	4.85			4.85		v	٧
	ou.put rollago	I _O = -1 mA		25°C	4.25	4.65		4.25	4.65		
		101111		Full range	4.25			4.25			
		V _{IC} = 0,	$I_O = 50 \mu A$	25°C		-4.99			-4.99		
	Maximum negative peak	V _{IC} = 0,	I _O = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91		
VOM-	output voltage	10 - 0,	10 = 900 ps.	Full range	-4.85			-4.85			V
		V _{IC} = 0,	IO = 5 mA	25°C	-3.5	-4.1		-3.5	-4.1		
		10 - 0,		Full range	-3.5			~3.5	·		
	Large-signal differential	1	$R_I = 10 \text{ k}\Omega$	25°C	25	50		25	50		
A_{VD}	voltage amplification	$V_O = \pm 4 V$	11[= 10 102	Full range	25			25			V/m'
			$R_L = 1 \text{ m}\Omega$	25°C		300			300		
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		1012			1012		Ω
cį	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω
CMRR	Common-mode rejection	$V_{IC} = -5 \text{ to } 2.$		25°C	75	80		75	80		dB
OIVII II I	ratio	$V_O = 0 V$	$R_S = 50 \Omega$	Full range	75			75			ub
ksvr	Supply-voltage rejection	V _{DD±} = 2.2 \	/ to ±8 V,	25°C	80	95		80	95		dB
2VH	ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	V _{IC} = 0,	No load	Full range	80			80			uD
lDD	Supply current	VO = 0 V	No load	25°C		2.4	3		2.4	3	mA
טטי	Cuppiy Culterit	1.0-01	110 1000	Full range			3			3	111/7

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2272C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	ADAMETED	TEST CONDITION	0110	-+	7	TLC22720	;	Т	LC2272A	С	UNIT
P	ARAMETER	TEST CONDITION	ONS	TΑ [†]	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at	V+22V) 10 kO	25°C	2.3	3.6		2.3	3.6	,	
SR	unity gain	$V_O = \pm 2.3 \text{ V},$ F $C_L = 100 \text{ pF}$	RL = 10 kΩ,	Full range	1.7			1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50			50	,	->4//15
V _n	noise voltage	f = 1 kHz		25°C		9			9		nV/√Hz
	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
VNPP	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
l _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	V _O = ±2.3 V,	A _V = 1			0.0011%			0.0011%		
THD + N	distortion pulse	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		,
	duration	$R_L = 10 \text{ k}\Omega$	Ay = 100			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, F C _L = 100 pF	R _L = 10 kΩ,	25°C		2.25			2.25		MHz
ВОМ	Maximum output- swing bandwidth		v = 1, CL = 100 pF	25°C		0.54			0.54		MHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
'S	Octoring title	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	25 0		3.2			3.2		μδ
φm	Phase margin at unity gain	R _L = 10 kΩ, C	նլ = 100 pF	25°C		52°			52°		
-	Gain margin			25°C		10			10		dB

[†] Full range is 0°C to 70°C.

TLC2274C electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST COI	PAOITIONS	T _A †	T	_C2274	С	TL	C2274A	C	UNIT
		1231 001	**************************************	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		300	2500		300	950	μ۷
۱IO	Input onset voltage			Full range			3000			1500	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 70°C		2			2		μ V /°(
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$		25°C		0.002	-		0.002		μV/m
lio	Input offset current			25°C		0.5	400		0.5	100	pА
		4		Full range	ļ		100			100	
lв	Input bias current			25°C		. 1		ļ	1		pА
		ļ		Full range			100			100	<u> </u>
Vion	Common-mode input	$R_S = 50\Omega$,	V _{IO} ≤ 5 m V,	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		v
VICR	voltage range	ng = 50sz,	1 v O ≥ 5 m v,	Full range	0 to 3.5			0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99			4.99		
				25°C	4.85	4.93		4.85	4.93		
Vон	High-level output	IOH = -200 μA		Full range	4.85			4.85			٧
•	voltage			25°C	4.25	4.65		4.25	4.65		1
		IOH = -1 mA		Full range	4.25			4.25			1
		$V_{IC} \approx 2.5 \text{ V},$	I _{OL} = 50 μA	25°C		0.01			0.01		
		V _{IC} = 2.5 V,		25°C		0.09	0.15		0.09	0.15	
v_{OL}	Low-level output	IOL = 500 μA		Full range			0.15			0.15	V
	voltage			25°C		0.9	1.5		0.9	1.5	
		$V_{IC} \approx 2.5 \text{ V},$	$I_{OL} = 5 \text{ mA}$	Full range			1.5			1.5	
			la totat	25°C	15	35		15	35		
AVD	Large-signal differential	V _{IC} = 2.5 V, V _O = 1 V to 4 V	$R_L = 10 \text{ k}\Omega^{\ddagger}$	Full range	15			15			V/m
	voltage amplification	VO = 1 V 10 4 V	$R_L = 1 \text{ m}\Omega^{\ddagger}$	25°C		175			175		1
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		1012			1012		Ω
cį	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		рF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
CMRR	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$		25°C	70	75		70	75		dB
	rejection ratio	$V_0 = 2.5 V$,	$R_S = 50\Omega$	Full range	70			70			Lub
kov-	Supply-voltage rejection	V _{DD} = 4.4 V to		25°C	80	95		80	95		dB
ksvr	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			Lub
	Cumply aureant	V= -25 V	No lood	25°C		4.4	6		4.4	6	
סס	Supply current	$V_0 = 2.5 \text{ V},$	No load	Full range			6	I		6	mA

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡] Referenced to 2.5 V

TLC2274C operating characteristics at specified free-air temperature, V_{DD} = 5 V

P.4	DAMETER	TEST CONDITIONS		_ +	T	LC2274C	TI	UNIT		
PA	RAMETER	IESI CONDI	IIONS	T _A †	MIN	TYP MAX	MIN	TYP	MAX	UNII
	Slew rate at	V _O = 0.5 V to 2.5 V,		25°C	2.3	3.6	2.3	3.6		
SR	unity gain	$R_L = 10 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF [‡]	Full range	1.7		1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50		50		N// (T)
v _n	noise voltage	f = 1 kHz		25°C		9		9		nV/√Hz
V	Peak-to-peak	f = 0.1 to 1 Hz		25°C		1		1		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 to 10 Hz		25°C		1.4		1.4		μV
In	Equivalent input noise current			25°C		0.6		0.6		fA/√Hz
	Total harmonic	V _O = 0.5 V to 2.5 V,	A _V = 1			0.0013%		0.0013%		
THD + N	distortion plus	f = 20 kHz,	Ay = 10	25°C		0.004%		0.004%		
	noise	$R_L = 10 \text{ k}\Omega^{\ddagger}$	A _V = 100			0.03%		0.03%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF [‡]	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	25°C		2.18		2.18		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_{L} = 10 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		. 1		1		MHz
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		1.5		1.5		μs
'S	Setting time	$R_L = 10 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	25 0		2.6		2.6		μο
φm	Phase margin at unity gain	R _L = 10 kΩ [‡] ,	C _L = 100 pF [‡]	25°C		50°		50°	,	
	Gain margin]		25°C		10		10		dB

[†] Full range is 0°C to 70°C.

[‡]Referenced to 2.5 V

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TLC2274C electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CO	ONDITIONS	T. +	TI	C2274	С	TL	C2274A	C	UNIT
	PARAMETER	1231 00	JNDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
Via	Input offset voltage			25°C		300	2500		300	950	μV
VIO	input onset voltage			Full range			3000			1500	μν
ανιο	Temperature coefficient of input offset voltage			25°C to 70°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	V _O = 0,	25°C		0.002			0.002		μV/mo
,				25°C		0.5			0.5		
lio	Input offset current			Full range			100			100	pΑ
1	Janua kian ayyent			25°C		. 1			1		- ^
IB	Input bias current			Full range			100			100	рA
					-5	-5.3		-5	-5.3		
				25°C	to	to		to	to		ŀ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV		4	4.2		4	4.2		V
	voltage range	•		Full range	−5 to			−5 to			
				l an range	3.5			3.5			ļ
		I _O = -20 μA		25°C		4.99			4.99		
				25°C	4.85	4.93		4.85	4.93		1
V _{OM+}	Maximum positive peak output voltage	$I_{O} = -200 \mu$	Α	Full range	4.85			4.85			V
	voitage			25°C	4.25	4.65		4.25	4.65		1
		$I_O = -1 \text{ mA}$		Full range	4.25		-	4.25			
		V - 0	L- 50A	0500		-4.9			-4.9		
		V _{IC} = 0,	IO = 50 μA	25°C		9			9		1
				25°C	-4.8	-4.9		-4.8	-4.9]
V _{OM} -	Maximum negative peak output	V _{IC} = 0,	IO = 500 μA		5	1		5	1		l v
VOIVI-	voltage	110 -	.0 ,	Full range	-4.8			-4.8], •
				0500	5	4.4		5			
		V _{IC} = 0,	$I_O = -5 \text{ mA}$	25°C	-3.5	-4.1		-3.5	-4.1		ļ
			,	Full range	-3.5			-3.5			<u> </u>
	Large-signal differential voltage	l	$R_L = 10 \text{ k}\Omega$	25°C	25	50		25	50		
AVD	amplification	V _O = ±4 V	- ING	Full range	25			25			V/mV
	D'''	<u> </u>	$R_L = 1 M\Omega$	25°C		300 10 ¹²		<u> </u>	300 10 ¹²		<u> </u>
^r id	Differential input resistance	· · · · · · · · · · · · · · · · · · ·		25°C					1012		Ω
ri	Common-mode input resistance			25°C		1012			1012		1 12
ci	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8		ļ	8	 	pF
z _O	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω
CMRR	Common-mode rejection ratio	V _{IC} = -5 V		25°C	75	80		75	80		dB
		V _O = 0,	$R_S = 50 \Omega$	Full range	75			75			
ksvr	Supply-voltage rejection ratio	V _{DD±} = ±2.		25°C	80	95		80	95		dB
-SVR	(ΔV _{DD±} /ΔV _{IO})	V _{IC} = 0,	No load	Full range	80			80			
I _{DD}	Supply current	V _O = 0,	No load	25°C		4.8	6		4.8	6	mA
יטטי	очры оппень	10-0,	140 1080	Full range			6			6	

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2274C operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

-	ARAMETER	TEST CONDITIO	Me	- +	T	LC22740	;	TI	_C2274A	C (UNIT
r	AHAMEIEH	TEST CONDITIO	JNS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	V _O = ±2.3 V, R _I =	10 kΩ,	25°C	2.3	3.6		2.3	3.6		
SR	gain	C _L = 100 pF	10 KS2,	Full range	1.7			1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50			50		->1//II
V _n	noise voltage	f = 1 Hz		25°C		9			9		nV/√Hz
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μV
l _n	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	$V_{O} = \pm 2.3 \text{ V},$	A _V = 1			0.0011%			0.0011%		
THD + N	distortion plus	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		
	noise	$R_L = 10 \text{ k}\Omega$	$A_{V} = 100$			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, R _L = 100 pF	10 kΩ,	25°C		2.25			2.25		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V}, A_{V} = R_{L} = 10 \text{ k}\Omega, C_{L} = 0.00$	1, 100 pF	25°C		0.54			0.54		MHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
' 5		$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	23 0	3	3.2			3.2		μο
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L =	100 pF	25°C		52°			52°		
	Gain margin	1		25°C		10			10		dB

[†] Full range is 0°C to 70°C.

TLC2272I electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	PARAMETER	TEST COI	NOITIONS	T _A †	т	LC2272	1	TI	_C2272	AI	UNIT
	PANAMETEN	IESI COI	ADITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
VIO	Input offset voltage			25°C		300	2500		300	950	μV
VIO	Input onset voltage			Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, V _O = 0,	$V_{DD\pm}=\pm 2.5V$ $R_S = 50 \Omega$	25°C		0.002			0.002		μV/mc
lio	Input offset current			25°C		0.5			0.5		pА
10	input onset current			Full range			150			150	РΑ
I _{IB}	Input bias current			25°C		1			1		рA
'16				Full range			150			150	P/.
V	Common-mode input			25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		v
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	0 to 3.5			0 to 3.5			V
		l _{OH} = -20 μA		25°C		4.99			4.99		
	I Bala Jarrahan dan d	1 2004		25°C	4.85	4.93		4.85	4.93		
V_{OH}	High-level output voltage	I _{OH} = -200 μA	\	Full range	4.85			4.85			V
	vollage	I _{OH} = -1 mA		25°C	4.25	4.65		4.25	4.65		
		IOH = - I IIIA		Full range	4.25			4.25			
		$V_{IC} = 2.5 V$,	$I_{OL} = 50 \mu A$	25°C		0.01			0.01		
	Low-level output	V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
VOL	voltage	VIC = 2.5 V,	IOL = 300 μA	Full range			0.15			0.15	٧
	3	V _{IC} = 2.5 V,	IOL = 5 mA	25°C		0.9	1.5		0.9	1.5	
		VIC = 2.5 V,	10L = 3 111A	Full range			1.5			1.5	
	Large-signal differential	V _{IC} = 2.5 V,	$R_I = 10 \text{ k}\Omega^{\ddagger}$	25°C	15	35		15	35		
A_{VD}	voltage amplification	$V_0 = 1 \text{ V to 4 V}$	_	Full range	15			15			V/m\
			$R_L = 1 \text{ m}\Omega^{\ddagger}$	25°C		175			175		
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		1012			10 ¹²		Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
CMRR	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$		25°C	70	75		70	75		dB
	rejection ratio	$V_{O} = 2.5 \text{ V},$	$R_S = 50 \Omega$	Full range	70			70			
ksvr	Supply-voltage rejection	$V_{DD} = 4.4 \text{ V to}$		25°C	80	95		80	95		dB
-ovr	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			45
lDD	Supply current	V _O = 2.5 V,	No load	25°C		2.2	3		2.2	3	mA
יטט.	Cupply culton	10-2.5 4,	140 1000	Full range			3			3	'''^

[†] Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^{\circ}C$ extrapolated to $T_A = 25^{\circ}C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡] Referenced to 2.5 V

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TLC2272I operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

D.	ARAMETER	NO	- +		TLC22721		7	TLC2272AI		UNIT	
P	AHAMEIEH	TEST CONDITIO	NS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at	V- 05V+005V		25°C	2.3	3.6		2.3	3.6		
SR	unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$ $R_L = 10 \text{ k}\Omega^{\ddagger},$ C_L	= 100 pF‡	Full range	1.7			1.7			V/µs
v ·	Equivalent input	f = 10 Hz		25°C		50			50		nV√Hz
V _n	noise voltage	f = 1 kHz		25°C		9			9		ūΛ∧HZ
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
VNPP	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
I _n	Equivalent input noise current	·		25°C		0.6			0.6		fA√Hz
	Total harmonic	$V_{O} = 0.5 \text{ V to } 2.5 \text{ V}$	A _V = 1			0.0013%			0.0013%		
THD + N	distortion plus	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		
	noise	R _L = 10 kه	$A_{V} = 100$			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, R _L C _L = 100 pF [‡]	= 10 kΩ [‡] ,	25°C		2.18			2.18		MHz
Вом	Maximum output- swing bandwidth		= 1, = 100 pF‡	25°C		1			1		MHz
	Cattling times	A _V = -1, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		1.5			1.5		
ts	Settling time	$R_L = 10 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	25°C		2.6			2.6		μs
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega^{\ddagger}$, C_L	= 100 pF‡	25°C		50°			50°		
	Gain margin			25°C		10			10		dB

[†] Full range is - 40°C to 85°C.

[‡] Referenced to 2.5 V

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TLC2272I electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise

	PARAMETER	TEST CON	DITIONS	TAT	T	LC2272		TI	_C2272A	<u> </u>	UNIT
	PANAMETEN	TEST CON	DITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		300	2500		300	950	μV
10				Full range			3000			1500	μν
αΛΙΟ	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ RS = 50 Ω	$V_O = 0$,	25°C		0.002			0.002		μV/mo
lio	Input offset current			25°C		0.5			0.5		pА
-10		1		Full range			150			150	μ
lв	Input bias current			25°C		1			1		рA
-10				Full range			150			150	F
	Common-mode input			25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	-5 to 3.5			-5 to 3.5			V
		I _O = -20 μA		25°C		4.99			4.99		
				25°C	4.85	4.93		4.85	4.93		
V _{OM+}	Maximum positive peak output voltage	I _O = -200 μA		Full range	4.85			4.85			V
	output voltage			25°C	4.25	4.65		4.25	4.65		
		I _O = -1 mA		Full range	4.25			4.25			
		V _{IC} = 0,	I _O = 50 μA	25°C		-4.99			-4.99		
	Manadan com a materia	V: 0 = 0	In 500 A	25°C	-4.85	-4.91		-4.85	-4.91		
V _{OM} -	Maximum negative peak output voltage	$V_{IC} = 0$,	$I_O = 500 \mu\text{A}$	Full range	-4.85			-4.85			٧
	pour output voilago	V _{IC} = 0,	IO = 5 mA	25°C	-3.5	-4.1		-3.5	-4.1		
		VIC = 0,	10 = 3 IIIA	Full range	-3.5			-3.5			
	Large-signal		R _L = 10 kΩ	25°C	25	50		25	50		
A_{VD}	differential voltage	V _O = ±4 V		Full range	25			25			V/mV
	amplification ————————————————————————————————————		$R_L = 1 \text{ m}\Omega$	25°C		300			300		
^r id	Differential input resistance			25°C		1012			10 ¹²		Ω
rį	Common-mode input resistance			25°C		1012			10 ¹²		Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω
CMRR	Common-mode	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$		25°C	75	80		75	80		dB
JIVINN	rejection ratio	$V_0 = 2.5 \text{ V},$	$R_S = 50 \Omega$	Full range	75			75			ub
ksvr	Supply-voltage rejection ratio	V _{DD} = 4.4 V to	16 V, No load	25°C	80	95		80	95		dB
	(ΔV _{DD±} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	INU IUAU	Full range	·80			80			
IDD	Supply current	V _O = 2.5 V,	No load	25°C		2.4	3		2.4	3	mA
<i></i>	CE-2			Full range			3			3	

[†] Full range is - 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2272I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	ADAMETED	TEST CONDITION	ONO	- +		TLC2272I			TLC2272A		UNIT
P	ARAMETER	TEST CONDITION	ONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at	V _O = ±2.3 V, F	$R_{\rm I} = 10 \rm k\Omega$	25°C	2.3	3.6		2.3	3.6		
SR	unity gain	C _L = 100 pF		Full range	1.7			1.7			V/μs
V _n	Equivalent input	f = 10 Hz		25°C		50			50		nV√Hz
vn	noise voltage	f = 1 kHz		25°C		9			9		nvvHz
V _{NPP}	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
MPP	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
l _n	Equivalent input noise current			25°C		0.6			0.6		fA√Hz
	Total harmonic	V _O = ±2.3 V	A _V = 1			0.0011%			0.0011%		
THD + N	distortion plus	$R_L = 10 \text{ k}\Omega$	A _V = 10	25°C		0.004%			0.004%		
	noise	f = 20 kHz	A _V = 100			0.03%			0.03%		
	Gain-bandwidth product	f =10 kHz, F C _L = 100 pF	R _L = 10 kΩ,	25°C		2.25			2.25		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ A $R_{L} = 10 \text{ k}\Omega,$ C	v = 1, L = 100 pF	25°C		0.54			0.54		MHz
t _s	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
' 5	Octaining time	R_L = 10 kΩ, C_L = 100 pF	To 0.01%	200		3.2			3.2		μο
φm	Phase margin at unity gain	R _L = 10 kΩ, C	L = 100 pF	25°C		52°			52°		
	Gain margin	1		25°C		10			10		dB

[†] Full range is -40°C to 85°C.

TLC2274I electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS		T	LC2274	H	TI	_C2274	Al	UNIT
	FANAMETEN	TEST CON	DITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		300	2500		300	950	μV
VIO				Full range			3000			1500	μν
αΛΙΟ	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, RS = 50 Ω	25°C		0.002			0.002		μV/mo
L -	l			25°C		0.5			0.5		
ΙΟ	Input offset current			Full range			150			150	pА
1	Input his a surrent			25°C		1			1		1
IB	Input bias current			Full range			150			150	рA
	Common-mode input			25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	Full range	0 to 3.5	7.2		0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99			4.99		
				25°C	4.85	4.93		4.85	4.93		
Vон	High-level output voltage	ΙΟΗ = -200 μΑ		Full range	4.85			4.85			V
		1 1 1		25°C	4.25	4.65		4.25	4.65		
		IOH = −1 mA		Full range	4.25			4.25			
	AAAAAA AAAAAA AAAAAAAAAAAAAAAAAAAAAAAA	V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
		V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15		0.09	0.15	
V_{OL}	Low-level output voltage	V ₁ C = 2.5 V,	-10[= 300 μΑ	Full range			0.15			0.15	٧
		V _{IC} = 2.5 V,	I _{OL} = 5 mA	25°C		0.9	1.5		0.9	1.5	
		VIC = 2.5 V,	IOL = 5 IIIA	Full range			1.5			1.5	
	1 1 1 1	v 05.v	R _L = 10 kΩ [‡]	25°C	15	35		15	35		
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $V_{O} = 1 \text{ V to 4 V}$	HL = 10 K32+	Full range	15			15			V/mV
			R _L = 1 Mه	25°C		175			175		
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		10 ¹²			1012		Ω
cį	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		рF
z _O	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
OMBE	Common-mode rejection	V _{IC} = 0 to 2.7 V,		25°C	70	75		70	75		
CMRR	ratio	V _O = 2.5 V,	$R_S = 50 \Omega$	Full range	70			70			dB
le=.	Supply-voltage rejection	V _{DD} = 4.4 V to 1	6 V,	25°C	80	95		80	95		*iD
ksvr	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			dB
I	Cumply suggest	V- 05V	No look	25°C		4.4	6		4.4	6	A
DD	Supply current	$V_{O} = 2.5 \text{ V},$	No load	Full range			6			6	mA

[†] Full range is - 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

TLC2274I operating characteristics at specified free-air temperature, V_{DD} = 5 V

	DADAMETED	TECT CONDITION	ONG		•	TLC22741		Т	LC2274A	J	UNIT
'	PARAMETER	TEST CONDITION	ONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Claw rate at unity	Va OFV to OFV		25°C	2.3	3.6		2.3	3.6		
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$ $R_L = 10 \text{ k}\Omega^{\ddagger}, C_L =$	100 pF‡	Full range	1.7			1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50			50		->4/17
v _n	noise voltage	f = 1 kHz		25°C		9			9		nV/√Hz
	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μV
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
		V _O = 0.5 V to 2.5 V,	A _V = 1			0.0013%		0.0013%			
THD + N	Total harmonic distortion plus noise	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		
	- allocation place molec	$R_L = 10 \text{ k}\Omega^{\ddagger}$	$A_{V} = 100$			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, R _L = C _L = 100 pF [‡]	10 kΩ [‡] ,	25°C		2.18			2.18		MHz
вом	Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V}, A_{V} = R_{L} = 10 \text{ k}\Omega^{\ddagger}, C_{L} = 0 \text{ K}\Omega^{4}$	1, 100 pF‡	25°C		1			1		MHz
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		1.5			1.5		μs
'S	Cetting time	$R_L = 10 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	20 0		2.6			2.6		μο
φm	Phase margin at unity gain	R _L = 10 kΩ [‡] , C _L =	100 pF‡	25°C		50°			50°		
	Gain margin] -	•	25°C		10			10		dB

[†] Full range is - 40°C to 85°C.

[‡] Referenced to 2.5 V

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TLC2274l electrical characteristics at specified free-air temperature, $V_{DD\pm}=\pm5$ V (unless otherwise noted)

	PARAMETER	TEST C	ONDITIONS	T. 1	T	LC2274	1	T	_C2274A	AI .	UNIT
	PARAMETER	1231 0		T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			25°C		300	2500		300	950	μV
VIO	Input onset voltage			Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 85°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	$V_O = 0$,	25°C		0.002			0.002		μV/mo
1.0	Input offset surrent]		25°C		0.5			0.5		ъ^
10	Input offset current			Full range			150			150	pΑ
l.m.	Input bias current			25°C		1			1		рA
lB l	input bias current			Full range			150			150	pΑ
	Common-mode input			25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		
VICR	voltage range	Hg = 50Ω ,	$ V_{IO} \le 5 \text{ mV}$	Full range	-5 to 3.5			−5 to 3.5			V
		IO = -20 μA	\	25°C		4.99			4.99		
				25°C	4.85	4.93		4.85	4.93		
V _{OM+}	Maximum positive peak output voltage	IO = -200 μ	А	Full range	4.85			4.85	<u> </u>		V
	output voltage			25°C	4.25	4.65		4.25	4.65		i
		IO = -1 mA		Full range	4.25			4.25			
		V _{IC} = 0,	I _O = 50 μA	25°C		-4.99			-4.99		
		V - 0	I- 500 · A	25°C	-4.85	-4.91		-4.85	-4.91		
V _{OM} -	Maximum negative peak output voltage	V _{IC} = 0,	$I_O = 500 \mu\text{A}$	Full range	-4.85			-4.85			٧
	output voltage	V 0		25°C	-3.5	-4.1		-3.5	-4.1		
		V _{IC} = 0,	$I_O = 5 \text{ mA}$	Full range	-3.5			-3.5			
	1		D. 10160	25°C	25	50		25	50		
AVD	Large-signal differential voltage amplification	V _O = ±4 V	$R_L = 10 \text{ k}\Omega$	Full range	25			25			V/m'
			$R_L = 1 M\Omega$	25°C		300			300		
^r id	Differential input resistance			25°C	1	10 ¹²			1012		Ω
rį	Common-mode input resistance			25°C		10 ¹²			10 ¹²		Ω
c _i	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω
CMRR	Common-mode rejection	V _{IC} = -5 to		25°C	75	80		75	80		dB
	ratio	$V_O = 0$,	$R_S = 50 \Omega$	Full range	75			75			uв
kovo	Supply-voltage rejection		2 V to ±8 V,	25°C	80	95		80	95		dB
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	V _{IC} = 0,	No load	Full range	80			80			uв
Inn	Supply current	V _O = 0,	No load	25°C		4.8	6		4.8	6	mA
IDD	Supply current	VO = 0,	NO IOAU	Full range			6			6	l IIIA

†Full range is - 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2274I operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	ARAMETER	TEST CONDITION	ONC.	_ +		TLC22741		Т	LC2274A	J	UNIT
Ρ.	AKAWEICK	TEST CONDITION	JNS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Slew rate at unity	V _O = ±2.3 V, R _I	L = 10 kΩ,	25°C	2.3	3.6		2.3	3.6		
SR	gain	C _L = 100 pF	L = 10 Ks2,	Full range	1.7			1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50			50		nV/√Hz
v _n	noise voltage	f = 1 kHz		25°C		9			9		nv/√HZ
	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	$V_{O} = \pm 2.3 \text{ V},$	A _V = 1			0.0011%			0.0011%		
THD + N	distortion plus	$R_L = 10 \text{ k}\Omega$,	A _V = 10	25°C		0.004%			0.004%		
	noise	f = 20 kHz	$A_V = 100$			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, R C _L = 100 pF	L = 10 kΩ,	25°C		2.25			2.25		MHz
Вом	Maximum output- swing bandwidth	1 0(11)	v = 1, L = 100 pF	25°C		0.54			0.54		MHz
+	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
t _S	Ceaning time	R_L = 10 kΩ, C_L = 100 pF	To 0.01%	25 0		3.2			3.2		μο
φm	Phase margin at unity gain	R _L = 10 kΩ, C	L = 100 pF	25°C		52°			52°		
	Gain margin	1		25°C		10			10		dB

[†] Full range is -40°C to 85°C.

TLC2272M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CO.	NDITIONS	TƠ	TI	C2272	М	TL	C2272A	M	UNIT
	PANAMETEN	1231 00		'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		300	2500		300	950	μV
*10				Full range			3000			1500	μ.
ανιο	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, V _O = 0,	$V_{DD\pm} = \pm 2.5 \text{ V},$ R _S = 50 Ω	25°C		0.002			0.00		μV/mo
lio	Input offset current	1		25°C		0.5			0.5		рA
10	Input onset current	ì		Full range			500			500	PΛ
lun	Input bias current]		25°C		1			1		рA
^I IB	input bias current			Full range			500			500	PA
VICR	Common-mode input	R _S = 50 Ω,	V _{IO} ≤5 mV	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V
VICH	voltage range		· · · · · · · · · · · · · · · · · · ·	Full range	0 to 3.5			0 to 3.5			v
		I _{OH} = -20 μA		25°C		4.99			4.99		
	I Pate I accel a decid	200		25°C	4.85	4.93		4.85	4.93		
V_{OH}	High-level output voltage	I _{OH} = -200 μA		Full range	4.85			4.85			٧
	vollage	4 - 4		25°C	4.25	4.65		4.25	4.65		
	•	I _{OH} = -1 mA		Full range	4.25			4.25			
		V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01			0.01		
				25°C		0.09	0.15		0.09	0.15	
V_{OL}	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA	Full range			0.15			0.15	V.
	voltage			25°C		0.9	1.5		0.9	1.5	
		V _{IC} = 2.5 V,	IOL = 5 mA	Full range			1.5			1.5	
	Large-signal		I	25°C	10	35		10	35		
AVD	differential voltage	V _{IC} = 2.5 V, V _O = 1 V to 4 V	$R_L = 10 \text{ k}\Omega^{\ddagger}$	Full range	10			10			V/mV
••	amplification	VO = 1 V 10 4 V	$R_L = 1 \text{ m}\Omega^{\ddagger}$	25°C		175			175		
^r id	Differential input resistance		L	25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		1012			1012		Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $V_{O} = 2.5 \text{ V},$	R _S = 50 Ω	25°C Full range	70 70	75		70 70	75		dB
1.	Supply-voltage rejection	$V_{DD} = 4.4 \text{ V to}$	16 V,	25°C	80	95		80	95		
ksvr	ratio (ΔV _{DD /} ΔV _{IO})	$V_{IC} = V_{DD}/2$,	No load	Full range	80			80			dB
	• • •	.,		25°C		2.2	3		2.2	3	
םס ^ו	Supply current	$V_0 = 2.5 V$,	No load	Full range			3			3	mA

[†] Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡]Referenced to 2.5 V

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TLC2272M operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

D.	ARAMETER	TEST CONDIT	IONE	T _A †		TLC2272N	ī	Т	LC2272A	М	UNIT
F#	ANAMETEN	TEST CONDIT	10113	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at	V _O = 0.5 V to 2.5 V,		25°C	2.3	3.6		2.3	3.6		
SR	unity gain		C _L = 100 pF‡	Full range	1.7			1.7			V/μs
V	Equivalent input	f = 10 Hz		25°C		50			50		nV/√Hz
V _n	noise voltage	f = 1 kHz		25°C		9			9		nv/√Hz
V	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
VNPP	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	V _O = 0.5 V to 2.5 V,	A _V = 1			0.0013%			0.0013%		
THD + N	distortion plus	f = 20 kHz,	A _V = 10	25°C		0.004%			0.004%		
	noise	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	$A_{V} = 100$			0.03%			0.03%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF‡	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	25°C		2.18			2.18		MHz
Вом	Maximum output- swing bandwidth		A _V = 1, C _L = 100 pF‡	25°C		1			1		MHz
ts	Settling time	Ay = -1, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		1.5			1.5		μs
ι 'S	Columny unio	$R_L = 10 \text{ k}\Omega^{\ddagger}$, $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%	20 0		2.6			2.6		μο
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	CL = 100 pF‡	25°C		50°			50°		
	Gain margin			25°C		10			10		dB

[†] Full range is – 55°C to 125°C. ‡ Referenced to 2.5 V

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TLC2272M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	PARAMETER	TEST CO	NDITIONS	_{T.} +	T	LC2272	Λ	TL	C2272A	М	UNIT
	PARAMETER	IESI CO	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V	Input offeet veltere			25°C		300	2500		300	950	μV
V _{IO}	Input offset voltage			Full range			3000			1500	μν
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0,$ R _S = 50 Ω	V _O = 0,	25°C	-	0.002			0.002		μV/m
lo lo	Input offset current			25°C		0.5			0.5		pА
				Full range			500			500	
lв	Input bias current			25°C		11			1		pА
-10				Full range			500			500	F: -
M	Common-mode input	D- 500	N 1 <5 1	25°C	-5 to 4	-5.3 to 4.2		-5 to 4	-5.3 to 4.2		·
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV	Full range	-5 to 3.5			-5 to 3.5			V
		$I_{O} = -20 \mu A$		25°C		4.99			4.99		
		l = 000 ·· A		25°C	4.85	4.93		4.85	4.93		
V _{OM+}	Maximum positive peak output voltage	IO = -200 μA		Full range	4.85			4.85			٧
	output voltage	IO = -1 mA		25°C	4.25	4.65		4.25	4.65		
		IO = - I IIIA		Full range	4.25			4.25			
		V _{IC} = 0,	$I_O = 50 \mu\text{A}$	25°C		-4.99			-4.99		
	Massinas na nativa na als	V _{IC} = 0,	I _O = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91		
v⁄oм−	Maximum negative peak output voltage	VIC = 0,	10 = 500 μΑ	Full range	-4.85			-4.85			٧
	ou.put ronlago	V _{IC} = 0,	I _O = 5 mA	25°C	-3.5	-4.1		-3.5	-4.1		
		VIC = 0,	10 = 5111A	Full range	-3.5			-3.5			
	Lorge signal differential		R _L = 10 kΩ	25°C	20	50	-	20	50		
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 4 V$	H_ = 10 KS2	Full range	20			20			V/m\
			$R_L = 1 \text{ m}\Omega$	25°C		300			300		
^r id	Differential input resistance			25°C		1012			1012		Ω
ri	Common-mode input resistance			25°C		1012			1012		΄ Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω
CMRR	Common-mode rejection	V _{IC} = 0 to 2.7		25°C	75	80		75	80		dB
OWINH	ratio	$V_0 = 2.5 \text{ V},$	$R_S = 50 \Omega$	Full range	75			75			Lub
kov ro	Supply-voltage rejection	V _{DD} = 4.4 V		25°C	80	95		80	95		dB
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{IC} = 0$,	No load	Full range	80			80			ub
lon	Supply current	V _O = 2.5 V,	No load	25°C		2.4	3		2.4	3	mA
dם ^ו	Supply current	VO = 2.5 V,	NO IDAU	Full range			3			3	'''A

† Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2272M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	DAMETED	TECT CONDITI	ONG	- +	TLC2272M TLC2272AM			UNIT			
PA	RAMETER	TEST CONDITI	ONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Slew rate at	V _O = ±2.3 V,	$R_1 = 10 \text{ k}\Omega$	25°C	2.3	3.6		2.3	3.6		
SR	unity gain	C _L = 100 pF		Full range	1.7			1.7	`		V/μs
Vn	Equivalent input	f = 10 Hz		25°C		50			50		nV/√Hz
٧n	noise voltage	f = 1 kHz		25°C		9					ΠV/∀HZ
V _{NPP}	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		1			1		μV
VNPP	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	V _O = ±2.3 V	Ay = 1			0.0011%			0.0011%		
THD + N	distortion plus	$R_L = 10 \text{ k}\Omega$	A _V = 10	25°C		0.004%			0.004%		
	noise	f = 20 kHz	Ay = 100			0.03%			0.03%		
	Gain-bandwidth product	f =10 kHz, C _L = 100 pF	$R_L = 10 \text{ k}\Omega$,	25°C		2.25			2.25		MHz
ВОМ	Maximum output-swing bandwidth	V _O (PP) = 4.6 V, R _L = 10 kΩ,	A _V = 1, C _L = 100 pF	25°C		0.54			0.54		MHz
ts	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
°5	Cotting time	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	25 0		3.2			3.2		μσ
φm	Phase margin at unity gain	R _L = 10 kΩ,	C _L = 100 pF	25°C		52°			52°		
	Gain margin			25°C		10			10		dB

[†] Full range is -55°C to 125°C.

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TLC2274M electrical characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$ (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	τ _Δ †	T	_C2274	M	TL	C2274A	M	UNIT
	FANAMETEN	TEST CON	DITIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNII
\/	Innuit officet veltors			25°C		300	2500		300	950	
VIO	Input offset voltage	ĺ		Full range			3000			1500	μV
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, R _S = 50 Ω	25°C		0.002			0.002		μV/mc
l.o	Input offset current			25°C		0.5			0.5		рA
10	input onset current			Full range			500			500	PΛ
lв	Input bias current	Ì		25°C		1			1		рA
'ID				Full range			500			500	
V	Common-mode input	D. 500	N - 1 - 5 - 14	25°C	0 to 4	-0.3 to 4.2		0 to 4	-0.3 to 4.2		V
VICR	voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	Full range	0 to 3.5			0 to 3.5			V
		I _{OH} = -20 μA		25°C		4.99			4.99		
	18.6.1			25°C	4.85	4.93		4.85	4.93		
Vон	High-level output voltage	IOH = -200 μA		Full range	4.85			4.85			٧
	voltago	I _{OH} = -1 mA		25°C	4.25	4.65		4.25	4.65		
		IOH ~ - I IIIA		Full range	4.25			4.25			
		$V_{IC} = 2.5 V,$	IOL = 50 μA	25°C		0.01			0.01		
	Low-level output	V _{IC} = 2.5 V,		25°C		0.09	0.15		0.09	0.15	
v_{OL}	voltage	I _{OL} = 500 μA		Full range	ļ		0.15			0.15	٧
		V _{IC} = 2.5 V,	IOL = 5 mA	25°C		0.9	1.5		0.9	1.5	
				Full range			1.5			1.5	
_	Large-signal differential	V _{IC} = 2.5 V,	R _L = 10 kه	25°C	10	35		10	35		
AVD	voltage amplification	V _O = 1 V to 4 V		Full range	10			10			V/mV
	5		$R_L = 1 M\Omega^{\ddagger}$	25°C		175			175		
^r id	Differential input resistance			25°C		1012			1012		Ω
rį	Common-mode input resistance			25°C		1012			1012		Ω
ci	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140			140		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $V_{O} = 2.5 \text{ V},$	R _S = 50 Ω	25°C Full range	70 70	75		70 70	75		dB
	Supply-voltage rejection	V _{DD} = 4.4 V to 1		25°C	80	95		80	95		
ksvr	ratio (ΔV _{DD} /ΔV _{IO})	$V_{IC} = V_{DD}/2$	No load	Full range	80			80			dB
				25°C	 	4.4	6		4.4	6	
IDD	Supply current	$V_{O} = 2.5 V$,	No load	Full range	l		6			6	mA

Full range is - 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



[‡] Referenced to 2.5 V

TLC2274M operating characteristics at specified free-air temperature, $V_{DD} = 5 \text{ V}$

PARAMETER		TEOT CONDITI	ONO		T	LC2274N	A	TI	_C2274A	М		
PA	ARAMETER	TEST CONDITIONS		TAT	MIN	TYP	MAX	MIN	MIN TYP MAX		UNIT	
	Slew rate at unity	V _O = 0.5 V to 2.5 V,		25°C	2.3	3.6		2.3	3.6			
SR	gain		L = 100 pF‡	Full range	1.7			1.7			V/μs	
V	Equivalent input	f = 10 Hz		25°C		50			50		>4//11	
V _n	noise voltage	f = 1 kHz		25°C		. 9			9		nV/√Hz	
Veren	Peak-to-peak equivalent input	f = 0.1 Hz to 1 Hz		25°C		1			1		μV	
V _{N(PP)}	noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4			1.4		μν	
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz	
	Total harmonic	$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1			0.0013%			0.0013%			
THD + N	distortion plus	$f = 20 \text{ kHz}, \qquad A_V = 10$	A _V = 10	25°C		0.004%		0.004%				
	noise	$R_L = 10 \text{ k}\Omega^{\ddagger}$	A _V = 100			0.03%			0.03%			
	Gain-bandwidth product	f = 10 kHz, R C _L = 100 pF [‡]	lL = 10 kΩ [‡] ,	25°C		2.18			2.18		MHz	
ВОМ	Maximum output- swing bandwidth		v = 1, L = 100 pF‡	25°C		1			1		MHz	
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	.5 V, To 0.1%			1.5			1.5		μs	
's	Setting time	$IR_{I} = 10 \text{ kO} + 1$	To 0.01%	250		2.6			2.6		μs	
φm	Phase margin at unity gain	R _L = 10 kΩ [‡] , C	L = 100 pF‡	25°C		50°			50°			
	Gain margin	-	- '	25°C		10			10		dB	

[†] Full range is – 55°C to 125°C.

[‡] Referenced to 2.5 V

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TLC2274M electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETER	TEST OF	NIDITIONS		T	LC2274	И	TL	C2274A	М	LIMIT	
	PARAMETER	IEST	ONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
Via	Input offset voltage			25°C		300	2500		300	950	μV	
VIO	input onset voltage			Full range			3000			1500	μν	
αVIO	Temperature coefficient of input offset voltage			25°C to 125°C		2			2		μV/°C	
	Input offset voltage long- term drift (see Note 4)	V _{IC} = 0, R _S = 50 Ω	V _O = 0,	25°C		0.002			0.002		μV/mo	
	I	1		25°C		0.5			0.5		- 4	
ΙO	Input offset current			Full range			500			500	pΑ	
1	Innut bigg gurrant			25°C		1			1		^	
IB	Input bias current			Full range			500			500	pΑ	
Vion	Common-mode input	Be - 50.0	1\(\text{in } \l < \in \mathred{m}\\)	25°C	-5 to 4	-5.3 to 4.2		–5 to 4	-5.3 to 4.2		V	
VICR	voltage range	HS = 50 12,	V _{IO} ≤ 5 mV	Full range	-5 to 3.5			-5 to 3.5			V	
		$I_{O} = -20 \mu$ A		25°C		4.99			4.99			
V _{OM+}		I= 200 ::	^	25°C	4.85	4.93		4.85	4.93			
	Maximum positive peak output voltage	I _O = -200 μ	A	Full range	4.85	_		4.85			٧	
	output voltago	IO = -1 mA		25°C	4.25	4.65		4.25	4.65			
		10 = - 1 IIIA		Full range	4.25			4.25				
		$V_{IC} = 0$,	$I_O = 50 \mu\text{A}$	25°C		-4.99			-4.99			
	Mandan and a street and a	V _{IC} = 0,	I _O = 500 μA	25°C	-4.85	-4.91		-4.85	-4.91			
VOM-	Maximum negative peak output voltage	V ₁ C = 0,	, ΙΟ = 500 μΑ	Full range	-4.85			-4.85			V	
	- - -	V _{IC} = 0,	IO = 5 mA	25°C	-3.5	-4.1		-3.5	-4.1			
		1,0 = 0,	10 = 2 IIIA	Full range	-3.5			-3.5				
	Large signal differential		R _L = 10 kΩ	25°C	20	50		20	50			
AVD	Large-signal differential voltage amplification	$V_O = \pm 4 V$	112 - 10 142	Full range	20			20			V/mV	
	• •		$R_L = 1 M\Omega$	25°C		300			300			
^r id	Differential input resistance			25°C		1012			1012		Ω	
rį	Common-mode input resistance			25°C		10 ¹²			1012		Ω	
Cį	Common-mode input capacitance	f = 10 kHz,	N package	25°C		8			8		pF	
z _O	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		130			130		Ω	
CMRR	Common-mode rejection	$V_{IC} = -5 V \text{ to } 2.7 V$	25°C	75	80		75	80		dР		
CIVINA	ratio	V _O = 0,	$R_S = 50 \Omega$	Full range	75			75			dB	
kove	Supply-voltage rejection	V _{DD±} = ± 2	± = ± 2.2 V to ±8 V,	25°C	80	95		80	95		dB	
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	V _{IC} = 0,	No load	Full range	80			80			dB	
Inc	Supply current	V _O = 0,	No load	25°C		4.8	6		4.8	6	mA	
IDD	очры очный	10 = 0,	140 loau	Full range			6			6	111/5	

[†] Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2274M operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

PARAMETER		TEST CONDITION	ONG		T	LC2274N	1	TLC2274AM			UNIT
"	AHAMETER	TEST CONDITION	ONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
	Class rate at insits	V- 100V D	10 10	25°C	2.3	3.6		2.3	3.6		
SR	Slew rate at unity gain	$V_O = \pm 2.3 \text{ V}, \qquad R_L$ $C_L = 100 \text{ pF}$	= 10 kΩ,	Full range	1.7			1.7			V/μs
V _n	Equivalent input	f = 10 Hz		25°C		50			50		nV/√Hz
٧n	noise voltage	f = 1 kHz		25°C		9			9		NV/VHZ
V	Peak-to-peak	f = 0.1 Hz to 1 Hz		25°C		1			1		
V _{N(PP)}	equivalent input noise voltage	f = 0.1 Hz to 10 Hz		25°C		1.4		1.4			μV ,
In	Equivalent input noise current			25°C		0.6			0.6		fA/√Hz
	Total harmonic	V _O = ±2.3 V,	A _V = 1			0.0011%			0.0011%		
THD + N	distortion plus	$R_L = 10 \text{ k}\Omega$,	A _V = 10	25°C		0.004%			0.004%		•
	noise	f = 20 kHz	A _V = 100			0.03%			0.03%		
	Gain-bandwidth product	f = 10 kHz, R _L C _L = 100 pF	= 10 kΩ,	25°C		2.25			2.25		MHz
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V}, \text{AV}$ $R_L = 10 \text{ k}\Omega, C_L$	= 1, = 100 pF	25°C		0.54			0.54		MHz
	Settling time	$A_V = -1$, Step = -2.3 V to 2.3 V,	To 0.1%	25°C		1.5			1.5		μs
ts	Cottoning time	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	To 0.01%	25 0		3.2			3.2		μο
φm	Phase margin at unit gain	R _L = 10 kΩ, C _L	= 100 pF	25°C		52°			52°		
	Gain margin			25°C		10			10		dB

[†] Full range is -55°C to 125°C.

TLC2272Y electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TF07 001	TEST CONDITIONS			TLC2274Y			
	PARAMETER	TEST CONL				MAX	UNIT		
V _{IO}	Input offset voltage				300	2500	μV		
lio	Input offset current	V _{IC} = 0, V _O = 0,	$V_{DD\pm} = \pm 2.5 \text{ V},$ R _S = 50 Ω		0.5	100	pА		
lв	Input bias current	VO = 0,	115 = 30 32		1	100	pА		
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω		0 to 4	-0.3 to 4.2		٧		
		V _{IO} ≤5 mV			4.99				
Vон	High-level output voltage	I _{OH} = -20 μA	I _{OH} = -20 μA				٧		
		I _{OH} = -200 μA		4.25	4.65				
	*	I _{OL} = -1 mA			0.01				
VOL	Low-level output voltage	$V_{IC} = 2.5 V$	I _{OL} = 50 μA		0.09	0.15	V,		
		$V_{IC} = 2.5 V$,	I _{OL} = 500 μA		0.9	1.5			
Δ		V _{IC} = 2.5 V,	R _L = 10 kΩ [†]	15	35	\//r	\//\/		
AVD	Large-signal differential voltage amplification	IOL = 5 mA	$R_L = 1 M\Omega^{\dagger}$		175		V/mV		
r _{id}	Differential input resistance	V _O = 1 V to 4 V			1012		Ω		
rį	Common-mode input resistance				1012		Ω		
Cį	Common-mode input capacitance	f = 10 kHz			8		pF		
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10		140		Ω		
CMRR	Common-mode rejection ratio	$V_{IC} = 0 \text{ to } 2.7 \text{ V},$ $R_S = 50 \Omega$	V _O = 2.5 V,	70	75		dB		
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, No load	$V_{IC} = V_{DD}/2$,	80	95		dB		
lDD	Supply current	$V_0 = 2.5 \text{ V},$	No load		4.4	6	mA		

לוטי † Referenced to 2.5 V

TLC2272Y electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS			TLC2272Y			
	PARAMETER				MIN	TYP	MAX	UNIT
VIO	Input offset voltage					300	2500	μV
liO	Input offset current	V _{IC} = 0, V _O = 0,	$V_{DD\pm} = \pm 2.5 \text{ V}$ R _S = 50 Ω	′ ,		0.5	100	pА
lв	Input bias current] *0 = 0,	115 - 50 12			1	100	рA
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤5 mV		0 to 4	-0.3 to 4.2		٧
		I _{OH} = -20 μA				4.99		
Vон	High-level output voltage	I _{OH} = -200 μA			4.85	4.93		V
		I _{OH} = -1 mA			4.25	4.65	,	
		V _{IC} = 2.5 V,	I _{OL} = 50 μA			0.01		
VOL	Low-level output voltage	$V_{IC} = 2.5 V$,	I _{OL} = 500 μA			0.09	0.15	٧
		$V_{IC} = 2.5 V$,	$I_{OL} = 5 \text{ mA}$			0.9	1.5	
AVD	Large-signal differential voltage	V _{IC} = 2.5 V,	$R_L = 10 \text{ k}\Omega^{\dagger}$		15	35		V/mV
~VD	amplification	$V_O = 1 \text{ V to 4 V}$	$R_L = 1 M\Omega^{\dagger}$			175		V/111V
^r id	Differential input resistance					1012		Ω
rį	Common-mode input resistance					1012		Ω
cį	Common-mode input capacitance	f = 10 kHz				8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10			140		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	$R_S = 50 \Omega$	70	75		dB
ksvr	Supply-voltage rejection ratio $(\Delta V_{DD}/\Delta V_{IO})$	V _{DD} = 4.4 V to 16 V,	V _{IC} = V _{DD} /2,	No load	80	95		dB
IDD	Supply current	V _O = 2.5 V,	No load			2.2	3	mA

[†] Referenced to 2.5 V

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TLC2272Y electrical characteristics at $V_{DD\pm}$ = ±5 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CO	TEST CONDITIONS			TLC2272Y		
	FARAMETER	1231 00				TYP	MAX	UNIT
۷ _{IO}	Input offset voltage					300	2500	μV
lo lo	Input offset current	V _{IC} = 0,	$R_S = 50 \Omega$	V _O = 0		0.5	100	pΑ
lВ	Input bias current					1	100	рA
VICR	Common-mode input voltage range	$R_S = 50 \Omega$	V _{IO} ≤5 m	v	-5 to 4	-5.3 to 4.2		V
		I _O = -20 μA				4.99		
V _{OM+}	Maximum positive peak output voltage	$I_{O} = -200 \mu\text{A}$			4.85	4.93		V
		IO = -1 mA			4.25	4.65		
		V _{IC} = 0,	I _{OL} = 50 μA			-4.99		
VOM-	Maximum negative peak output voltage	V _{IC} = 0,	ΙΟL = 500 μ	A	-4.85	-4.91		٧
		V _{IC} = 0,	IOL = 5 mA		-3.5	-4.1		
AVD	Large-signal differential voltage	V _O = ±4 V	$R_L = 10 \text{ k}\Omega$		25	50		V/mV
, VD	amplification	VO = ± + V	$R_L = 1 M\Omega$	ļ	300		•////	
rid	Differential input resistance					1012		Ω
rj	Common-mode input resistance					1012		Ω
Cį	Common-mode input capacitance	f = 10 kHz				8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10			130		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$	V _O = 0,	$R_S = 50 \Omega$	75	80		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD\pm} = \pm 2.2 \text{ V to } \pm 8 \text{ V},$	V _{IC} = 0,	No load	80	95		dB
lDD	Supply current	V _O = 0,	No load			2.4	3	mA

TLC2274Y electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

DADAMETED			TEST CONDITIONS		TLC2274Y		
	PARAMETER	IESI CONI	DITIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage				300	2500	μV
lio	Input offset current	V _{IC} = 0, V _O = 0,	$V_{DD\pm} = \pm 2.5 \text{ V},$ R _S = 50 Ω		0.5	100	pА
lв	Input bias current	1 v 0 = v ,	NS = 30 12		1	100	pA
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω		0 to 4	-0.3 to 4.2		٧
		V _{IO} ≤5 mV			4.99		
Vон	High-level output voltage	I _{OH} = -20 μA	I _{OH} = -20 μA				٧
		I _{OH} = -200 μA		4.25	4.65		*
		I _{OL} = -1 mA			0.01		
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 50 μA		0.09	0.15	V
	•	$V_{IC} = 2.5 V$	l _{OL} = 500 μA		0.9	1.5	
		V _{IC} = 2.5 V,	$R_L = 10 \text{ k}\Omega^{\dagger}$	15	35		
AVD	Large-signal differential voltage amplification	IOL = 5 mA	$R_L = 1 M\Omega^{\dagger}$		175		V/mV
^r id	Differential input resistance	V _O = 1 V to 4 V			1012		Ω
ri	Common-mode input resistance				1012		Ω
Cį	Common-mode input capacitance	f = 10 kHz			8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	Ay = 10		140		Ω
CMRR	Common-mode rejection ratio	V _{IC} = 0 to 2.7 V, R _S = 50 Ω	V _O = 2.5 V,	70	75		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, No load	$V_{IC} = V_{DD}/2$,	80	95		dB
IDD	Supply current	V _O = 2.5 V,	No load		4.4	6	mA

[†]Referenced to 2.5 V

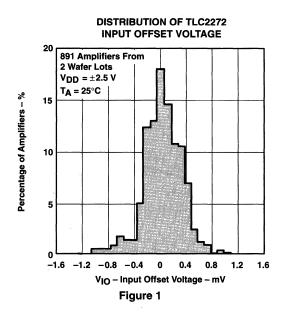
TLC2274Y electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_A = 25°C (unless otherwise noted)

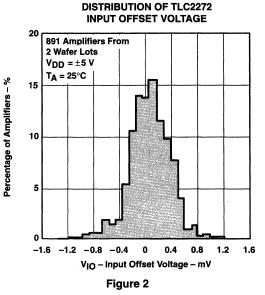
		T-07-00-10-1	TEST COMPLETIONS			TLC2274Y		
	PARAMETER	TEST CONDIT	TEST CONDITIONS		TYP	MAX	UNIT	
V _{IO}	Input offset voltage				300	2500	μV	
IIO	Input offset current	$V_{IC} = 0,$ $R_S = 50 \Omega$	$V_O = 0$,		0.5	100	pА	
lв	Input bias current	118 - 30 22			1	100	pА	
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,	V _{IO} ≤ 5 mV	-5 to 4	-5.3 to 4.2		٧	
		I _O = -20 μA			4.99			
V _{OM+}	Maximum positive peak output voltage	$I_O = -200 \mu A$		4.85	4.93		v	
		$I_O = -1 \text{ mA}$		4.25	4.65			
		V _{IC} = 0,	I _{OL} = 50 μA		-4.99			
V _{OM} -	Maximum negative peak output voltage	$V_{IC} = 0$,	I _{OL} = 500 μA	-4.85	-4.91		V	
		$V_{IC} = 0$,	I _{OL} = 5 mA	-3.5	-4.1			
Δ	Large-signal differential voltage amplification	V _O = ±4 V	$R_L = 10 \text{ k}\Omega$	25	50		V/mV	
AVD	Large-Signal unierential voltage amplification	VO = ±4 V	$R_L = 1 M\Omega$		300		V/IIIV	
^r id	Differential input resistance				1012		Ω	
rį	Common-mode input resistance				1012		Ω	
Cį	Common-mode input capacitance	f = 10 kHz	`		8		pF	
z _o	Closed-loop output impedance	f = 1 MHz,	Ay = 10		130		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = -5 \text{ V to } 2.7 \text{ V},$ $R_S = 50 \Omega$	V _O = 0,	75	80		dB	
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD\pm} = \pm 2.2 \text{ V to } \pm 8 \text{ V},$	V _{IC} = 0	80	95		dB	
qal	Supply current	$V_{O} = 0$,	No load		4.8	6	mA	

Table of Graphs

		·	FIGURE
V _{IO}	Input offset voltage	Distribution vs Common-mode voltage	1 – 4 5, 6
αVIO	Input offset voltage temperature coefficient	Distribution	7 – 10
I _{IB} /I _{IO}	Input bias and input offset current	vs Free-air temperature	11
VI	Input voltage range	vs Supply voltage vs Free-air temperature	12 13
Vон	High-level output voltage	vs High-level output current	14
VOL	Low-level output voltage	vs Low-level output current	15, 16
V _{OM+}	Maximum positive peak output voltage	vs Output current	17
V _{OM} -	Maximum negative peak output voltage	vs Output current	18
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	19
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	20 21
v _o	Output voltage	vs Differential Input voltage	22, 23
AVD	Large-signal differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	24 25, 26 27, 28
z _o	Output impedance	vs Frequency	29, 30
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	31 32
ksvr	Supply-voltage rejection ratio	vs Frequency vs Free-air temperature	33, 34 35
DD	Supply current	vs Supply voltage vs Free-air temperature	36, 37 38, 39
SR	Slew rate	vs Load capacitance vs Free-air temperature	40 41
	Inverting large-signal pulse response	vs Time	42, 43
Vo	Voltage-follower large-signal pulse response	vs Time	44, 45
v O	Inverting small-signal pulse response	vs Time	46, 47
	Voltage-follower small-signal pulse response	vs Time	48, 49
V _n	Equivalent input noise voltage	vs Frequency	50, 51
	Noise voltage (referred to input)	Over a 10-second period	52
	Integrated noise voltage	vs Frequency	53
THD + N	Total harmonic distortion plus noise	vs Frequency	54
	Gain-bandwidth product	vs Supply voltage vs Free-air temperature	55 56
φm	Phase margin	vs Load capacitance vs Frequency	57 25, 26
	Gain margin	vs Load capacitance	58

NOTE: For all graphs where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.





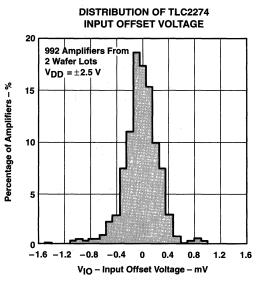


Figure 3

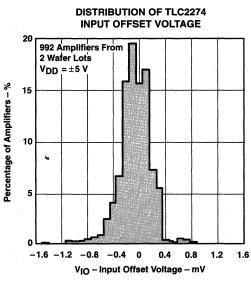
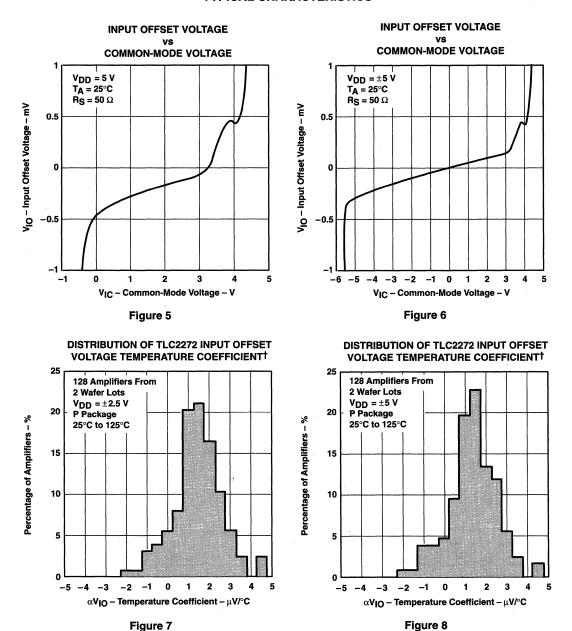


Figure 4



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS

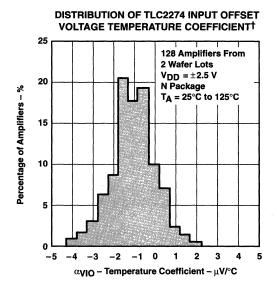


Figure 9

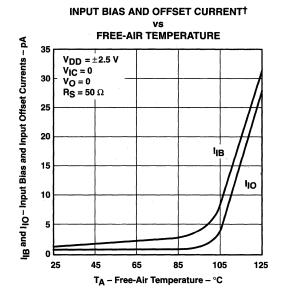


Figure 11

DISTRIBUTION OF TLC2274 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

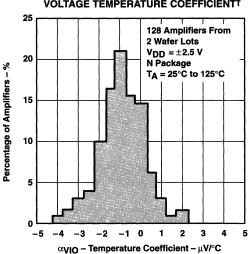


Figure 10

INPUT VOLTAGE RANGE vs

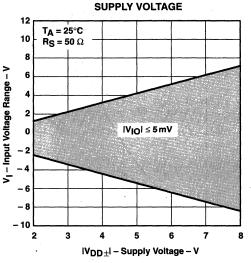
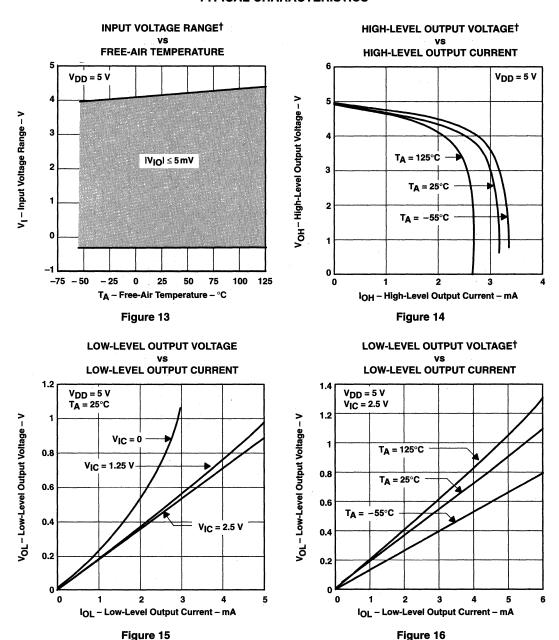


Figure 12

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



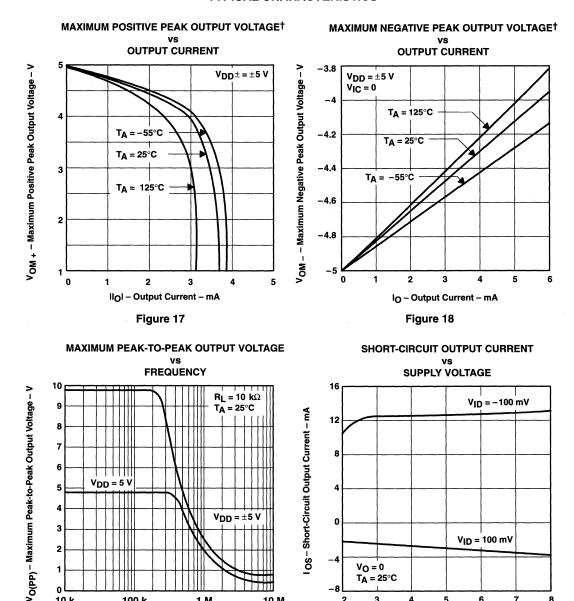


[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS



10 M

 $V_{DD} = \pm 5 \text{ V}$

1 M

3

10 k

100 k

f - Frequency - Hz

Figure 19



 $V_0 = 0$ TA = 25°C

2

 $V_{ID} = 100 \text{ mV}$

IVDD±I - Supply Voltage - V

Figure 20

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

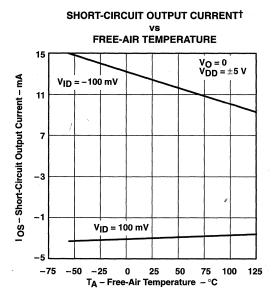


Figure 21

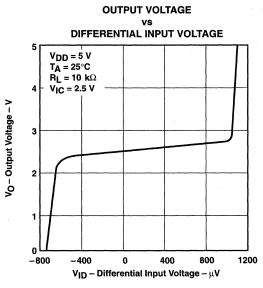
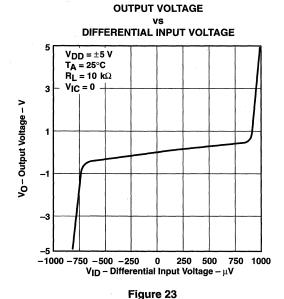


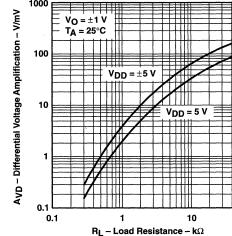
Figure 22

LARGE-SIGNAL DIFFERENTIAL

VOLTAGE AMPLIFICATION VS

LOAD RESISTANCE





1000

Figure 24

100

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

vs **FREQUENCY** 80 180° $V_{DD} = 5 V$ $R_L = 10 \text{ k}\Omega$ CL = 100 pF 135° 60 TA = 25°C A_{VD}- Large-Signal Differential Voltage Amplification - dB 40 90° _m – Phase Margin 20 45° 0 **0**° -20 -45° -90° -40 10 k 100 k 10 M 1 k 1 M f - Frequency - Hz

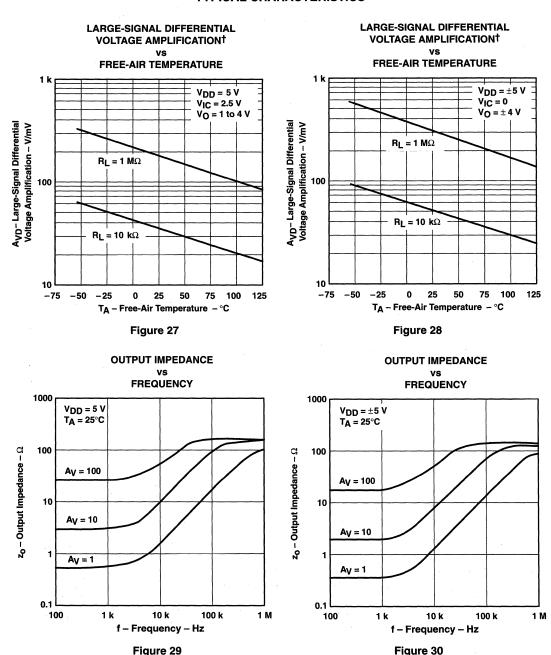
Figure 25

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

vs **FREQUENCY** 80 180° $V_{DD} = \pm 5 \text{ V}$ $R_L = 10 \text{ k}\Omega$ CL = 100 pF 135° 60 TA = 25°C A_{VD}- Large-Signal Differential Voltage Amplification - dB 90° ^φm – Phase Margin 40 45° 20 0° 0 -20 -45° -40 -90° 100 k 10 k 1 M 1 k 10 M f - Frequency - Hz

Figure 26





[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



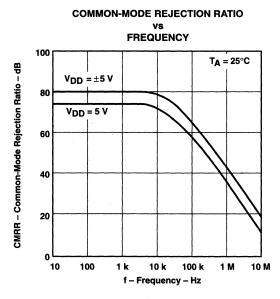
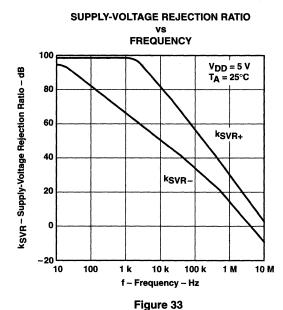


Figure 31



COMMON-MODE REJECTION RATIO

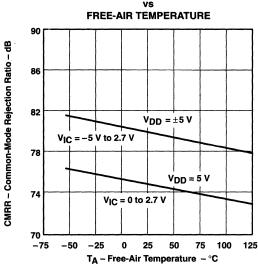


Figure 32

SUPPLY-VOLTAGE REJECTION RATIO

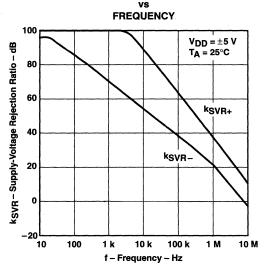
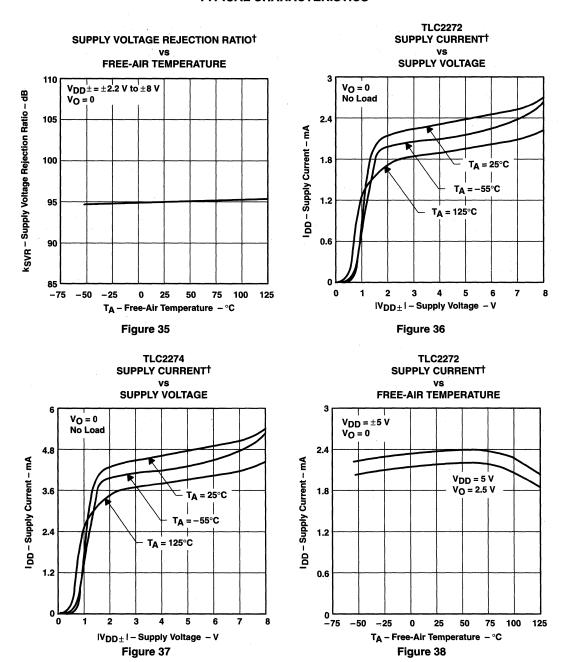


Figure 34

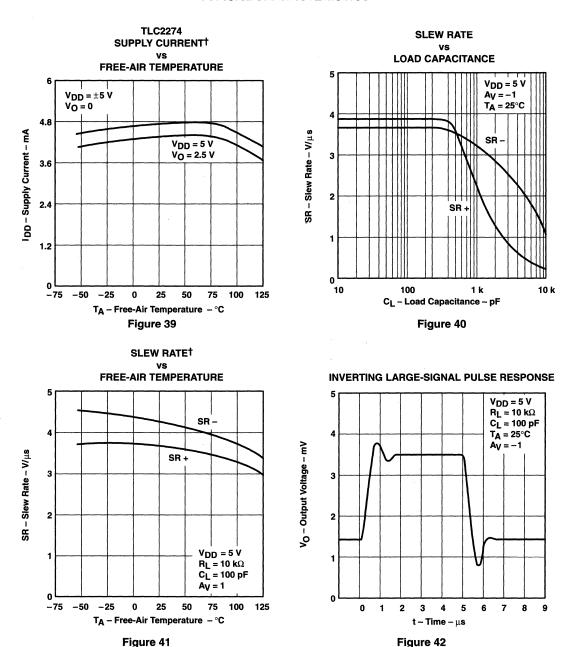


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS



[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



INVERTING LARGE-SIGNAL PULSE RESPONSE $V_{DD} = \pm 5 V$ $R_L = 10 \text{ k}\Omega$ C_ = 100 pF 3 TA = 25°C $A_V = -1$ V_O - Output Voltage - V 1 0 -1 -2 -3 0 1 2 3 4 5 6 7 8 $\textbf{t-Time}-\mu \textbf{s}$

Figure 43

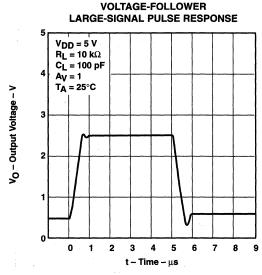


Figure 44

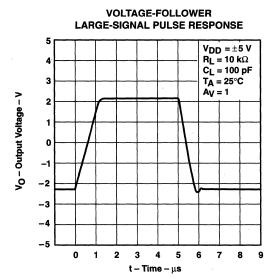


Figure 45

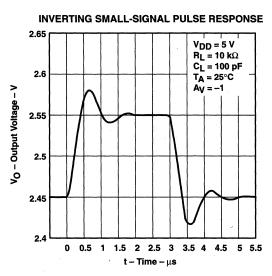


Figure 46

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TYPICAL CHARACTERISTICS

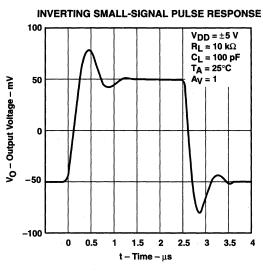


Figure 47

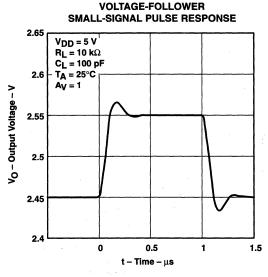
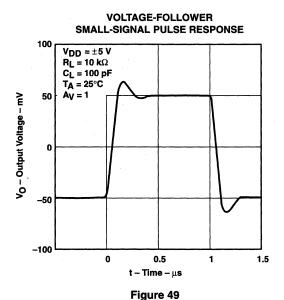


Figure 48

EQUIVALENT INPUT NOISE VOLTAGE



vs **FREQUENCY** 60 V_n – Equivalent Input Noise Voltage – nV/ ∜Hz $V_{DD} = 5 V$ TA = 25°C $R_S = 20 \Omega$ 50 40 30 20 10 0 10 100 1 k 10 k f - Frequency - Hz

Figure 50

TEXAS INSTRUMENTS

EQUIVALENT INPUT NOISE VOLTAGE

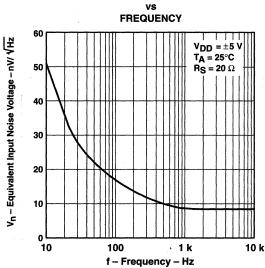


Figure 51

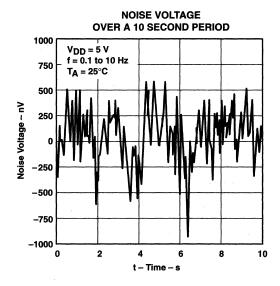


Figure 52

INTEGRATED NOISE VOLTAGE

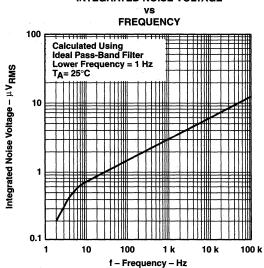


Figure 53

TOTAL HARMONIC DISTORTION PLUS NOISE

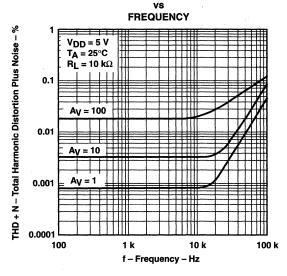
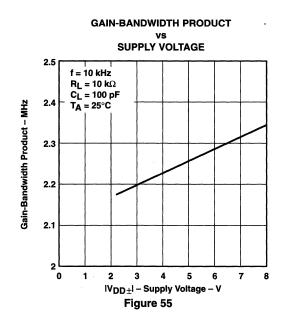


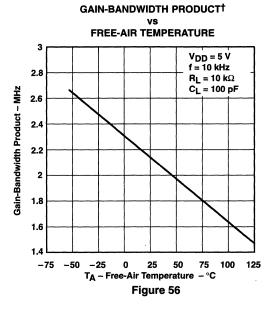
Figure 54

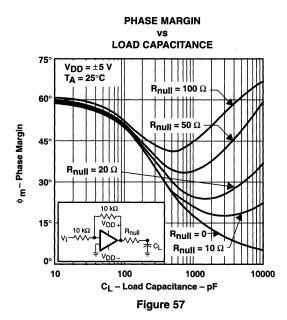


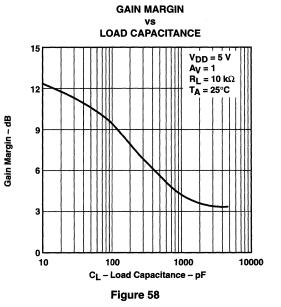
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TYPICAL CHARACTERISTICS









[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim $Parts^{TM}$, the model generation software used with Microsim $PSpice^{TM}$. The Boyle macromodel (see Note 5) and subcircuit in Figure 59 were generated using the TLC227x typical electrical and operating characteristics at $T_A = 25^{\circ}C$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Intergrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

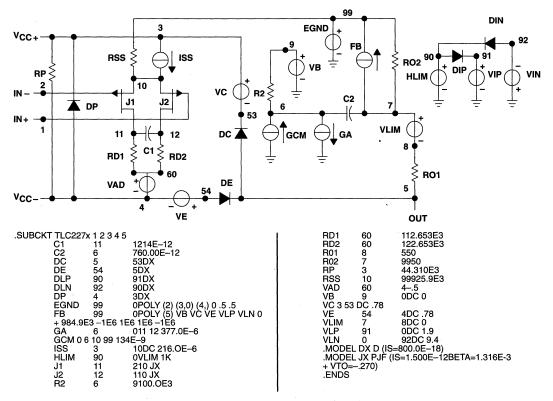
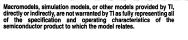


Figure 59. Boyle Macromodel and Subcircuit

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3-982



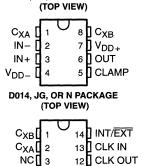
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- Extremely Low Offset Voltage . . . 1 μV Max
- Extremely Low Change on Offset Voltage With Temperature . . . 0.003 μV/°C Typ
- Low Input Offset Current
 500 pA Max at T_A = 55°C to 125°C
- A_{VD} . . . 135 dB Min
- CMRR and k_{SVR} . . . 120 dB Min
- Single-Supply Operation
- Common-Mode Input Voltage Range Includes the Negative Rail
- No Noise Degradation With External Capacitors Connected to V_{DD}_

description

The TLC2652 and TLC2652A are high-precision chopper-stabilized operational amplifiers using Texas Instruments Advanced LinCMOS™ process. This process in conjunction with unique chopper-stabilization circuitry produces operational amplifiers whose performance matches or exceeds that of similar devices available today.

Chopper-stabilization techniques make possible extremely high dc precision by continuously nulling input offset voltage even during variation in temperature, time, common-mode voltage, and power supply voltage. In addition, low-frequency noise voltage is significantly reduced. This high precision, coupled with the extremely high input impedance of the CMOS input stage, makes the



0 V_{DD+}

9 CLAMP

8 C RETURN

10 OUT

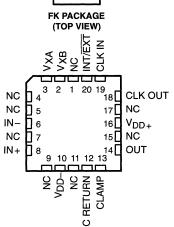
IN−¶ 4

IN+[] 5

NC∏ 6

 V_{DD} _ \parallel

D008, JG, OR P PACKAGE



NC - No internal connection

AVAILABLE OPTIONS

				PA	CKAGED DEVICES	}			
	V _{IO} max		8 PIN			14 PIN		20 PIN	CHIP
TA	AT 25°C	SMALL OUTLINE (D008)	CERAMIC DIP (JG)	PLASTIC DIP (P)	SMALL OUTLINE (D014)	CERAMIC DIP (J)	PLASTIC DIP (N)	CHIP CARRIER (FK)	FORM (Y)
0°C to 70°C	1 μV 3 μV	TLC2652AC-8D TLC2652C-8D	=	TLC2652ACP TLC2652CP	TLC2652AC-14D TLC2652C-14D	=	TLC2652ACN TLC2652CN	-	TLC2652Y
-40°C to 85°C	1 μV 3 μV	TLC2652AI-8D TLC2652A-8D		TLC2652AIP TLC2652IP	TLC2652AI-14D TLC2652I-14D	_	TLC2652AIN TLC2652IN		_
−55°C to 125°C	1 μV 3 μV	TLC2652AM-8D TLC2652M-8D	TLC2652AMJG TLC2652MJG	TLC2652AMP TLC2652MP	TLC2652AM-14D TLC2652M-14D	TLC2652AMJ TLC2652MJ	TLC2652AMN TLC2652MN	TLC2652AMFK TLC2652MFK	_

The D008 and D014 packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2652AC-8DR). Chips are tested at 25°C.

Advanced LinCMOS is a trademark of Texas Instruments Incorporated



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description (continued)

TLC2652 and TLC2652A an ideal choice for low-level signal processing applications such as strain gauges, thermocouples, and other transducer amplifiers. For applications that require extremely low noise and higher usable bandwidth, use the TLC2654 or TLC2654A device, which has a chopping frequency of 10 kHz.

The TLC2652 and TLC2652A input common-mode range includes the negative rail, thereby providing superior performance in either single-supply or split-supply applications, even at power supply voltage levels as low as ±1.9 V.

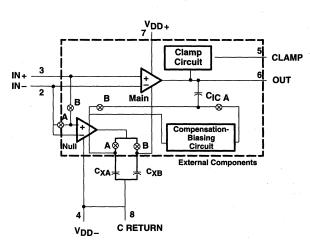
Two external capacitors are required for operation of the device; however, the on-chip chopper control circuitry is transparent to the user. On devices in the 14-pin and 20-pin packages, the control circuitry is made accessible to allow the user the option of controlling the clock frequency with an external frequency source. In addition, the clock threshold level of the TLC2652 and TLC2652A require no level shifting when used in the single-supply configuration with a normal CMOS or TTL clock input.

Innovative circuit techniques are used on the TLC2652 and TLC2652A to allow exceptionally fast overload recovery time. If desired, an output clamp pin is available to reduce the recovery time even further.

The device inputs and output are designed to withstand -100-mA surge currents without sustaining latch-up. Additionally the TLC2652 and TLC2652A incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

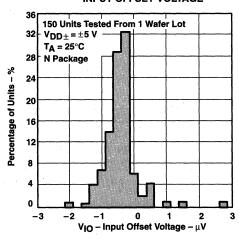
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to125°C.

functional block diagram



Pin numbers shown are for the D (14 pin), JG, and N packages.

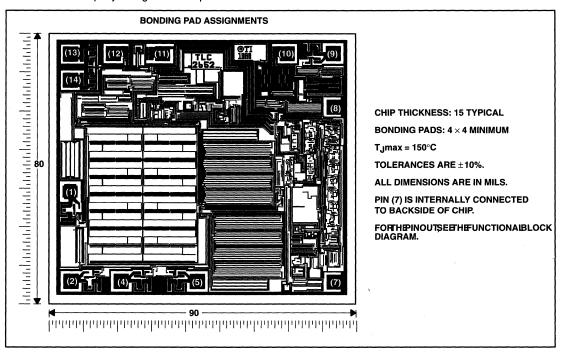
DISTRIBUTION OF TLC2652 INPUT OFFSET VOLTAGE



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TLC2652Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2652C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Supply voltage V _{DD+} (see Note 1)	8 V
Supply voltage V _{DD} (see Note 1)	8 V
Differential input voltage, V _{ID} (see Note 2)	
Input voltage, V _I (any input, see Note 1)	±8 V
Voltage range on CLK IN and INT/EXT	V_{DD} – to V_{DD-} + 5.2 V
Input current, I _I (each input)	±5 mA
Output current, I _O	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Current into CLK IN and INT/EXT	±5 mA
Continuous total dissipation	. See Dissipation Rating Table
Operating free-air temperature range, TA: C suffix	0°C to 70°C
I suffix	40°C to 85°C
M suffix	–55°C to 125°C
Storage temperature range	65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or P p	ackage 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or JG pack	kage 300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VDD+ and VDD-.

2. Differential voltages are at IN+ with respect to IN-.

The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D008	725 mV	5.8 mW/°C	464 mW	377 mW	145 mW
D014	950 mV	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mV	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mV	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mV	8.4 mW/°C	672 mW	546 mW	210 mW
N	1575 mV	12.6 mW/°C	1008 mW	819 mW	315 mW
P	1000 mV	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

	c s	UFFIX	IS	UFFIX	MS	UFFIX	UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±1.9	±8	±1.9	±8	±1.9	±8	V
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} –1.9	V _{DD} _	V _{DD+} –1.9	V _{DD} _ '	V _{DD+} −1.9	٧
Clock input voltage	V _{DD} _	V _{DD} _+5	V _{DD} _	V _{DD} _+5	V _{DD} _	V _{DD-} +5	٧
Operating free-air temperature, TA	0	70	-40	85	-55	125	°C



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electrical characteristics at specified free-air temperature, $V_{DD} \pm = \pm 5 \text{ V}$ (unless otherwise noted)

	DADAMETED	7507.00	TIONO	- +	TLC2652C T		TL	.C2652A	C		
	PARAMETER	TEST CONDI	HONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V:0	Input offset voltage			25°C		0.6	3		0.5	1	μV
VIO	input onset voitage			Full range			4.35			2.35	μν
ανιο	Temperature coefficient of input offset voltage			Full range		0.003	0.03		0.003	0.03	μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0, F	Rs = 50 Ω	25°C		0.003	0.06		0.003	0.02	μV/mo
li o	Input offset current			25°C		2			2		рA
lio	input onset current			Full range			100			100	PΑ
l _{IB}	Input bias current			25°C		4			4		pА
'IB	mpat bias current			Full range			100			100	PΛ
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 3.1			-5 to 3.1			٧
V _{OM+}	Maximum positive peak output voltage swing	R _L = 10 kΩ, S	See Note 5	25°C	4.7 4.7	4.8		4.7 4.7	4.8		٧
		 		Full range 25°C	-4.7	-4.9		-4.7	-4.9		
VOM-	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$, §	See Note 5	Full range	-4.7	-4.9		-4.7	-4.9		V
AVD	Large-signal differential voltage amplification	V _O = ±4 V, F	RL = 10 kΩ	25°C Full range	120 120	150		135 130	150		dB
fch	Internal chopping frequency			25°C	120	450			450		Hz
CII				25°C	25			25			
	Clamp on-state current	R _L = 100 kΩ		Full range	25			25			μА
				25°C			100			100	
	Clamp off-state current	$V_0 = -4 \text{ V to 4 V}$		Full range			100			100	pΑ
CMRR	Common-mode rejection	V _O = 0, V _{IC} = V _{ICR} min,		25°C	120	140		120	140		dB
CWITH	ratio	$R_S = 50 \Omega$		Full range	120			120			ub
kovo	Supply-voltage rejection ratio	$V_{DD\pm} = \pm 1.9 \text{ V to}$	±8 V,	25°C	120	135		120	135		dB
ksvr	$(\Delta V_{DD\pm}/\Delta V_{IO})$	V _O = 0, F	$R_S = 50 \Omega$	Full range	120			120			ub
Inn	Supply current			25°C		1.5	2.4		1.5	2.4	mA
1DD	oupply outlett			Full range			2.5			2.5	ША

† Full range is 0° to 70°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated at T_A = 25° using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. Output clamp is not connected.

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operating characteristics specified free-air temperature, $V_{DD\pm} = \pm 5 \text{ V}$

	DADAMETED	TEST	- +	TI	_C26520		TL	C2652A	С	
	PARAMETER	CONDITIONS TAT		MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain		25°C	2	2.8		2	2.8		V/μs
3n+	Positive siew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	Full range	1.5			1.5			V/μS
SR-	Negative class rate at units rain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C	2.3	3.1		2.3	3.1		V/µs
3n-	Negative slew rate at unity gain	1-2	Full range	1.8			1.8			V/μs
V	Equivalent input noise voltage	f = 10 Hz	25°C		94			94	140	->4/51
V _n	(see Note 6)	f = 1 kHz	25°C		23			23	35	nV/√Hz
V	Peak-to-peak equivalent input	f = 0 to 1 Hz	25°C		0.8			0.8		
V _{N(PP)}	noise voltage	f = 0 to 10 Hz	25°C		2.8			2.8		μ۷
In	Equivalent input noise current	f = 10 kHz	25°C		0.004			0.004		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, R _L = 10 kΩ, C _L = 100 pF	25°C		1.9			1.9		MHz
φm .	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		48°			48°		

[†] Full range is 0° to 70°C.

NOTE 6: This parameter is tested on a sample basis for the TLC2652A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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electrical characteristics at specified free-air temperature, $V_{DD}\pm=\pm5$ V (unless otherwise noted)

	DADAMETED		UDITIONO	- +	1	LC2652		T	LC2652A	1	UNIT
	PARAMETER	I LEST COI	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V/o	Input offset voltage			25°C		0.6	3		0.5	1	μV
VIO	input onset voltage	}		Full range			4.95			2.95	μν
αVIO	Temperature coefficient of input offset voltage			Full range		0.003	0.03		0.003	0.03	μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.003	0.06		0.003	0.02	μV/mo
lio	Input offset current]		25°C		2			2		рA
lo lo	input onset current			Full range			150			150	PΑ
lв	Input bias current			25°C		4			4		рА
אוי	Input bias current			Full range			150			150	PA
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 3.1			-5 to 3.1			v
\/ - ·	Maximum positive peak	D 4010	O N-4- 5	25°C	4.7	4.8		4.7	4.8		V
V _{OM+}	output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 5	Full range	4.7			4.7			V
V	Maximum negative peak	$R_{\rm i} = 10 k\Omega$	Can Note F	25°C	-4.7	-4.9		-4.7	-4.9		V
VOM~	output voltage swing		See Note 5	Full range	-4.7			-4.7			·
AVD	Large-signal differential	Vo = +4 V	$R_{l} = 10 \text{ k}\Omega$	25°C	120	150		135	150		dB
~VD	voltage amplification	VO = 14 V,	11[10 K32	Full range	120			125			ub
	Internal chopping frequency			25°C		450			450		Hz
	Clamp on-state current	R _I = 100 kΩ		25°C	25			25			μА
		1100102		Full range	25			25			μπ
	Clamp off-state current	$V_0 = -4 V to$	n 4 V	25°C			100			100	рA
	oramp on state surrent	10-11		Full range			100			100	P/.
OMBE	Common-mode rejection	$V_0 = 0,$		25°C	120	140		120	140		4D
CMRR	ratio	$V_{IC} = V_{ICR}^{m}$ $R_S = 50 \Omega$	nin,	Full range	120			120			dB
kovo	Supply-voltage rejection	$V_{DD\pm} = \pm 1.9$	9 V to ±8 V,	25°C	120	135		120	135		dB
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	V _O = 0,	$R_S = 50 \Omega$	Full range	120			120			ub
l _{DD}	Supply current	V _O = 0,	No load	25°C		1.5	2.4		1.5	2.4	mA
טטי		1 0 - 0,	140 1000	Full range			2.5			2.5	,,,,

†Full range is -40° to 85°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated at T_A = 25° using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. Output clamp is not connected.

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operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST	. .+	Т	LC2652		TL	.C2652A	d .	
	PARAMETER	CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain		25°C	2	2.8		2	2.8		V/µs
3N+	Positive siew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	Full range	1.4			1.4			V/μS
SR-	Negative slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C	2.3	3.1		2.3	3.1		V/µs
on-	Negative siew rate at unity gain		Full range	1.7			1.7			V/μS
V	Equivalent input noise voltage	f = 10 Hz	25°C		94			94	140	nV/√Hz
V _n	(see Note 6)	f = 1 kHz	25°C		23			23	35	NV/VM2
V	Peak-to-peak equivalent input	f = 0 to 1 Hz	25°C		0.8			0.8		
VN(PP)	noise voltage	f = 0 to 10 Hz	25°C		2.8			2.8		μV
In	Equivalent input noise current	f = 1 kHz	25°C		0.004			0.004	7	pA/√Hz
	Gain-bandwidth product	f = 10 kHz, R _L = 10 kΩ, C _L = 100 pF	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°			48°		

† Full range is -40° to 85°C.

NOTE 6: This parameter is tested on a sample basis for the TLC2652A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

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electrical characteristics at specified free-air temperature, $V_{DD} \pm = \pm 5 \text{ V}$ (unless otherwise noted)

		ľ			Т	LC26521	VI .	TL	TLC2652AM				
	PARAMETER	TEST CO	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT		
.,	Input offset voltage			25°C		0.6	3.5		0.5	3	·		
V _{IO}	(see Note 7)			Full range			10			8	μV		
αVIO	Temperature coefficient of input offset voltage			Full range		0.003	0.03*		0.003	0.03*	μV/°C		
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.003	0.06*		0.003	0.02*	μV/mo		
1	Input offeet ourrent			25°C		2			2				
lo lo	Input offset current			Full range			500			500	рA		
lın.	Input bias current			25°C		4			4		рA		
lВ	input bias current			Full range			500			500	PΑ		
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	–5 to 3.1			-5 to 3.1	ı		٧		
Vare	Maximum positive peak	D 10 kO	See Note 5	25°C	4.7	4.8		4.7	4.8		V		
V _{OM+}	output voltage swing	n[= 10 ksz,	See Note 5	Full range	4.7			4.7			·		
V _{OM} -	Maximum negative peak	$R_{\rm J} = 10 k\Omega$	See Note 5	25°C	-4.7	-4.9		-4.7	-4.9		V		
VOIVI-	output voltage swing	11[= 10 K32,	<u> </u>	Full range	-4.7			-4.7			.		
AVD	Large-signal differential	Vo = +4 V	$R_I = 10 \text{ k}\Omega$	25°C	120	150		135	150		dB		
· VD	voltage amplification	10-2.1,		Full range	120			120					
^f ch	Internal chopping frequency			25°C		450			450	.,	Hz		
	Clamp on-state current	$R_1 = 100 \text{ k}\Omega$		25°C	25			25			μА		
				Full range	25			25	<u>·</u> _				
	Clamp off-state current	V _O = -4 V t	o 4 V	25°C			100			100	рA		
				Full range			500			500			
CMRR	Common-mode rejection	V _O = 0,	-:	25°C	120	140		120	140		dB		
CIVINA	ratio	$V_{IC} = V_{ICR}^n$ $R_S = 50 \Omega$		Full range	120			120			UB		
ksvr	Supply-voltage rejection	$V_{DD\pm} = \pm 1.9$	9 V to ±8 V,	25°C	120	135		120	135		dB		
··ovn	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	120			120					
lon	Supply current	V _O = 0,	No load	25°C		1.5	2.4		1.5	2.4	mA		
DD S	Supply current	Supply current	Supply current		140 1000	Full range			2.5			2.5	''''

^{*} On products complaint to MIL-STD-883, Class B, this parameter is not production tested.

[†] Full range is -55° to 125°C

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated at T_A = 25° using the Arrhenius equation and assuming an activation energy of 0.96 eV.

^{5.} Output clamp is not connected.

^{7.} This parameter is not production tested. Thermocouple effects preclude measurement of the actual V_{IO} of these devices in high speed automated testing. V_{IO} is measured to a limit determined by the test equipment capability at the temperature extremes. The test ensures that the stabilization circuitry is performing properly.

TLC2652, TLC2652A, TLC2652Y Advanced LinCMOSTM PRECISION CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS SLOS019B - SEPTEMBER 1988 - REVISED AUGUST 1994

operating characteristics specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	TEST CONDITIONS	T _A †		.C2652N C2652AI		UNIT
			-	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain		25°C	2	2.8		V/µs
3N+	rositive siew rate at unity gain	V _O = ±2.3 V,	Full range	1.3			V/μS
SR-	Negative elements at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C	2.3	3.1		VIII
on-	Negative slew rate at unity gain		Full range	1.6			V/μs
V	Equivalent input paids valtage	f = 10 Hz	25°C		94		->4/15
V _n	Equivalent input noise voltage	f = 1 kHz	25°C	i	23		nV/√Hz
V	Dook to peak as it point input pains valtage	f = 0 to 1 Hz	25°C		0.8		
VN(PP)	Peak-to-peak equivalent input noise voltage	f = 0 to 10 Hz	25°C		2.8		μV
In	Equivalent input noise current	f = 1 kHz	25°C		0.004		pA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		48°		

[†] Full range is -55° to 125°C.

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electrical characteristics at $V_{DD\pm}$ = ± 5 V, T_A = $25^{\circ}C$ (unless otherwise noted)

	DADAMETED		ONDITIONS	Т	LC2652	Y	
	PARAMETER	IESIC	ONDITIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage			İ	0.6	3	μV
	Input offset voltage long-term drift (see Note 4)	7,,,	D- 50.0		0.003	0.006	μV/mo
IЮ	Input offset current	V _{IC} = 0,	$R_S = 50 \Omega$		2		pА
IB	Input bias current				4		рA
VICR	Common-mode input voltage range	R _S = 50 Ω		-5 to 3.1			٧
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 5	4.7	4.8		٧
V _{OM} -	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 5	-4.7	-4.9		٧
AVD	Large-signal differential voltage amplification	$V_0 = \pm 4 V$,	R _L = 10 kΩ	120	150		dB
fch	Internal chopping frequency				450		Hz
	Clamp on-state current	$R_L = 100 \text{ k}\Omega$		25			μΑ
	Clamp off-state current	$V_0 = -4 \text{ V to}$	4 V			100	pА
CMRR	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	V _{IC} = V _{ICR} min,	120	140		dB
ksvr	Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 1.9$ $R_S = 50 \cdot \Omega$	V to ± 8 V, V _O = 0,	120	135		dB
IDD	Supply current	V _O = 0,	No load		1.5	2.4	mA

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated at T_A = 25° using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. Output clamp is not connected.

operating characteristics at $V_{DD\pm}$ = ± 5 V, T_A = 25°C

	DADAMETER	TEST COMPLETIONS		TL	.C2652Y	MAX	
	PARAMETER	TEST CONDITIONS	ſ	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	V _O = ±2.3 V, R _I = 10 k	Ω,	2	2.8		V/μs
SR-	Negative slew rate at unity gain	C _L = 100 pF	Ī	2.3	3.1		V/μs
V	Facility and in the second sec	f = 10 Hz			94		
v _n	Equivalent input noise voltage	f = 1 kHz			23		nV/√Hz
V	Park to mark a minimum to make	f = 0 to 1 Hz			0.8		
VN(PP)	Peak-to-peak equivalent input noise voltage	f = 0 to 10 Hz			2.8		μV
In	Equivalent input noise current	f = 1 kHz					pA/√Hz
	Gain-bandwidth product	f = 10 kHz, R _L = 10 k C _L = 100 pF	:Ω,		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100$	pF		48°		

Table of Graphs

			FIGURE		
V _{IO}	Normalized input offset voltage	vs Chopping frequency	1		
I _{IB}	Input bias current	vs Common-mode input voltage vs Chopping frequency vs Free-air temperature	2 3 4		
10	Input offset current	vs Chopping frequency vs Free-air temperature			
	Clamp current vs Output voltage		7		
V _(OPP)	Maximum peak-to-peak output voltage	vs Frequency	8		
V _{OM}	Maximum peak output voltage	vs Output current vs Free-air temperature			
AVD	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	13 14		
	Chopping frequency	vs Supply voltage vs Free-air temperature	15 16		
lDD	Supply current	vs Supply voltage vs Free-air temperature	17 18		
los	Short-circuit output current	cuit output current vs Supply voltage vs Free-air temperature			
SR	Slew rate	vs Supply voltage vs Free-air temperature	21 22		
	Pulse response	Small-signal Large-signal	23 24		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	vs Chopping frequency	25, 26		
٧ _n	Equivalent input noise voltage	vs Frequency	27		
	Gain-bandwidth product	vs Supply voltage vs Free-air temperature	28 29		
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	30 31 32		
	Phase shift	13			

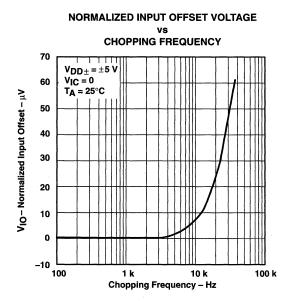
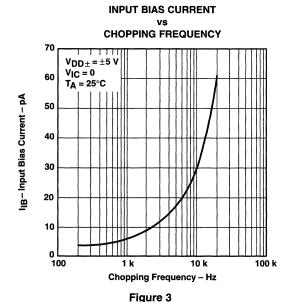
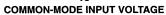


Figure 1



INPUT BIAS CURRENT



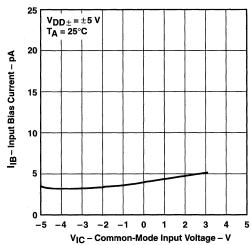


Figure 2

INPUT BIAS CURRENT

vs

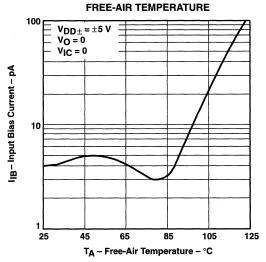
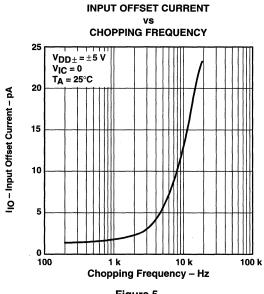


Figure 4

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]



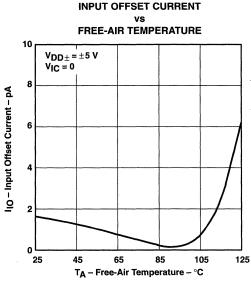
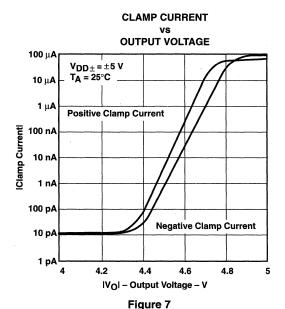


Figure 5



MAXIMUM PEAK-TO-PEAK OUTPUT



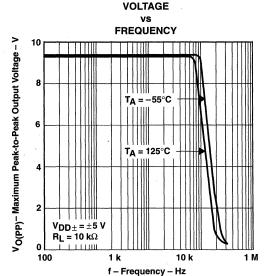


Figure 8

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

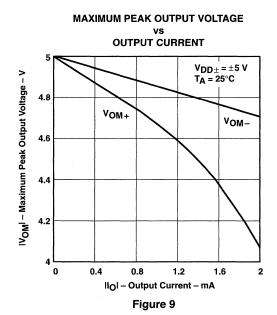
MAXIMUM PEAK OUTPUT VOLTAGE

TYPICAL CHARACTERISTICS[†]

6.7

0

0.4



7.5 Note that the second of t

Figure 10

8.0

1.2

IIOI - Output Current - mA

1.6

2



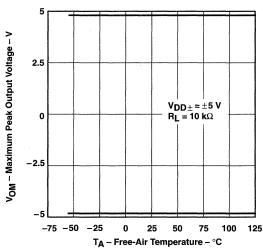


Figure 11

MAXIMUM PEAK OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE 8

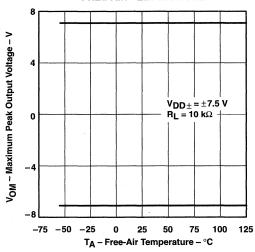


Figure 12

[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

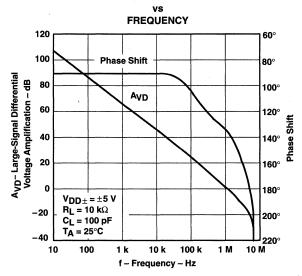
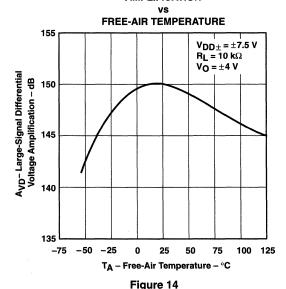


Figure 13

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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TYPICAL CHARACTERISTICS†

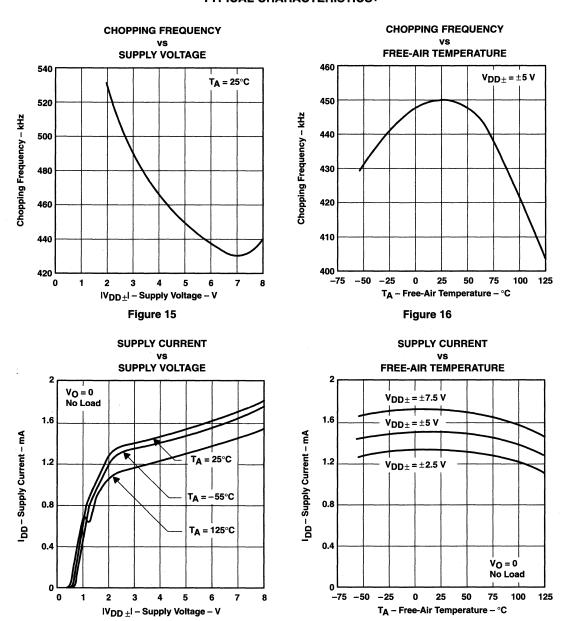
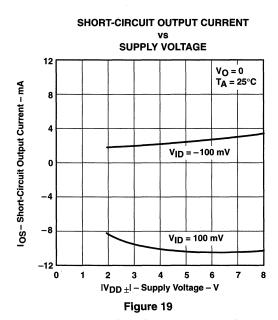


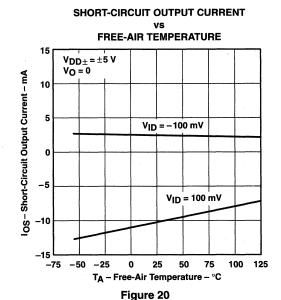
Figure 17

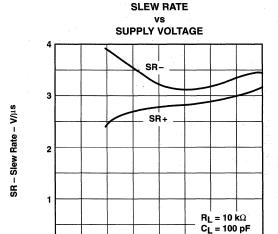


Figure 18

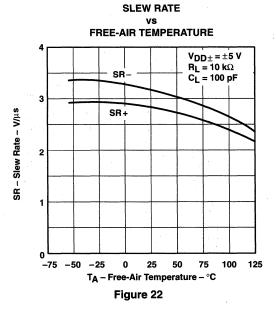
[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.







IV_{DD±}I – Supply Voltage – V Figure 21



 \dagger Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TA = 25°C



0

0

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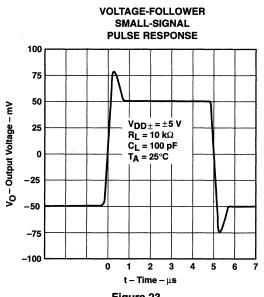
VOLTAGE-FOLLOWER

LARGE-SIGNAL

PULSE RESPONSE

TYPICAL CHARACTERISTICS

-3



 $V_{DD\pm} = \pm 5 \text{ V}$ $R_L = 10 \text{ k}\Omega$ 3 $C_L = 100 pF$ T_A ≈ 25°C Vo - Output Voltage - V 0 -1 -2

0 5 10 15 20 25 30 35 40

Figure 23

Figure 24

PEAK-TO-PEAK INPUT NOISE VOLTAGE

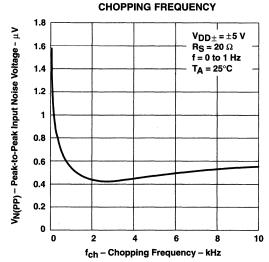


Figure 25

PEAK-TO-PEAK INPUT NOISE VOLTAGE

t - Time - μs

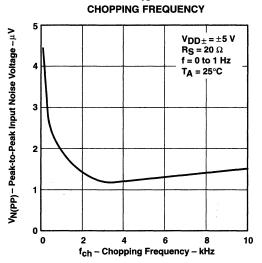
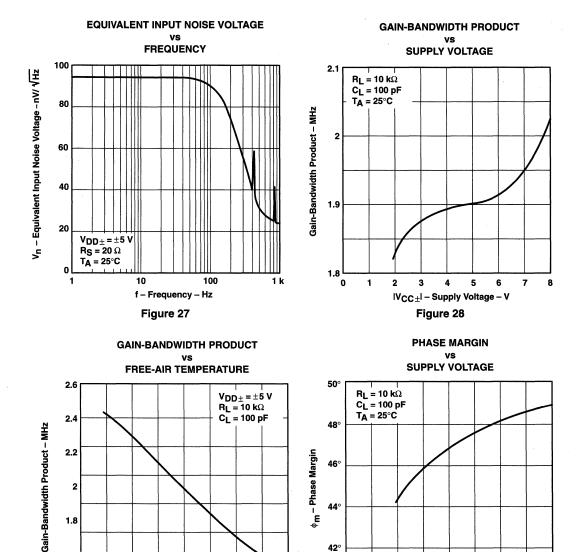


Figure 26

TYPICAL CHARACTERISTICS[†]



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

100 125

25

TA - Free-Air Temperature - °C Figure 29

50

42°

40°

0 1

IVCC±I - Supply Voltage - V

Figure 30



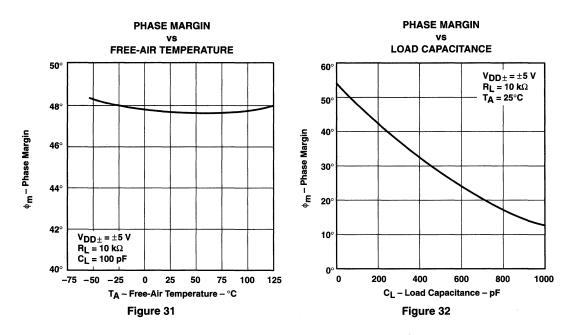
1.4

1.2

-50 -25

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TYPICAL CHARACTERISTICS†



[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



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APPLICATION INFORMATION

capacitor selection and placement

The two important factors to consider when selecting external capacitors C_{XA} and C_{XB} are leakage and dielectric absorption. Both factors can cause system degradation, negating the performance advantages realized by using the TLC2652.

Degradation from capacitor leakage becomes more apparent with the increasing temperatures. Low-leakage capacitors and standoffs are recommended for operation at $T_A = 125^{\circ}C$. In addition, guard bands are recommended around the capacitor connections on both sides of the printed circuit board to alleviate problems caused by surface leakage on circuit boards.

Capacitors with high dielectric absorption tend to take several seconds to settle upon application of power, which directly affects input offset voltage. In applications where fast settling of input offset voltage is needed, it is recommended that high-quality film capacitors, such as mylar, polystyrene, or polypropylene, be used. In other applications, however, a ceramic or other low-grade capacitor can suffice.

Unlike many choppers available today, the TLC2652 is designed to function with values of C_{XA} and C_{XB} in the range of 0.1 μ F to 1 μ F without degradation to input offset voltage or input noise voltage. These capacitors should be located as close as possible to the C_{XA} and C_{XB} pins and returned to either V_{DD-} or C RETURN. On many choppers, connecting these capacitors to V_{DD-} causes degradation in noise performance. This problem is eliminated on the TLC2652.

internal/external clock

The TLC2652 has an internal clock that sets the chopping frequency to a nominal value of 450 Hz. On 8-pin packages, the chopping frequency can only be controlled by the internal clock; however, on all 14-pin packages and the 20-pin FK package, the device chopping frequency can be set by the internal clock or controlled externally by use of the INT/ $\overline{\text{EXT}}$ and CLK IN pins. To use the internal 450-Hz clock, no connection is necessary. If external clocking is desired, connect INT/ $\overline{\text{EXT}}$ to V_{DD-} and the external clock to CLK IN. The external clock trip point is 2.5 V above the negative rail; however, CLK IN can be driven from the negative rail to 5 V above the negative rail. If this level is exceeded, damage could occur to the device unless the current into CLK IN is limited to ± 5 mA. When operating in the single-supply configuration, this feature allows the TLC2652 to be driven

directly by 5-V TTL and CMOS logic. A divide-by-two frequency divider interfaces with CLK IN and sets the clock chopping frequency. The duty cycle of the external is not critical but should be kept between 30% and 60%.

overload recovery/output clamp

When large differential input voltage conditions are applied to the TLC2652, the nulling loop attempts to prevent the output from saturating by driving C_{XA} and C_{XB} to internally-clamped voltage levels. Once the overdrive condition is removed, a period of time is required to allow the built-up charge to dissipate. This time period is defined as overload recovery time (see Figure 33). Typical overload recovery time for the TLC2652 is significantly faster than competitive products; however, if required, this time can be reduced further by use of internal clamp circuitry accessible through CLAMP if required.

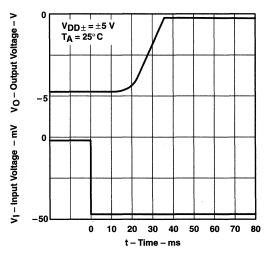


Figure 33. Overload Recovery



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APPLICATION INFORMATION

overload recovery/output clamp (continued)

The clamp is a switch that is automatically activated when the output is approximately 1 V from either supply rail. When connected to the inverting input (in parallel with the closed-loop feedback resistor), the closed-loop gain is reduced, and the TLC2652 output is prevented from going into saturation. Since the output must source sink current through the switch (see Figure 7), the maximum output voltage swing is slightly reduced.

thermoelectric effects

To take advantage of the extremely low offset voltage drift of the TLC2652, care must be taken to compensate for the thermoelectric effects present when two dissimilar metals are brought into contact with each other (such as device leads being soldered to a printed circuit board). Dissimilar metal junctions can produce thermoelectric voltages in the range of several microvolts per degree Celsius (orders of magnitude greater than the $0.01-\mu V/^{\circ}C$ typical of the TLC2652).

To help minimize thermoelectric effects, careful attention should be paid to component selection and circuit-board layout. Avoid the use of nonsoldered connections (such as sockets, relays, switches, etc.) in the input signal path. Cancel thermoelectric effects by duplicating the number of components and junctions in each device input. The use of low-thermoelectric-coefficient components, such as wire-wound resistors, is also beneficial.

latch-up avoidance

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC2652 inputs and output are designed to withstand –100-mA surge currents without sustaining latch-up; however, techniques to reduce the chance of latch-up should be used whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltages should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the supply rails and is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor. The chance of latch-up occurring increases with increasing temperature and supply voltage.

electrostatic discharge protection

The TLC2652 incorporates internal ESD-protection circuits that prevent functional failures at voltages at or below 2000 V. Care should be exercised in handling these devices, as exposure to ESD may result in degradation of the device parametric performance.

theory of operation

Chopper-stabilized operational amplifiers offer the best dc performance of any monolithic operational amplifier. This superior performance is the result of using two operational amplifiers, a main amplifier and a nulling amplifier, plus oscillator-controlled logic and two external capacitors to create a system that behaves as a single amplifier. With this approach, the TLC2652 achieves submicrovolt input offset voltage, submicrovolt noise voltage, and offset voltage variations with temperature in the nV/°C range.

The TLC2652 on-chip control logic produces two dominant clock phases: a nulling phase and an amplifying phase. The term chopper-stabilized derives from the process of switching between these two clock phases. Figure 34 shows a simplified block diagram of the TLC2652. Switches A and B are make-before-break types.

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APPLICATION INFORMATION

theory of operation (continued)

During the nulling phase, switch A is closed shorting the nulling amplifier inputs together and allowing the nulling amplifier to reduce its own input offset voltage by feeding its output signal back to an inverting input node. Simultaneously, external capacitor C_{XA} stores the nulling potential to allow the offset voltage of the amplifier to remain nulled during the amplifying phase.

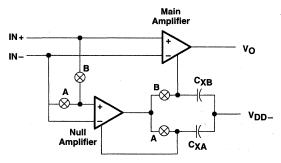


Figure 34. TLC2652 Simplified Block Diagram

During the amplifying phase, switch B is closed connecting the output of the nulling amplifier to a noninverting input of the main amplifier. In this configuration, the input offset voltage of the main amplifier is nulled. Also, external capacitor C_{XB} stores the nulling potential to allow the offset voltage of the main amplifier to remain nulled during the next nulling phase.

This continuous chopping process allows offset voltage nulling during variations in time and temperature over the common-mode input voltage range and power supply range. In addition, because the low-frequency signal path is through both the null and main amplifiers, extremely high gain is achieved.

The low-frequency noise of a chopper amplifier depends on the magnitude of the component noise prior to chopping and the capability of the circuit to reduce this noise while chopping. The use of the Advanced LinCMOS process, with its low-noise analog MOS transistors and patent-pending input stage design, significantly reduces the input noise voltage.

The primary source of nonideal operation in chopper-stabilized amplifiers is error charge from the switches. As charge imbalance accumulates on critical nodes, input offset voltage can increase, especially with increasing chopping frequency. This problem has been significantly reduced in the TLC2652 by use of a patent-pending compensation circuit and the Advanced LinCMOS process.

The TLC2652 incorporates a feed-forward design that ensures continuous frequency response. Essentially, the gain magnitude of the nulling amplifier and compensation network crosses unity at the break frequency of the main amplifier. As a result, the high-frequency response of the system is the same as the frequency response of the main amplifier. This approach also ensures that the slewing characteristics remain the same during both the nulling and amplifying phases.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

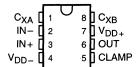
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- Input Noise Voltage
 0.5 μV (Peak-to-Peak) Typ, f = 0 to 1 Hz
 1.5 μV (Peak-to-Peak) Typ, f = 0 to 10 Hz
 47 nV/√Hz Typ, f = 10 Hz
 13 nV/√Hz Typ, f = 1 kHz
- High Chopping Frequency . . . 10 kHz Typ
- No Clock Noise Below 10 kHz
- No Intermodulation Error Below 5 kHz
- Low Input Offset Voltage 10 μV Max (TLC2654A)
- Excellent Offset Voltage Stability
 With Temperature . . . 0.05 μV/°C Max
- A_{VD} . . . 135 dB Min (TLC2654A)
- CMRR . . . 110 dB Min (TLC2654A)
- k_{SVR} . . . 120 dB Min (TLC2654A)
- Single-Supply Operation
- Common-Mode Input Voltage Range Includes the Negative Rail
- No Noise Degradation With External Capacitors Connected to V_{DD}_

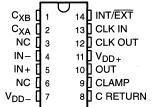
description

The TLC2654 and TLC2654A are low-noise chopper-stabilized operational amplifiers using the Advanced LinCMOS™ process. Combining this process with chopper-stabilization circuitry makes excellent dc precision possible. In addition, circuit techniques are added that give the TLC2654 and TLC2654A noise performance unsurpassed by similar devices.

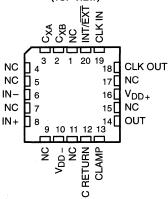
D, JG, OR P PACKAGE (TOP VIEW)



D, J, OR N PACKAGE (TOP VIEW)



FK PACKAGE (TOP VIEW)



NC - No internal connection

AVAILABLE OPTIONS

TA	V _{IO} max AT 25°C	PACKAGED DEVICES							
		8 PIN			14 PIN			20 PIN	CHIP
		SMALL OUTLINE (D)	CERAMIC DIP (JG)	PLASTIC DIP (P)	SMALL OUTLINE (D)	CERAMIC DIP (J)	PLASTIC DIP (N)	CERAMIC DIP (FK)	FORM (Y)
0°C to 70°C	10 μV 20 mV	TLC2654AC-8D TLC2654C-8D	_	TLC2654ACP TLC2654CP	TLC2654AC-14D TLC2654C-14D	<u>-</u>	TLC2654ACN TLC2654CN	<u> </u>	TLC2654Y
-40°C to 85°C	10 μV 20 μV	TLC2654AI-8D TLC2654I-8D	_	TLC2654AIP TLC2654IP	TLC2654AI-14D TLC2654I-14D	_	TLC2654AIN TLC2654IN		_
−55°C to 125°C	10 μV 20 μV	TLC2654AM-8D TLC2654M-8D	TLC2654AMJG TLC2654MJG	TLC2654AMP TLC2654MP	TLC2654AM-14D TLC2654M-14D	TLC2654AMJ TLC2654MJ	TLC2654AMN TLC2654MN	TLC2654AMFK TLC2654MFK	_

The 8-pin and 14-pin D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2654AC-8DR).

Advanced LinCMOS is a trademark of Texas Instruments Incorporated.



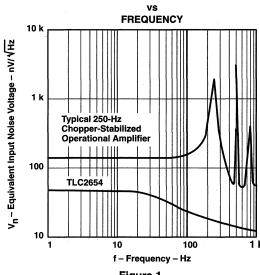
TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

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description (continued)

Chopper-stabilization techniques provide for extremely high dc precision by continuously nulling input offset voltage even during variations in temperature, time, common-mode voltage, and power-supply voltage. The high chopping frequency of the TLC2654 and TLC2654A (see Figure 1) provides excellent noise performance in a frequency spectrum from near dc to 10 kHz. In addition, intermodulation or aliasing error is eliminated from frequencies up to 5 kHz.

This high dc precision and low noise, coupled with the extremely high input impedance of the CMOS input stage, makes the TLC2654 and TLC2654A ideal choices for a broad range of applications such as low-level, low-frequency thermocouple amplifiers and strain gauges and wide-bandwidth and subsonic circuits. For applications requiring even greater dc precision, use the TLC2652 or TLC2652A devices, which have a chopping frequency of 450 Hz.



EQUIVALENT INPUT NOISE VOLTAGE

Figure 1

The TLC2654 and TLC2654A common-mode input voltage range includes the negative rail, thereby providing superior performance in either single-supply or split-supply applications, even at power supply voltage levels as low as ± 2.3 V.

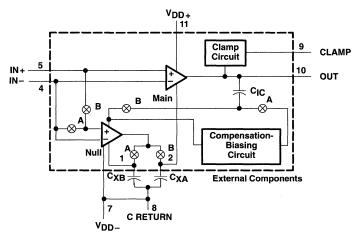
Two external capacitors are required to operate the device; however, the on-chip chopper-control circuitry is transparent to the user. On devices in the 14-pin and 20-pin packages, the control circuitry is accessible, allowing the user the option of controlling the clock frequency with an external frequency source. In addition, the clock threshold of the TLC2554 and TLC2654A requires no level shifting when used in the single-supply configuration with a normal CMOS or TTL clock input.

Innovative circuit techniques used on the TLC2654 and TLC2654A allow exceptionally fast overload recovery time. An output clamp pin is available to reduce the recovery time even further.

The device inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up. In addition, the TLC2654 and TLC2654A incorporate internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015; however, exercise care in handling these devices, as exposure to ESD may result in degradation of the device parametric performance.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from -40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of -55°C to 125°C.

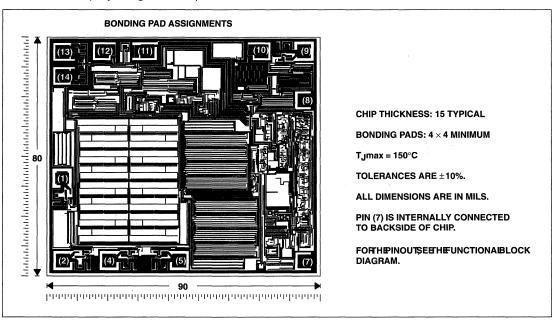
functional block diagram



Pin numbers shown are for the D (14 pin), J, and N packages.

TLC2654Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2654C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	±16 V
Input voltage, V _I (any input, see Note 1)	±8 V
Voltage range on CLK IN and INT/EXT	V _{DD} _ to V _{DD} _ + 5.2 V
Input current, I _I (each input)	±5 mA
Output current, I _O	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Current into CLK IN and INT/EXT	±5 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A : C suffix	0°C to 70°C
I suffix	–40°C to 85°C
M suffix	
Storage temperature range	– 65°C to 150°C
Case temperature for 60 seconds: FK package	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or P pa	ckage 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or JG pack	age 300°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VDD+ and VDD+.

2. Differential voltages are at IN+ with respect to IN-.

The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 85°C POWER RATING	T _A = 125°C POWER RATING
D (8 pin)	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
D (14 pin)	950 mW	7.6 mW/°C	608 mW	494 mW	190 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	230 mW
Р	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

	С	SUFFIX	15	SUFFIX	М	UNIT	
	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.3	±8	±2.3	±8	±2.3	±8	V
Common-mode input voltage, V _{IC}	V _{DD} -	V _{DD+} -2.3	V _{DD} _	V _{DD+} -2.3	V _{DD} _	V _{DD+} -2.3	٧
Clock input voltage	V _{DD} _	V _{DD} _+5	V_{DD-}	V _{DD} _+5	V _{DD} _	V _{DD} _+5	٧
Operating free-air temperature, TA	0	70	-40	85	-55	125	°C

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

	DADAMETED	TEOT 00	NOTIONO	- +	Т	LC26540	;	TL	.C2654A	С	UNIT
	PARAMETER	TEST CO	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		5	20		4	10	μV
VIO	(see Note 4)			Full range			34			24	μν
αΛΙΟ	Temperature coefficient of input offset voltage			Full range		0.01	0.05		0.01	0.05	μV/°C
	Input offset voltage long-term drift (see Note 5)	V _{IC} ≈ 0,	$R_S = 50 \Omega$	25°C		0.003	0.06		0.003	0.02	μV/mo
lio	Input offset current			25°C		30			30		pA
10	input onset current	[Full range			150			150	pΑ
lв	Input bias current]		25°C		50			50		pА
'IB	Input bias current			Full range			150			150	PA.
VICR	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7			-5 to 2.7			٧
	Maximum positive peak	D 4010	0 11 1 0	25°C	4.7	4.8		4.7	4.8		.,
V _{OM+}	output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 6	Full range	4.7			4.7			٧
Vou	Maximum negative peak	B 10 kO	See Note 6	25°C	-4.7	-4.9		-4.7	-4.9		V
VOM-	output voltage swing	H_ = 10 K32,	See Note 6	Full range	-4.7			-4.7			V
AVD	Large-signal differential	Vo = +4 V	R _L = 10 kΩ	25°C	120	155		135	155		dB
7.00	voltage amplification	VO = ± + v,		Full range	120			130			u.b
	Internal chopping frequency			25°C		10			10		kHz
	Clamp on-state current	R _I = 100 kΩ		25°C	25			25			μА
	Olamp on-state current	11L = 100 KS2		Full range	25			25			μΑ
	Clamp off-state current	$V_0 = -4 V t$	0.4 V	25°C			100			100	рA
	Olamp on-state current	10411		Full range			100			100	PΑ
CMRR	Common-mode rejection	V _O = 0, V _{IC} = V _{ICB} n	nin	25°C	105	125		110	125		dB
	ratio	$R_S = 50 \Omega$,	Full range	105			110			
kovp	Supply voltage rejection	V _{DD±} = ±2.3		25°C	110	125		120	125		dB
ksvr	ratio (ΔV _{DD±} /ΔV _{IO})	$V_O = 0$,	$R_S = 50 \Omega$	Full range	110			120			uБ
Inn	Supply current	VO = 0,	No load	25°C		1.5	2.4		1.5	2.4	mA
IDD	oupply cultoni	VO - 0,	140 loau	Full range			2.5			2.5	'''^

† Full range is 0°C to 70°C.

NOTES: 4. This parameter is not production tested full range. Thermocouple effects preclude measurement of the actual V_{IO} of these devices in high-speed automated testing. V_{IO} is measured to a limit determined by the test equipment capability at the temperature extremes. The test ensures that the stabilization circuitry is performing properly.

Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25° using the Arrhenius equation and assuming an activation energy of 0.96 eV.

6. Output clamp is not connected.

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operating characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V

	_									
-,	DADAMETED	TEST	- +	TL	C26540	;]	TL	C2654A	С	
	PARAMETER	CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR+	Desitive alow rate at unity sain		25°C	1.5	2		1.5	2		V/µs
on+	Positive slew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	Full range	1.3			1.3			V/μS
SR-	Negative slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C	2.3	3.7		2.3	3.7		V/μs
3n-	Negative siew rate at unity gain	1-6	Full range	1.7			1.7			V/μS
V	Equivalent input noise voltage	f = 10 Hz	25°C		47			47	75	nV/√Hz
v _n	(see Note 7)	f = 1 kHz	25 0		13			13	20	nv/√Hz
Va.com	Peak-to-peak equivalent input	f = 0 to 1 Hz	25°C		0.5			0.5		μV
V _{N(PP)}	noise voltage	f = 0 to 10 Hz	25 0		1.5			1.5		Ι μν
In	Equivalent input noise current	f = 10 kHz	25°C		0.004			0.004		pA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		48°			48°		

† Full range is 0°C to 70°C.

NOTE 7: This parameter is tested on a sample basis for the TLC2654A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, $V_{DD\,\pm}$ = ±5 V (unless otherwise noted)

	D. D	7707 001171710110	T _ +	1	LC2654		T	_C2654A	d.	
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage		25°C		5	20		4	10	μV
٧١٥	(see Note 4)		Full range			40			30	μ.ν.
ανιο	Temperature coefficient of input offset voltage		Full range		0.01	0.05		0.01	0.05	μV/°C
	Input offset voltage long-term drift (see Note 5)	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.003	0.06		0.003	0.02	μV/mo
l.o	Input offset current	1	25°C		30			30		pА
lio	input onset current		Full range			200			200	pΑ
lв	Input bias current		25°C		50			50		pА
אוי	input bias current		Full range			200			200	PΛ
VICR	Common-mode input voltage range	$R_S = 50 \Omega$	Full range	-5 to 2.7			-5 to 2.7			v
	Maximum positive peak		25°C	4.7	4.8		4.7	4.8		
V _{OM+}	output voltage swing	$R_L = 10 \text{ k}\Omega$, See Note 6	Full range	4.7			4.7			V
1/	Maximum negative peak	D 401-0 0 N-+- (25°C	-4.7	-4.9		-4.7	-4.9		`,,
VOM-	output voltage swing	$R_L = 10 \text{ k}\Omega$, See Note 6	Full range	-4.7			-4.7			٧
AVD	Large-signal differential	VO = ±4 V, RL = 10 ks	25°C	120	155		135	155		dB
^VU	voltage amplification	VO=14 V, H[= 10 K2	Full range	120			125			GD.
	Internal chopping frequency		25°C		10			10		kHz
	Clamp on-state current	R _L = 100 kΩ	25°C	25			25			μА
	Ciamp on-state current	HE = 100 K22	Full range	25			25			μΛ
	Clamp off-state current	$V_{O} = -4 \text{ V to 4 V}$	25°C			100			100	рA
		VO = -4 V 10 4 V	Full range			100			100	PA
OMBB	Common-mode rejection	V _O = 0,	25°C	105	125		110	125		40
CMRR	ratio	V _{IC} = V _{ICR} min, R _S = 50 Ω	Full range	105			110			dB
ksvr	Supply voltage rejection	$V_{DD\pm} = \pm 2.3 \text{ V to } \pm 8 \text{ V},$	25°C	110	125		120	125		dB
	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{O} = 0$, $R_{S} = 50 \Omega$	Full range	110			120			ub
lDD	Supply current	V _O = 0, No load	25°C		1.5	2.4		1.5	2.4	mA
יטט.	Cappily Contonic	1.0 = 0, 140,0au	Full range			2.5			2.5	''"'

†Full range is -40°C to 85°C

NOTES: 4. This parameter is not production tested full range. Thermocouple effects preclude measurement of the actual V_{IO} of these devices in high-speed automated testing. V_{IO} is measured to a limit determined by the test equipment capability at the temperature extremes. The test ensures that the stabilization circuitry is performing properly.

5. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

6. Output clamp is not connected.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS SLOS020D - NOVEMBER 1988 - REVISED AUGUTST 1994

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

_	•		-							
	DADAMETED	TEST		Т	LC2654		TL	.C2654A	NI .	
	PARAMETER	CONDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
SR+	Desitive eleverate at write sain		25°C	1.5	2		1.5	2		1//
on+	Positive slew rate at unity gain	$V_0 = \pm 2.3 \text{ V},$	Full range	1.2			1.2			V/μs
SR-	Negative class sets at units sain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C	2.3	3.7	i	2.3	3.7		1///
SH-	Negative slew rate at unity gain		Full range	1.5			1.5	,		V/μs
V	Equivalent input noise voltage	f = 10 Hz	25°C		47			47	75	->4/5
V _n	(see Note 7)	f = 1 kHz	25°C		13			13	20	nV/√Hz
V	Peak-to-peak equivalent input	f = 0 to 1 Hz	0500		0.5			0.5		
V _{N(PP)}	noise voltage	f = 0 to 10 Hz	25°C		1.5			1.5		μV
In	Equivalent input noise current	f = 10 kHz	25°C		0.004			0.004		pA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz},$ $R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.9			1.9		MHz
φm	Phase margin at unity gain	R _L = 10 kΩ, C _L = 100 pF	25°C		48°			48°		

[†]Full range is -40°C to 85°C.

NOTE 7: This parameter is tested on a sample basis for the TLC2654A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, $V_{DD\,\pm}$ = ±5 V (unless otherwise noted)

	DADAMETED	7507.001	IDITIONO	- +	TI	LC2654	Л	TL	.C2654A	М	UNIT
	PARAMETER	TEST CON	NDITIONS	TAT	MIN	TYP	MAX	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		5	20		4	10	μV
۷۱٥	(see Note 4)			Full range			50			40	μV
αVIO	Temperature coefficient of input offset voltage			Full range		0.01	0.05*		0.01	0.05*	μV/°C
	Input offset voltage long-term drift (see Note 5)	V _{IC} = 0,	R _S = 50 Ω	25°C		0.003	0.06*		0.003	0.02*	μV/mo
lio	Input offset current			25°C		30			30		pА
lo l	input onset current			Full range			500			500	PΑ
lв	Input bias current			25°C		50			50		рA
чв	Input bias current			Full range			500			500	PA
VICR	Common-mode input voltage range	$R_S = 50 \Omega$		Full range	-5 to 2.7			-5 to 2.7			v
	Maximum positive peak	D 4010	0 11 1 0	25°C	4.7	4.8		4.7	4.8		.,
V _{OM+}	output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 6	Full range	4.7			4.7			٧
V	Maximum negative peak	D. 1010	Coo Note C	25°C	-4.7	-4.9		-4.7	-4.9		v
V _{OM} -	output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 6	Full range	-4.7			-4.7			
A	Large-signal differential	V _O = ±4 V,	D: - 10 kO	25°C	120	155		135	155		dB
AVD	voltage amplification	VO = ±4 V,	UL = 10 K22	Full range	120			120			ub
	Internal chopping frequency			25°C		10			10		kHz
	Clamp on atota aurrent	D. 100 kg		25°C	25			25			
	Clamp on-state current	$R_L = 100 \text{ k}\Omega$		Full range	25			25	*****		μΑ
	Clamp off state ourrent	V∩ = −4 V to	. 4 \/	25°C			100			100	pA
	Clamp off-state current	VO = -4 V (C) 4 V	Full range			500			500	PA
CMRR	Common-mode rejection	V _O = 0,	in	25°C	105	125		110	125		dB
JWII IIT	ratio	$V_{IC} = V_{ICRm}$ R _S = 50 Ω		Full range	105			110			ub
ksvr	Supply voltage rejection	$V_{DD\pm} = \pm 2.3$	V to ± 8 V,	25°C	110	125		120	125		dB
"SVH	ratio (ΔV _{DD±} /ΔV _{IO})	$V_{O} = 0$,	$R_S = 50 \Omega$	Full range	105			115			45
lDD	Supply current	V _O = 0,	No load	25°C		1.5	2.4		1.5	2.4	mA
יטט.		10-0,	140 1000	Full range			2.5			2.5	111/2

^{*} On products complaint to MIL-STD-883, Class B, this parameter is not production tested.

NOTES: 4. This parameter is not production tested full range. Thermocouple effects preclude measurement of the actual V_{IO} of these devices in high-speed automated testing. V_{IO} is measured to a limit determined by the test equipment capability at the temperature extremes. The test ensures that the stabilization circuitry is performing properly.

- 5. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.
- 6. Output clamp is not connected.

[†] Full range is -55°C to 125°C.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS SLOS020D - NOVEMBER 1988 - REVISED AUGUTST 1994

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

	PARAMETER	PARAMETER TEST CONDITIONS			C2654M C2654AI		UNIT
			TAT	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain		25°C	1.5	2		V/µs
on+	Positive siew rate at unity gain	$V_{\Omega} = \pm 2.3 \text{ V}, R_{\parallel} = 10 \text{ k}\Omega, C_{\parallel} = 100 \text{ pF}$	Full range	1.1		- '	V/μS
SR-	No gative class rate at units rain	1 VO = ±2.3 V, HL = 10 K12, CL = 100 PF	25°C	2.3	3.7		1////
3n-	Negative slew rate at unity gain		Full range	1.3			V/μs
	Facilitation of paint value	f = 10 Hz	25°C		47		nV/√Hz
V _n	Equivalent input noise voltage	f = 1 kHz	25°C		13		ΠV/VHZ
	Peak-to-peak equivalent input	f = 0 to 1 Hz	25°C		0.5		
V _{N(PP)}	noise voltage	f = 0 to 10 Hz	25°C		1.5		μV
In	Equivalent input noise current	f = 1 kHz	25°C		0.004		pA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°		

[†] Full range is -55°C to 125°C.

TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS SLOS020D - NOVEMBER 1988 - REVISED AUGUTST 1994

electrical characteristics, $V_{DD\pm}$ = ± 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEST COND	UTIONS	T	LC2654Y	7	UNIT
	PARAMETER	TEST COND	ITIONS	MIN	TYP	MAX	UNIT
V _{IO}	Input offset voltage (see Note 4)				5	20	μV
	Input offset voltage long-term drift (see Note 5)	1,,	D- 500		0.003	0.06	μV/mo
IЮ	Input offset current	VIC = 0,	$R_S = 50 \Omega$		30		pА
I _{IB}	Input bias current				50		pΑ
VICR	Common-mode input voltage range	R _S = 50 Ω		-5 to 2.7			٧
V _{OM+}	Maximum positive peak output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 5	4.7	4.8		٧
V _{OM} -	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$,	See Note 5	-4.7	-4.9		٧
AVD	Large-signal differential voltage amplification	$V_0 = \pm 4 V$,	$R_L = 10 \text{ k}\Omega$	120	155		dB
fch	Internal chopping frequency				10		Hz
	Clamp on-state current	$R_L = 100 \text{ k}\Omega$		25			μΑ
	Clamp off-state current	$V_0 = -4 \text{ V to } 4 \text{ V}$				100	pА
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	V _O = 0,	105	125		dB
ksvr	Supply voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	$V_{DD\pm} = \pm 2.3 \text{ V to}$ $V_{O} = 0$,	±8 V, R _S = 50 Ω	110	125		dB
lDD	Supply current	$V_{O} = 0$,	No load		1.5	2.4	mA

NOTES: 4. This parameter is not production tested full range. Thermocouple effects preclude measurement of the actual V_{IO} of these devices in high-speed automated testing. V_{IO} is measured to a limit determined by the test equipment capability at the temperature extremes. The test ensures that the stabilization circuitry is performing properly.

5. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to TA = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

operating characteristics, $V_{DD\pm}$ = ±5 V, T_A = 25°C

	PARAMETER	TEST CONDITIONS		TLC2654	1	UNIT
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	$V_O = \pm 2.3 \text{ V}, \qquad R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	1.5	2		V/μs
SR-	Negative slew rate at unity gain	CL = 100 pF	2.3	3.7		V/μs
V	Equivalent input noise voltage	f = 10 Hz		47		nV/√ Hz
V _n	Equivalent input noise voltage	f = 1 kHz		13		nv/v⊓z
V	Peak-to-peak equivalent input noise voltage	f = 0 to 1 Hz		0.5		μV
V _{N(PP)}	reak-to-peak equivalent input noise voitage	f = 0 to 10 Hz		1.5		μν
In	Equivalent input noise current	f = 1 kHz		0.004		pA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, \qquad R_L = 10 \text{ k}\Omega, \\ C_L = 100 \text{ pF}$		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		48°		

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	1
	Normalized input offset voltage	vs Chopping frequency	2
lio	Input offset current	vs Chopping frequency vs Free-air temperature	3 4
lв	Input bias current	vs Common-mode input voltage vs Chopping frequency vs Free-air temperature	5 6 7
	Clamp current	vs Output voltage	8
V _{OM}	Maximum peak output voltage swing	vs Output current vs Free-air temperature	9 10
V _{O(PP)}	Maximum peak-to-peak output voltage swing	vs Frequency	11
CMRR	Common-mode rejection ratio	vs Frequency	12
AVD	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	13 14
	Chopping frequency	vs Supply voltage vs Free-air temperature	15 16
lDD	Supply current	vs Supply voltage vs Free-air temperature	17 18
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	19 20
SR	Slew rate	vs Supply voltage vs Free-air temperature	21 22
	Pulse response	Small signal Large signal	23 24
V _{N(PP)}	Peak-to-peak input noise voltage	vs Chopping frequency	25, 26
Vn	Equivalent input noise voltage	vs Frequency	27
ksvr	Supply voltage rejection ratio	vs Frequency	28
	Gain-bandwidth product	vs Supply voltage vs Free-air temperature	29 30
φm	Phase margin	vs Supply voltage vs Load capacitance	31 32
	Phase shift	vs Frequency	13

TYPICAL CHARACTERISTICS[†]

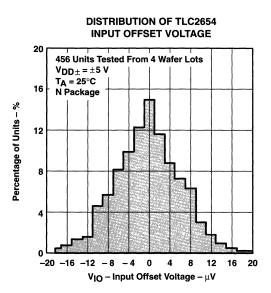
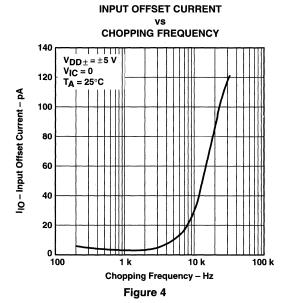


Figure 2



NORMALIZED INPUT OFFSET VOLTAGE
vs

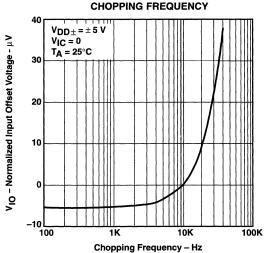
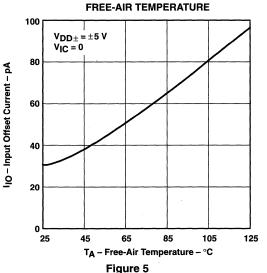


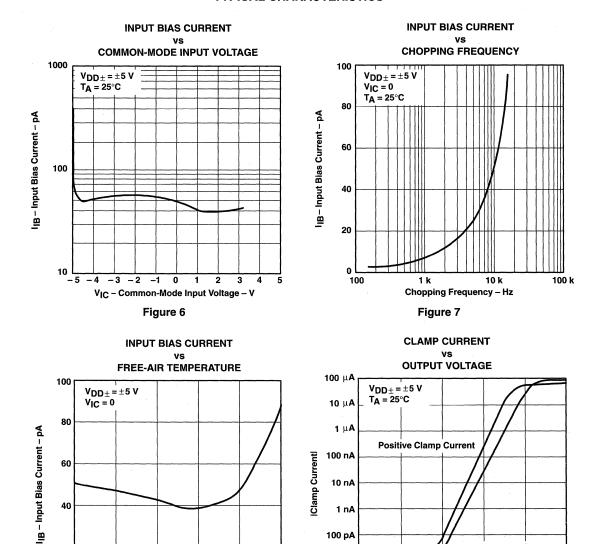
Figure 3

INPUT OFFSET CURRENT vs



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.





†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

125



10 pA

Negative Clamp Current

4.8

5

4.4

Figure 9

IVOI - Output Voltage - V

20

0

25

45

85

T_A – Free-Air Temperature – °C Figure 8

105

TYPICAL CHARACTERISTICS†

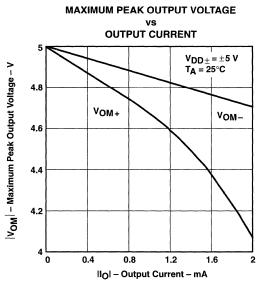


Figure 10

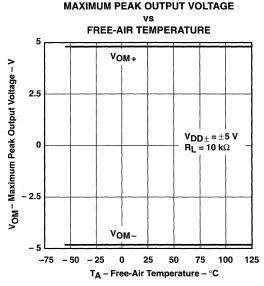
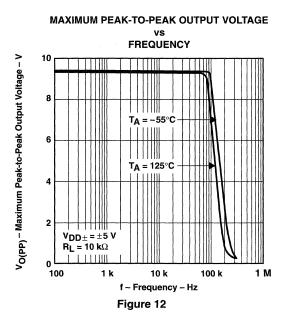


Figure 11

COMMOM-MODE REJECTION RATIO



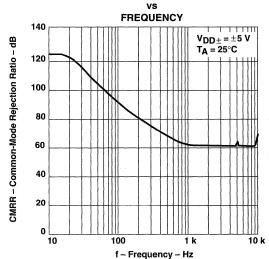


Figure 13

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE **AMPLIFICATION AND PHASE SHIFT** vs **FREQUENCY** A_{VD} - Large-Signal Differential Voltage Amplification - dB 60° 120 100 80° **Phase Shift** 80 100° Avd 60 120° Phase Shift 40 140° 20 160° 0 V_{DD±} = ±5 V 1809 $R_L = 10 \text{ k}\Omega$ C_L = 100 pF -20 200° T_A = 25°C 220° 100 10 M 10 1 k 10 k 100 k 1 M f - Frequency - Hz

Figure 14

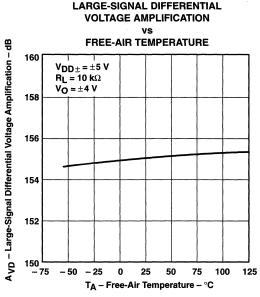
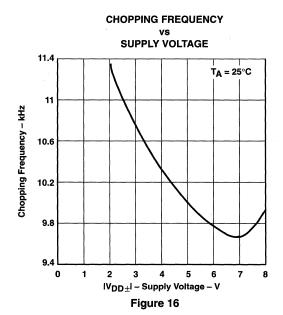
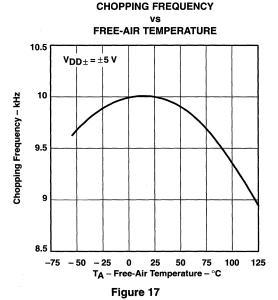


Figure 15

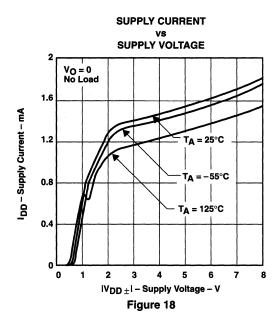




[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

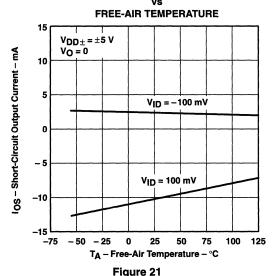


TYPICAL CHARACTERISTICS†

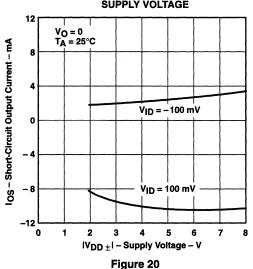


SUPPLY CURRENT vs FREE-AIR TEMPERATURE $V_{DD\pm} = \pm 7.5 \text{ V}$ 1.6 $V_{DD\pm} = \pm 5 V$ IDD - Supply Current - mA 1.2 $V_{DD\pm} = \pm 2.5 \text{ V}$ 8.0 0.4 V_O = 0 No Load -75 - 50 - 25 0 25 75 100 50 TA - Free-Air Temperature - °C Figure 19

SHORT-CIRCUIT OUTPUT CURRENT SUPPLY VOLTAGE 12 Vo = 0 TA = 25°C



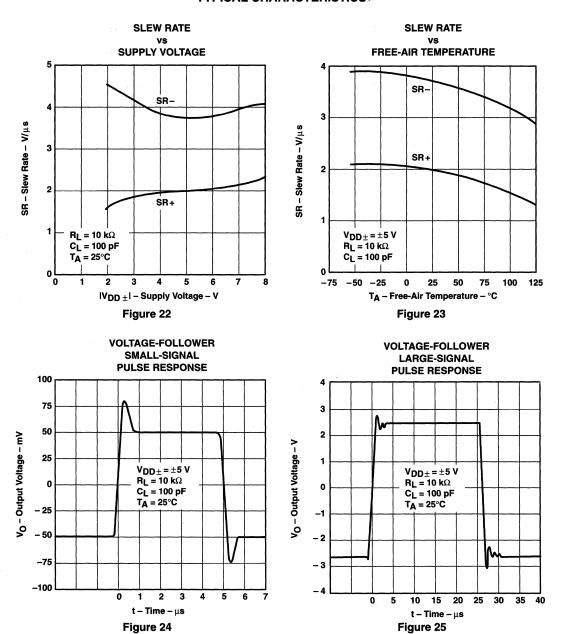
SHORT-CIRCUIT OUTPUT CURRENT



[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†



[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



PEAK-TO-PEAK INPUT NOISE VOLTAGE

TYPICAL CHARACTERISTICS

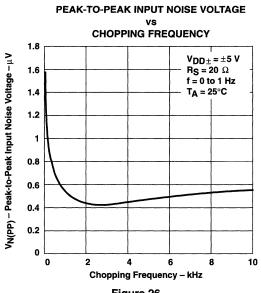


Figure 26

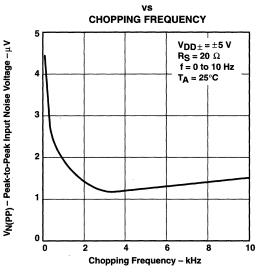
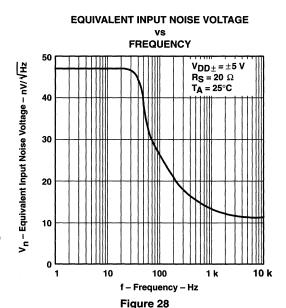


Figure 27



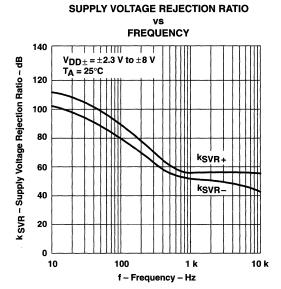
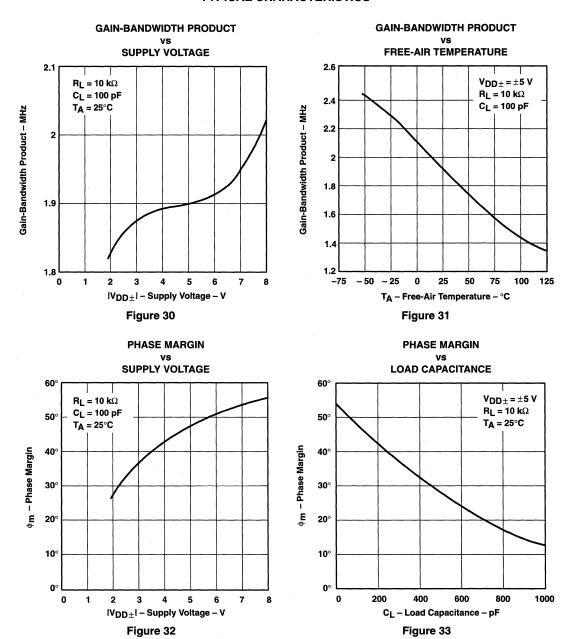


Figure 29

TYPICAL CHARACTERISTICS[†]



[†]Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



APPLICATION INFORMATION

capacitor selection and placement

Leakage and dielectric absorption are the two important factors to consider when selecting external capacitors C_{XA} and C_{XB} . Both factors can cause system degradation, negating the performance advantages realized by using the TLC2654.

Degradation from capacitor leakage becomes more apparent with increasing temperatures. Low-leakage capacitors and standoffs are recommended for operation at $T_A = 125^{\circ}C$. In addition, guard bands are recommended around the capacitor connections on both sides of the printed-circuit board to alleviate problems caused by surface leakage on circuit boards.

Capacitors with high dielectric absorption tend to take several seconds to settle upon application of power, which directly affects input offset voltage. In applications needing fast settling of input voltage, high-quality film capacitors such as mylar, polystyrene, or polypropylene should be used. In other applications, a ceramic or other low-grade capacitor can suffice.

Unlike many choppers available today, the TLC2654 is designed to function with values of C_{XA} and C_{XB} in the range of 0.1 μ F to 1 μ F without degradation to input offset voltage or input noise voltage. These capacitors should be located as close as possible to C_{XA} and C_{XB} and return to either V_{DD-} or C RETURN. On many choppers, connecting these capacitors to V_{DD-} causes degradation in noise performance; this problem is eliminated on the TLC2654.

internal/external clock

The TLC2654 has an internal clock that sets the chopping frequency to a nominal value of 10 kHz. On 8-pin packages, the chopping frequency can only be controlled by the internal clock; however, on all 14-pin packages and the 20-pin FK package the device chopping frequency can be set by the internal clock or controlled externally by use of the INT/EXT and CLK IN. To use the internal 10-kHz clock, no connection is necessary. If external clocking is desired, connect INT/EXT to V_{DD} and the external clock to CLK IN. The external clock trip point is 2.5 V above the negative rail; however, CLK IN can be driven from the negative rail to 5 V above the negative rail. This allows the TLC2654 to be driven directly by 5-V TTL and CMOS logic when operating in the single-supply configuration. If this 5-V level is exceeded, damage could occur to the device unless the current

into CLK IN is limited to ± 5 mA. A divide-by-two frequency divider interfaces with CLK IN and sets the chopping frequency. The chopping frequency appears on CLK OUT.

overload recovery/output clamp

When large differential-input-voltage conditions are applied to the TLC2654, the nulling loop attempts to prevent the output from saturating by driving C_{XA} and C_{XB} to internally-clamped voltage levels. Once the overdrive condition is removed, a period of time is required to allow the built-up charge to dissipate. This time period is defined as overload recovery time (see Figure 34). Typical overload recovery time for the TLC2654 is significantly faster than competitive products; however, this time can be reduced further by use of internal clamp circuitry accessible through CLAMP if required.

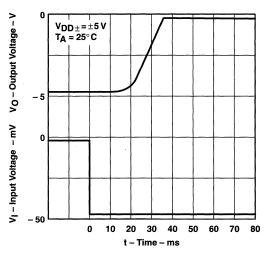


Figure 34. Overload Recovery



TLC2654, TLC2654A, TLC2654Y Advanced LinCMOS™ LOW-NOISE CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS

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APPLICATION INFORMATION

overload recovery/output clamp (continued)

The clamp is a switch that is automatically activated when the output is approximately 1 V from either supply rail. When connected to the inverting input (in parallel with the closed-loop feedback resistor), the closed-loop gain is reduced and the TLC2654 output is prevented from going into saturation. Since the output must source or sink current through the switch (see Figure 9), the maximum output voltage swing is slightly reduced.

thermoelectric effects

To take advantage of the extremely low offset voltage temperature coefficient of the TLC2654, care must be taken to compensate for the thermoelectric effects present when two dissimilar metals are brought into contact with each other (such as device leads being soldered to a printed-circuit board). It is not uncommon for dissimilar metal junctions to produce thermoelectric voltages in the range of several microvolts per degree Celsius (orders of magnitude greater than the 0.01 μV/°C typical of the TLC2654).

To help minimize thermoelectric effects, pay careful attention to component selection and circuit-board layout. Avoid the use of nonsoldered connections (such as sockets, relays, switches, etc.) in the input signal path. Cancel thermoelectric effects by duplicating the number of components and junctions in each device input. The use of low-thermoelectric-coefficient components, such as wire-wound resistors, is also beneficial.

latch-up avoidance

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC2654 inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques to reduce the chance of latch-up should be used whenever possible. Internal protection diodes should not, by design, be forward biased. Applied input and output voltages should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be stunted by the use of decoupling capacitors (0.1 µF typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the supply rails and is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor. The chance of latch-up occurring increases with increasing temperature and supply voltage.

electrostatic-discharge protection

The TLC2654 incorporates internal ESD-protection circuits that prevent functional failures at voltages at or below 2000 V. Care should be exercised in handling these devices, as exposure to ESD may result in degradation of the device parametric performance.

theory of operation

Chopper-stabilized operational amplifiers offer the best dc performance of any monolithic operational amplifier. This superior performance is the result of using two operational amplifiers - a main amplifier and a nulling amplifier - plus oscillator-controlled logic and two external capacitors to create a system that behaves as a single amplifier. With this approach, the TLC2654 achieves submicrovolt input offset voltage, submicrovolt noise voltage, and offset voltage variations with temperature in the nV/°C range.

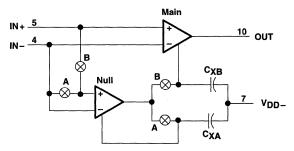
The TLC2654 on-chip control logic produces two dominant clock phases: a nulling phase and an amplifying phase. The term chopper-stabilized derives from the process of switching between these two clock phases. Figure 35 shows a simplified block diagram of the TLC2654. Switches A and B are make-before-break types.



APPLICATION INFORMATION

theory of operation (continued)

During the nulling phase, switch A is closed, shorting the nulling amplifier inputs together and allowing the nulling amplifier to reduce its own input offset voltage by feeding its output signal back to an inverting input node. Simultaneously, external capacitor C_{XA} stores the nulling potential to allow the offset voltage of the amplifier to remain nulled during the amplifying phase.



Pin numbers shown are for the D (14 pin), J, and N packages.

Figure 35. TLC2654 Simplified Block Diagram

During the amplifying phase, switch B is closed, connecting the output of the nulling amplifier to a noninverting input of the main amplifier. In this configuration, the input offset voltage of the main amplifier is nulled. Also, external capacitor C_{XB} stores the nulling potential to allow the offset voltage of the main amplifier to remain nulled during the next nulling phase.

This continuous chopping process allows offset voltage nulling during variations in time and temperature and over the common-mode input voltage range and power supply range. In addition, because the low-frequency signal path is through both the null and main amplifiers, extremely high gain is achieved.

The low-frequency noise of a chopper amplifier depends on the magnitude of the component noise prior to chopping and the capability of the circuit to reduce this noise while chopping. The use of the Advanced LinCMOS process, with its low-noise analog MOS transistors and patent-pending input stage design, significantly reduces the input noise voltage.

The primary source of nonideal operation in chopper-stabilized amplifiers is error charge from the switches. As charge imbalance accumulates on critical nodes, input offset voltage can increase especially with increasing chopping frequency. This problem has been significantly reduced in the TLC2654 by use of a patent-pending compensation circuit and the Advanced LinCMOS process.

The TLC2654 incorporates a feed-forward design that ensures continuous frequency response. Essentially, the gain magnitude of the nulling amplifier and compensation network crosses unity at the break frequency of the main amplifier. As a result, the high-frequency response of the system is the same as the frequency response of the main amplifier. This approach also ensures that the slewing characteristics remain the same during both the nulling and amplifying phases.

The primary limitation on ac performance is the chopping frequency. As the input signal frequency approaches the chopper's clock frequency, intermodulation (or aliasing) errors result from the mixing of these frequencies. To avoid these error signals, the input frequency must be less than half the clock frequency. Most choppers available today limit the internal chopping frequency to less than 500 Hz in order to eliminate errors due to the charge imbalancing phenomenon mentioned previously. However, to avoid intermodulation errors on a 500-Hz chopper, the input signal frequency must be limited to less than 250 Hz.

APPLICATION INFORMATION

theory of operation (continued)

The TLC2654 removes this restriction on ac performance by using a 10-kHz internal clock frequency. This high chopping frequency allows amplification of input signals up to 5 kHz without errors due to intermodulation and greatly reduces low-frequency noise.

THERMAL INFORMATION

temperature coefficient of input offset voltage

Figure 36 shows the effects of package-included thermal EMF. The TLC2654 can null only the offset voltage within its nulling loop. There are metal-to-metal junctions outside the nulling loop (bonding wires, solder joints, etc.) that produce EMF. In Figure 36, a TLC2654 packaged in a 14-pin plastic package (N package) was placed in an oven at 25°C at t=0, biased up, and allowed to stabilize. At t=3 min, the oven was turned on and allowed to rise in temperature to 125°C. As evidenced by the curve, the overall change in input offset voltage with temperature is less than the specified maximum limit of 0.05 μ V/°C.

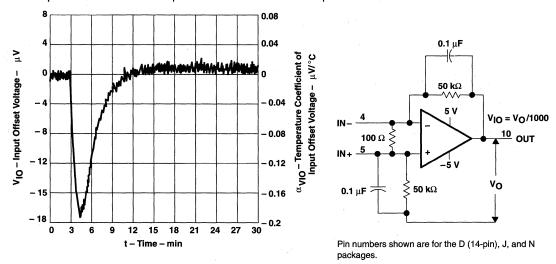


Figure 36. Effects of Package-Induced Thermal EMF

TLC2801Z, TLC2801Y Advanced LinCMOS™ LOW-NOISE PRECISION OPERATIONAL AMPLIFIERS

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- Low Input Noise Voltage:
 35 nV/√Hz Max at f = 10 Hz
 15 nV/√Hz Max at f = 1 kHz
- Low Input Offset Voltage:
 500 μV Max at T_A = 25°C
 1.5 mV Max at T_A = Full Range
- Excellent Offset Voltage Stability With Temperature . . . 4 μV/°C Typ

description

The TLC2801 is a precision, low-noise operational amplifier manufactured using Texas Instruments Advanced LinCMOS™ process. The TLC2801 combines the noise performance of the lowest-noise JFET amplifiers with the dc precision available previously only in bipolar amplifiers. The Advanced LinCMOS™ process uses silicon-gate technology to obtain input offset voltage stability with temperature and time that far exceeds that obtainable using metal-gate technology. In addition, this technology makes possible input impedance levels that meet or exceed levels offered by top-gate JFET and expensive dielectric-isolated devices.

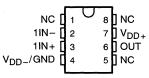
The combination of excellent dc and noise performance with a common-mode input voltage range that includes the negative rail makes the TLC2801 an ideal choice for high-impedance, low-level signal conditioning applications in either single-supply or split-supply configurations.

The device inputs and output are designed to withstand -100-mA surge currents without sustaining latch-up. In addition, internal ESD-protection circuits prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

The TLC2801 is characterized for operation over the temperature range of -40°C to 150°C.

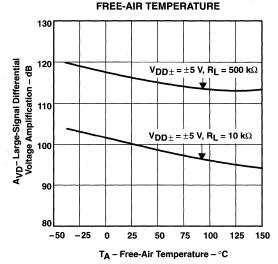
- Low Input Bias Current:
 1 pA Typ at T_A = 25°C
 250 pA Typ at T_A = 150°C
- Specified for Both Single-Supply and Split-Supply Operation
- Common-Mode Input Voltage Range Includes the Negative Rail

D OR P PACKAGE (TOP VIEW)



NC - No internal connection

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs



AVAILABLE OPTIONS

	V	PACKAGED DEVICES			
TA	V _{IO} max AT 150°C	SMALL OUTLINE (D)			
-40°C to 150°C	1.5 mV	TLC2801ZD	TLC2801ZP	TLC2801Y	

The D packages are available taped and reeled. Add R suffix to the device type when ordering (e.g., TLC2801ZDR).

Advanced LinCMOS is a trademark of Texas Instruments Incorporated.

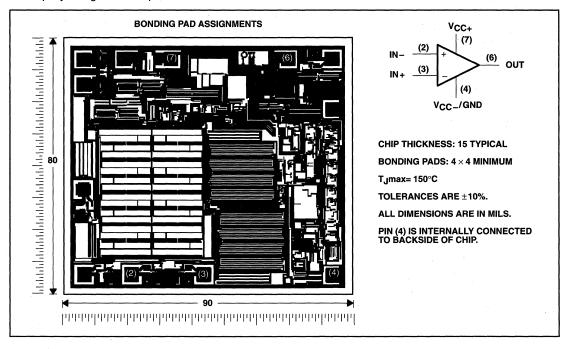


TLC2801Z, TLC2801Y Advanced LinCMOS™ LOW-NOISE PRECISION OPERATIONAL AMPLIFIERS

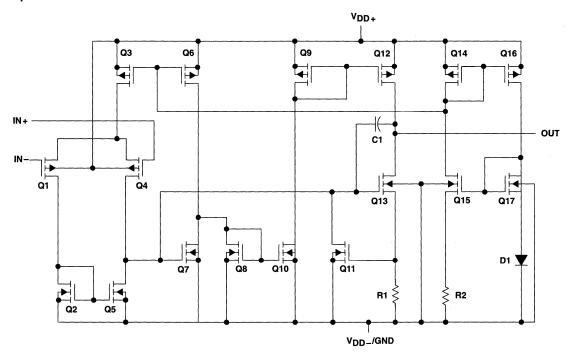
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TLC2801Y chip information

This chip, properly assembled, displays characteristics similar to the TLC2801. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic



TLC2801Z, TLC2801Y Advanced LinCMOS™ LOW-NOISE PRECISION OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+} (see Note 1)	8 V
Supply voltage, V _{DD} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input, see Note 1)	$\dots \dots \pm 8 \ V$
Input current, I ₁ (each input)	±5 mA
Output current, IO	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Operating free-air temperature range, T _A	40°C to 150°C
Storage temperature range	65°C to 175°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between VDD± and VDD—.
 - 2. Differential voltages are at the noninverting input with respect to the inverting point.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.3	±8	٧
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} -2.3	٧
Operating free-air temperature, TA	-40	150	°C

TLC2801Z, TLC2801Y Advanced LinCMOS™ LOW-NOISE PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

PARAMETER		TEST	ONDITIONS	- +	TLC2801Z			UNIT
	PARAMETER	IESIC	ONDITIONS	T _A †	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		100	500	μV
VIO	input onset voltage	1		Full range			1500	μν
^α VIO	Temperature coefficient of input offset voltage			-55°C to 150°C		4		μV/°C
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		0.001	0.005	μV/mo
lio.	Input offset current			25°C		0.5		pА
10	input onset current	j					3	nA
lв	Input bias current					1		pА
אוי –	input bias current			Full range			30	nA
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω		Full range	-5 to 2.7		:	V
1/	Manian un anisia anna la suma de al la suma de la suma				4.7	4.8		V
VOM+	Maximum positive peak output voltage swing	D. 1010		Full range	4.5			V
V0.4	Maximum negative peak output voltage swing	$R_L = 10 \text{ k}\Omega$		25°C	-4.7	-4.9		V
VOM-	Maximum negative peak output voitage swing			Full range	-4.5			V
		$V_{O} = \pm 4 \text{ V},$	R _I = 500 kΩ	25°C	300	460		
A	Large-signal differential voltage amplification	VO = ±4 V,	nt = 500 ks2	Full range	100			V/mV
AVD	Large-signal differential voltage amplification	Vo = +4 V	R _I = 10 kΩ	25°C	50	100		V/IIIV
		VO = ±4 V,	$V_O = \pm 4 \text{ V}, R_L = 10 \text{ k}\Omega$		15			
CMRR	Common-mode rejection ratio	$V_{O} = 0$,	V _{IC} = V _{ICR} min,	25°C	90	115		dB
Civiliti				Full range	85			ub
ksvr	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	VDD = +23	$V_{DD+} = \pm 2.3 \text{ V to } \pm 8 \text{ V}$		90	110		dB
"SVH		*DD±-±2.0	· 10 ± 0 v	Full range	85			ub
IDD	Supply current	Vo = 0	No load	25°C		1.1	1.5	mA
טט.	cappy canon	1.0 - 0,	$V_O = 0$, No load				1.5	111/5

operating characteristics at specified free-air temperature, $V_{DD\pm}$ = $\pm 5~V$

PARAMETER		TEST CONDITIONS	T - +	TLC2801Z			UNIT
	PARAMETER	1EST CONDITIONS	TA [†]	MIN	TYP	MAX	UNIT
SR	Slew rate unity gain	$V_0 = \pm 2.3 \text{ V}, R_L = 10 \text{ k}\Omega,$	25°C	2	2.7		V/μs
on	Siew rate unity gain	$C_L = 100 \text{ pF}$	Full range	1			
V	Equivalent input noise voltage	f = 10 Hz	25°C		18	35	->1//
Vn	Equivalent input noise voltage	f = 1 kHz	7 250		8	15	nV/√Hz
V	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.5		
V _{N(PP)}	reak-to-peak equivalent input hoise voltage	f = 0.1 to 10 Hz	25 0		0.7		μV
In	Equivalent input noise current		25°C		0.6		fA/√Hz
	Gain-bandwidth product	f = 10 kHz, R_L = 10 k Ω , C_L = 100 pF	25°C		1.9		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		48°		

[†] Full range is -40°C to 150°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC2801Z, TLC2801Y Advanced LinCMOS™ LOW-NOISE PRECISION OPERATIONAL AMPLIFIERS SLOS116B - JULY 1982 - REVISED SEPTEMBER 1996

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST COMPLIANCE	T	TLC2801Z			LIAUT
Ì	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNIT
V	land offert wells are		25°C		100	500	
VIO	Input offset voltage		Full range			1500	μV
αVIO	Temperature coefficient of input offset voltage		Full range		4		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.001	0.005	μV/mo
li o	Input offset current	$V_{IC} = 0$, $R_S = 50 \Omega$	25°C		0.5		рA
lo	input offset current		Full range			3	PΑ
lin	Input bias current		25°C		1		pА
lВ	input bias current		Full range			30	PΛ
V _{ICR}	Common-mode input voltage range	R _S = 50 Ω	Full range	-5 to 2.7			٧
	Management I and I am I am I am I am I am I am I am I a		25°C	4.7	4.8		
VOH	Maximum high-level output voltage	D. 1010	Full range	4.4			v
Vai	Maximum law lavel output voltage	$R_L = 10 \text{ k}\Omega$	25°C		0	50	mV
VOL	Maximum low-level output voltage		Full range			50	1110
		V _O = 1 V to 4 V,	25°C	150	315		
AVD	Large-signal differential voltage amplification	$R_L = 500 \text{ k}\Omega$	Full range	50			V/mV
	Large-signal differential voltage amplification	V _O = 1 V to 4 V,	25°C	25	55		V/111V
		$R_L = 10 \text{ k}\Omega$	Full range	5			
CMBB	Common-mode rejection ratio	V _O = 0, V _{IC} = V _{ICR} min,	25°C	90	110		dB
Civil ii i	Common-mode rejection ratio	$R_S = 50 \Omega$	Full range	85			· ub
ksvr	Supply-voltage rejection ratio (ΔV _{DD+} /ΔV _{IO})	V _{DD} = 4.6 V to 16 V	25°C	90	110		dB
"OVH	Supply voilings rojourin ratio (AvDD±/AvIO)	VDD = 4.5 V 15 16 V	Full range	85			
IDD	Supply current	$V_{O} = 0$, No load	25°C		1.1	1.5	mA
יטט.	Supply Sulfolit	170 - 0, 110 1044	Full range			1.5	

operating characteristics at specified free-air temperature, $V_{DD} = 5 V$

PARAMETER		TEST CONDITIONS	- +	TLC2801Z			UNIT
	PARAMETER	TEST CONDITIONS	T _A †	MIN	TYP	MAX	UNIT
SR	Slew rate unity gain	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	25°C	1.8	2.5		V/μs
Jon	Siew rate unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	Full range	0.8			V/μS
V Fourier land to produce well-see		f = 10 Hz	25°C		18	35	->4/57=
Vn	Equivalent input noise voltage	f = 1 kHz	25°C		8	15	nV/√Hz
V	Dook to most againstant input paige valtage	f = 0.1 to 1 Hz	25°C		0.5		
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	25°C		0.7		μV
In	Equivalent input noise current		25°C		0.6		fA/√Hz
	Gain-bandwidth product	$f = 10 \text{ kHz}, \qquad R_L = 10 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	25°C		1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	25°C		45°		

[†] Full range is -40°C to 150°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TLC2801Z			
		l ESI CO	RUITIONS	MIN	TYP	MAX	UNIT
VIO	Input offset voltage				100	500	μV
	Input offset voltage long-term drift (see Note 4)	V 0	l., <u> </u>		0.001	0.005	μV/mo
10	Input offset current	$V_{IC}=0$, $R_S=50 \Omega$			0.5		pА
Iв	Input bias current		ľ		1		pА
VICR	Common-mode input voltage range	R _S = 50 Ω	R _S = 50 Ω	0 to 2.7			V
Vон	Maximum high-level output voltage	R _L = 10 kΩ	R _L = 10 kΩ	4.7	4.8		٧
VOL	Maximum low-level output voltage	IO = 0	IO = 0		0	50	mV
A	Large-signal differential voltage amplification	$V_0 = 1 \text{ V to 4 V},$	R _L = 500 kΩ	150	315		V/mV
AVD	Large-signal differential voltage amplification	$V_O = 1 \text{ V to 4 V},$	R _L = 10 kΩ	25	55		
CMRR	Common-mode rejection ratio	$V_O = 0$, $R_S = 50 \Omega$	$V_{IC} = V_{ICR}^{min}$, R _S = 50 Ω	90	110		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	$V_{DD} = 4.6 \text{ V to } 16 \text{ V}$	V _{DD} = 4.6 V to 16 V	90	110		dB
IDD	Supply current	$V_O = 2.5 \text{ V},$	No load		1	1.5	mA

operating characteristics at $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

PARAMETER		TEST CONDITIONS		TLC2801Z			UNIT
	PARAMEIER	TEST CONDITI	IONS	MIN	TYP	MAX	UNII
SR	Positive slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V}, R$ $C_L = 100 \text{ pF}$	L = 10 kΩ,	1.8	2.5		V/µs
Vn Equivalent input noise voltage		f = 10 Hz			18		
		f = 1 kHz		8			nV/√Hz
V2.455	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz			0.5		μV
V _N (PP)		f = 0.1 to 10 Hz			0.7		μν
l _n	Equivalent input noise current				0.6		pA/√Hz
	Gain-bandwidth product	f = 10 kHz, R C _L = 100 pF	L = 10 kΩ,		1.8		MHz
φm	Phase margin at unity gain	$R_L = 10 kΩ$, C	L = 100 pF		45°		

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at TA = 150°C extrapolated to $T_A = 25$ °C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

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PARAMETER MEASUREMENT INFORMATION

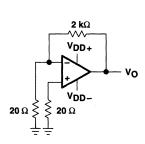
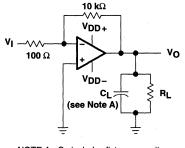
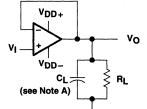


Figure 1. Noise-Voltage Test Circuit



NOTE A: C_L includes fixture capacitance. Figure 2. Phase-Margin Test Circuit



NOTE A: C₁ includes fixture capacitance.

Figure 3. Slew-Rate Test Circuit

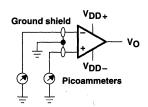


Figure 4. Input-Bias and Offset-Current Test Circuit

typical values

Typical values as presented in this data sheet represents the median (50% point) of device parametric performance.

input bias and offset current

At the picoamp bias-current level typical of the TLC2801, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltage applied but with no device in the socket. The device is then inserted in the socket and a second test measuring both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

Table of Graphs

			FIGURE
Iв	Input bias current	vs Free-air temperature	5
Vом	Maximum peak output voltage	vs Free-air temperature	6
Vон	High-level output voltage	vs Free-air temperature	7
VOL	Low-level output voltage	vs Free-air temperature	8
AVD	Differential voltage amplification	vs Free-air temperature	9
los	Short-circuit output current	vs Free-air temperature	10
IDD	Supply current	vs Free-air temperature	11
SR	Slew rate	vs Free-air temperature	12
	Gain-bandwidth product	vs Free-air temperature	13

INPUT BIAS CURRENT

FREE-AIR TEMPERATURE

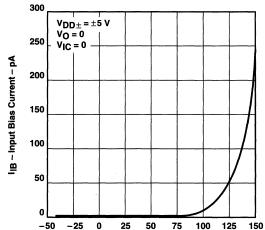


Figure 5

T_A - Free-Air Temperature - °C

-50

MAXIMUM PEAK OUTPUT VOLTAGE

FREE-AIR TEMPERATURE

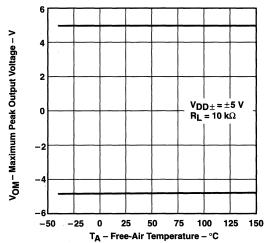
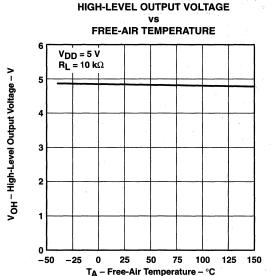


Figure 6

150



V_{OL} - Low-Level Output Voltage - V

LOW-LEVEL OUTPUT VOLTAGE FREE-AIR TEMPERATURE 1.5 $V_{DD} = 5 V$ IOL = 5 mA 0.5 IOL = 1 mA -50 -25 25 50 75 100

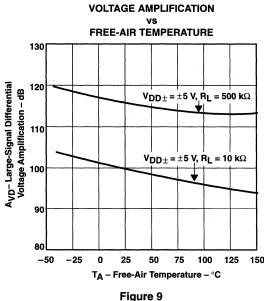
Figure 7

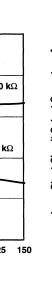
LARGE-SIGNAL DIFFERENTIAL

Figure 8

TA - Free-Air Temperature - °C

125 150





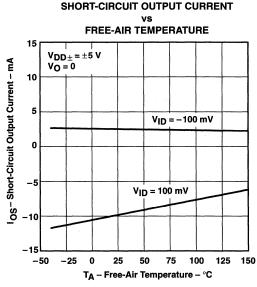
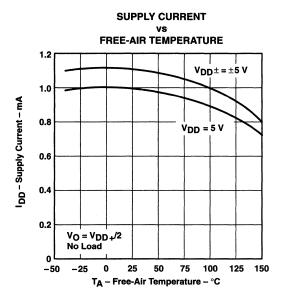


Figure 10



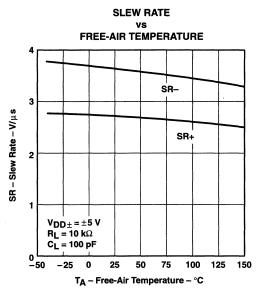
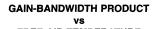


Figure 11

Figure 12



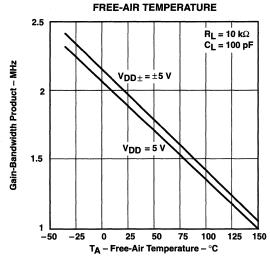


Figure 13

TLC2810Z, TLC2810Y LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIE

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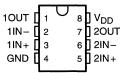
- **Trimmed Input Offset Voltage:** 10 mV Max at 25°C, V_{DD} = 5 V
- Input Offset Voltage Drift Typically 0.1 μV/Month, Including the First 30 Days
- Wide Range of Supply Voltages Over Specified Temperature Range: -40°C to 150°C . . . 4 V to 16 V
- **Single-Supply Operation**
- Common-Mode Input Voltage Range Extends to the Negative Rail

description

The TLC2810Z dual operational amplifiers combine low offset voltage drift with high input impedance, low noise, and speeds approaching that of general-purpose JFET devices. In addition, the use of Texas Instruments silicon-gate LinCMOS technology assures offset stability that greatly exceeds the stability available with conventional metal-gate processes.

- Low Noise . . . 25 nV/ $\sqrt{\text{Hz}}$ Typ at f = 1 kHz
- **Output Voltage Range Includes Negative**
- High Input Impedance . . . $10^{12} \Omega$ Typ
- **ESD-Protection Circuitry**
- **Small-Outline Package Option Also** Available in Tape and Reel
- **Designed-In Latch-Up Immunity**

D OR P PACKAGE (TOP VIEW)



The high input impedance, low bias current, and high slew rate make the TLC2810Z ideal for applications that have previously been reserved for JFET and NFET products. These advantages, in combination with an upper operating temperature of 150°C, make the TLC2810Z an ideal choice for precision, extremely high-temperature applications.

In general, many features associated with bipolar technology are available on the TLC2810Z without the power penalties of bipolar technology. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are designed easily with the TLC2810Z.

The TLC2810Z package options include a small-outline version for high-density system applications.

The device inputs and outputs are designed to withstand –100-mA surge currents without sustaining latch-up at 25°C. The TLC2810Z incorporates internal ESD-protection circuits that prevent functional failures at voltages up to 2000 V as tested under MIL-STD 883C, Method 3015.2. However, care should be exercised in handling the TLC2810Z as exposure to ESD may result in the degradation of the device parametric performance. Additional care should be exercised to prevent V_{DD} supply line transients under power conditions. Transients of greater than 20 V can trigger the ESD-protection structure, inducing a low-impedance path to GND. Should this condition occur, the sustained current supplied to the device must be limited to 100 mA or less. Failure to do so can result in a latched condition and device failure.

The TLC2810Z is characterized for operation over the extended temperature range from -40°C to 150°C.

AVAILABLE OPTIONS

	PACKAGEI	CHIP	
TA	SMALL OUTLINE (D)†	PLASTIC DIP (P)	FORM (Y)
-40°C to 150°C	TLC2810ZD	TLC2810ZP	TLC2810Y

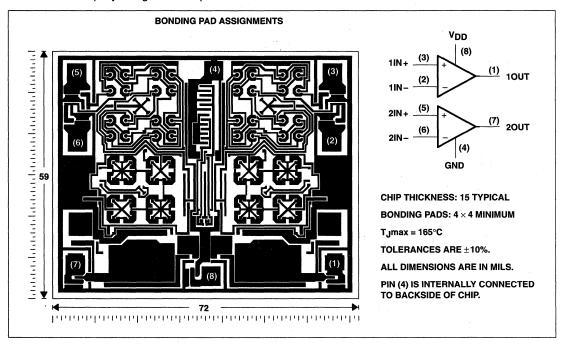
[†]The D packages are available taped and reeled. Add R suffix to the device type when ordering (e.g., TLC2810ZDR).

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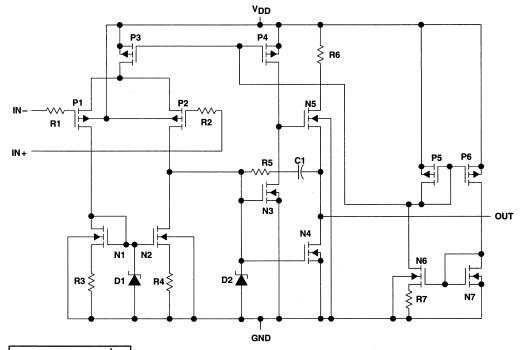


TLC2810Y chip information

This chip, when properly assembled, displays characteristics similar to the TLC2810Z. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



equivalent schematic (each amplifier)



COMPONENT COUNT †					
Transistors	26				
Diodes	4				
Resistors	14				
Capacitors	2				

[†] Includes both amplifiers

TLC2810Z, TLC2810Y LinCMOS™ PRECISION DUAL OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, V _{DD} (see Note 1)	16 V
Differential input voltage, V _{ID} (see Note 2)	±V _{DD}
Input voltage range, V _I (any input)	
Input current, I ₁	
Output current, IO (each output)	±30 mA
Total current into V _{DD}	
Total current out of GND	
Duration of short-circuit current at (or below) T _A = 25°C (see Note 3)	unlimited
Continuous total dissipation	
Operating free-air temperature range, T_A	
Storage temperature range	65°C to 165°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.

- 2. Differential voltages are at IN+ with respect to IN-.
- 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded (see application selection).

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 105°C POWER RATING	T _A = 125°C POWER RATING	T _A = 150°C POWER RATING
D	812 mV	5.8 mW/°C	551 mW	348 mW	232 mW	87 mW
Р	1120 mV	8.0 mW/°C	760 mW	480 mW	320 mW	120 mW

recommended operating conditions

		N	MIN	MAX	UNIT
Supply voltage, V _{DD}			4	16	V
Common-mode input voltage, V _{IC}	V _{DD} = 5 V, T _A = 25°C	(0.2	3.5	٧
Input voltage, V _I	V _{DD} = 5 V	-(0.2	3.5	V
Operating free-air temperature, TA		_	-40	150	°C

electrical characteristics, $V_{DD} = 5 V$ (unless otherwise noted)

PARAMETER		TEST COMPITIONS	- +	T	C28102	2	UNIT
	PARAMETER	TEST CONDITIONS	TAT	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage	V _O = 1 V, V _{IC} = 1 V	, 25°C		1.8	10	mV
VIO	input onset voitage	$R_S = 50 \Omega$, $R_L = 10 k$	Ω Full range			12	IIIV
αVIO	Average temperature coefficient of input offset voltage		25°C to 150°C		3.5		μV/°C
lio.	Input offset current (see Note 4)	V _{IC} = 1 V, V _O = 1 V	25°C		2.4	100	рA
ΙΟ	input onset current (see Note 4)	AIC = 1 A' AO = 1 A	150°C		5.2	30	nA
lв	Input bias current (see Note 4)	V _{IC} = 1 V, V _O = 1 V	25°C		7	100	pА
'IB	mput bias current (see Note +)	VIC = 1 V, VO = 1 V	150°C		50	150	nA
VICR	Common-mode input voltage range (see Note 5)	R _S = 50 Ω	25°C	-0.2 to 4	-0.3 to 4.2		٧
VICH		ng = 50 12	Full range	-0.2 to 3.8			٧
			25°C	3.2	3.8		
Vон	High-level output voltage	V _{ID} = 100 mV, I _{OH} = -1 mA	Full range	3			V
		V _{IC} = 1 V,	25°C		80	150	
VOL	Low-level output voltage	V _{ID} = -100 mV, I _{OL} = 1 mA	Full range			190	mV
۸	Large-signal differential voltage amplification	V _{IC} = 1 V,	25°C	5	25		\//\/
AVD	Large-signal differential voltage amplification	$V_O = 0.25 \text{ V to 2 V},$ $R_L = 10 \text{ k}\Omega$	Full range	4			V/mV
CMRR	Common-mode rejection ratio	V _O = 1 V,	25°C	65	90		dB
CIVINN	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min, R _S = 50 Ω	Full range	60			UB
ksvr	Supply-voltage rejection ratio (ΔVDD /ΔVIO)	V _{DD} = 4 V to 16 V, V _O = 1 V, V _{IC} = 1 V	25°C	65	75		dB
~SVH	eabbit-agirage relection ratio (7aDD /7a IQ)	$R_S = 50 \Omega$	Full range	60			ub
lDD	Supply current	V _O = 1 V, V _{IC} = 1 V	, 25°C		1	3.2	mA
-טט	Supply Surrollt	No load	Full range			4.4	111/5

† Full range is -40°C to 150°C.

NOTES:
4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

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operating characteristics, V_{DD} = 5 V (unless otherwise noted)

		TEST CONDITIONS			TLC2810Z			
	PARAMETER			TA	MIN	TYP	MAX	UNIT
			V 1 V	25°C		3.6		
SR	Clourate at unity agin	$R_L = 10 \text{ k}\Omega$	$V_{I(PP)} = 1 V$	150°C		2.8		- V/μs
	Slew rate at unity gain	C _L = 20 pF, See Figure 26	V.(22) = 2.5.V	25°C		2.2		V/μS
		See Figure 26 $V_{I(PP)} = 2.5 V$		150°C		2.1		
v _n	Equivalent input noise voltage	f =1 kHz, See Figure 27	$R_S = 20 \Omega$,	25°C		25		nV/√Hz
D	Maximum autust assis a bandssidth	VO = VOH,	C _L = 20 pF,	25°C		320		lel Im
ВОМ	Maximum output-swing bandwidth	$R_L = 10 \text{ k}\Omega$,	See Figure 26	150°C		200		kHz
В.	Unity gain handwidth	V _I = 10 mV,	C _L = 20 pF,	25°C		1.7		MHz
В1	Unity-gain bandwidth	See Figure 28		150°C		0.8		IVITIZ
Α	Phase margin	V _I = 10 mV,	f = B ₁ ,	25°C		46°		
φm		C _L = 20 pF,	See Figure 28	150°C		40°		

electrical characteristics at V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	PARAMETER	TEST CON	TEST CONDITIONS			TLC2810Y		
	PARAMETER	IEST CON	TEST CONDITIONS		TYP	MAX	UNIT	
V _{IO}	Input offset voltage					10	mV	
IЮ	Input offset current (see Note 4)	$V_{IC} = 1 \text{ V},$ $R_S = 50 \Omega$	$V_O = 1 V$,			100	pΑ	
Iв	Input bias current (see Note 4)	7"5"				100	pА	
VICR	Common-mode input voltage range (see Note 5)	R _S = 50 Ω		-0.2 to 4			V	
Vон	High-level output voltage	V _{IC} = 1 V, I _{OH} = -1 mA	V _{ID} = 100 mV,	3.2			٧	
VOL	Low-level output voltage	V _{IC} = 1 V, I _{OL} = 1 mA	$V_{ID} = -100 \text{ mV},$			150	mV	
AVD	Large-signal differential voltage amplification	V _O = 0.25 V to 2 V, V _{IC} = 1 V	R _L = 10 kΩ,	5			V/mV	
CMRR	Common-mode rejection ratio	$V_O = 1 V$, $R_S = 50 \Omega$	V _{IC} = V _{ICR} min,	65			dB	
ksvr	Supply-voltage rejection ratio ($\Delta V_{DD\pm}/\Delta V_{IO}$)	V _{DD} = 4 V to 16 V, V _O = 1 V,	$V_{IC} = 1 V$, R _S = 50 Ω	65			dB	
lDD	Supply current	V _O = 1 V, No load	V _{IC} = 1 V,			3.2	mA	

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.

5. This range also applies to each input individually.

operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	PARAMETER	TEST CO	TEST CONDITIONS			TLC2810Y		
	PARAMETER TEST CONDITIONS		NDITIONS	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 20 \text{ pF}$,	V _{I(PP)} = 1 V		3.6		V/μs	
John	Siew rate at unity gain	See Figure 26	V _{I(PP)} = 2.5 V		2.9		ν/μδ	
v _n	Equivalent input noise voltage	f =1 kHz, See Figure 27	$R_S = 20 \Omega$,		25		nV/√Hz	
ВОМ	Maximum output-swing bandwidth	$V_O = V_{OH}$, $R_L = 10 \text{ k}\Omega$,	C _L = 20 pF, See Figure 26		320		kHz	
B ₁	Unity-gain bandwidth	V _I = 10 mV, See Figure 28	C _L = 20 pF,		1.7		MHz	
φm	Phase margin	V _I = 10 mV, C _L = 20 pF,	f = B ₁ , See Figure 28		46°			

Table of Graphs

			FIGURE
VIO	Input offset voltage	Distribution	1
αVIO	Input offset voltage temperature coefficient	Distribution	2
Vон	High-level output voltage	vs Output current vs Supply voltage vs Free-air temperature	3 4 5
VOL	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	6 7 8 9
AVD	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	10 11 21
IB/IO	Input bias and offset current	vs Free-air temperature	12
VIC	Common-mode input voltage	vs Supply voltage	13
IDD	Supply current	vs Supply voltage vs Free-air temperature	14 15
SR	Slew rate	vs Supply voltage vs Free-air temperature	16 17
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	18
B ₁	Gain-bandwidth product	vs Free-air temperature vs Supply voltage	19 20
φm	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	22 23 24
Vn	Equivalent input noise voltage	vs Frequency	25
	Phase shift	vs Frequency	21

DISTRIBUTION OF TLC2810Z INPUT OFFSET VOLTAGE 60 $V_{DD} = 5 V$ T_A = 25°C P Package 50 Percentage of Units - % 40 30 20 10 -5 -4 -3 -2 -1 0 2 3 4 V_{IO} - Input Offset Voltage - mV

Figure 1

HIGH-LEVEL OUTPUT VOLTAGE VS **HIGH-LEVEL OUTPUT CURRENT**

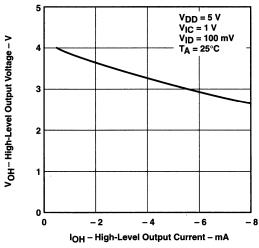


Figure 3

DISTRIBUTION OF TLC2810Z INPUT OFFSET VOLTAGE **TEMPERATURE COEFFICIENT**

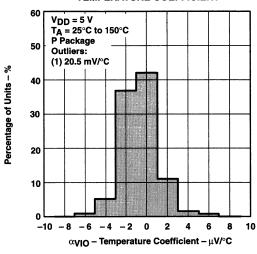


Figure 2

HIGH-LEVEL OUTPUT VOLTAGE

SUPPLY VOLTAGE

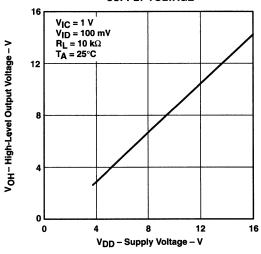
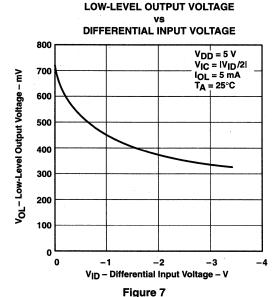


Figure 4

HIGH-LEVEL OUTPUT VOLTAGE vs **FREE-AIR TEMPERATURE** 4.5 V_{OH} - High-Level Output Voltage - V 3.5 3 $I_{OH} = -500 \mu A$ IOH = -1 mA IOH = -2 mA 2.5 $V_{DD} = 5 V$ IOH = -3 mA V_{IC} = 1 V IOH = -4 mAVID = 100 mV -75 -50 -25 25 50 75 100 125 150 T_A - Free-Air Temperature - °C

Figure 5



LOW-LEVEL OUTPUT VOLTAGE

VS

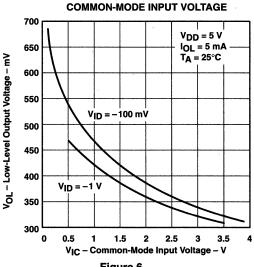


Figure 6

LOW-LEVEL OUTPUT VOLTAGE vs

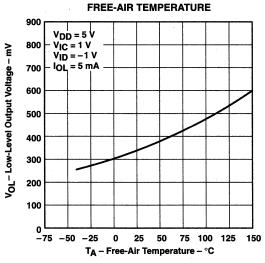
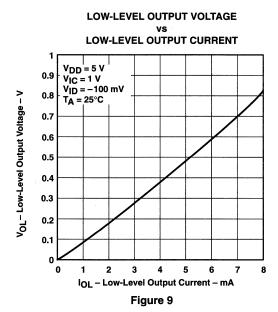


Figure 8



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION

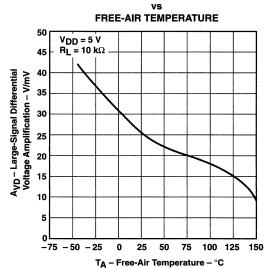
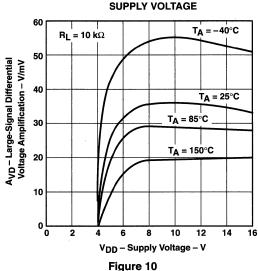


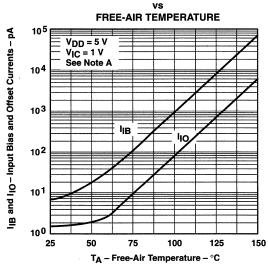
Figure 11

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION VS



INPUT BIAS CURRENT AND INPUT

OFFSET CURRENT



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 12



COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT

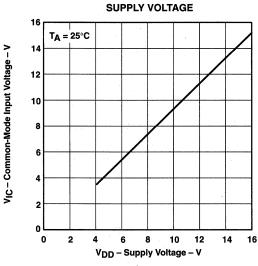
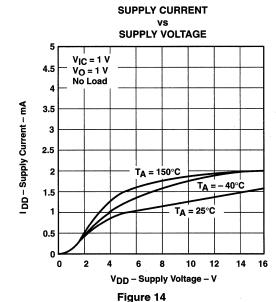


Figure 13



SUPPLY CURRENT

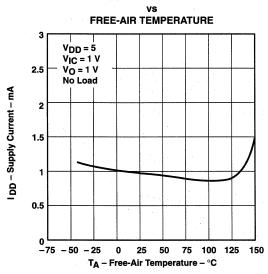


Figure 15

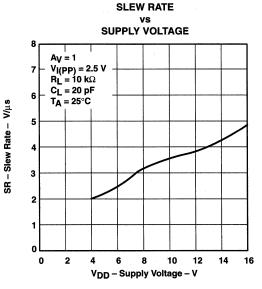
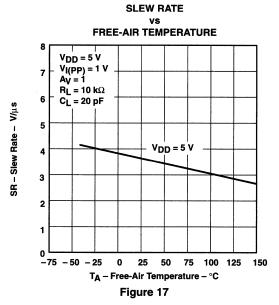


Figure 16

Vo(PP) - Output Voltage - V

THE STATE OF LINE TO





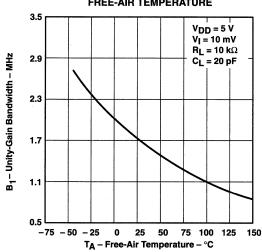


Figure 19

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs

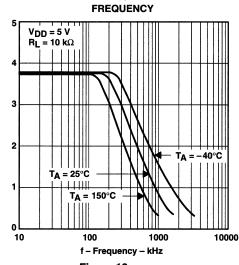
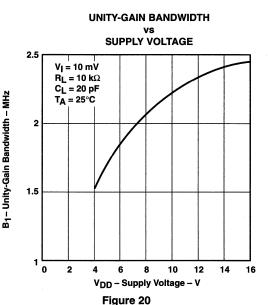


Figure 18



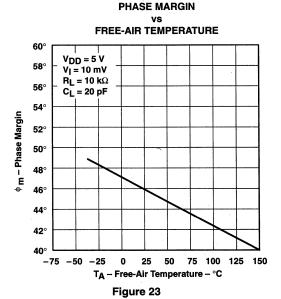
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT

vs **FREQUENCY** 107 $V_{DD} = 5 V$ $R_L = 10 \text{ k}\Omega$ 106 C_L = 20 pF A_{VD} - Large-Signal Differential T_A = 25°C 105 0° Voltage Amplification 104 30° Phase Shift Avd 103 60° 102 90° **Phase Shift** 101 120° 150° 180° 0.1 10 100 10 k 100 k 1 M 10 M 1 k f - Frequency - Hz

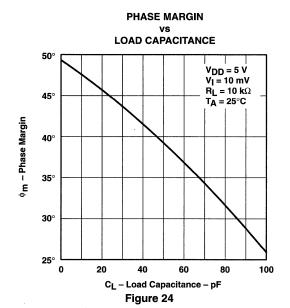
Figure 21

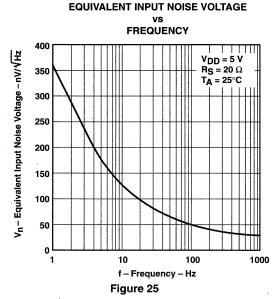
PHASE MARGIN SUPPLY VOLTAGE **53**° **52**° 51° _{0m} – Phase Margin 50° 49° 489 V_j = 10 mV 47° $R_L = 10 \text{ k}\Omega$ $C_L = 20 pF$ 46° T_A = 25°C 45° 0 2 8 12 14 16 V_{DD} - Supply Voltage - V

Figure 22



TEXAS INSTRUMENTS





PARAMETER MEASUREMENT INFORMATION

single-supply versus split-supply test circuits

Because the TLC2810Z is optimized for single-supply operation, circuit configurations used for the various tests often present some inconvenience since the input signal, in many cases, must be offset from ground. This inconvenience can be avoided by testing the device with split supplies and the output load tied to the negative rail. A comparison of single-supply and split-supply test circuits is shown below. The use of either circuit gives the same result.

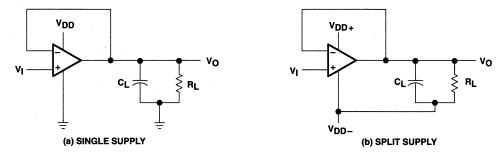


Figure 26. Unity-Gain Amplifier

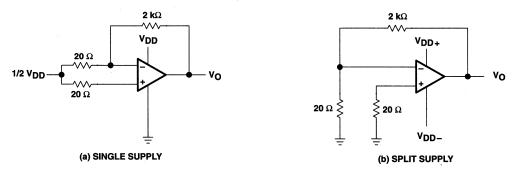


Figure 27. Noise-Test Circuit

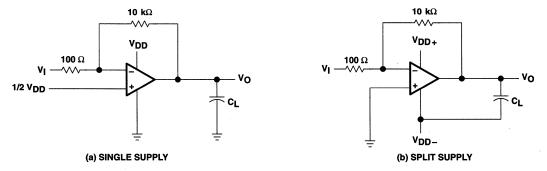


Figure 28. Gain-of-100 Inverting Amplifier



PARAMETER MEASUREMENT INFORMATION

input bias current

Because of the high input impedance of the TLC2810Z operational amplifier, attempts to measure the input bias current can result in erroneous readings. The bias current at normal ambient temperature is typically less than 1 pA, a value that is easily exceeded by leakages on the test socket. Two suggestions are offered to avoid erroneous measurements:

- 1. Isolate the device from other potential leakage sources. Use a grounded shield around and between the device inputs (see Figure 29). Leakages that would otherwise flow to the inputs are shunted away.
- Compensate for the leakage of the test socket by actually performing an input bias current test (using a picoammeter) with no device in the test socket. The actual input bias current can then be calculated by subtracting the open-socket leakage readings from the readings obtained with a device in the test socket.

One word of caution: many automatic testers as well as some bench-top operational amplifier testers use the servo-loop technique with a resistor in series with the device input to measure the input bias current (the voltage drop across the series resistor is measured and the bias current is calculated). This method requires that a device be inserted into a test socket to obtain a correct reading: therefore, an open-socket reading is not feasible using this method.

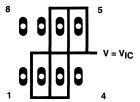


Figure 29. Isolation Metal Around Device Inputs (P package)

low-level output voltage

To obtain low-supply-voltage operation, some compromise is necessary in the input stage. This compromise results in the device low-level output being dependent on both the common-mode input voltage level as well as the differential input voltage level. When attempting to correlate low-level output readings with those quoted in the electrical specifications, these two conditions should be observed. If conditions other than these are to be used, please refer to the Typical Characteristics of this data sheet.

input offset voltage temperature coefficient

Erroneous readings often result from attempts to measure temperature coefficient of input offset voltage. This parameter is actually a calculation using input offset voltage measurements obtained at two different temperatures. When one (or both) of the temperatures is below freezing, moisture can collect on both the device and the test socket. This moisture results in leakage and contact resistance that can cause erroneous input offset voltage readings. The isolation techniques previously mentioned have no effect on the leakage since the moisture also covers the isolation metal itself, thereby rendering it useless. It is suggested that these measurements be performed at temperatures above freezing to minimize error.

full-power response

Full-power response, the frequency above which the operational amplifier slew rate limits the output voltage swing, is often specified two ways: full-linear response and full-peak response. The full-linear response is generally measured by monitoring the distortion level of the output while increasing the frequency of a sinusoidal



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full-power response (continued)

input signal until the maximum frequency above which the output contains significant distortion is found. The full-peak response is defined as the maximum output frequency, without regard to distortion, above which full peak-to-peak output swing cannot be maintained.

Because there is no industry-wide accepted value for significant distortion, the full-peak response is specified in this data sheet and is measured using the circuit of Figure 26. The initial setup involves the use of a sinusoidal input to determine the maximum peak-to-peak output of the device (the amplitude of the sinusoidal wave is increased until clipping occurs). The sinusoidal wave is then replaced with a square wave of the same amplitude. The frequency is then increased until the maximum peak-to-peak output can no longer be maintained (Figure 30). A square wave is used to allow a more accurate determination of the point at which the maximum peak-to-peak output is reached.

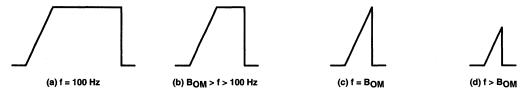


Figure 30. Full-Power-Response Output Signal

test time

Inadequate test time is a frequent problem, especially when testing CMOS devices in a high-volume, short-test-time environment. Internal capacitances are inherently higher in CMOS than in bipolar and BiFET devices; hence, CMOS devices require longer test times than their bipolar and BiFET counterparts. The problem becomes more pronounced with reduced power supply levels and lower temperatures.

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APPLICATION INFORMATION

single-supply operation

While the TLC2810Z performs well using dual-power supplies (also called balanced or split supplies), the design is optimized for singlesupply operation. This includes an input commonmode voltage range that encompasses ground as well as an output voltage range that pulls down to ground. The supply voltage range extends down to 4 V, thus allowing operation with supply levels commonly available for TTL and CMOS.

Many single-supply applications require that a voltage be applied to one input to establish a reference level that is above ground. This virtual ground can be generated using two large resistors, but a preferred technique is to use a

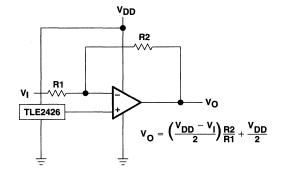


Figure 31. Inverting Amplifier With Voltage Reference

virtual ground generator such as the TLE2426 (see Figure 31). The TLE2426 supplies an accurate voltage equal to V_{DD}/2, while consuming very little power and is suitable for supply voltages of greater than 4 V.

The TLC2810Z works well in conjunction with digital logic. However, when powering both linear devices and digital logic from the same power supply, the following precautions are recommended:

- 1. Power the linear devices from separate bypassed supply lines (see Figure 32). Otherwise, the linear device supply rails can fluctuate due to voltage drops caused by high switching currents in the digital logic.
- 2. Use proper bypass techniques to reduce the probability of noise-induced errors. Single capacitive decoupling is often adequate. However, RC decoupling may be necessary in high-frequency applications.

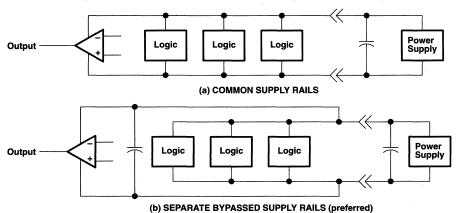


Figure 32. Common Versus Separate Supply Rails

APPLICATION INFORMATION

input characteristics

The TLC2810Z is specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction. Exceeding this specified range is a common problem, especially in single-supply operation. The lower range limit includes the negative rail, while the upper range limit is specified at $V_{DD}-1$ V at $T_A=25^{\circ}$ C and at $V_{DD}-1.2$ V at all other temperatures.

The use of the polysilicon-gate process and the careful input circuit design give the TLC2810Z very good input offset voltage drift characteristics relative to conventional metal-gate processes. Offset voltage drift in CMOS devices is influenced by threshold voltage shifts caused by polarization of the phosphorus dopant implanted in the oxide. Placing the phosphorus dopant in a conductor (such as a polysilicon gate) alleviates the polarization problem, thus reducing threshold voltage shifts by more than an order of magnitude. The offset voltage drift with time has been calculated to be typically 0.1 μ V/month, including the first month of operation.

Because of the extremely high input impedance and resulting low-bias current requirements, the TLC2810Z is well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets can easily exceed bias-current requirements and cause a degradation in device performance. It is good practice to include guard rings around inputs (similar to those of Figure 29 in the Parameter Measurement Information section). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input (see Figure 33).

Unused amplifiers should be connected as grounded voltage followers to avoid possible oscillation.

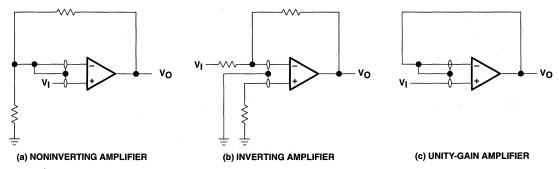


Figure 33. Guard-Ring Schemes

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input bias current requirements of the TLC2810Z results in a very low noise current, which is insignificant in most applications. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than $50\,\mathrm{k}\Omega$ since bipolar devices exhibit greater noise currents.

APPLICATION INFORMATION

feedback

Operational amplifier circuits nearly always employ feedback and, since feedback is the first prerequisite for oscillation, a little caution is appropriate. Most oscillation problems result from driving capacitive loads and ignoring stray input capacitance. A small-value capacitor connected in parallel with the feedback resistor is an effective remedy (see Figure 34). The value of this capacitor is optimized empirically.

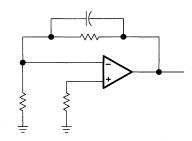


Figure 34. Compensation for Input Capacitance

electrostatic discharge protection

The TLC2810Z incorporates an internal electrostatic discharge (ESD) protection circuit that prevents functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. Care should be exercised, however, when handling these devices, as exposure to ESD may result in the degradation of the device parametric performance. The protection circuit also causes the input bias currents to be temperature dependent and have the characteristics of a reverse-biased diode.

latch-up

Because CMOS devices are susceptible to latch-up due to their inherent parasitic thyristors, the TLC2810Z inputs and outputs are designed to withstand -100-mA surge currents without sustaining latch-up; however, techniques should be used to reduce the chance of latch-up whenever possible. Internal protection diodes should not by design be forward biased. Applied input and output voltages should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μ F typical) located across the supply rails as close to the device as possible.

The current path established if latch-up occurs is usually between the positive supply rail and ground and can be triggered by surges on the supply lines and/or voltages on either the output or inputs that exceed the supply voltage. Once latch-up occurs, the current flow is limited only by the impedance of the power supply and the forward resistance of the parasitic thyristor and usually results in the destruction of the device. The chance of latch-up occurring increases with increasing temperature and supply voltages.

APPLICATION INFORMATION

output characteristics

The output stage of the TLC2810Z is designed to sink and source relatively high amounts of current (see Typical Characteristics). If the output is subjected to a short-circuit condition, this high-current capability can cause device damage under certain conditions. Output current capability increases with supply voltage.

Although the TLC2810Z possesses excellent high-level output voltage and current capability, methods are available for boosting this capability if needed. The simplest method involves the use of a pullup resistor (Rp) connected from the output to the positive supply rail (see Figure 35). There are two disadvantages to the use of this circuit. First, the NMOS pulldown transistor, N4 (see equivalent schematic), must sink a comparatively large amount of current. In this circuit, N4 behaves like a linear resistor with an on-resistance between approximately 60 Ω and 180 Ω , depending on how hard the operational amplifier input is driven. With very low values of Rp. a voltage offset from 0 V at the output occurs. Secondly, pullup resistor Rp acts as a drain load to N4, and the gain of the operational amplifier is reduced at output voltage levels where N5 is not supplying the output current.

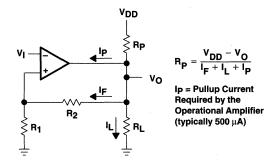


Figure 35. Resistive Pullup to Increase VOH

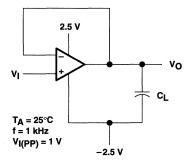
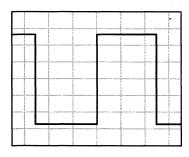
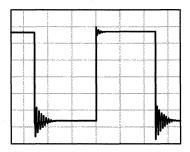


Figure 36. Test Circuit for Output Characteristics

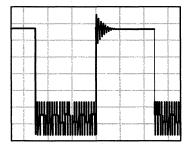
All operating characteristics of the TLC2810Z are measured using a 20-pF load. The devices can drive higher capacitive loads; however, as output load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation (see Figure 37). In many cases, adding some compensation in the form of a series resistor in the feedback loop alleviates the problem.



(a) $C_1 = 20 pF$, $R_1 = NO LOAD$



(b) C_L = 130 pF, R_L = NO LOAD



(c) $C_L = 150 \text{ pF}$, $R_L = NO \text{ LOAD}$

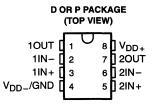
Figure 37. Effect of Capacitive Loads

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- Free-Air Operating Temperature -40°C to 150°C
- Output Swing Includes Both Supply Rails
- Low Noise . . . 9 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Tvp
- Common-Mode Input Voltage Range Includes Negative Rail
- High Unity-Gain Bandwidth . . . 2.2 MHz Typ
- High Slew Rate . . . 3.6 V/μs Typ
- Low Input Offset Voltage 300 μV Typ at T_A = 25°C
- Macromodel Included

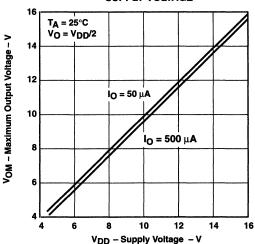
description

The TLC2872Z is a dual rail-to-rail output operational amplifier manufactured using Texas Instruments Advanced LinCMOS™ process. These devices offer comparable ac performance while having better noise, input offset voltage and power dissipation than existing CMOS operational amplifiers. In addition, the commonmode input voltage range is wider than typical standard CMOS type amplifiers. To take advantage of this improvement in performance, making this device available for a wider range of applications, V_{ICR} is specified with a larger maximum input offset voltage test limit of ±5 mV. The Advanced LinCMOS™ process uses a



MAXIMUM OUTPUT VOLTAGE

SUPPLY VOLTAGE



silicon-gate technology to obtain input offset voltage stability with temperature and time that far exceeds that obtainable using metal-gate technology. Also, this technology makes possible input impedance levels that meet or exceed levels offered by top-gate JFET and expensive dielectric-isolated devices.

The TLC2872Z, manufactured using Texas Instruments high-temperature process flow, allows extended temperature operation up to 150°C in a plastic package. This adds extra reliability at the extended temperature and reduces the need for expensive hermetically sealed ceramic packages.

The TLC2872Z, which exhibits high input impedance and low noise, is excellent for small signal conditioning of high impedance sources, such as piezoelectric transducers. In addition, the rail-to-rail output feature with single or split supplies makes this device a great choice for inputs to ADCs in either the unipolar or bipolar mode of operation. This feature, combined with its temperature performance, makes the TLC2872Z ideal for sonobuoys, pressure sensors, temperature controls, active VR sensors, accelerometers, and many other applications.

AVAILABLE OPTIONS

	Vienney	PACKAGED	DEVICES	CHIP FORM
TA	V _{IO} max AT 25°C	SMALL OUTLINE (D)	PLASTIC DIP (P)	(Y)
-40°C to 150°C	2.5 mV	TLC2872ZD	TLC2872ZP	TLC2872Y

The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2872DR).

Advanced LinCMOS is a trademark of Texas Instruments Incorporated.



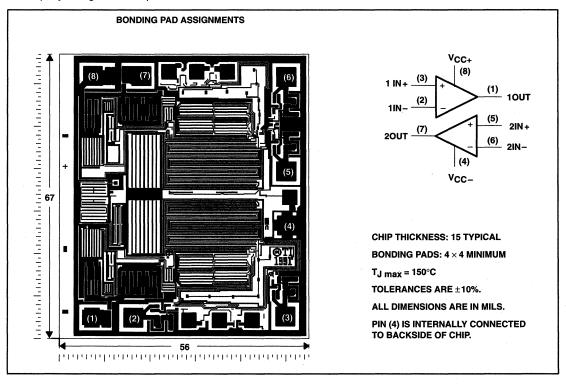
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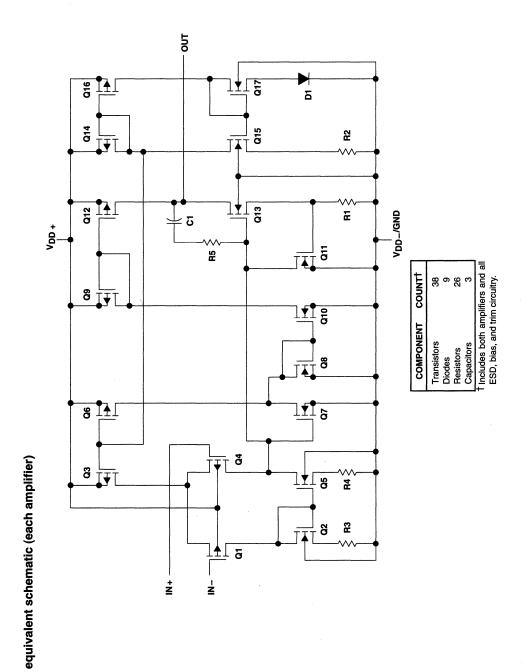
description (continued)

The inputs and outputs of this device are designed to withstand 100-mA surge current without sustaining latch-up. In addition, internal ESD-protection circuits prevent functional failures up to 2000 V. The device is characterized for operation over the extended (Z) temperature range of -40°C to 150°C.

TLC2872Y chip information

This chip, when properly assembled, displays characteristics similar to TLC2872Z. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.





TLC2872Z, TLC2872Y Advanced LinCMOS™ RAIL-TO-RAIL DUAL OPERATIONAL AMPLIFIERS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V _{DD+}	8 V
Supply voltage, V _{DD}	8 V
Differential input voltage, V _{ID} (see Note 1)	±16 V
Input voltage range, V _I (any input, see Note 2)	±8 V
Input current, I _I (each input)	
Output current, I _O	±50 mA
Total current into V _{DD+}	±50 mA
Total current out of V _{DD}	±50 mA
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A	–40°C to 150°C
Storage temperature range	–65°C to 165°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. Differential voltages are at IN+ with respect to IN-. Excessive current will flow if input is brought below V_{DD}_ 0.3 V.
 - 2. All voltage values, except differential voltages, are with respect to the midpoint between VDD+ and VDD-...
 - The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C POWER RATING	DERATING FACTOR ABOVE T _A = 25°C	T _A = 70°C POWER RATING	T _A = 105°C POWER RATING	T _A = 125°C POWER RATING	T _A = 150°C POWER RATING
D	812 mW	5.8 mW/°C	551 mW	348 mW	232 mW	87 mW
P	1120 mW	8 mW/°C	760 mW	480 mW	320 mW	120 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V _{DD±}	±2.2	±8	V
Input voltage range, V _I	V _{DD} _	V _{DD+} –1.5	V
Common-mode input voltage, V _{IC}	V _{DD} _	V _{DD+} –1.5	V
Operating free-air temperature, TA	-40	150	°C

TLC2872Z, TLC2872Y Advanced LinCMOS™ RAIL-TO-RAIL DUAL OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

	DADAMETED	TEST COME	UTIONS	-+	TI	LC2872Z		UNIT
	PARAMETER	TEST CONDITIONS		T _A †	MIN	TYP	MAX	UNII
V _{IO}	Input offset voltage			25°C		300	2500	μV
VIO	mput onset voltage			Full range			3000	μν
αΛΙΟ	Temperature coefficient of input offset voltage			25°C to 150°C		2		μV/°C
	Input offset voltage long-term drift (see Note 4)	$V_{DD\pm} = \pm 2.5 \text{ V},$ $V_{O} = 0,$	$V_{IC} = 0$, R _S = 50 Ω	25°C		0.002		μV/mo
ما	Input offset current			25°C		0.0005		nA
ΙΟ	input onset current			Full range			3	IIA
1	Input bigg gurrent	1	*	25°C		0.001		nA
lΒ	Input bias current			Full range			5	IIA
V	Common mode input veltage range	Pa = 50 O	V _{IO} ≤ 5 mV	25°C	0 to 4	-0.3 to 4.2		V
VICR	Common-mode input voltage range	$R_S = 50 \Omega$,		Full range	0 to 3.5			V
	High-level output voltage	I _{OH} = -20 μA		25°C	4.95	4.99		
		I _{OH} = -200 μA		25°C	4.85	4.93		
V_{OH}				Full range	4.75		***************************************	V
		I _{OH} = -1 mA		25°C	4.25	4.65		
				Full range	4.25			
	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 50 μA	25°C		0.01	0.02	V
		V _{IC} = 2.5 V,	I _{OL} = 500 μA	25°C		0.09	0.15	
V_{OL}				Full range			0.2	
		V _{IC} = 2.5 V,	I _{OL} = 5 mA	25°C		0.9	1.5	
				Full range			2	
	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	R _L = 10 kΩ [‡]	25°C	15	35		
A_{VD}				Full range	10			V/mV
		10-10040	$R_L = 1 M\Omega^{\ddagger}$	25°C		175		
rid	Differential input resistance			25°C		1012		Ω
rį	Common-mode input resistance			25°C		1012		Ω
ci	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8		pF
z _o	Closed-loop output impedance	f = 1 MHz,	A _V = 10	25°C		140		Ω
		V _{IC} = 0 to 2.7 V,	V _O = 2.5 V,	25°C	70	75		-UD
CMRR	Common-mode rejection ratio	$R_S = 50 \Omega$. 0 = = = = = =	Full range	70			dB
1	Supply voltage rejection ratio	V _{DD} = 4.4 V to 16 V, No load	V _{IC} = V _{DD} /2.	25°C	80 /	95		4ID
ksvr	(∆V _{DD} /∆V _{IO})		10 1001-1	Full range	80			dB
I	Supply autropt	V- 05V	NI- II	25°C		2.2	3	m ^
IDD	Supply current	$V_0 = 2.5 V$,	No load	Full range			3	mA

[†] Full range is -40°C to 150°C.

[‡] Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2872Z, TLC2872Y Advanced LinCMOS™ RAIL-TO-RAIL DUAL OPERATIONAL AMPLIFIERS SLOS117 - OCTOBER 1992

operating characteristics at specified free-air temperature, V_{DD} = 5 V

	PARAMETER	TEST CONDITIONS		- +	TLC2872Z				
	PARAMETER	IEST COND	IIIONS	T _A †	MIN TYP		MAX	UNIT	
SR	Clause rate at units sain	$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	25°C	2.3	3.6		1//	
on	Slew rate at unity gain	C _L = 100 pF‡	_	Full range	1.1			V/μs	
V	Equivalent input poice veltage	f = 10 Hz		25°C		50		T	
Vn	Equivalent input noise voltage	f = 1 kHz		25°C		9		nV/√Hz	
Verm	Peak-to-peak equivalent input noise	f = 0.1 to 1 Hz		25°C		11			
V _{N(PP)}	voltage	f = 0.1 to 10 Hz		25°C		1.4		μν	
In	Equivalent input noise current			25°C		0.6		fA/√Hz	
		$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1			0.0013%			
THD + N	Total harmonic distortion plus noise	$f = 20 \text{ kHz},$ $R_L = 10 \text{ k}\Omega^{\ddagger}$	A _V = 10	25°C		0.004%			
			Ay = 100			0.03%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF [‡]	$R_L = 10 \text{ k}\Omega^{\ddagger}$,	25°C		2.18		MHz	
ВОМ	Maximum output-swing bandwidth	$V_{O(PP)} = 2 \text{ V},$ $R_L = 10 \text{ k}\Omega^{\ddagger},$	A _V = 1, C _L = 100 pF‡	25°C		1		MHz	
	Cattling time	A _V = -1, Step = 0.5 V to 2.5 V,	To 0.1%	25°C		1.5			
	Settling time	$R_L = 10 \text{ k}\Omega^{\ddagger},$ $C_L = 100 \text{ pF}^{\ddagger}$	To 0.01%			2.6	,	μs	
φm	Phase margin at unity gain	D. tokot	C. 100 pFt	25°C		50°			
	Gain margin	$R_L = 10 \text{ k}\Omega^{\ddagger}$	C _L = 100 pF [‡]			10		dB	

[†] Full range is -40°C to 150°C.

[‡] Referenced to 2.5 V

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electrical characteristics, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

	DADAMETED	TEST COMPLTIONS		TLC2872Y			
	PARAMETER	TEST CONL	EST CONDITIONS		TYP	MAX	UNIT
VIO	Input offset voltage				300	2500	μV
	Input offset voltage long-term drift (see Note 4)	V _{IC} = 0,	$V_{\Omega} = 0$,		0.002		μV/mo
10	Input offset current	$R_S = 50 \Omega$			0.0005		nA
IВ	Input bias current				0.001		nA
Vian	Common-mode input voltage range	Rs = 50 Ω.	\\\.\< F m\\	0 to 4	-0.3 to 4.2		V
V _{ICR} Con	Common-mode input voltage range	ng = 50 12,	V _{IO} ≤ 5 mV	0 to 3.5			ľ
	High-level output voltage	I _{OH} = -20 μA		4.95	4.99		
VOH		IOH = -200 μA		4.85	4.93		V
		IOH = -1 mA		4.25	4.65		
	Low-level output voltage	V _{IC} = 2.5 V,	l _{OL} = 50 μA	1	0.01	0.02	
VOL		V _{IC} = 2.5 V,	I _{OL} = 500 μA		0.09	0.15	V
		V _{IC} = 2.5 V,	$I_{OL} = 5 \text{ mA}$		0.9	1.5	
AVD	Large-signal differential voltage amplification	V _{IC} = 2.5 V, V _O = 1 V to 4 V	$R_L = 10 \text{ k}\Omega^{\dagger}$ $R_L = 1 \text{ M}\Omega^{\dagger}$	15	35 175		V/mV
rid	Differential input resistance	+	111[-1101221		1012		Ω
r _i	Common-mode input resistance			 	1012		Ω
Cj	Common-mode input capacitance	f = 10 kHz,	P package		8		pF
z _o	Closed-loop output impedance	f = 1 MHz.	A _V = 10	1	140		Ω
CMRR		V _{IC} = 0 to 2.7 V, R _S = 50 Ω	V _O = 2.5 V,	70	75		dB
ksvr	Supply voltage rejection ratio (ΔV _{DD±} /ΔV _{IO})	V _{DD} = 4.4 V to 16 V, No load	$V_{IC} = V_{DD}/2$,	80	95		dB
IDD	Supply current	V _O = 2.5 V,	No load		2.2	3	mA

[†] Referenced to 2.5 V

TLC2872Z, TLC2872Y Advanced LinCMOS™ RAIL-TO-RAIL DUAL OPERATIONAL AMPLIFIERS SLOS117 - OCTOBER 1992

operating characteristics, V_{DD} = 5 V, T_A = 25°C

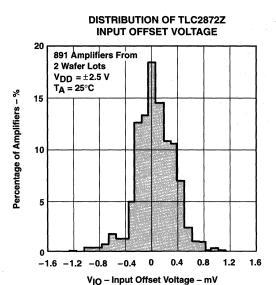
PARAMETER		TEST CONDITIONS		TLC2872Y				
				MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	V _O = 0.5 V to 2.5 V, C _L = 100 pF†	$R_L = 10 \text{ k}\Omega^{\dagger}$,	2.3	3.6		V/μs	
V	Equivalent input noise voltage	f = 10 Hz			50		- N// TT	
V _n		f = 1 kHz			9		nV/√Hz	
Varion	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz			1		μV	
V _{N(PP)}	Peak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz		1.4			μν	
In	Equivalent input noise current	3			0.6		fA/√Hz	
	Total harmonic distortion plus noise	$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$ f = 20 kHz, $R_{L} = 10 \text{ k}\Omega^{\dagger}$	A _V = 1		0.0013%			
THD + N			Ay = 10		0.004%			
			Ay = 100		0.03%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF†	$R_L = 10 \text{ k}\Omega^{\dagger}$,		2.18		MHz	
вом	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6 \text{ V},$ $R_L = 10 \text{ k}\Omega^{\dagger},$	A _V = 1 C _L = 100 pF†		1		MHz	
	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V, $R_L = 10 \text{ k}\Omega^{\dagger}$, $C_L = 100 \text{ pF}^{\dagger}$	To 0.1%		1.5			
			To 0.01%		2.6		μs	
φm	Phase margin at unity gain	$R_1 = 10 \text{ k}\Omega^{\dagger}$	C _L = 100 pF†		50°			
	Gain margin	T nL = 10 ks21,	OL = 100 pF1		10		dB	

[†] Referenced to 2.5 V

Table of Graphs

			FIGURE
V _{IO}	Input offset voltage	Distribution	1
αVIO	Input offset voltage temperature coefficient	Distribution	2
liB/liO	Input bias and offset currents	vs Free-air temperature	3
٧ _I	Input voltage range	vs Free-air temperature	4
VOH	High-level output voltage	vs Output current	5
VOL	Low-level output voltage	vs Output current	6, 7
Vом	Maximum output voltage	vs Frequency	8
los	Short-circuit output current	vs Supply voltage vs Free-air temperature	9 10
A _{VD}	Large-signal differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	11 12 13
I _{DD}	Supply current	vs Supply voltage vs Free-air temperature	14 15
SR	Slew rate	vs Load capacitance vs Free-air temperature	16 17
φm	Phase margin	vs Frequency vs Load capacitance	12 18
	Gain margin	vs Load capacitance	19

NOTE: All loads are referenced to 2.5 V.



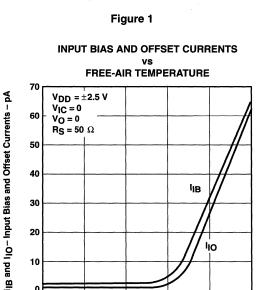


Figure 3

T_A - Free-Air Temperature - °C

75

100

125

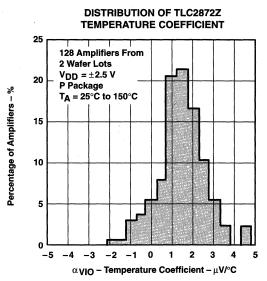


Figure 2

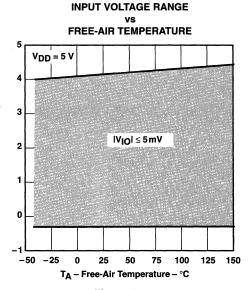


Figure 4

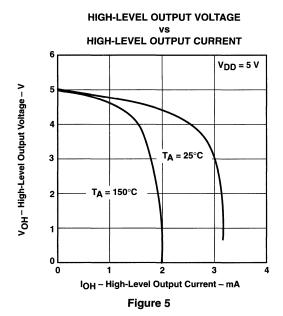
150

V_I - Input Voltage Range - V

0 E 25

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TYPICAL CHARACTERISTICS



LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

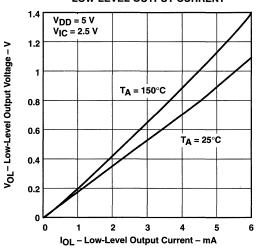
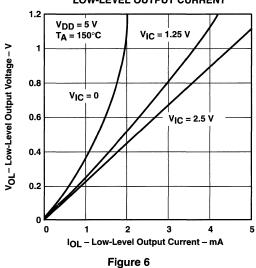
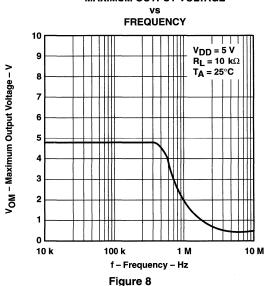


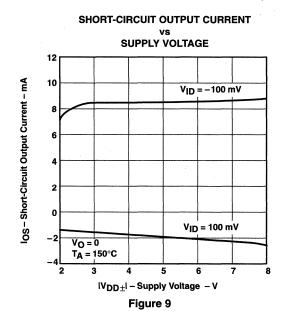
Figure 7

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT



MAXIMUM OUTPUT VOLTAGE





SHORT-CIRCUIT OUTPUT CURRENT VS FREE-AIR TEMPERATURE 15 V_O = 0 V_{DD} = 5 V V_{DD} = 5 V V_D = 0 V_{DD} = 5 V V_D = 0 V_{DD} = 5 V T_A - Free-Air Temperature - °C

Figure 10

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION

LOAD RESISTANCE

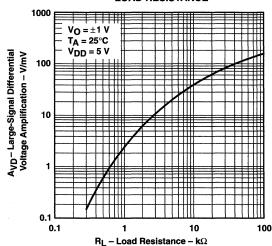
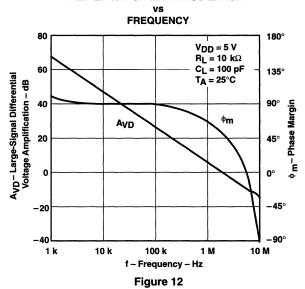


Figure 11

LARGE-SIGNAL DIFFERENTIAL VOLTAGE **AMPLIFICATION and PHASE MARGIN**



LARGE-SIGNAL DIFFERENTIAL **VOLTAGE AMPLIFICATION** vs

FREE-AIR TEMPERATURE 1 k $V_{DD} = 5 V$ V_{IC} = 2.5 V V_O = 1 to 4 V A_{VD}-Large-Signal Differential Voltage Amplification - V/mV $R_L = 1 M\Omega$ 100 $R_L = 10 \text{ k}\Omega$ 10 150

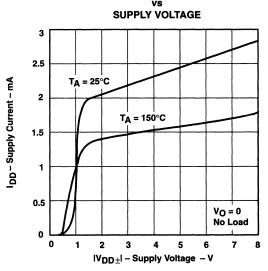
Figure 13

-50 -25

50 75

T_A - Free-Air Temperature - °C

SUPPLY CURRENT





125

100

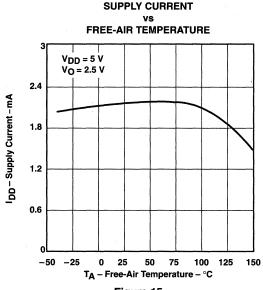


Figure 15

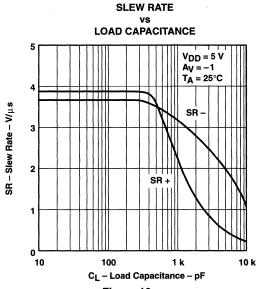
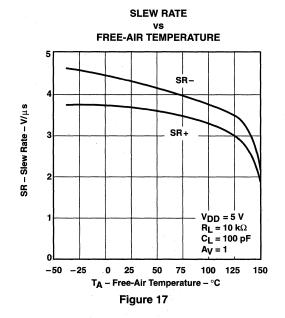


Figure 16

PHASE MARGIN



LOAD CAPACITANCE $V_{DD} = 5 V$ TA = 25°C $R_{null} = 100 \Omega$ 60° $R_{null} = 50 \Omega$ om – Phase Margin 45° $R_{null} = 20 \Omega$ 309 10 kΩ 15° V_{DD+} R_{null} = 0 $R_{null} = 10 \Omega$ 10 1000 10000

Figure 18

C_L - Load Capacitance - pF

GAIN MARGIN vs LOAD CAPACITANCE

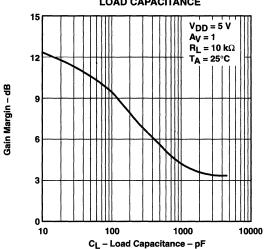


Figure 19

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



APPLICATION INFORMATION

macromodel information

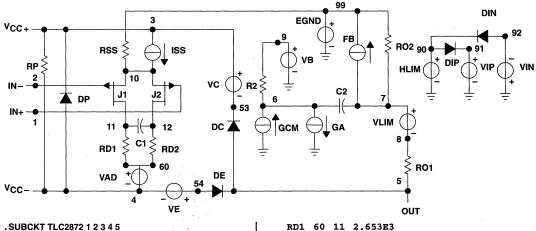
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Macromodel information provided was derived using *PSpice™ Parts™* model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figure 20 were generated using the TLC2872Z typical electrical and operating characteristics at T_A = 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification

- Unity gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers," *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).



```
C1
         11
             12
                  14E-12
                  60.00E-12
   C2
         6
   DC
         5
             53
                  DX
   DE
         54
            5
                  DX
   DLP
         90
                  DX
             91
   DLN
        92
             90
                  DX
   DP
                  DX
             0 POLY (2) (3,0) (4,0) 0 .5 .5
POLY (5) VB VC VE VLP VLN 0
   EGND99
   FB 7 99
+ 984.9E3 -1E6 1E6 1E6 -1E6
             0
                  11 12 377.0E-6
   GA 6
   GCM 0 6 10 99 134E-9
   ISS
              10
                  DC 216.OE-6
   HLIM 90
             0
                  VLIM 1K
   JI
         11
             2
                  10 JX
   J2
         12
             1
                  10 JX
                  100.OE3
```

```
RD1
       60
              2.653E3
  RD2
       60
          12
              2.653E3
  R01
       8
          5
              50
  R02
      7
          99
              50
  RP
              4.310E3
      10
  RSS
         99
              925.9E3
  VAD
      60
          4
              DC 0
  VC 3 53 DC
              .78
  VE
      54
          4
              DC
              DC 0
  VLP
      91 0
              DC 1.9
  O MIV
         92 DC 9.4
.MODEL DX D(IS=800.0E-18)
.MODELJXPJF(IS=1.500E-12BETA=1.316E3
+ VTO=-.270)
. ENDS
```

Figure 20. Boyle Macromodel and Subcircuit

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Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specification and operating characteristics of the semiconductor product to which the model relates.



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Power-On Calibration of Input Offset Voltage

 Low Input Offset Voltage . . . < 40 μV Max (TLC4501A)

• Low Input Offset Voltage Drift . . . < 1 μ V/°C

Low Input Bias Current

High Output Drive Capability
 C₁ < 1 nF and R₁ > 1 kΩ

- High Open Loop Gain . . . > 120 dB
- Rail-To-Rail Output Voltage Swing
- Low Distortion . . . < 0.01% at 10 kHz
- Low Noise . . . 12 nV/√Hz at 1 kHz
- High Slew Rate . . . 2.5 V/μs
- Low Power Consumption . . .< 1.5 mA (Typical)
- Short Calibration Time . . . 300 ms Typ

description

The TLC4501 self-calibrating operational amplifier utilizes the recent availability of on-chip digital and analog signal processing to automatically null the input offset voltage at powerup. This self-calibrating feature requires typically 300 ms to complete and is repeatable to within $\pm 3~\mu V$ on successive calibrations. The technique involves the extraction and digital storage of the key offset-nulling information. This information is retained without degradation as long as the circuit is powered. This eliminates the need for continuous chopping of the input signal to refresh the offset information. Once the process is complete, the bulk of the calibration circuitry drops out of the signal path and shuts down. This minimizes or eliminates any effect the calibration circuitry might have on the desired signal path. It also allows the TLC4501 to be used exactly like any other operational amplifier after the calibration cycle is complete.

The TLC4501 is a high-performance operational amplifier fabricated in a 1- μ m 5-V digital CMOS technology. It achieves very high dc gain, as well as excellent power supply rejection ratio (PSRR) and common-mode rejection ratio (CMRR). It uses a mixed-mode (analog/digital) internal compensation loop with digital storage of the offset information and a current-mode output to reduce its input offset to < 40 μ V. The TLC4501 also features a rail-to-rail output structure capable of driving loads to 1 $k\Omega$ and 1 nF. Unlike existing commercially available low-offset high-precision amplifiers, the TLC4501 needs only a single 5-V supply, requires no trimming, and uses no bipolar transistors or JFETs.

AVAILABLE OPTIONS

TA	V _{IO} max AT 25°C	PACKAGED DEVICE [†] SMALL OUTLINE (D)	CHIP FORM (Y)
0°C to 70°C	40 μV	TLC4501ACDR	1
0.0 10 70.0	80 μV	TLC4501CDR	TI 04504V
-40°C to 85°C	40 μV	V TLC4501AIDR TLC4501Y	
-40°C (0 85°C	80 μV	TLC4501IDR	

[†]The D package is also available taped and reeled.

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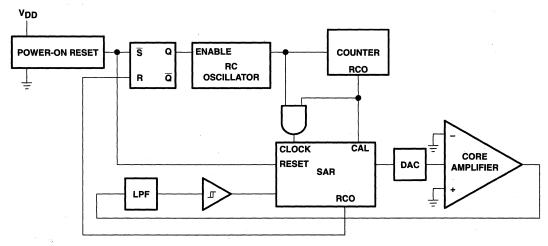


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description (continued)

To achieve high dc gain, large bandwidth, high CMRR and PSRR, as well as good output drive capability, the TLC4501 is built around a 3-stage topology: two gain stages, one rail-to-rail, and a class-AB output stage. A nested Miller topology is used for frequency compensation.

functional block diagram (during calibration)



During the calibration procedure, the operational amplifier is removed from the signal path and both inputs are tied to GND.

The class AB output stage features rail-to-rail voltage swing and incorporates additional switches to put the output node into a high-impedance mode during the calibration cycle. Small-replica output transistors (matched to the main output transistors) provide the amplifier output signal for the calibration circuit. The TLC4501 also features built-in output short-circuit protection. The output current flowing through the main output transistors is continuously being sensed. If the current through either of these transistors exceeds the preset limit (60 mA - 70 mA) for more than about 1 μ s, the output transistors are shut down to essentially their quiescent operating point for approximately 5 ms. The device is then returned to normal operation. If the short circuit is still in place, it is detected in less than 1 μ s and the device is shutdown for another 5 ms.

The offset cancellation uses a current-mode digital-to-analog converter (DAC), whose full-scale current allows for an adjustment of approximately ± 5 mV to the input offset voltage. The digital code producing the cancellation current is stored in the successive-approximation register (SAR).

During power up, when the offset cancellation procedure is initiated, an on-chip RC oscillator is activated to provide the timing of the successive-approximation algorithm. To prevent wide-band noise from interfering with the calibration procedure, an analog low-pass filter followed by a Schmidt trigger is used in the decision chain to implement an averaging process. Once the calibration procedure is complete, the RC oscillator is deactivated to reduce supply current and the associated noise.

The key operational-amplifier parameters CMRR, PSRR, and offset drift were optimized to achieve superior offset performance. The TLC4501 calibration DAC is implemented by a binary-weighted current array using a pseudo-R-2R MOSFET ladder architecture, which minimizes the silicon area required for the calibration circuitry, and thereby reduces the cost of the TLC4501.



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description (continued)

Due to the performance (precision, PSRR, CMRR, gain, output drive, and ac performance) of the TLC4501, it is ideal for applications like:

- Data acquisition systems
- Medical equipment
- Portable digital scales
- Strain gauges
- Automotive sensors
- Digital audio circuits
- Industrial control applications

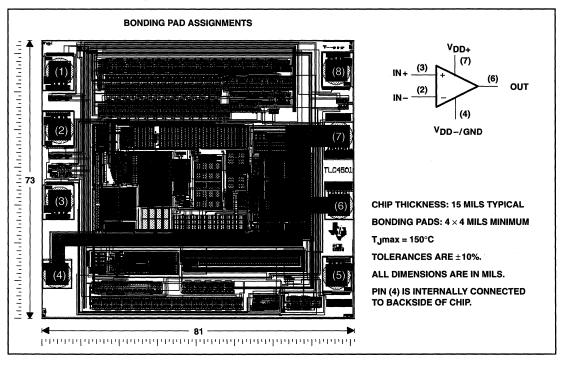
It is also ideal in circuits like:

- A precision buffer for current-to-voltage converters, a/d buffers, or bridge applications
- High-impedance buffers or preamplifiers
- Long term integration
- Sample-and-hold circuits
- Peak detectors

The TLC4501 self-calibrating operational amplifier is manufactured using Texas instruments LinEPIC process technology and is available in an 8-pin SOIC (D) Package. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C.

TLC4501Y chip information

This chip, when properly assembled, display characteristics similar to the TLC4501C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip can be mounted with conductive epoxy or a gold-silicon preform.



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absolute maximum ratings over operating free-air temperature rar	nge (unless otherwise noted)†
Supply voltage, V _{DD+} (see Note 1)	
Differential input voltage, V _{ID} (see Note 2)	
Input voltage range, V _I (any input, see Note 1)	0.3 V to 7 V
Input current, I _I (each input)	
Output current, IO	
Total current into V _{DD+}	±100 mA
Total current out of V _{DD} _/GND	±100 mA
Electrostatic discharge (ESD)	
Duration of short-circuit current at (or below) 25°C (see Note 3)	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A : TLC4501C	
TLC4501I	40°C to 85°C
Storage temperature range, T _{stg}	65°C to 150°C
Case temperature for 60 seconds, T _C : FK package	
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD} _/GND.

- 2. Differential voltages are at IN+ with respect to IN-. Excessive current flows when an input is brought below VDD--0.3 V.
- 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING	POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW

recommended operating conditions

	T	TLC4501C TLC450		TLC45011		
	MIN			MAX	UNIT	
Supply voltage, V _{DD}	4	6	4	6	٧	
Input voltage range, V _I	V _{DD} -	V _{DD+} - 2.3	V _{DD} ~	V _{DD+} 2.3	V	
Common-mode input voltage, V _{IC}	V _{DD} -	V _{DD+} - 2.3	V _{DD} -	V _{DD+} - 2.3	V	
Operating free-air temperature, T _A	0	70	-40	85	°C	

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0 (unless otherwise noted)

	DAMETED	TEST CONDITIONS		T. †	TI	_C45010	>	TL	C4501A	С	LIMIT
PA	RAMETER	TEST CC	ONDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
V _{IO}	Input offset			25°C	-80		80	-40		40	μV
VIO	voltage			Full range	-80		80	-40		40	μ ν
αVIO	Temperature coefficient of input offset voltage	$V_{DD} = \pm 2.5 \text{ V},$ $V_{IC} = 0,$	$V_O = 0$, $R_S = 50 \Omega$	Full range	,	1			1		μV/°C
l.o	Input offset cur-] "	G	25°C		1			1		- n A
10	rent			Full range	ļ		500			500	pΑ
l	Input bias current			25°C		1			1		pA
liB	Input bias current			Full range			500			500	PΑ
	I Park I and and and	IOH = - 500 μA		25°C		4.99			4.99		
VOH	High-level output voltage	IOH = - 5 mA		25°C		4.9			4.9		V
		IOH = -3 IIIA		Full range	4.7			4.7			
		$V_{IC} = 2.5 V$,	I _{OL} = 500 μA	25°C		0.01			0.01		
VOL	Low-level output voltage	V _{IC} = 2.5 V,	IOL = 5 mA	25°C		0.1			0.1		V
		VIC = 2.5 V,	IOL = 5 IIIA	Full range			0.3			0.3	
AVD	Large-signal differential voltage	V _{IC} = 2.5 V,	V _O = 1 V to 4 V, See Note 4	25°C	200	1000		200	1000		V/mV
	amplification	$R_L = 1 k\Omega$,	See Note 4	Full range	200			200			
R _{I(D)}	Differential input resistance			25°C		10			10		kΩ
RL	Input resistance	See Note 4		25°C		1012			1012		Ω
CL	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		рF
zO	Closed-loop output impedance	A _V = 10,	f = 100 kHz	25°C		1			1		Ω
	Common-mode	V _{IC} = 0 to 2.7 \	′,	25°C	90	100		90	100		
CMRR	rejection ratio	$V_O = 2.5 \text{ V},$ $R_S = 1 \text{ k}\Omega$		Full range	85			85			dB
	Supply-voltage		V _{DD} = 4 V to 6 V,		90	100		90	100		
ksvr-	rejection ratio $(\Delta V_{DD} \pm /\Delta V_{IO})$	V _{IC} = 0, No load		Full range	90			90			dB
laa	Supply ourrent	Vo - 25 V	No lood	25°C		1	1.5		1	1.5	m۸
DD	Supply current	$V_0 = 2.5 V$,	No load	Full range			2			2	mA
VIT(CAL)	Calibration input threshold voltage			Full range	4			4			٧

† Full range is 0°C to 70°C.

electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0 (unless otherwise noted)

D/	ARAMETER	TEST CONDITIONS		T _A †	Т	LC4501		TL	C4501A	TLC4501AI		
PA	AHAMEIEH	TEST CC	SNOTTIONS	'A'	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
V _{IO}	Input offset			25°C	-80		80	-40		40	μV	
VIO	voltage	ľ		Full range	-80		80	-40		40	μ ν	
^α VIO	Temperature coefficient of input offset voltage	$V_{DD} = \pm 2.5 \text{ V},$ $V_{IC} = 0,$	$V_O = 0$, $R_S = 50 \Omega$	Full range		1			1		μV/°C	
li a	Input offset cur-	1 "		25°C		1		-	1		^	
lo	rent]		Full range			500			500	pΑ	
lin	Input bias current	1		25°C		1			1		pΑ	
IВ	input bias current			Full range			500			500	ÞΑ	
	High lavel and and	I _{OH} = - 500 μA		25°C		4.99			4.99			
Vон	High-level output voltage	I _{OH} = - 5 mA		25°C		4.9			4.9		V	
		IOH = - 5 IIIA		Full range	4.7			4.7				
	($V_{IC} = 2.5 V$,	$I_{OL} = 500 \mu\text{A}$	25°C		0.01			0.01			
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 5 mA	25°C		0.1			0.1		٧	
	-	V ₁ C = 2.5 V,	10L = 3111A	Full range			0.3			0.3		
AVD	Large-signal differential voltage	$V_{IC} = 2.5 \text{ V},$ $R_{I} = 1 \text{ k}\Omega,$	V _O = 1 V to 4 V, See Note 4	25°C	200	1000		200	1000		V/mV	
	amplification	11_ 1 142,		Full range	200			200				
R _{I(D)}	Differential input resistance			25°C		10			10		kΩ	
RL	Input resistance	See Note 4		25°C		1012			1012		Ω	
CL	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF	
zO	Closed-loop output impedance	A _V = 10,	f = 100 kHz	25°C		1			1		Ω	
01.100	Common-mode	V _{IC} = 0 to 2.7 V	' ,	25°C	90	100		90	100			
CMRR	rejection ratio	$V_O = 2.5 \text{ V},$ $R_S = 1 \text{ k}\Omega$		Full range	85			85			dB	
ksvr	Supply-voltage rejection ratio	V _{DD} = 4 V to 6 V _{IC} = 0,	V,	25°C	90	100		90	100		dB	
HVG	(ΔV _{DD ±} /ΔV _{IO})	No load		Full range	90			90			ub.	
IDD	Supply current	V _O = 2.5 V,	No load	25°C		1	1.5		1	1.5	mA	
טטי		VO = 2.5 V,	140 1080	Full range			2			2	1110	
VIT(CAL)	Calibration input threshold voltage			Full range	4			4			٧	

† Full range is -40°C to 85°C.

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operating characteristics, $V_{DD} = 5 \text{ V}$

	DADAMETED	TEST CONDITIONS		TAT	TLC4501C, TLC4501AC			UNIT	
	PARAMETER	1EST COND	TEST CONDITIONS		MIN	TYP	MAX	UNII	
00		V. 05V4-05V	0 100 - 5	25°C	1.5	2.5		V/µs	
SR	Slew rate at unity gain	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	CL = 100 pF	Full range	, 1			V/μs	
· ·		f = 10 Hz		25°C		70			
v _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		nV/√Hz	
Vivin	Peak-to-peak equivalent input	f = 0.1 to 1 Hz		25°C		1		μV	
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz		25°C		1.5		μν	
In	Equivalent input noise current			25°C		0.6		fA/√Hz	
THD + N		$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.02%			
	Total harmonic distortion plus noise	$f = 10 \text{ kHz},$ $R_L = 1 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	A _V = 10	25°C		0.08%			
			A _V = 100	25°C		0.55%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 1 k\Omega$,	25°C		4.7		MHz	
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	A _V = 1, C _L = 100 pF	25°C		1		MHz	
	Cattling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	to 0.1%	25°C		1.6			
t _S	Settling time	$R_L = 1 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	to 0.01%	25°C		2.2		μs	
φm	Phase margin at unity gain	$R_L = 1 k\Omega$,	C _L = 100 pF	25°C		74			
	Calibration time			25°C		300		ms	

† Full range is 0°C to 70°C.

operating characteristics, $V_{DD} = 5 \text{ V}$

	DADAMETED		TEST CONDITIONS		TLC450	11, TLC4	501AI	UNIT
	PARAMETER	I EST COND			MIN	TYP	MAX	UNIT
SR	Clauret at units anim	V- 05V-05V	C: 100 = E	25°C	1.5	2.5		V/μs
SH	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	C[= 100 pr	Full range	1			V/μs
V	Equivalent innut pains valtage	f = 10 Hz		25°C		70		\u. 5T
v _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		nV/√Hz
V	Peak-to-peak equivalent input	f = 0.1 to 1 Hz		25°C		1		
V _{N(PP)}	noise voltage	f = 0.1 to 10 Hz		25°C		1.5		μV
l _n	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	$V_0 = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1	25°C		0.02%		
		$f = 10 \text{ kHz},$ $R_L = 1 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	A _V = 10	25°C		0.08%		
			A _V = 100	25°C		0.55%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 1 \text{ k}\Omega$,	25°C		4.7		MHz
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	Ay = 1, C _L = 100 pF	25°C		1		MHz
	Sottling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	to 0.1%	25°C		1.6		
ts	Settling time	$R_L = 1 k\Omega$, $C_L = 100 pF$	to 0.01%	25°C		2.2		μs
φm	Phase margin at unity gain	$R_L = 1 k\Omega$,	C _L = 100 pF	25°C		74		
	Calibration time			25°C		300		ms

† Full range is -40°C to 85°C. NOTE 4: R_L and C_L values are referenced to 2.5 V.

electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0, T_{A} = 25°C (unless otherwise noted)

	DADAMETED	TEGT COM	OLTIONIC	TLC4501Y			UNIT
	PARAMETER	TEST CONI	SHORS	MIN	TYP	MAX	UNII
VIO	Input offset voltage				10		μV
lo	Input offset current	$V_{DD} = \pm 2.5 \text{ V},$ $V_{IC} = 0,$	$V_O = 0$, $R_S = 50 \Omega$		1		pΑ
lв	Input bias current	VIC = 0,	115 - 30 32		1		pА
Vari	High-level output voltage	ΙΟΗ = - 500 μΑ	I _{OH} = - 500 μA I _{OH} = - 5 mA		4.99		V
Vон	High-level output voltage	I _{OH} = – 5 mA			4.9		٧
V	Low level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA		0.01		V
VOL	Low-level output voltage	$V_{IC} = 2.5 \text{ V},$	IOL = 5 mA	0.1		, v	
AVD	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $R_L = 1 \text{ k}\Omega,$	V _O = 1 V to 4 V, See Note 4		1000		V/mV
R _{I(D)}	Differential input resistance				10		kΩ
RL	Input resistance	See Note 4			1012		Ω
CL	Common-mode input capacitance	f = 10 kHz,	P package		8		pF
^z O	Closed-loop output impedance	A _V = 10,	f = 100 kHz		1		Ω
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 2.7 V, R _S = 1 k Ω	V _O = 2.5 V,		100		dB
ksvr	Supply-voltage rejection ratio (ΔV _{DD ±} /ΔV _{IO})	$V_{DD} = \pm 2 \text{ V to } \pm 3 \text{ V},$ No load	V _{IC} = 0,		100		dB
lDD	Supply current	V _O = 2.5 V,	No load		1		mA

NOTE 4: RL and CL values are referenced to 2.5 V.

operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	DADAMETED	TEST COM	TEST CONDITIONS			TLC4501Y		
-	PARAMETER	TEST CON	DITIONS	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	C _L = 100 pF		2.5		V/μs	
V _n	Equivalent input noise voltage	f = 10 Hz f = 1 kHz			70		nV/√Hz	
٧n	Equivalent input noise voltage				12		Π V /∀ H Z	
VALCED	$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage				1		μV	
V _{N(PP)}	reak-to-peak equivalent input hoise voltage	f = 0.1 to 10 Hz			1.5		μν	
l _n	Equivalent input noise current				0.6		fA/√Hz	
		$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$			0.02%			
THD + N	Total harmonic distortion plus noise	$f = 10 \text{ kHz},$ $R_L = 1 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	A _V = 10		0.08%			
			A _V = 100		0.55%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	R _L = 1 kΩ,		4.7		MHz	
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	A _V = 1, C _L = 100 pF		1		MHz	
	$A_V = -1$, Step = 0.5 V to 2.5 V,		to 0.1%		1.6			
ts	Settling time	$R_L = 1 k\Omega$, $C_L = 100 pF$	to 0.01%		2.2		μs	
φm	Phase margin at unity gain	$R_L = 1 k\Omega$,	C _L = 100 pF		74			
	Calibration time				300		ms	



TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V	land a Mark valle and	Distribution	1, 2, 3
VIO	Input offset voltage	vs Common-mode input voltage	4
αVIO	Input offset voltage temperature coefficient	Distribution	5, 6
Voн	High-level output voltage	vs High-level output current	7
VOL	Low-level output voltage	vs Low-level output current	8
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	9
los	Short-circuit output current	vs Free-air temperature	10
Vo	Output voltage	vs Differential input voltage	11
AVD	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	12 13
z _o	Output impedance	vs Frequency	14
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	15 16
SR	Slew rate	vs Load capacitance vs Free-air temperature	17 18
	Inverting large-signal pulse response	vs Time	19
	Voltage-follower large-signal pulse response	vs Time	20
	Inverting small-signal pulse response	vs Time	21
	Voltage-follower small-signal pulse response	vs Time	22
Vn	Equivalent input noise voltage	vs Frequency	23
	Input noise voltage	Over a 10-second period	24
THD + N	Total harmonic distortion plus noise	vs Frequency	25
	Gain-bandwidth product	vs Free-air temperature	26
	Phone margin	vs Load capacitance	27, 28
φm	Phase margin	vs Frequency	13
PSRR	Power-supply rejection ratio	vs Free-air temperature	29
	Calibration time at -40°C	vs Time	30
	Calibration time at 25°C	vs Time	31
	Calibration time at 85°C	vs Time	32

16

14

12 10

Percentage Of Amplification – %

TYPICAL CHARACTERISTICS

Percentage of Amplifiers - %

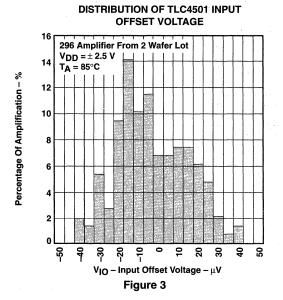
8

DISTRIBUTION OF TLC4501 INPUT OFFSET VOLTAGE 339 Amplifier From 2 Wafer Lot $V_{DD} = \pm 2.5 \text{ V}$ TA = 40°C

Figure 1

VIO - Input Offset Voltage - µV

20



DISTRIBUTION OF TLC4501 INPUT OFFSET VOLTAGE

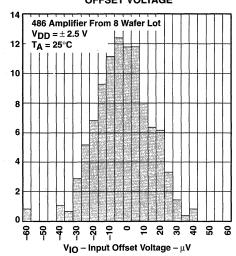


Figure 2

INPUT OFFSET VOLTAGE COMMON-MODE INPUT VOLTAGE

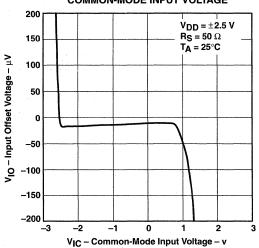


Figure 4

TYPICAL CHARACTERISTICS

Percentage Of Amplifiers – %

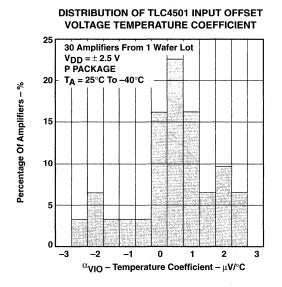
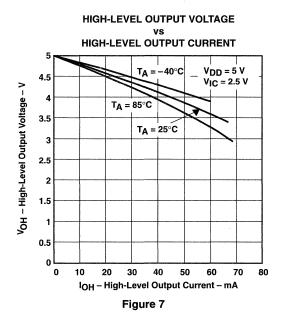


Figure 5



DISTRIBUTION OF TLC4501 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT

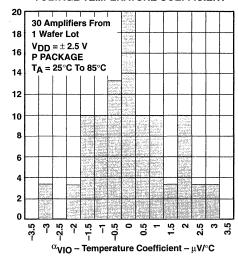


Figure 6

LOW-LEVEL OUTPUT VOLTAGE vs

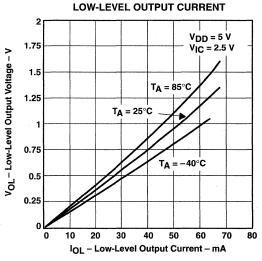


Figure 8

VO(PP) - Maximum Peak-To-Peak Output Voltage -- V

100

1 k

TYPICAL CHARACTERISTICS

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE FREQUENCY $V_{DD} = 5 V$ 8 6 2

Figure 9

f - Frequency - Hz

100 k

1 M

10 M

10 k

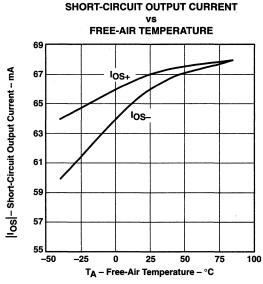


Figure 10

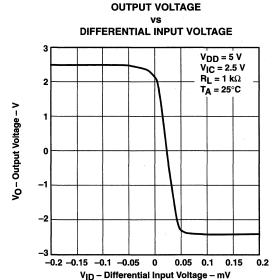
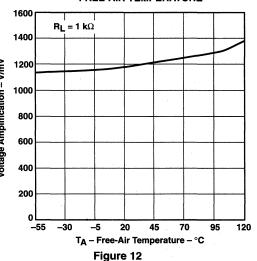


Figure 11

A_{VD} – Large-Signal Differential Voltage Amplification – V/mV

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION VS

FREE-AIR TEMPERATURE



TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

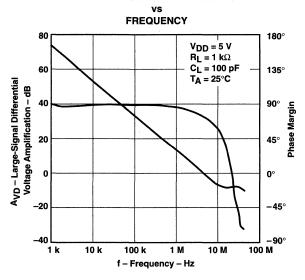
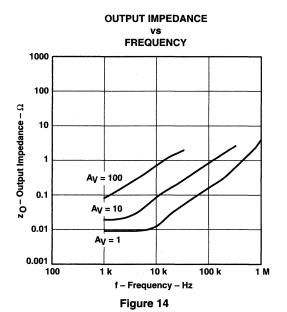
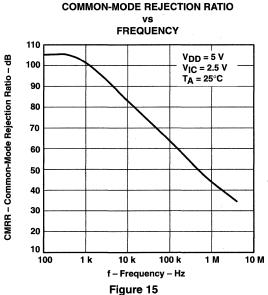
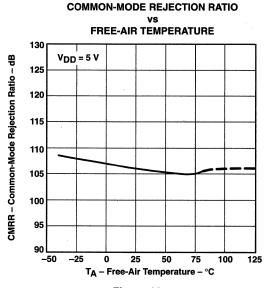


Figure 13





TYPICAL CHARACTERISTICS



SR – Slew Rate – V/μs

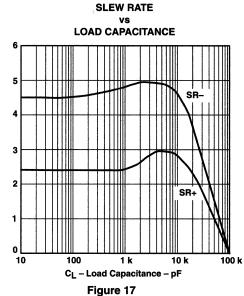
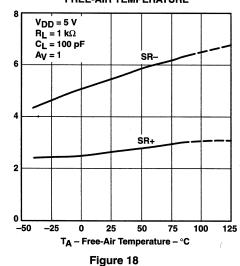


Figure 16





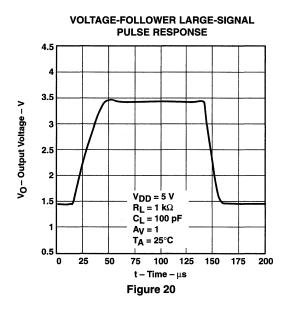
V_O – Output Voltage – V

INVERTING LARGE-SIGNAL PULSE RESPONSE 3.5 3 2.5 2 $V_{DD} = 5 V$ $R_L = 1 k\Omega$ 1.5 CL = 100 pF $A_{V} = -1$ T_A = 25°C 0.5 25 0 50 75 100 125 150 175 200 t - Time - μs

8 Figure 19

SR – Slew Rate – V/µs

TYPICAL CHARACTERISTICS



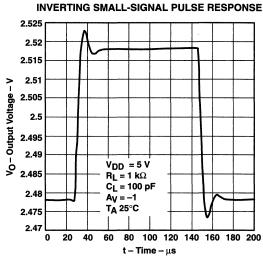


Figure 21

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

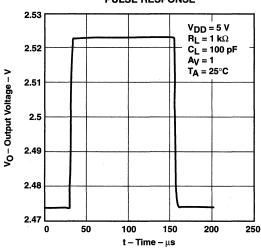


Figure 22

EQUIVALENT INPUT NOISE VOLTAGE vs

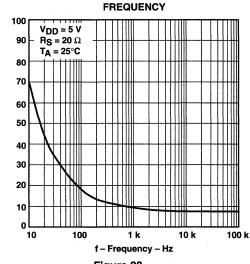
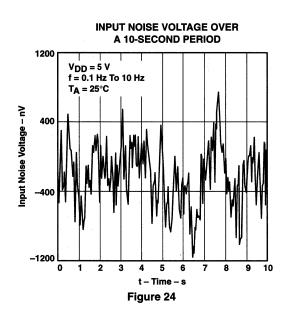


Figure 23

Vn – Equivalent Input Noise Voltage – nV/√Hz

TYPICAL CHARACTERISTICS



TOTAL HARMONIC DISTORTION PLUS NOISE vs

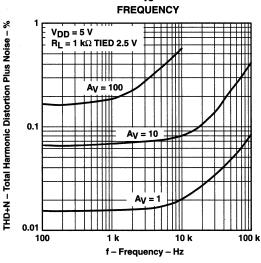


Figure 25



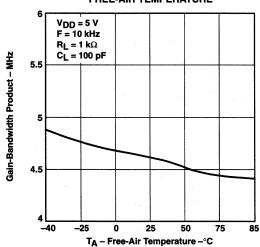


Figure 26

PHASE MARGIN

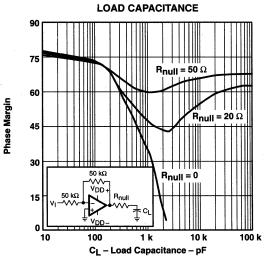


Figure 27

TYPICAL CHARACTERISTICS

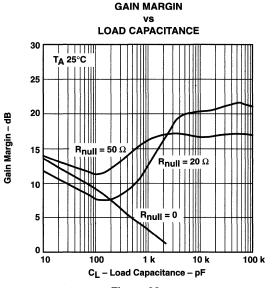


Figure 28

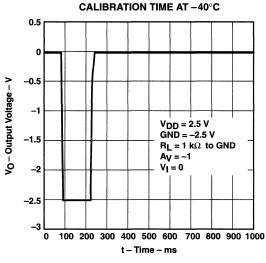
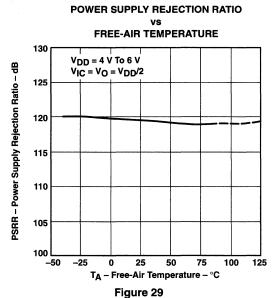


Figure 30



CALIBRATION TIME AT 25°C 0.5 0 -0.5Vo - Output Voltage - V -1.5 $V_{DD} = 2.5 V$ -2 GND = -2.5 V $R_L = 1 k\Omega$ to GND $A_{V} = -1$ -2.5 Vi = 0 -3 100 200 300 400 500 600 700 800 900 1000 t - Time - ms

Figure 31

TYPICAL CHARACTERISTICS

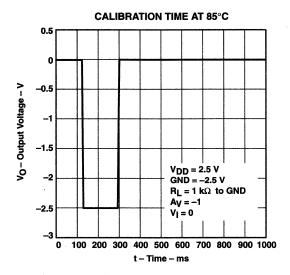


Figure 32

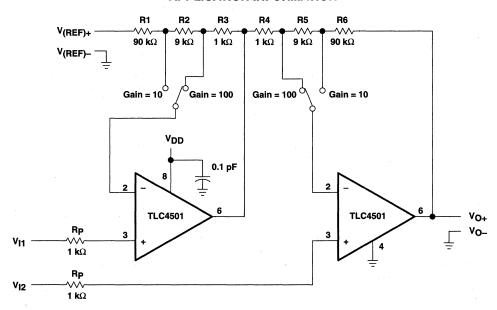
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APPLICATION INFORMATION

- The TLC4501 is designed to operate with only a single 5-V power supply, have true differential inputs, and remain in the linear mode with an input common-mode voltage of 0.
- The TLC4501 has a standard single-amplifier pinout allowing for easy design upgrades.
- Large differential input voltages can be easily accommodated and, as input differential-voltage protection
 diodes are not needed, no large input currents result from large differential input voltage. Protection should
 be provided to prevent the input voltages from going negative more than -0.3 V at 25°C. An input clamp
 diode with a resistor to the device input terminal can be used for this purpose.
- For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor can be
 used from the output of the amplifier to ground. This increases the class-A bias current and prevents
 crossover distortion. Where the load is directly coupled, for example dc applications, there is no crossover
 distortion.
- Capacitive loads, which are applied directly to the output of the amplifier, reduce the loop stability margin.
 Values of 500 pF can be accommodated using the worst-case noninverting unity-gain connection. Resistive isolation should be considered when larger load capacitance must be driven by the amplifier.

The following typical application circuits emphasize operation on only a single power supply. When complementary power supplies are available, the TLC4501 can be used in all of the standard operational amplifier circuits. In general, introducing a pseudo-ground (a bias voltage of $V_1/2$ like that generated by the TLE2426) allows operation above and below this value in a single-supply system. Many application circuits are shown which take advantage of the wide common-mode input-voltage range of the TLC4501, which includes ground. In most cases, input biasing is not required and input voltages that range to ground can easily be accommodated.

APPLICATION INFORMATION



(Gain = 10)
$$V_O = (V_{11} - V_{12})(1 + \frac{R6}{R4 + R5}) + V_{(REF)}$$
 Where R1 = R6, R2 = R5, and R3 = R4 (Gain = 100) $V_O = (V_{11} - V_{12})(1 + \frac{R5 + R6}{R4}) + V_{(REF)}$ Where R1 = R6, R2 = R5, and R3 = R4

Figure 33. Single-Supply Programmable Instrumentation Amplifier Circuit

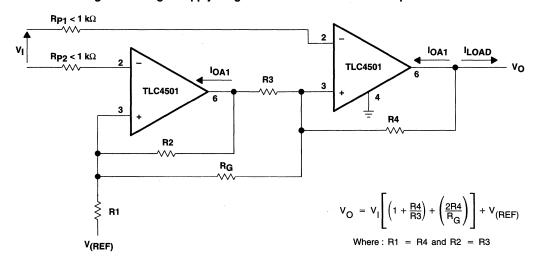
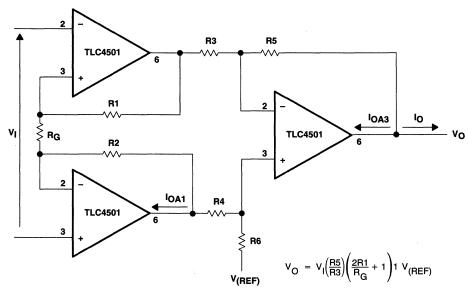


Figure 34. Two Operational-Amplifier Instrumentation Amplifier Circuit

APPLICATION INFORMATION



Where: R1 = R2, R3 = R4, and R5 = R6

Figure 35. Three Operational-Amplifier Instrumentation Amplifier Circuit

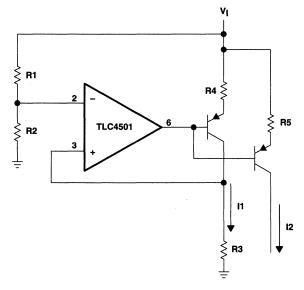


Figure 36. Fixed Current-Source Circuit

APPLICATION INFORMATION

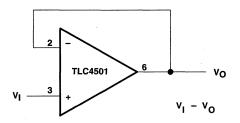


Figure 37. Voltage-Follower Circuit

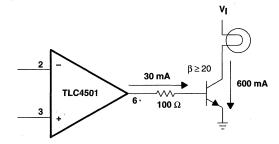


Figure 38. Lamp-Driver Circuit

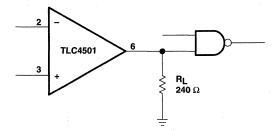


Figure 39. TTL-Driver Circuit

APPLICATION INFORMATION

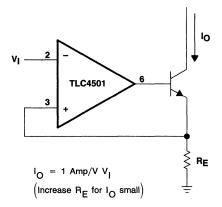


Figure 40. High-Compliance Current-Sink Circuit

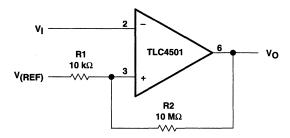


Figure 41. Comparator With Hysteresis Circuit

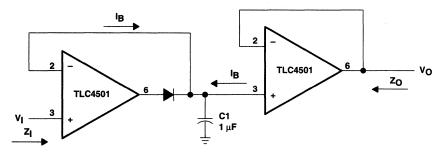


Figure 42. Low-Drift Detector Circuit

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D PACKAGE

(TOP VIEW)

Power On Calibration of Input Offset Voltage

 Low Input Offset Voltage . . . < 50 μV Max (TLC4502A)

• Low Input Offset Voltage Drift . . . < 1 μ V/°C

Low Input Bias Current

• High Output Drive Capability $C_L < 1 \text{ nF and } R_L > 1 \text{ k}\Omega$

- High Open Loop Gain . . . > 120 dB
- Rail-To-Rail Output Voltage Swing
- Low Distortion . . . < 0.01% at 10 kHz
- Low Noise . . . 12 nV/√Hz at 1 kHz
- High Slew Rate . . . 2.5 V/µs
- Low Power Consumption . . .< 1.5 mA (Typical) Per Amplifier
- Short Calibration Time . . . 300 ms Typ

1OUT [1 8] V_{DD} 1IN - [2 7] 2OUT 1IN + [3 6] 2IN -V_{DD -}/GND [4 5] 2IN+

description

The TLC4502 self-calibrating operational amplifier utilizes the recent availability of on-chip digital and analog signal processing to automatically null the input offset voltage at power-up. This self-calibrating feature requires typically 300 ms to complete and is repeatable to within $\pm 3~\mu V$ on successive calibrations. The technique involves the extraction and digital storage of the key offset-nulling information. This information is retained without degradation as long as the circuit is powered. This eliminates the need for continuous chopping of the input signal to refresh the offset information. Once the process is complete, the bulk of the calibration circuitry drops out of the signal path and shuts down. This minimizes or eliminates any effect the calibration circuitry might have on the desired signal path. It also allows the TLC4502 to be used exactly like any other operational amplifier after the calibration cycle is complete.

The TLC4502 is a high-performance operational amplifier fabricated in a 1- μ m 5-V digital CMOS technology. It achieves very high dc gain, as well as excellent power supply rejection ratio (PSRR) and common-mode rejection ratio (CMRR). It uses a mixed-mode (analog/digital) internal compensation loop with digital storage of the offset information and a current-mode output to reduce its input offset to < 50 μ V. The TLC4502 also features a rail-to-rail output structure capable of driving loads to 1 $k\Omega$ and 1 nF. Unlike existing commercially available low-offset high-precision amplifiers, the TLC4502 needs only a single 5-V supply, requires no trimming, and uses no bipolar transistors or JFETs.

AVAILABLE OPTIONS

		PACKAGED DEVICET	CHIP FORM
T _A	V _{IO} max AT 25°C	SMALL OUTLINE (D)	(Y)
0°C to 70°C	50 μV	TLC4502ACDR	
0.01070.0	100 μV	TLC4502CDR	TI 04500V
-40°C to 85°C	50 μV	TLC4502AIDR	TLC4502Y
-40°C to 85°C	100 μV	TLC4502IDR	

[†]The D package is also available taped and reeled.

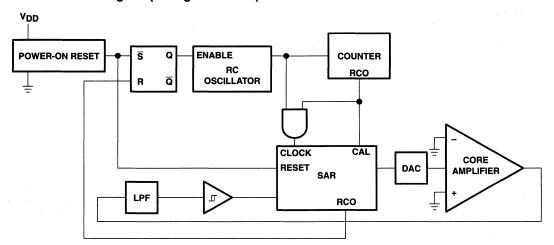
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description (continued)

To achieve high dc gain, large bandwidth, high CMRR and PSRR, as well as good output drive capability, the TLC4502 is built around a 3-stage topology: two gain stages, one rail-to-rail, and a class-AB output stage. A nested Miller topology is used for frequency compensation.

functional block diagram (during calibration)



During the calibration procedure, the operational amplifier is removed from the signal path and both inputs are tied to GND.

The class AB output stage features rail-to-rail voltage swing and incorporates additional switches to put the output node into a high-impedance mode during the calibration cycle. Small-replica output transistors (matched to the main output transistors) provide the amplifier output signal for the calibration circuit. The TLC4502 also features built-in output short-circuit protection. The output current flowing through the main output transistors is continuously being sensed. If the current through either of these transistors exceeds the preset limit (60 mA - 70 mA) for more than about 1 µs, the output transistors are shut down to essentially their quiescent operating point for approximately 5 ms. The device is then returned to normal operation. If the short circuit is still in place, it is detected in less than 1 us and the device is shutdown for another 5 ms.

The offset cancellation uses a current-mode digital-to-analog converter (DAC), whose full-scale current allows for an adjustment of approximately ±5 mV to the input offset voltage. The digital code producing the cancellation current is stored in the successive-approximation register (SAR).

During power up, when the offset cancellation procedure is initiated, an on-chip RC oscillator is activated to provide the timing of the successive-approximation algorithm. To prevent wide-band noise from interfering with the calibration procedure, an analog low-pass filter followed by a Schmidt trigger is used in the decision chain to implement an averaging process. Once the calibration procedure is complete, the RC oscillator is deactivated to reduce supply current and the associated noise.

The key operational-amplifier parameters CMRR, PSRR, and offset drift were optimized to achieve superior offset performance. The TLC4502 calibration DAC is implemented by a binary-weighted current array using a pseudo-R-2R MOSFET ladder architecture, which minimizes the silicon area required for the calibration circuitry, and thereby reduces the cost of the TLC4502.



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description (continued)

Due to the performance (precision, PSRR, CMRR, gain, output drive, and ac performance) of the TLC4502, it is ideal for applications like:

- Data acquisition systems
- Medical equipment
- Portable digital scales
- Strain gauges
- Automotive sensors
- Digital audio circuits
- Industrial control applications

It is also ideal in circuits like:

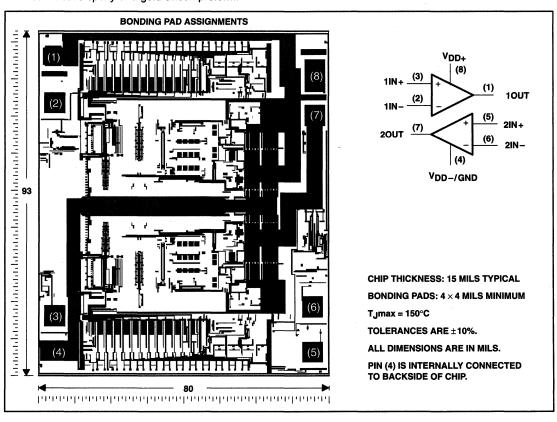
- A precision buffer for current-to-voltage converters, a/d buffers, or bridge applications
- High-impedance buffers or preamplifiers
- Long term integration
- Sample-and-hold circuits
- Peak detectors

The TLC4502 self-calibrating operational amplifier is manufactured using Texas instruments LinEPIC process technology and is available in an 8-pin SOIC (D) Package. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C.

TLC4502Y chip information

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This chip, when properly assembled, display characteristics similar to the TLC4502C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip can be mounted with conductive epoxy or a gold-silicon preform.



TLC4502, TLC4502A, TLC4502Y Advanced LinEPIC™ SELF-CALIBRATING (Self-Cal PRECISION DUAL OPERATIONAL AMPLIFIERS SLOS161A - OCTOBER 1996 - REVISED NOVEMBER 1996

absolute maximum ratings over operating free-air temperatu	are range (unless otherwise noted)†
Supply voltage, V _{DD+} (see Note 1)	7 V
Differential input voltage, V _{ID} (see Note 2)	±7 V
Input voltage range, V _I (any input, see Note 1)	0.3 V to 7 V
Input current, I _I (each input)	±5 mA
Output current, IO (each output)	
Total current into V _{DD+}	±100 mA
Total current out of V _{DD} _/GND	±100 mA
Electrostatic discharge (ESD)	> 2 kV
Duration of short-circuit current at (or below) 25°C (see Note 3) .	unlimited
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, T _A : TLC4502C	0°C to 70°C
TLC4502I	–40°C to 85°C
Storage temperature range, T _{stq}	
Case temperature for 60 seconds, T _C : FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

[†] Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values, except differential voltages, are with respect to V_{DD} _/GND.
 - 2. Differential voltages are at IN+ with respect to IN−. Excessive current flows when an input is brought below V_{DD} − 0.3 V.
 - 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

PACKAGE	T _A ≤ 25°C	DERATING FACTOR	T _A = 70°C	T _A = 85°C
	POWER RATING	ABOVE T _A = 25°C	POWER RATING	POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW

recommended operating conditions

	TI	LC4502C	TI	UNIT	
	MIN MAX MIN MAX		MAX	JONII	
Supply voltage, V _{DD}	4	6	4	6	٧
Input voltage range, V _I	V_{DD-}	V _{DD+} - 2.3	V _{DD} _	V _{DD+} – 2.3	٧
Common-mode input voltage, V _{IC}	V_{DD-}	V _{DD+} – 2.3	V_{DD-}	V _{DD+} - 2.3	٧
Operating free-air temperature, TA	0	70	-40	85	°C

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electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0 (unless otherwise noted)

D.	ARAMETER	TEST OF	ONDITIONS	- +	TI	_C45020	>	TL	C4502A	С	UNIT	
F#	ANAMEIER	lesi co	CHOITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNII	
Via	Input offset			25°C	-100		100	-50		50	μV	
VIO	voltage			Full range	-100		100	-50		50	μν	
αVIO	Temperature coefficient of input offset voltage	V _{DD} = ±2.5 V,		Full range		1			1		μV/°C	
lio	Input offset	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		1			1		рA	
_I IO	current			Full range			500			500	рд	
l _{IB}	Input bias current			25°C		1			1		pА	
מוי	input bias current			Full range			500			500	PA	
	High layed andmod	IOH = - 500 μA		25°C		4.99			4.99			
Vон	High-level output voltage	IOH = - 5 mA		25°C		4.9			4.9		V	
	IOH =	IOH = - 3 IIIA		Full range	4.7			4.7				
V _{OL} Low-level output voltage		$V_{IC} = 2.5 V$,	I _{OL} = 500 μA	25°C		0.01			0.01			
	V _{IC} = 2.5 V, I _{OL} =	I _{OL} = 5 mA	25°C		0.1			0.1		v		
		VIC = 2.5 V,	IOF = 2 UIV	Full range			0.3			0.3		
AvD	Large-signal differential voltage	V _{IC} = 2.5 V,	V _O = 1 V to 4 V,	25°C	200	1000		200	1000		V/mV	
,,,	amplification	$R_L = 1 \text{ k}\Omega$, See Note 4	TRI≡1KU SEENOTE	See Note 4	Full range	200			200			
R _{I(D)}	Differential input resistance			25°C		10			10		kΩ	
RL	Input resistance	See Note 4		25°C		1012			1012		Ω	
CL	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF	
zO	Closed-loop output impedance	A _V = 10,	f = 100 kHz	25°C		1	***************************************		1		Ω	
CMRR	Common-mode	V _{IC} = 0 to 2.7 \	<i>I</i> ,	25°C	90	100		90	100		dB	
CMAA	rejection ratio	$V_O = 2.5 V$, $R_S = 1 k\Omega$		Full range	85			85			ав	
	Supply-voltage	V _{DD} = 4 V to 6	V,	25°C	90	100		90	100			
ksvr	rejection ratio $(\Delta V_{DD \pm}/\Delta V_{IO})$	V _{IC} = 0, No load			90			90			dB	
Inn	Supply current	V _O = 2.5 V,	No load	25°C		2.5	3.5		2.5	3.5	mA	
IDD	эцрру сипеп	VO = 2.5 V,	INU IUAU	Full range			4			4	IIIA	
VIT(CAL)	Calibration input threshold voltage			Full range	4			4			٧	

[†] Full range is 0°C to 70°C.

TLC4502, TLC4502A, TLC4502Y Advanced LinEPIC™ SELF-CALIBRATING (Self-Cal™) PRECISION DUAL OPERATIONAL AMPLIFIERS SLOS161A - OCTOBER 1996 - REVISED NOVEMBER 1996

electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0 (unless otherwise noted)

D/	ARAMETER	TEST OF	NDITIONS	- +	Т	LC4502		TL	C4502A	J	UNIT		
Ρ,	ARAMETER	TEST CC	NDITIONS	T _A †	MIN	TYP	MAX	MIN	TYP	MAX	UNIT		
VIO	Input offset		-	25°C	-100		100	-50		50	μV		
۷۱٥	voltage			Full range	-100		100	-50		50	μν		
^α VIO	Temperature coefficient of input offset voltage	V _{DD} = ±2.5 V,		Full range		1			1		μV/°C		
lio	Input offset	V _{IC} = 0,	$R_S = 50 \Omega$	25°C		1			1		pA		
10	current			Full range			500			500	PA		
Iв	Input bias current			25°C		1		:	1		Aq		
чв	Input bias current			Full range			500			500	PΛ		
	High-level output	IOH = - 500 μA		25°C		4.99			4.99				
VOH	voltage	I _{OH} = - 5 mA		25°C		4.9			4.9		V		
		IOH - SIIIA		Full range	4.7			4.7					
	Low-level output	$V_{IC} = 2.5 V$,	I _{OL} = 500 μA	25°C		0.01			0.01				
VOL	voltage	V _{IC} = 2.5 V,	i	' 1	IOL = 5 mA	25°C		0.1			0.1		٧
		VIC = 2.5 V,	IOL = 3 IIIA	Full range			0.3			0.3			
AvD	Large-signal differential voltage	V _{IC} = 2.5 V, R _I = 1 kΩ,	V _O = 1 V to 4 V, See Note 4	25°C	200	1000		200	1000		V/mV		
	amplification	L = 1 K22,	See Note 4	Full range	200			200					
R _{I(D)}	Differential input resistance			25°C		10			10		kΩ		
RL	Input resistance	See Note 4		25°C		1012			1012		Ω		
CL	Common-mode input capacitance	f = 10 kHz,	P package	25°C		8			8		pF		
zO	Closed-loop output impedance	A _V = 10,	f = 100 kHz	25°C		. 1			1		Ω		
CMRR	Common-mode	V _{IC} = 0 to 2.7 V V _O = 2.5 V,	',	25°C	90	100		90	100		dB		
CIVILL	rejection ratio	$R_S = 1 k\Omega$		Full range	85			85			uБ		
ksvr	Supply-voltage rejection ratio	V _{DD} = 4 V to 6 V _{IC} = 0,	V,	25°C	90	100		90	100		dB		
HVG	(ΔV _{DD ±} /ΔV _{IO})	No load		Full range	90			90			uD		
lDD	Supply current	V _O = 2.5 V,	No load	25°C		2.5	3.5		2.5	3.5	mA		
				Full range			4			4			
VIT(CAL)	Calibration input threshold voltage			Full range	4			4			٧		

† Full range is -40°C to 85°C.

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operating characteristics, V_{DD} = 5 V

		=======================================			TLC4502	TLC4502C, TLC4502		
	PARAMETER	TEST COND	ITIONS	TAT	MIN	TYP	MAX	UNIT
SR	Claus rate at units gain	V- 05V+05V	C: 100 = E	25°C	1.5	2.5		V/μs
on	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	C[= 100 pr	Full range	1			V/μs
V	Equivalent input noise voltage	f = 10 Hz		25°C		70		
v _n	Equivalent input noise voltage	f = 1 kHz		25°C		12		nV/√Hz
Variant	Peak-to-peak equivalent input noise	f = 0.1 to 1 Hz		25°C		1		μV
VN(PP)	voltage	f = 0.1 to 10 Hz		25°C		1.5		μν
In	Equivalent input noise current			25°C		0.6		fA/√Hz
THD + N	Total harmonic distortion plus noise	$V_{O} = 0.5 \text{ V to } 2.5 \text{ V},$ f = 10 kHz, $R_{L} = 1 \text{ k}\Omega,$ $C_{L} = 100 \text{ pF}$	A _V = 1	25°C		0.02%		
			A _V = 10	25°C		0.08%		
			A _V = 100	25°C		0.55%		
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 1 k\Omega$,	25°C		4.7		MHz
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	A _V = 1, C _L = 100 pF	25°C		1		MHz
+.	Settling time	A _V = -1, Step = 0.5 V to 2.5 V,	to 0.1%	25°C		1.6		ue
t _S		$R_L = 1 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	to 0.01%	25°C		2.2		μs
φm	Phase margin at unity gain	R _L = 1 kΩ,	C _L = 100 pF	25°C		74		
	Calibration time			25°C		300		ms

† Full range is 0°C to 70°C.

NOTE 4: RL and CL values are referenced to 2.5 V.

TLC4502, TLC4502A, TLC4502Y Advanced LinEPICTM SELF-CALIBRATING (Self-CalTM) PRECISION DUAL OPERATIONAL AMPLIFIERS SLOS161A - OCTOBER 1996 - REVISED NOVEMBER 1996

operating characteristics, V_{DD} = 5 V

	DADAMETED	TEST SOUR	TIONS		TLC450	2I, TLC4	502AI		
	PARAMETER	TEST COND	TIONS	TAT	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	Ol	V _O = 0.5 V to 2.5 V,	C: - 100 pE	25°C	1.5	2.5		V/μs
5		VO = 0.5 V to 2.5 V,	CL = 100 pr	Full range	1			V/μs	
Vn	Equivalent input noise voltage	f = 10 Hz		25°C		70		->///II-	
٧n	Equivalent input hoise voltage	f = 1 kHz		25°C		12		nV/√Hz	
Vivon	Peak-to-peak equivalent input noise	f = 0.1 to 1 Hz		25°C		1		μV	
VN(PP)	voltage	f = 0.1 to 10 Hz		25°C		1.5		μν	
In	Equivalent input noise current			25°C		0.6		fA/√Hz	
THD + N	Total harmonic distortion plus noise	$\begin{split} &V_O = 0.5 \text{ V to } 2.5 \text{ V,} \\ &f = 10 \text{ kHz,} \\ &R_L = 1 \text{ k}\Omega, \\ &C_L = 100 \text{ pF} \end{split}$	A _V = 1	25°C		0.02%			
			A _V = 10	25°C		0.08%			
			A _V = 100	25°C		0.55%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 1 k\Omega$,	25°C		4.7		MHz	
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	A _V = 1, C _L = 100 pF	25°C		1		MHz	
ts	Settling time	$A_V = -1$, Step = 0.5 V to 2.5 V,	to 0.1%	25°C		1.6			
's		$R_L = 1 \text{ k}\Omega$, $C_L = 100 \text{ pF}$	to 0.01%	25°C		2.2		μs	
φm	Phase margin at unity gain	$R_L = 1 k\Omega$,	C _L = 100 pF	25°C		74			
	Calibration time			25°C		300		ms	

† Full range is -40°C to 85°C.

TLC4502, TLC4502A, TLC4502Y Advanced LinEPIC™ SELF-CALIBRATING (Self-Cal™) PRECISION DUAL OPERATIONAL AMPLIFIERS SLOS161A - OCTOBER 1996 - REVISED NOVEMBER 1996

electrical characteristics at specified free-air temperature, V_{DD} = 5 V, GND = 0, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST COM	TEST CONDITIONS		TLC4502Y			
		IESI CONI			TYP	MAX	UNIT	
V _{IO}	Input offset voltage				10		μV	
Iю	Input offset current	$V_{DD} = \pm 2.5 \text{ V},$ $V_{IC} = 0,$	$V_{O} = 0$, $R_{S} = 50 \Omega$		1		pА	
Iв	Input bias current	• (C = 0,	115 - 50 12		1		pА	
VOH	High-level output voltage	I _{OH} = – 500 μA	I _{OH} = - 500 μA			4.99		
		$I_{OH} = -5 \text{ mA}$		4.9			٧	
VOL	Low-level output voltage	V _{IC} = 2.5 V,	I _{OL} = 500 μA		0.01	,	V	
		$V_{IC} = 2.5 V$,	I _{OL} = 5 mA		0.1		V	
AVD	Large-signal differential voltage amplification	$V_{IC} = 2.5 \text{ V},$ $R_L = 1 \text{ k}\Omega,$	V _O = 1 V to 4 V, See Note 4		1000		V/mV	
R _{I(D)}	Differential input resistance				10		kΩ	
RL	Input resistance	See Note 4			1012		Ω	
CL	Common-mode input capacitance	f = 10 kHz,	P package		8		pF	
zO	Closed-loop output impedance	A _V = 10,	f = 100 kHz		1		Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 2.7 V, R _S = 1 k Ω	V _O = 2.5 V,		100		dB	
ksvr	Supply-voltage rejection ratio (ΔV _{DD ±} /ΔV _{IO})	$V_{DD} = \pm 2 \text{ V to } \pm 3 \text{ V},$ No load	V _{IC} = 0,		100		dB	
IDD	Supply current	V _O = 2.5 V,	No load		2.5		mA	

NOTE 4: RL and CL values are referenced to 2.5 V.

operating characteristics, $V_{DD} = 5 \text{ V}$, $T_A = 25^{\circ}\text{C}$

	DADAMETED	TEST SOND	TEST CONDITIONS		TLC4502Y			
	PARAMETER	IEST COND			TYP	MAX	UNIT	
SR	Slew rate at unity gain	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	C _L = 100 pF		2.5		V/μs	
٧ _n	Equipplent input pains walks as	f = 10 Hz	f = 10 Hz		70		nV/√ Hz	
٧n	Equivalent input noise voltage	f = 1 kHz	f = 1 kHz				ΠV/VHZ	
VALCED	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	f = 0.1 to 1 Hz		1		μ٧	
V _{N(PP)}	r eak-to-peak equivalent input noise voltage	f = 0.1 to 10 Hz	f = 0.1 to 10 Hz		1.5		μν	
In	Equivalent input noise current			1	0.6		fA/√Hz	
	Total harmonic distortion plus noise	$V_O = 0.5 \text{ V to } 2.5 \text{ V},$	A _V = 1		0.02%			
THD + N		$f = 10 \text{ kHz},$ $R_1 = 1 \text{ k}\Omega,$	A _V = 10		0.08%	WALLES AND THE STREET		
		C _L = 100 pF	A _V = 100		0.55%			
	Gain-bandwidth product	f = 10 kHz, C _L = 100 pF	$R_L = 1 \text{ k}\Omega$,		4.7		MHz	
ВОМ	Maximum output swing bandwidth	$V_{O(PP)} = 2 V$, $R_L = 1 k\Omega$,	A _V = 1, C _L = 100 pF		1		MHz	
t _S	Settling time	A _V = -1, Step = 0.5 V to 2.5 V,	to 0.1%		1.6	1.6		
		$R_L = 1 \text{ k}\Omega,$ $C_L = 100 \text{ pF}$	to 0.01%		2.2		μs	
φm	Phase margin at unity gain	R _L = 1 kΩ,	C _L = 100 pF		74			
	Calibration time				300		ms	

NOTE 4: RL and CL values are referenced to 2.5 V.



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TYPICAL CHARACTERISTICS

Table of Graphs

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V	lanut offect valte as	Distribution	1, 2, 3
VIO	Input offset voltage	vs Common-mode input voltage	4
ανιο	Input offset voltage temperature coefficient	Distribution	5, 6
Vон	High-level output voltage	vs High-level output current	7
VOL	Low-level output voltage	vs Low-level output current	8
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency	9
ios	Short-circuit output current	vs Free-air temperature	10
V _O	Output voltage	vs Differential input voltage	11
AVD	Large-signal differential voltage amplification	vs Free-air temperature vs Frequency	12 13
z _O	Output impedance	vs Frequency	14
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	15 16
SR	Slew rate	vs Load capacitance vs Free-air temperature	17 18
	Inverting large-signal pulse response	vs Time	19
	Voltage-follower large-signal pulse response	vs Time	20
	Inverting small-signal pulse response	vs Time	21
	Voltage-follower small-signal pulse response	vs Time	22
Vn	Equivalent input noise voltage	vs Frequency	23
	Input noise voltage	Over a 10-second period	24
THD + N	Total harmonic distortion plus noise	vs Frequency	25
	Gain-bandwidth product	vs Free-air temperature	26
1	Dhaga mayain	vs Load capacitance	27, 28
φm	Phase margin	vs Frequency	13
PSRR	Power-supply rejection ratio	vs Free-air temperature	29
	Calibration time at -40°C	vs Time	30
	Calibration time at 25°C	vs Time	31
	Calibration time at 85°C	vs Time	32

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE

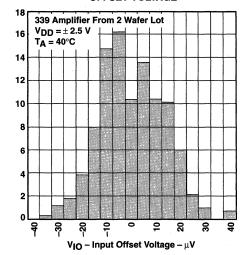


Figure 1

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE

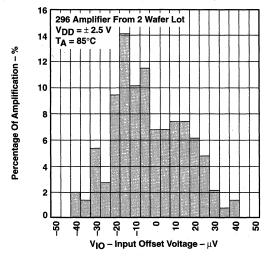


Figure 3

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE

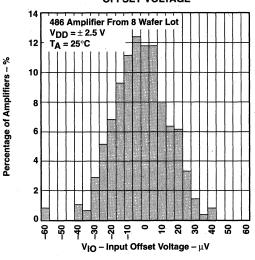


Figure 2

INPUT OFFSET VOLTAGE

vs COMMON-MODE INPUT VOLTAGE

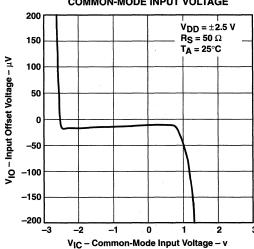


Figure 4

Percentage Of Amplification - %

TYPICAL CHARACTERISTICS

Percentage Of Amplifiers – %

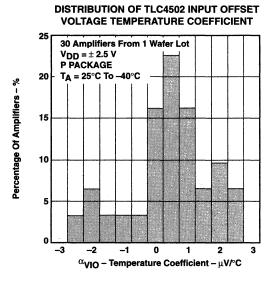


Figure 5

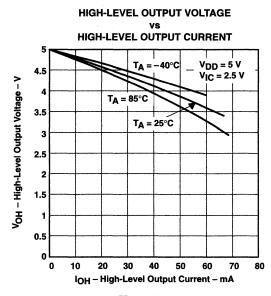
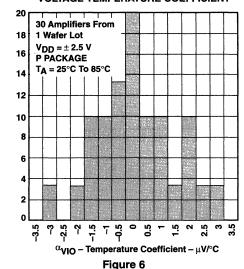


Figure 7

DISTRIBUTION OF TLC4502 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT



rigare o

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

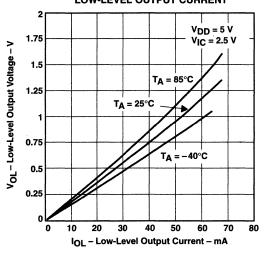
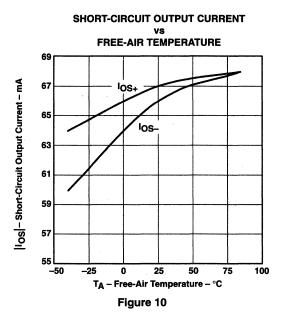
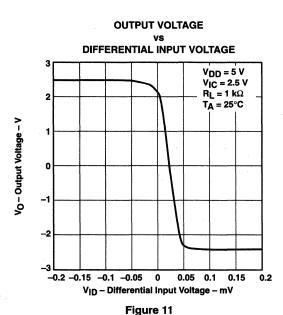


Figure 8

Figure 9



LARGE-SIGNAL DIFFERENTIAL



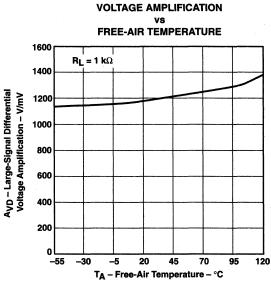


Figure 12

TEXAS INSTRUMENTS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

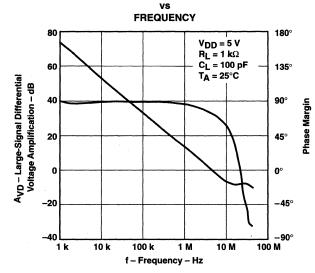


Figure 13

OUTPUT IMPEDANCE

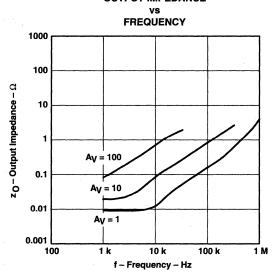
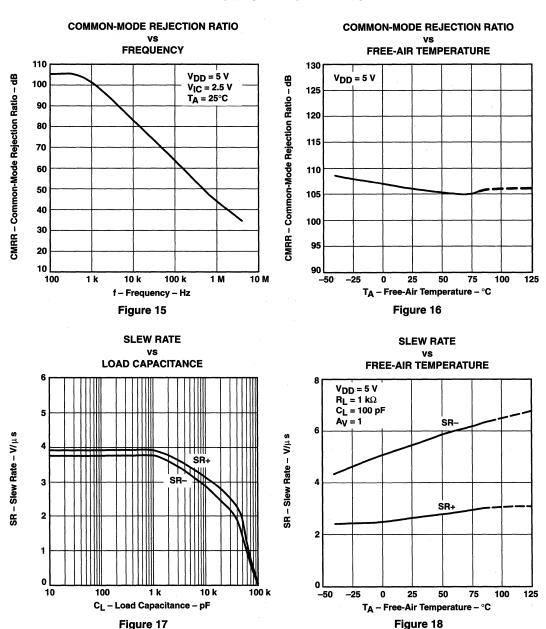


Figure 14

TYPICAL CHARACTERISTICS



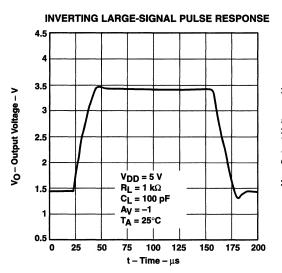


Figure 19

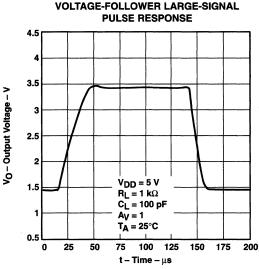


Figure 20

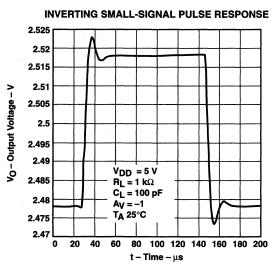


Figure 21

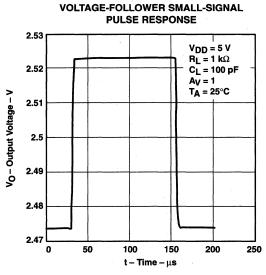
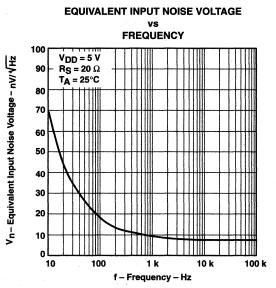


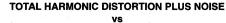
Figure 22



INPUT NOISE VOLTAGE OVER A 10-SECOND PERIOD 1200 $V_{DD} = 5 V$ f = 0.1 Hz To 10 Hz TA = 25°C Input Noise Voltage - nV 400 -12002 3 5 8 9 10 t - Time - s

Figure 23

Figure 24



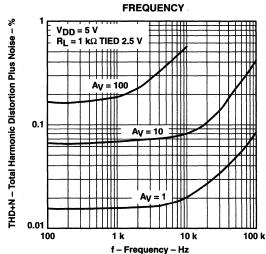


Figure 25

GAIN-BANDWIDTH PRODUCT

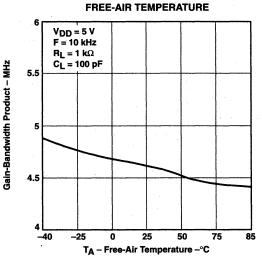
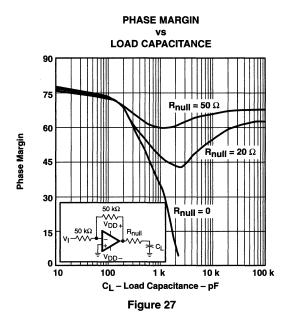


Figure 26



GAIN MARGIN LOAD CAPACITANCE 30 TA 25°C 25 20 Gain Margin – dB 15 R_{null} $R_{null} = 20 \Omega$ 10 5 0 10 10 k 100 k CL - Load Capacitance - pF

Figure 28

POWER SUPPLY REJECTION RATIO FREE-AIR TEMPERATURE

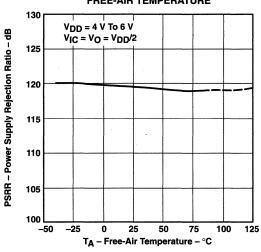


Figure 29

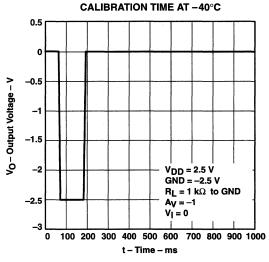
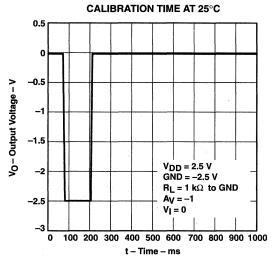


Figure 30

TYPICAL CHARACTERISTICS



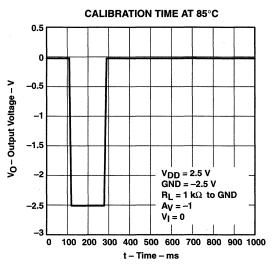


Figure 31

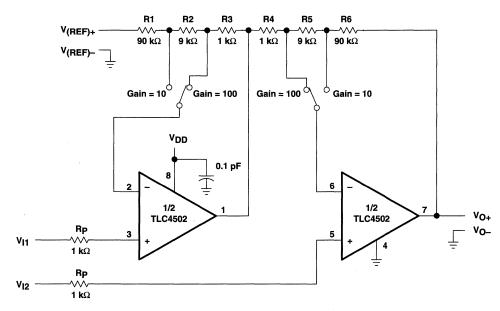
Figure 32

APPLICATION INFORMATION

- The TLC4502 is designed to operate with only a single 5-V power supply, have true differential inputs, and remain in the linear mode with an input common-mode voltage of 0.
- The TLC4502 has a standard dual-amplifier pinout allowing for easy design upgrades.
- Large differential input voltages can be easily accommodated and, as input differential-voltage protection
 diodes are not needed, no large input currents result from large differential input voltage. Protection should
 be provided to prevent the input voltages from going negative more than -0.3 V at 25°C. An input clamp
 diode with a resistor to the device input terminal can be used for this purpose.
- For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor can be
 used from the output of the amplifier to ground. This increases the class-A bias current and prevents
 crossover distortion. Where the load is directly coupled, for example dc applications, there is no crossover
 distortion.
- Capacitive loads, which are applied directly to the output of the amplifier, reduce the loop stability margin.
 Values of 500 pF can be accommodated using the worst-case noninverting unity-gain connection. Resistive isolation should be considered when larger load capacitance must be driven by the amplifier.

The following typical application circuits emphasize operation on only a single power supply. When complementary power supplies are available, the TLC4502 can be used in all of the standard operational amplifier circuits. In general, introducing a pseudo-ground (a bias voltage of V_I/2 like that generated by the TLE2426) allows operation above and below this value in a single-supply system. Many application circuits are shown which take advantage of the wide common-mode input-voltage range of the TLC4502, which includes ground. In most cases, input biasing is not required and input voltages that range to ground can easily be accommodated.





(Gain = 10)
$$V_O = (V_{I1} - V_{I2})(1 + \frac{R6}{R4 + R5}) + V_{(REF)}$$
 Where R1 = R6, R2 = R5, and R3 = R4 (Gain = 100) $V_O = (V_{I1} - V_{I2})(1 + \frac{R5 + R6}{R4}) + V_{(REF)}$ Where R1 = R6, R2 = R5, and R3 = R4

Figure 33. Single-Supply Programmable Instrumentation Amplifier Circuit

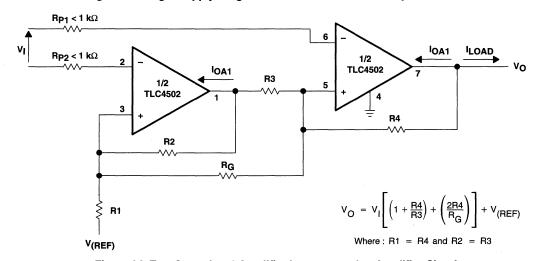


Figure 34. Two Operational-Amplifier Instrumentation Amplifier Circuit

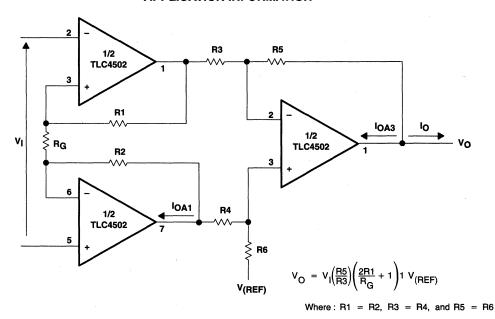


Figure 35. Three Operational-Amplifier Instrumentation Amplifier Circuit

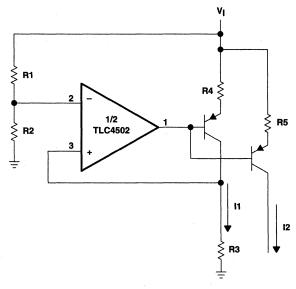


Figure 36. Fixed Current-Source Circuit

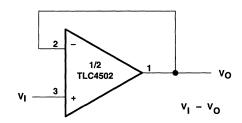


Figure 37. Voltage-Follower Circuit

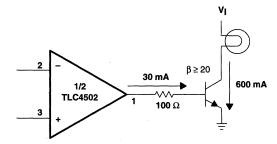


Figure 38. Lamp-Driver Circuit

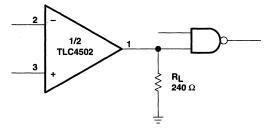


Figure 39. TTL-Driver Circuit

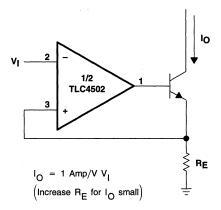


Figure 40. High-Compliance Current-Sink Circuit

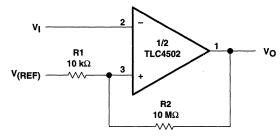


Figure 41. Comparator With Hysteresis Circuit

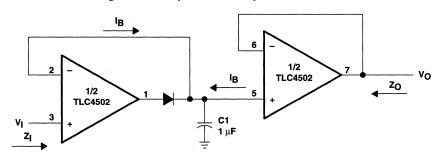


Figure 42. Low-Drift Detector Circuit

General Information (Volume A)	1
Audio Power Amplifiers	2
Operational Amplifiers	3
Mechanical Data	4
General Information (Volume B)	5
Operational Amplifiers (Continued)	6
Comparators	7
Special Functions	8
Mechanical Data	9

Electrical characteristics presented in this data book, unless otherwise noted, apply for the circuit type(s) listed in the page heading regardless of package. The availability of a circuit function in a particular package is denoted by an alphabetical reference above the pin-connection diagram(s). These alphabetical references refer to mechanical outline drawings shown in this section.

Factory orders for circuits described in this data book should include a four-part type number as shown in the following example.

			Example:	TLE	2022	PW	LE
Prefix							
MUST CONTA	AIN TWO O	R THREE LE	TTERS			į	
			TI Linear Products				
STANDARD S	ECOND-S	OURCE PREF	FIXES				
LF, LM, or L LT MC NE, SA, or S OP RC, RM, or uA Unique Circui	RV	ion Including R MORE CHA	Analog Devices Nationa Linear Technology Motorola Signetics PM Raytheor Fairchild/Nationa Temperature Range ARACTERS	 / a s 			
Examples:	592	34070 1451AC 2217-285					
Package							
MUST CONTA							
			, NE, P, PW, U, W dividual data sheet)				
Available Tap	ed and Re	eled or Left-E	Ended Taped and Ree	led			
R – Availab			-				



LE - Available Only Left-Ended Taped and Reeled

ORDERING INSTRUCTIONS

Circuits are shipped in one of the carriers below. Unless a specific method of shipment is specified by the customer (with possible additional costs), circuits will be shipped via the most practical carrier.

Dual-In-Line (J, JG, N, NE, P)

– A-Channel Antistatic or
Conductive Plastic Tubing

Shrink Small Outline (DB, DBV)

- Tape and Reel
Thin Shrink Small Outline (PW)

- Tape and Reel

Small Outline (D, DW, DWP)

- Tape and Reel

- Antistatic or Conductive

Plastic Tubing

Chip Carriers (FK)

- Antistatic or Conductive
Plastic Tubing

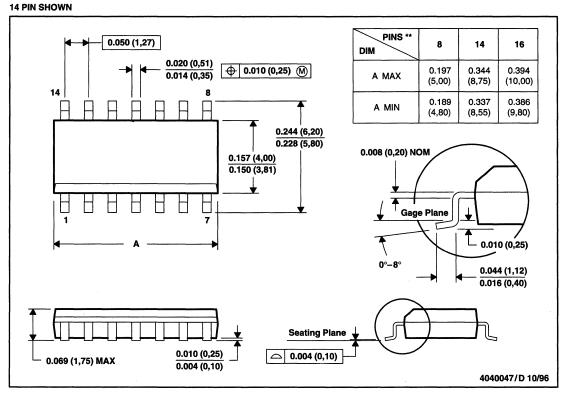
Flat (U, W)

- Milton Ross Carriers



D (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE.



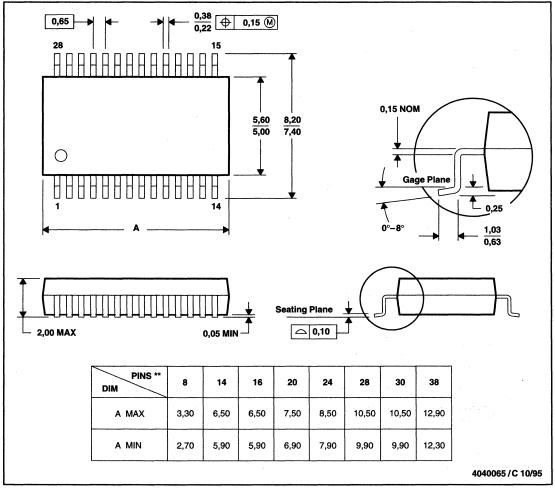
NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-012

DB (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

28 PIN SHOWN

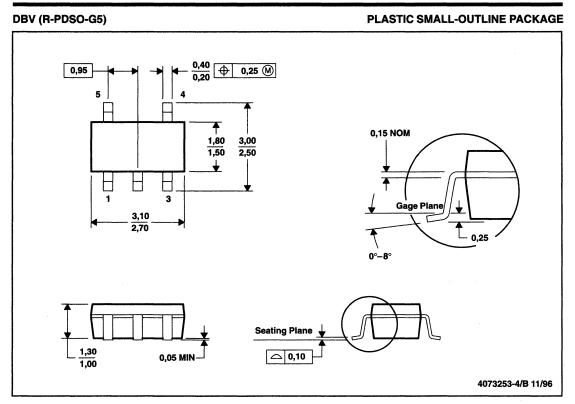


NOTES: A. All linear dimensions are in millimeters.

B. This drawing is subject to change without notice.

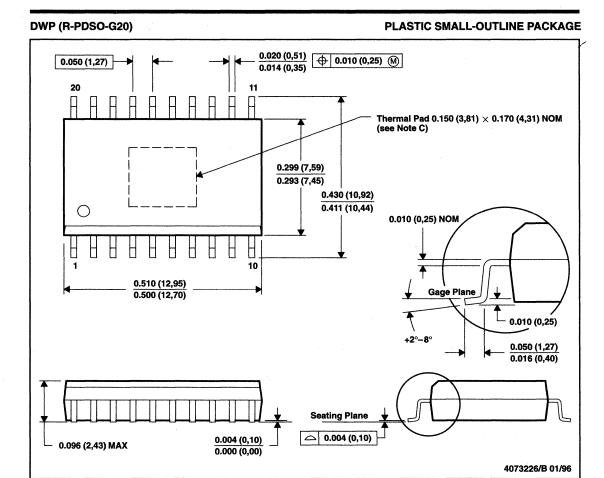
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.

D. Falls within JEDEC MO-150



NOTES: A. All linear dimensions are in millimeters.

- B. This drawing is subject to change without notice.
- C. Body dimensions include mold flash or protrusion.

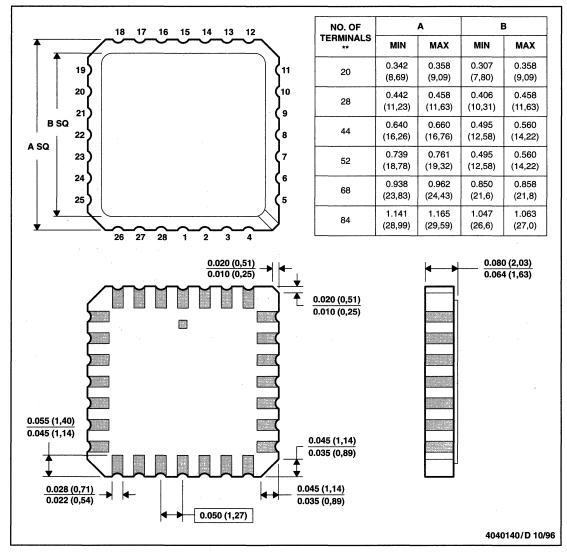


- NOTES: A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. The thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This solderable pad is electrically and thermally connected to the backside of the die and leads 1, 10, 11 and 20.

FK (S-CQCC-N**)

28 TERMINAL SHOWN

LEADLESS CERAMIC CHIP CARRIER



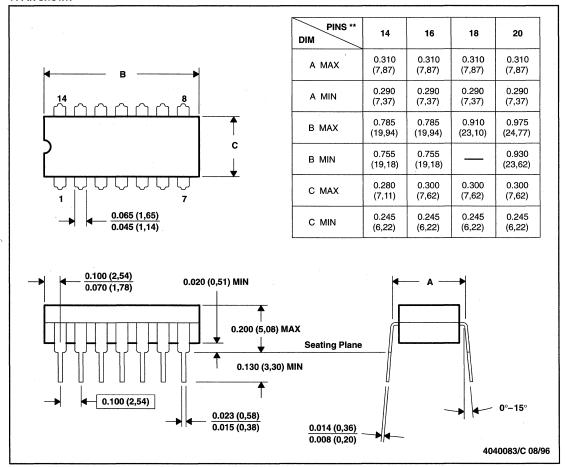
- NOTES: A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a metal lid.
 - D. The terminals are gold plated.
 - E. Falls within JEDEC MS-004



J (R-GDIP-T**)

14 PIN SHOWN

CERAMIC DUAL-IN-LINE PACKAGE

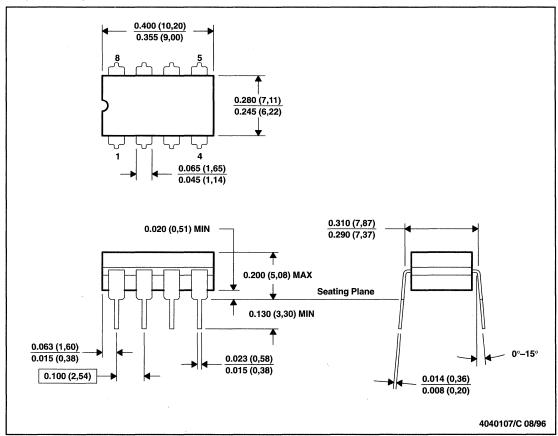


NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL-STD-1835 GDIP1-T14, GDIP1-T16, GDIP1-T18, and GDIP1-T20



CERAMIC DUAL-IN-LINE PACKAGE



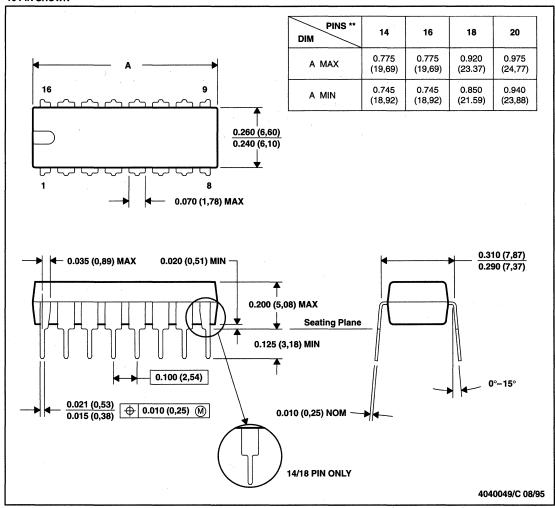
NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL-STD-1835 GDIP1-T8

N (R-PDIP-T**)

16 PIN SHOWN

PLASTIC DUAL-IN-LINE PACKAGE



NOTES: A. All linear dimensions are in inches (millimeters).

B. This drawing is subject to change without notice.

C. Falls within JEDEC MS-001 (20 pin package is shorter then MS-001.)

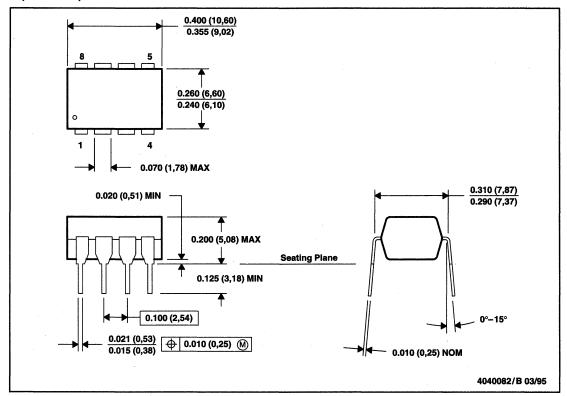
NE (R-PDIP-T**) PLASTIC DUAL-IN-LINE PACKAGE 20 PIN SHOWN 0.070 (1,78) MAX PINS ** 16 20 DIM 0.914 (23,22) MIN Α С MAX 0.780 (19,80) 0.975 (24,77) 0.930 (23,62) MIN В 1.000 (25,40) MAX MIN 0.240 (6,10) 0.260 (6,61) С MAX 0.260 (6,60) 0.280 (7,11) 0.020 (0,51) MIN 0.200 (5,08) MAX Seating Plane 0.155 (3,94) 0.125 (3,17) 0.100 (2,54) 0.310 (7,87) 0.020 (0,51) MIN 0.290 (7,37) 0.200 (5,08) MAX Seating Plane 0.155 (3,94) 0.125 (3,17) 0.100 (2,54) 0.010 (0,25) NOM 4040054/B 04/95

NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS-001 (16 pin only)



PLASTIC DUAL-IN-LINE PACKAGE



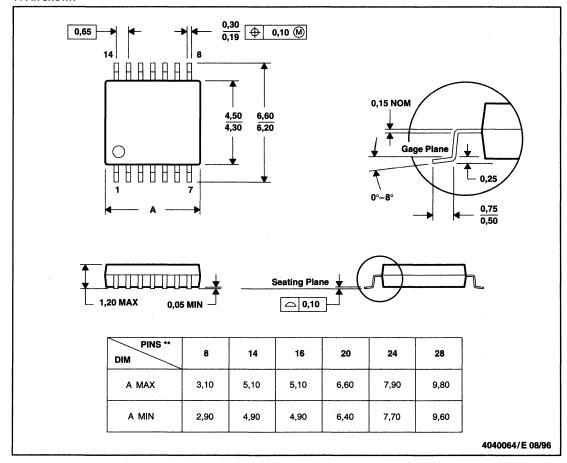
NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS-001

PW (R-PDSO-G**)

14 PIN SHOWN

PLASTIC SMALL-OUTLINE PACKAGE



NOTES: A. All linear dimensions are in millimeters.

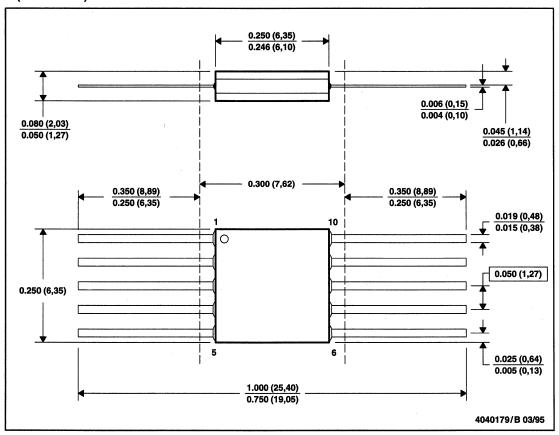
B. This drawing is subject to change without notice.

C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.

D. Falls within JEDEC MO-153

U (S-GDFP-F10)

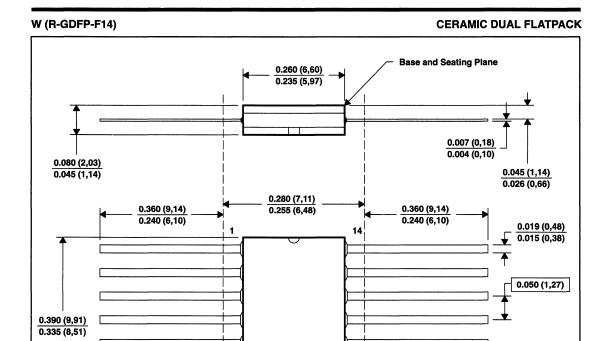
CERAMIC DUAL FLATPACK



- NOTES: A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a ceramic lid using glass frit.
 - D. Index point is provided on cap for terminal identification only.
 - E. Falls within MIL STD 1835 GDFP1-F10 and JEDEC MO-092AA

0.025 (0,64) 0.015 (0,38)

4040180-2/B 03/95



1.000 (25,40) 0.735 (18,67)

NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only.
- E. Falls within MIL STD 1835 GDFP1-F14 and JEDEC MO-092AB



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