



 **TEXAS  
INSTRUMENTS**

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# **Linear Circuits**

**Power+™ Products, Peripheral Drivers/Actuators**

*Data Book*

*Data Book*

**Linear Circuits**  
**Power+™ Products, Peripheral Drivers/  
Actuators**

1996

1996

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# **Linear Circuits Data Book 1996**

***Power+™ Products, Peripheral Drivers/Actuators***



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## INTRODUCTION

Texas Instruments offers an extensive line of the industry-standard integrated circuits designed to provide highly reliable circuits for switching inductive loads such as lamps, solenoids, motors, valves, and relays.

TI power devices represent technologies from the classic bipolar process to the Texas Instruments PRISM process, which offer improvements in power consumption and temperature stability.

This data book provides information on the following types of products:

- Power+ Arrays™ – integrated multiple, rugged power FETs in surface-mount packaging
- Power+ Logic™ – control logic integrated on same substrate with multiple power FETs
- Power+™ Control – integrated power ICs and pre-FET drivers to complement the Power+ Array family
- Peripheral drivers/actuators

TI continues to enhance quality and reliability of integrated circuits by improving materials, processes, test methods, and test equipment. Quality and performance are monitored throughout all phases of manufacturing; quality specifications and programs are continuously enhanced.

The Alphanumeric Index provides a method of quickly locating the correct device type. The Selection Guide includes a functional description of each device providing key parameter information and packaging types. Ordering Instructions and Mechanical Data are in the last section of this data book.

While this data book offers design and specification data for TI power integrated circuits, complete technical data for any TI semiconductor product is available from your nearest TI field sales office, local authorized TI distributor, or by writing directly to:

Texas Instruments Incorporated  
LITERATURE RESPONSE CENTER  
P.O. Box 809066  
DALLAS, TEXAS 75380-9066

We believe the new 1996 Linear Circuits Data Book is a significant addition to your library of technical literature from Texas Instruments.



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**Power+ Arrays™**

DEVICE	DESCRIPTION	V <sub>DS</sub> MAX (V)	I <sub>CONT</sub> (A)	I <sub>PEAK</sub> (A)	r <sub>DS(on)</sub> TYP (Ω)	t <sub>rr</sub> TYP (ns)	Q <sub>g</sub> TYP (nC)	PKG	PAGE
TPIC1301†	3-Half H-bridge	60	2.25	11.25	0.23	50	6.2	DW	2-3
TPIC1321L‡	3-Half H-bridge	60	1.25	4	0.35	45	4.6	DW	2-15
TPIC1501A§	H-Bridge & 3-phase bridge	20	3 & 1.5	12 & 6	0.1 & 0.4	70 & 60	5.6 & 1.6	DW	2-27
TPIC2202	2-Channel common-source	60	7.5	15	0.09	200	13.6	KC	2-51
TPIC2301	3-Channel common-source	60	7.5	15	0.09	200	13.6	KV	2-61
TPIC2302	3-Channel common-source	60	1	5	0.4	65	3.1	D	2-69
TPIC2322L¶	3-Channel common-source	60	0.75	2.25	0.6	85	1.8	D	2-79
TPIC2701	7-Channel common-source	60	0.5	3	0.5	165	2.8	N	2-95
TPIC3302	3-Channel common-drain	60	1	5	0.4	35	3.1	D	2-105
TPIC3322L¶	3-Channel common-drain	60	0.75	2.25	0.6	30	1.8	D	2-115
TPIC5201	2-Channel independent	60	7.5	15	0.09	200	13.6	KV	2-125
TPIC5203†	2-Channel independent	60	1.6	8	0.26	50	4.7	D	2-133
TPIC5223L‡	2-Channel independent	60	1	3	0.38	50	3.1	D	2-143
TPIC5302	3-Channel independent	60	1.4	7	0.3	35	8	D	2-153
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TPIC5323L‡	3-Channel independent	60	1	3	0.6	75	2	D	2-183
TPIC5401†	H-Bridge	60	1.7/2	10	0.3	120	6.6	DW/NE	2-193
TPIC5403†	4-Channel independent	60	2.25	11.25	0.23	80	6.6	DW	2-205
TPIC5404	H-Bridge	60	1.7/2	10	0.3	120	6.6	DW/NE	2-217
TPIC5421L‡	H-Bridge	60	1/1.5	3	0.4	55	3.9	DW/NE	2-229
TPIC5423L‡	4-Channel independent	60	1.25	4	0.32	80	6.6	DW	2-241
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TPIC5621L¶	3-Phase bridge	60	1	3	0.4	65	3.1	DW	2-273

† Gate-protected

‡ Gate-protected and 5-V logic-level interface

§ Preliminary data only

¶ 5-V Logic-level interface



# POWER+ PRODUCTS SELECTION GUIDE

## Power+ Logic™

DEVICE	DESCRIPTION	V <sub>DS</sub> MAX (V)	I <sub>CONT</sub> (mA)	I <sub>PEAK</sub> (A)	r <sub>DS(on)</sub> TYP (Ω)	t <sub>PLH</sub> TYP (ns)	INPUT COMP.	PKG	PAGE
TPIC6259	8-Bit addressable latch	45	250	1.5	1.3	625	CMOS	DW, N	2-283
TPIC6273	Octal D-type latch	45	250	1.5	1.3	625	CMOS	DW, N	2-293
TPIC6595	8-Bit shift register	45	250	1.5	1.3	650	CMOS	DW, N	2-301
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TPIC6A595†	8-Bit shift register	50	350	1.1	1	125	CMOS	DW, NE	2-319
TPIC6B259‡	8-Bit addressable latch	50	150	0.5	5	150	CMOS	DW, N	2-331
TPIC6B273‡	Octal D-type latch	50	150	0.5	5	150	CMOS	DW, N	2-341
TPIC6B595‡	8-Bit shift register	50	150	0.5	5	150	CMOS	DW, N	2-349
TPIC6E175¶	Quad D-type latch	40	§	1	1	650	CMOS	NE	2-359
TPIC6E261¶	4-Bit addressable latch	40	§	1	1	650	CMOS	NE	2-375
TPIC6E585¶	4-Bit shift register	40	§	1	1	650	CMOS	NE	2-391

† Short-circuit and current-limit protection

‡ Current-limit capability

§ User-programmable from 300 mA – 1 A

¶ Preliminary data only

## Power+™ Control

DEVICE	DESCRIPTION	V <sub>bat</sub> (V)	I <sub>bat</sub> TYP (mA)	f <sub>(osc)</sub> (kHz)	I <sub>GD</sub> MAX (mA)	t <sub>r</sub> /t <sub>f</sub> MAX (μs)	Fault Protection	PKG	PAGE
TPIC2101	Single-phase low-side pre-FET	8-16	4	20	50	1/0.8	Yes	D, N	2-33

DEVICE	DESCRIPTION	V <sub>bat</sub> (V)	f TYP (MHz)	V <sub>DS</sub> MAX (V)	I <sub>D</sub> /I <sub>PEAK</sub> (A)	r <sub>DS(on)</sub> TYP (Ω)	Diagnostics	PKG	PAGE
TPIC2603¶	6-Channel serial interface low-side	5.5 - 25	4	70	0.35/2.25	1.7	Yes	DW, NE	2-89

¶ Preliminary data only

**general-purpose drivers and actuators**

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						OR	18	SN55453B	FK, JG	3-15
						NOR	27	SN55454B	FK, JG	3-15
						AND	18	SN75451B	D, P	3-15
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NOR	27	SN75454B	3-15							
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			4					SN75374	D, N	3-39
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						NAND	45	SN55462		3-23
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						NAND	45	SN75462		3-23
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40	50	1500	4	Yes	TTL, CMOS	Invert & Noninvert w/ Enable	1500	SN75439	NE	3-55
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						NAND	45	SN75472		3-81
			OR			30	SN75473	3-81		
	100	500	Yes	TTL, CMOS	AND	200	SN75476	3-87		
					NAND		SN75477	3-87		
					OR		SN75478	3-87		
	60	60	100	4	Yes	TTL, CMOS	Telecom Relay Driver	1000		DS3680

# POWER+ PRODUCTS SELECTION GUIDE

## motor drivers and power actuators

SWITCHING VOLTAGE MAX (V)	OFF-STATE VOLTAGE MAX (V)	PEAK OUTPUT CURRENT (mA)	DRIVERS PER PKG	OUTPUT CLAMP DIODES	INPUT COMP.	FUNCTION	DELAY TIME TYP (ns)	TYPE	PKG	PAGE
36	36	1200	4	Yes	TTL	Quad Half-H	800	L293D	NE	3-11
		2000		No				L293		3-7
		Yes		TTL, CMOS	SN754410			3-61		

# POWER+ ARRAYS CROSS-REFERENCE GUIDE

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.

Texas Instruments makes no warranty as to the information furnished and the buyer assumes all risk in the use thereof. No liability is assumed for damages resulting from the use of the information contained herein.

Manufacturers are arranged in alphabetical order.

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† Littlefoot



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## GLOSSARY SYMBOLS, TERMS, AND DEFINITIONS

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<b><math>C_{gd}</math></b>	<b>Gate-Drain Capacitance</b> Capacitance measured between the gate and drain with $V_{GS} = 0\text{ V}$ ( $C_{gd} = C_{rSS}$ )
<b><math>C_{ds}</math></b>	<b>Drain-Source Capacitance</b> Capacitance measured between the drain and source with $V_{GS} = 0\text{ V}$ ( $C_{ds} = C_{iSS} - C_{rSS}$ )
<b><math>C_{gs}</math></b>	<b>Gate-Source Capacitance</b> Capacitance measured between the gate and source with $V_{GS} = 0\text{ V}$ ( $C_{ds} = C_{oss} - C_{rSS}$ )
<b><math>C_{iSS}</math></b>	<b>Short-Circuit Input Capacitance</b> Input capacitance with drain and source shorted ( $C_{iSS} = C_{gd} + C_{gs}$ , $C_{ds}$ shorted)
<b><math>C_{oss}</math></b>	<b>Short-Circuit Output Capacitance</b> Total capacitance between drain and source with gate and source shorted ( $C_{oss} = C_{ds} + C_{gd}$ , $C_{gs}$ shorted)
<b><math>C_{rSS}</math></b>	<b>Short-Circuit Reverse Transfer Capacitance</b> Gate-drain capacitance with $V_{GS} = 0$ ( $C_{rSS} = C_{gd}$ )
<b><math>E_{AS}</math></b>	<b>Single-Pulse Avalanche Energy</b> Maximum energy dissipation allowed during avalanche breakdown for a single pulse of avalanche current
<b><math>g_{fs}</math></b>	<b>Common-Source Small-Signal Transconductance</b> Ratio of change in drain current due to a change in gate-to-source voltage
<b><math>I_{AS}</math></b>	<b>Peak Avalanche Current</b> Maximum allowable current during avalanche breakdown
<b><math>I_{CC}</math></b>	<b>Power Supply Current</b> Total current from the $V_{CC}$ supply
<b><math>I_D</math></b>	<b>DC Drain Current</b> Measured dc current into the drain
<b><math>I_{DM}</math></b>	<b>Peak-Drain Current, Single Output</b> Maximum allowable value of drain current
<b><math>I_{DSS}</math></b>	<b>Zero-Gate-Voltage Drain Current</b> Current into drain when gate-to-source voltage is zero
<b><math>I_{DSX}</math></b>	<b>Off-State Drain Current</b> See Zero-Gate-Voltage Drain Current ( $I_{DSS}$ )
<b><math>I_F</math></b>	<b>Clamp Diode Forward Current</b> Measurement of current through the clamp diode
<b><math>I_{GSSF}</math></b>	<b>Forward Gate Current, Drain-to-Source Short Circuited</b> Direct current into gate with forward gate-to-source voltage and drain shorted to source

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# GLOSSARY

## SYMBOLS, TERMS, AND DEFINITIONS

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<b><math>I_{GSSR}</math></b>	<b>Reverse Gate Current, Drain-to-Source Short Circuited</b> Direct current into gate with reverse gate-to-source voltage and drain shorted to source
<b><math>I_I</math></b>	<b>Input Current</b> Direct current to the gate
<b><math>I_{IH}</math></b>	<b>High-Level Input Current</b> Current the device uses to switch state from low to high
<b><math>I_{IL}</math></b>	<b>Low-Level Input Current</b> Current the device uses to switch state from high to low
<b><math>I_O</math></b>	<b>Continuous Output Current</b> Direct output current across the drain-to-source junction
<b><math>I_{O(chp)}</math></b>	<b>Output Chopping Current</b> Value at which output current changes from continuous current to low duty cycle pulsed current
<b><math>I_{OM}</math></b>	<b>Maximum Output Current</b> Maximum output current in the on state
<b><math>I_R</math></b>	<b>Reverse Current</b> Current flow across reverse-biased junction at specified applied voltage
<b><math>I_{SD}</math></b>	<b>Source-Drain Diode Current</b> Maximum continuous forward diode current
<b><math>P_D</math></b>	<b>Maximum Off-State Power Dissipation</b> Amount of power consumed by the die such that maximum junction temperature is not exceeded at held case temperature
<b><math>Q_g</math></b>	<b>Total Gate Charge</b> Maximum charge drawn by gate at a specified $V_{GS}$
<b><math>Q_{gd}</math></b>	<b>Gate-Drain Charge</b> Charge between the gate and drain of the device
<b><math>Q_{gs}</math></b>	<b>Gate-Source Charge</b> Charge between the gate and source of the device
<b><math>r_{DS(on)}</math></b>	<b>Static Drain-Source On-State Resistance</b> Resistance between the drain and source during on state
<b><math>r_i</math></b>	<b>Input Resistance</b> Resistance between gate and source
<b><math>R_{\theta JA}</math></b>	<b>Junction-to-Ambient Thermal Resistance</b> Thermal resistance (steady state) from the device case to the ambient (air)

## GLOSSARY SYMBOLS, TERMS, AND DEFINITIONS

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$R_{\theta JC}$	<b>Junction-to-Case Thermal Resistance</b> Thermal resistance (steady state) from the device junction to case
$r_o$	<b>Output Resistance</b> Resistance between drain and source
$t_a$	<b>Reverse-Recovery-Current Rise Time</b> Elapsed time for diode current to reach maximum value during reverse recovery
$T_A$	<b>Ambient Operating Temperature (Free Air)</b> Air temperature measured below a device in an environment cooled only by natural air convection
$t_c$	<b>Cycle Time</b> Time interval between the start and end of a cycle
$T_C$	<b>Case Operating Temperature</b> Temperature measured at a specific location on the case of a device
$t_{d(off)}$	<b>Turn-Off Delay Time</b> Time interval during which an input pulse falls from 90% of its peak value to 10% of its off-state amplitude
$t_{d(on)}$	<b>Turn-On Delay Time</b> Time interval during which an input pulse rises from 10% of its peak value to 90% of its off-state amplitude
$t_f$	<b>Fall Time</b> Time interval for signal to change from 90% to 10% of its peak value
$t_h$	<b>Hold Time</b> Time interval during which a signal is retained at a specified input terminal after an active transition occurs at another specified input terminal
$T_J$	<b>Virtual Junction Temperature</b> Calculated value of the silicon junction(s) temperature based on the thermal and electrical behavior of the device
$t_{off}$	<b>Turn-Off Time</b> Time interval between gate turn off and drain-to-source shutdown
$t_{on}$	<b>Turn-On Time</b> Time interval between gate turn on and drain-to-source turn on
$t_{PHL}$	<b>Propagation Delay Time, High-to-Low Level Output</b> Time interval for drain-to-source signal to fall from 90% to 10% of its peak value
$t_{PLH}$	<b>Propagation Delay Time, Low-to-High Level Output</b> Time interval for drain-to-source signal to rise from 10% to 90% of its peak value

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## GLOSSARY SYMBOLS, TERMS, AND DEFINITIONS

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$t_r$	<b>Rise Time</b> Time interval for signal to rise from 10% to 90% of its peak value
$t_{rr}$	<b>Reverse-Recovery Time</b> Time required to remove excess carriers from a diode after reverse of carrier flow
$t_{su}$	<b>Setup Time</b> Time interval between the application of a signal at a specified input terminal and a subsequent active transition at another specified input terminal
$t_v$	<b>Valid Time</b> Delay time from 50% rising edge of serial clock input to 10% change in serial output
$t_w$	<b>Pulse Duration</b> Active pulse time measured at 50% of steady-state amplitude from leading edge to trailing edge of the same pulse
$V_{(BR)}$	<b>Breakdown Voltage</b> Drain-to-source voltage at which device avalanche multiplication occurs
$V_{DS}$	<b>Drain-Source Voltage</b> Voltage measured across the drain to source
$V_{GS}$	<b>Gate-Source Voltage</b> Measurement of the input voltage in reference to the source
$V_i$	<b>Input Voltage</b> Voltage measured from gate to source
$V_{IH}$	<b>High-Level Input Voltage</b> Voltage on gate that initiates drain-to-source turn on
$V_{IL}$	<b>Low-Level Input Voltage</b> Voltage on gate that initiates drain-to-source turn off
$V_{OH}$	<b>High-Level Output Voltage</b> Voltage measured on the source-to-drain in high state
$V_{OK}$	<b>Output Clamp Voltage</b> Voltage measured on the source to clamp input
$V_{OL}$	<b>Low-Level Output Voltage</b> Voltage measured on the drain-to-source in low state
$V_{SD}$	<b>Forward On-Voltage</b> Voltage measured on the source-to-drain in the forward direction
$V_{SD(ov)}$	<b>Overvoltage Shutdown Voltage</b> Specified temperature at which overvoltage shutdown circuit is activated
$V_{TGS}$	<b>Gate-Source Threshold Voltage</b> Gate voltage required to produce a specified amount of drain current

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**2 Power+™ Products**

# TPIC1301

## 3-HALF H-BRIDGE GATE-PROTECTED POWER DMOS ARRAY

SLIS037 – NOVEMBER 1994

- Low  $r_{DS(on)}$  . . . 0.23  $\Omega$  Typ
- High Voltage Output . . . 60 V
- Extended ESD Capability . . . 4000 V
- Pulsed Current . . . 11.25 A Per Channel
- Fast Commutation Speed

### description

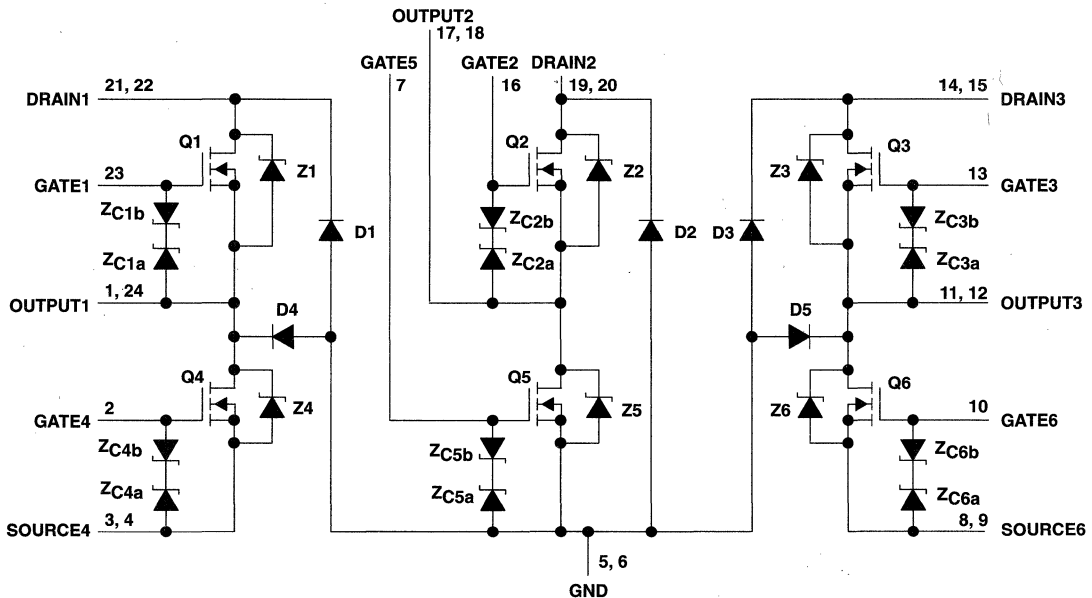
The TPIC1301 is a monolithic gate-protected power DMOS array that consists of six electrically isolated N-channel enhancement-mode DMOS transistors configured as three half H-bridges. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC1301 is offered in a 24-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

DW PACKAGE  
(TOP VIEW)

OUTPUT1	1	24	OUTPUT1
GATE4	2	23	GATE1
SOURCE4	3	22	DRAIN1
SOURCE4	4	21	DRAIN1
GND	5	20	DRAIN2
GND	6	19	DRAIN2
GATE5	7	18	OUTPUT2
SOURCE6	8	17	OUTPUT2
SOURCE6	9	16	GATE2
GATE6	10	15	DRAIN3
OUTPUT3	11	14	DRAIN3
OUTPUT3	12	13	GATE3

### schematic



NOTE: For correct operation, no terminal pin may be taken below GND.

**TPIC1301**  
**3-HALF H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-GND voltage, $V_{DG}$ .....	100 V
Drain-to-source voltage, $V_{DS}$ .....	60 V
Output-to-GND voltage .....	60 V
SOURCE4, SOURCE6-to-GND voltage .....	60 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	2.25 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	2.25 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	11.25 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15, and 16) .....	17.2 mJ
Continuous total dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15) .....	1.39 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC1301**  
**3-HALF H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**  
 SLIS037 – NOVEMBER 1994

**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.75	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1–D5)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 2.25 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.52	0.62	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 2.25 \text{ A}$ , $V_{GS} = 0$ (Z1–Z6), See Notes 2 and 3 and Figure 12			1	1.2	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 2.25 \text{ A}$ (D1–D5) See Notes 2 and 3			5		V
$I_{DSS}$	Drain current-gate shorted to source	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ ,	$V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND Gate shorted to source	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 2.25 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$		0.23	0.275	$\Omega$
			$T_C = 125^\circ\text{C}$		0.35	0.4	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ ,	$I_D = 1.125 \text{ A}$ , See Notes 2 and 3 and Figure 9	1.6	2.21		S
$C_{iss}$	Short-circuit input capacitance, common source				200	250	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ ,	$V_{GS} = 0$ , See Figure 11		175	220	
$C_{rss}$	Short-circuit reverse transfer capacitance, common source	$f = 1 \text{ MHz}$ ,			40	75	

- NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 1.125 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ ,	Z1, Z2, and Z3		50		ns
$Q_{RR}$	Total diode charge					65		nC



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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

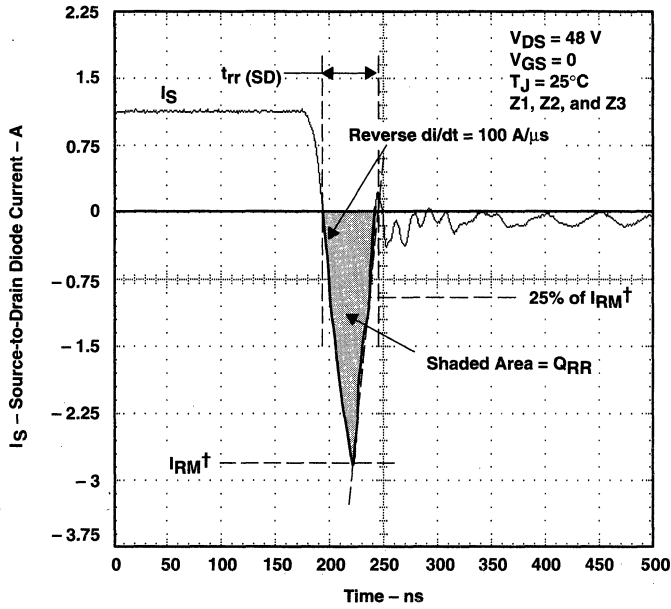
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 20\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		25	50	ns
$t_{d(off)}$	Turn-off delay time			25	50	
$t_r$	Rise time			15	30	
$t_f$	Fall time			7	15	
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3 $I_D = 1.125\text{ A}$ , $V_{GS} = 10\text{ V}$		6.2	7.4	nC
$Q_{gs(th)}$	Threshold gate-to-source charge			0.7	0.8	
$Q_{gd}$	Gate-to-drain charge			2.4	2.9	
$L_D$	Internal drain inductance			5		nH
$L_S$	Internal source inductance			5		
$R_g$	Internal gate resistance			0.25		$\Omega$

**thermal resistance**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	See Notes 4 and 7		90		$^\circ\text{C/W}$
$R_{\theta JB}$	Junction-to-board thermal resistance	See Notes 5 and 7		45		$^\circ\text{C/W}$
$R_{\theta JP}$	Junction-to-pin thermal resistance	See Notes 6 and 7		28		$^\circ\text{C/W}$

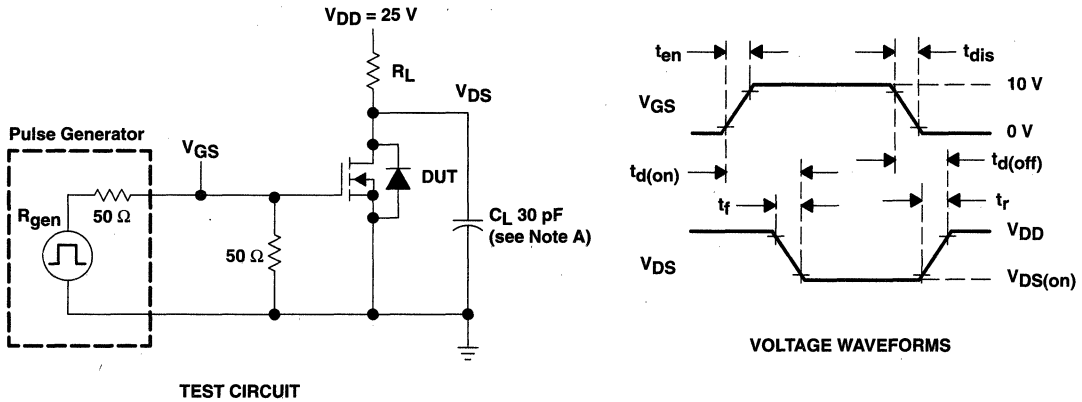
- NOTES:
4. Package mounted on an FR4 printed-circuit board with no heatsink.
  5. Package mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board.
  6. Package mounted in intimate contact with infinite heatsink.
  7. All outputs with equal power

**PARAMETER MEASUREMENT INFORMATION**



$^\dagger I_{RM}$  = maximum recovery current

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**

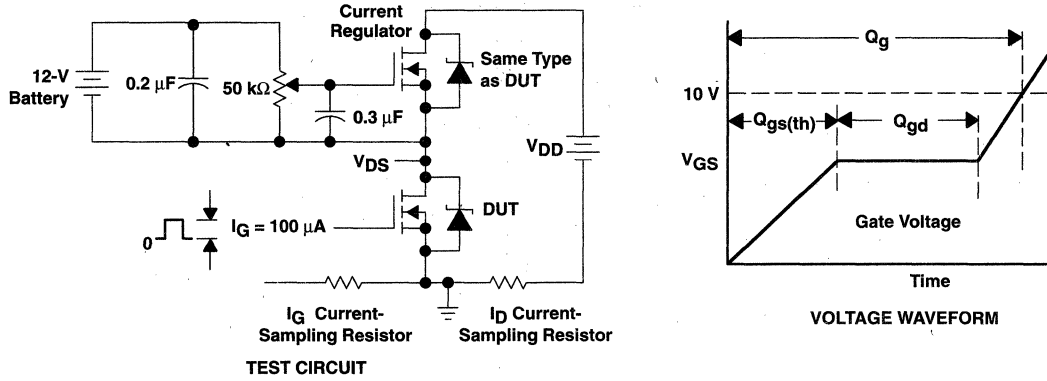


NOTE A:  $C_L$  includes probe and jig capacitance.

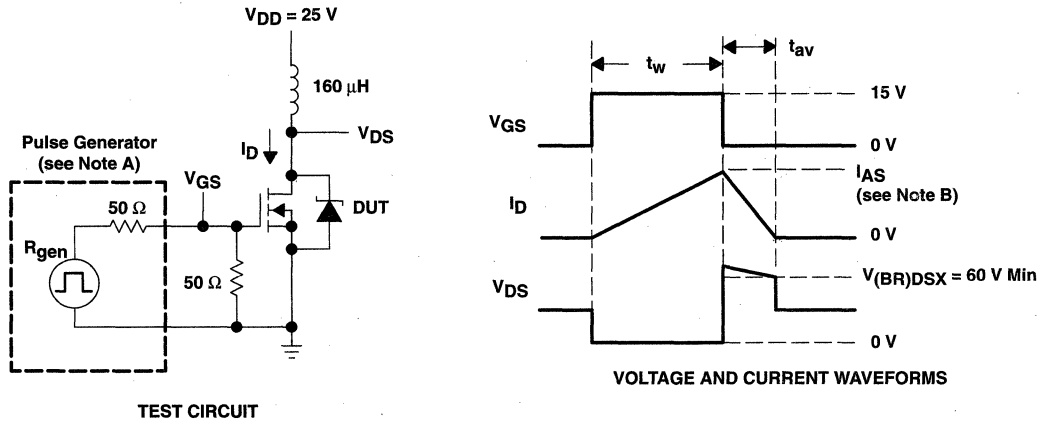
**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**



**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 11.25$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 17.2 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**

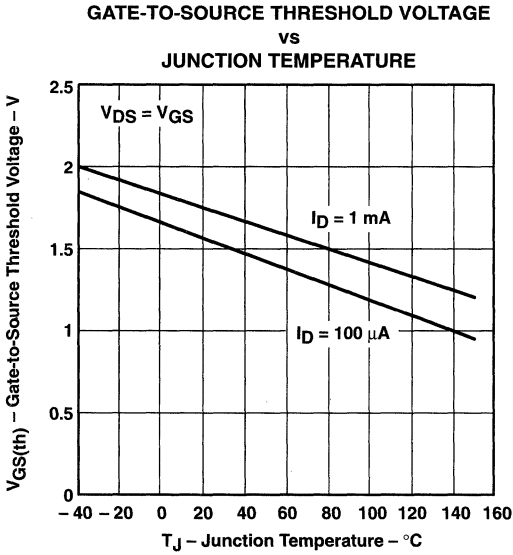


Figure 5

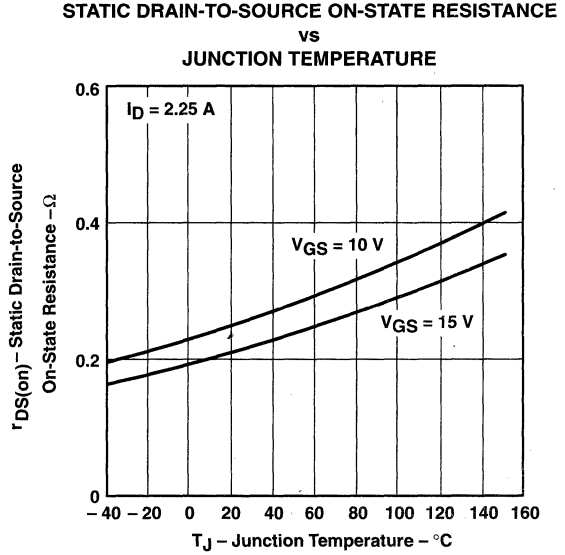


Figure 6

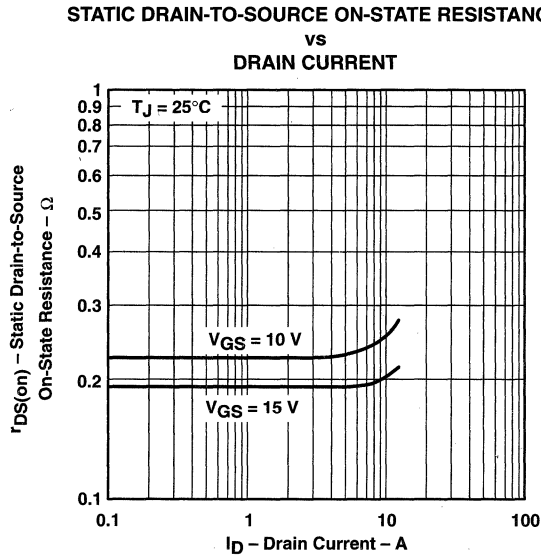


Figure 7

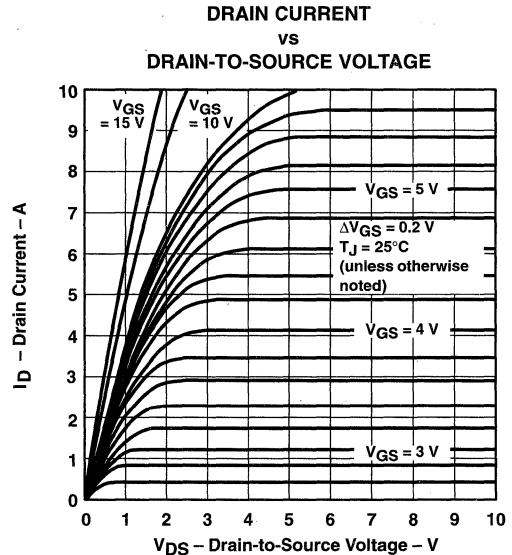


Figure 8

**TPIC1301**  
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**TYPICAL CHARACTERISTICS**

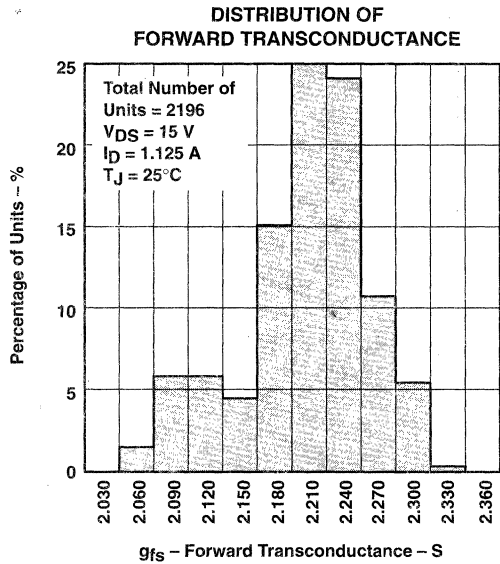


Figure 9

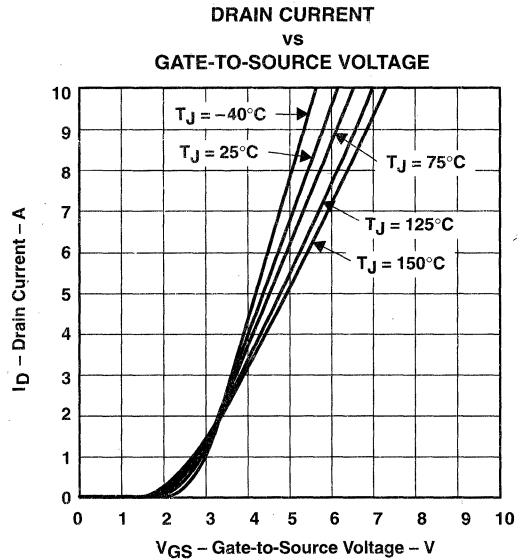


Figure 10

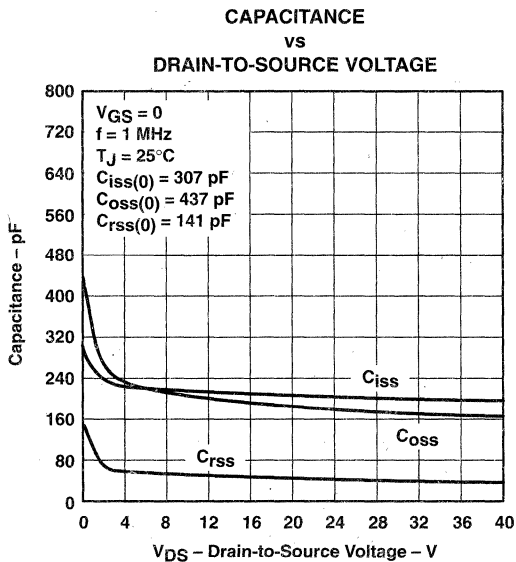


Figure 11

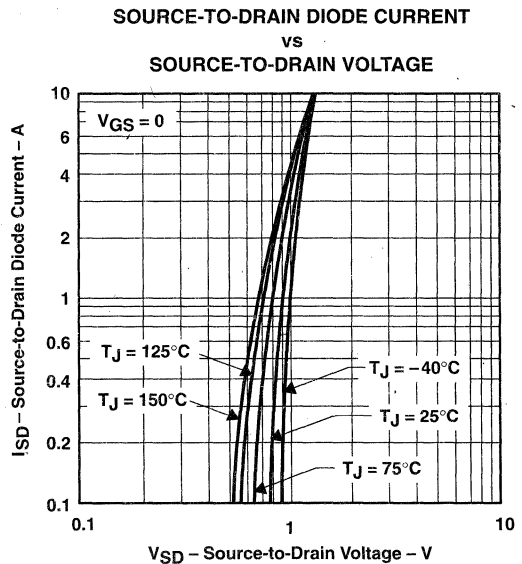


Figure 12

TYPICAL CHARACTERISTICS

DRAIN-TO-SOURCE VOLTAGE AND  
 GATE-TO-SOURCE VOLTAGE  
 vs  
 GATE CHARGE

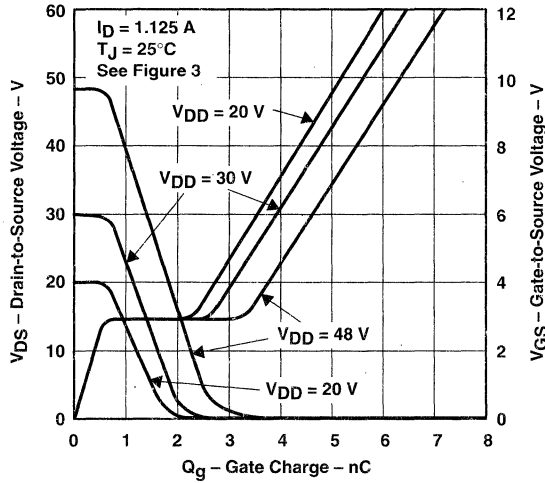


Figure 13

REVERSE RECOVERY TIME  
 vs  
 REVERSE  $di/dt$

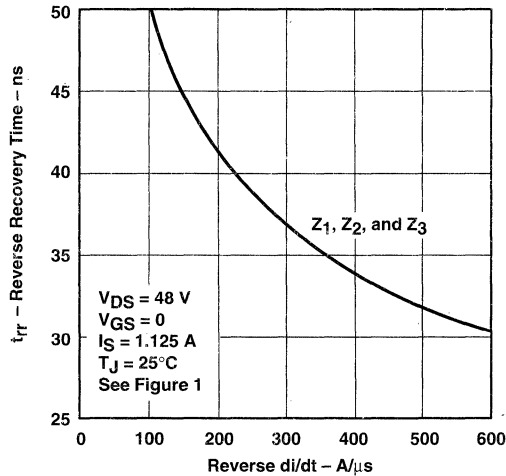
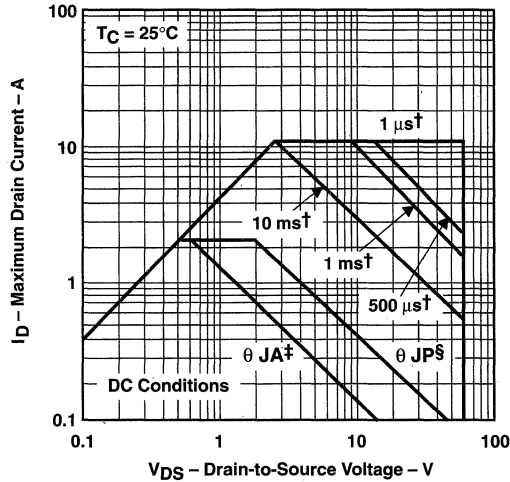


Figure 14

**THERMAL INFORMATION**

**MAXIMUM DRAIN CURRENT  
 vs  
 DRAIN-TO-SOURCE VOLTAGE**



† Less than 2% duty cycle  
 ‡ Device mounted on FR4 printed-circuit board with no heatsink.  
 § Device mounted in intimate contact with infinite heatsink.

Figure 15

**MAXIMUM PEAK AVALANCHE CURRENT  
 vs  
 TIME DURATION OF AVALANCHE**

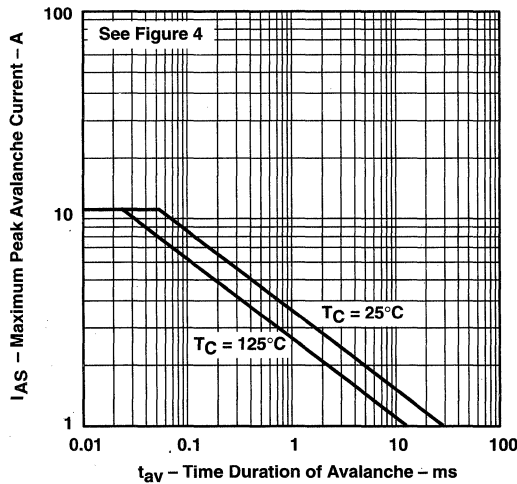
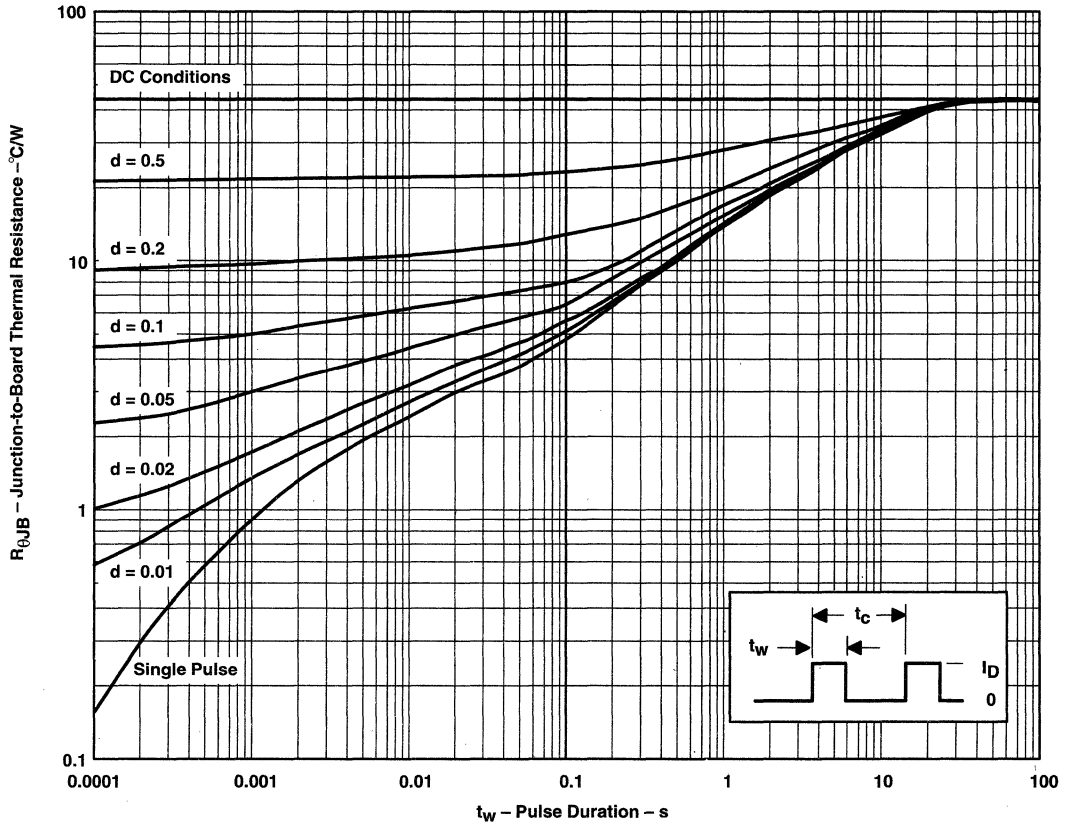


Figure 16

THERMAL INFORMATION

DW PACKAGE†  
 JUNCTION-TO-BOARD THERMAL RESISTANCE  
 vs  
 PULSE DURATION



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink

NOTE A.  $Z_{\theta B}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17



# TPIC1321L

## 3-HALF H-BRIDGE GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

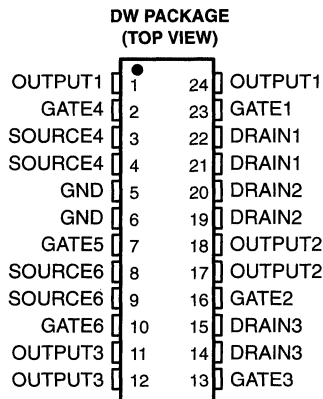
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- Low  $r_{DS(on)}$  . . . 0.35  $\Omega$  Typ
- Voltage Output . . . 60 V
- Input Protection Circuitry . . . 18 V
- Pulsed Current . . . 4 A Per Channel
- Extended ESD Capability . . . 4000 V
- Direct Logic-Level Interface

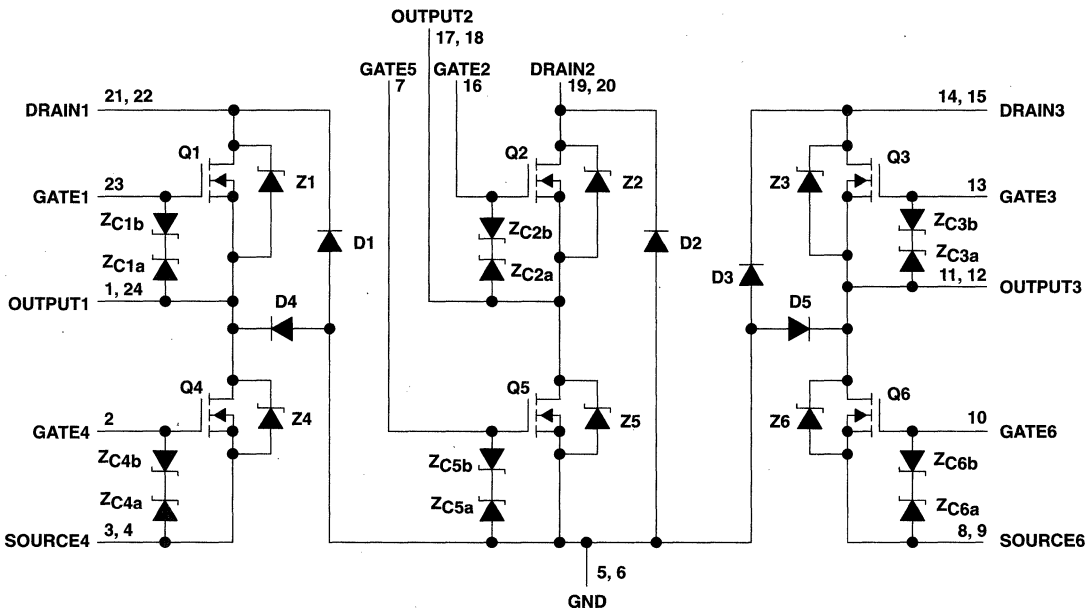
### description

The TPIC1321L is a monolithic gate-protected logic-level power DMOS array that consists of six electrically isolated N-channel enhancement-mode DMOS transistors configured as 3-half H-bridges. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC1321L is offered in a 24-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



### schematic



NOTE A: For correct operation, no terminal may be taken below GND.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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**TPIC1321L**  
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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Output-to-GND voltage .....	60 V
Drain-to-GND voltage .....	100 V
SOURCE4, SOURCE6-to-GND voltage .....	60 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1.25 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1.25 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	4 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16) .....	96 mJ
Continuous total dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15) .....	1.39 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



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**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250\ \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1\ \text{mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.75	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250\ \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250\ \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, D3, D4, D5)	Drain-to-GND current = $250\ \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.25\ \text{A}$ , See Notes 2 and 3	$V_{GS} = 5\ \text{V}$ ,		0.44	0.5	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.25\ \text{A}$ , $V_{GS} = 0$ (Z1 – Z6), See Notes 2 and 3 and Figure 12			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.25\ \text{A}$ (D1 – D5) See Notes 2 and 3			4		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48\ \text{V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15\ \text{V}$ ,	$V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5\ \text{V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48\ \text{V}$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5\ \text{V}$ , $I_D = 1.25\ \text{A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.35	0.4		$\Omega$
			$T_C = 125^\circ\text{C}$	0.57	0.6		
$g_{fs}$	Forward transconductance	$V_{DS} = 15\ \text{V}$ ,	$I_D = 625\ \text{mA}$ , See Notes 2 and 3 and Figure 9	1.6	1.74		S
$C_{iss}$	Short-circuit input capacitance, common source				200	250	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25\ \text{V}$ ,	$V_{GS} = 0$ , See Figure 11		175	220	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source	$f = 1\ \text{MHz}$ ,			40	75	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 625\ \text{mA}$ ,	$V_{DS} = 48\ \text{V}$ ,			45		ns
$Q_{RR}$	Total diode charge	$V_{GS} = 0$ , See Figures 1 and 14	$di/dt = 100\ \text{A}/\mu\text{s}$ , Z1, Z2, and Z3			50		

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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 40\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		34	70	ns
$t_{d(off)}$ Turn-off delay time			80	150	
$t_r$ Rise time			28	55	
$t_f$ Fall time			15	30	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 625\text{ mA}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		4.6	5.8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.7	0.88	
$Q_{gd}$ Gate-to-drain charge			2.5	3.13	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

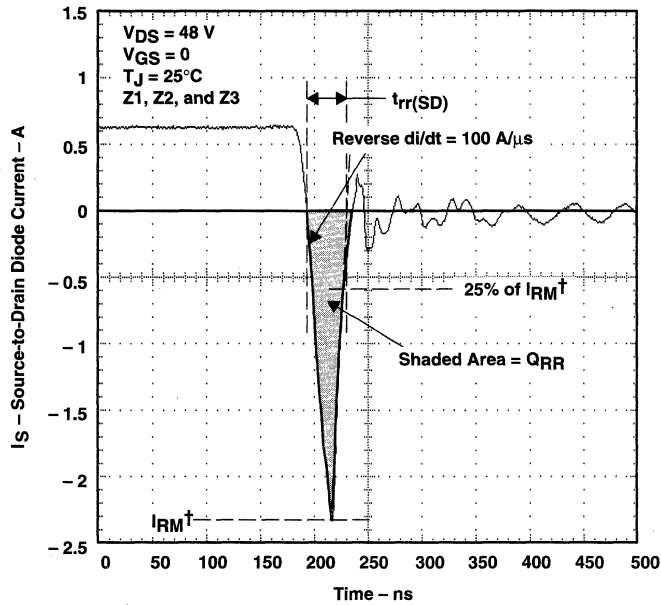
**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		90		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		44.5		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		28		

- NOTES: 4. Package mounted on an FR4 printed-circuit board with no heatsink.  
5. Package mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board.  
6. Package mounted in intimate contact with infinite heatsink.  
7. All outputs with equal power

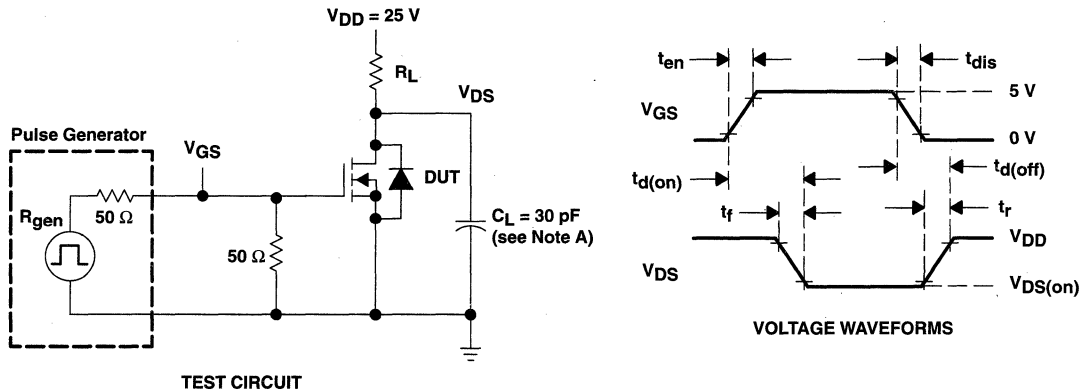


**PARAMETER MEASUREMENT INFORMATION**



$^\dagger I_{RM}$  = maximum recovery current

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**

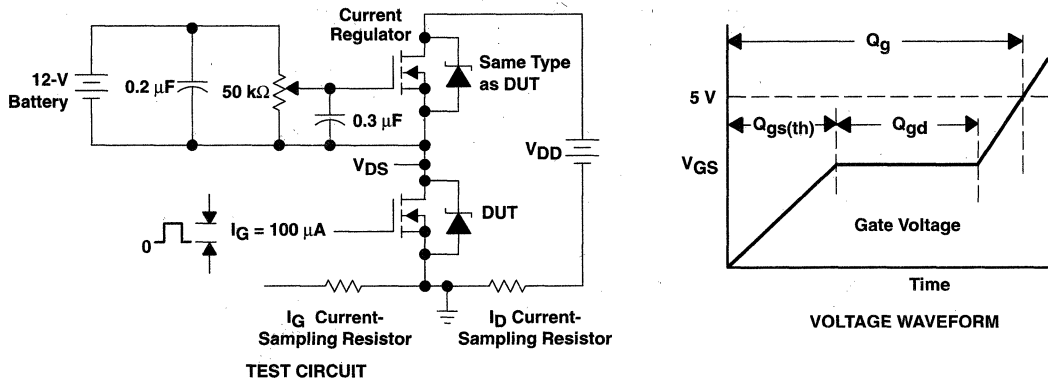


NOTE A:  $C_L$  includes probe and jig capacitance.

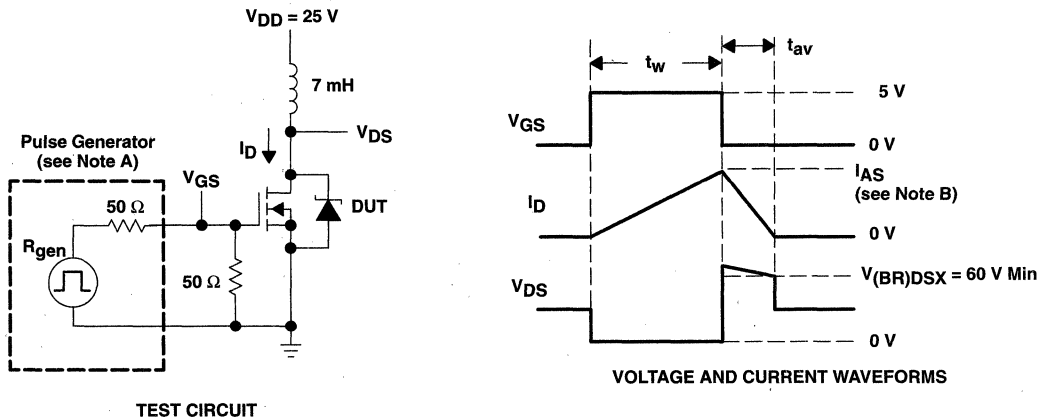
**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**

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**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 4$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 96 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

TYPICAL CHARACTERISTICS

GATE-TO-SOURCE THRESHOLD VOLTAGE  
 vs  
 JUNCTION TEMPERATURE

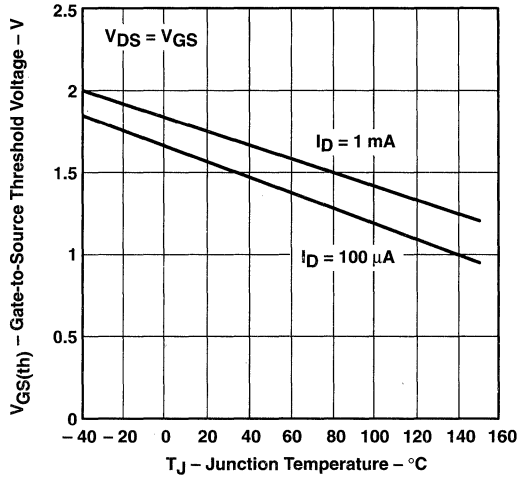


Figure 5

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
 vs  
 JUNCTION TEMPERATURE

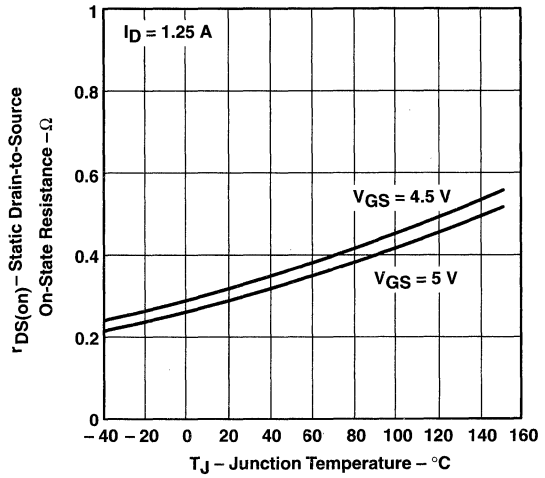


Figure 6

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
 vs  
 DRAIN CURRENT

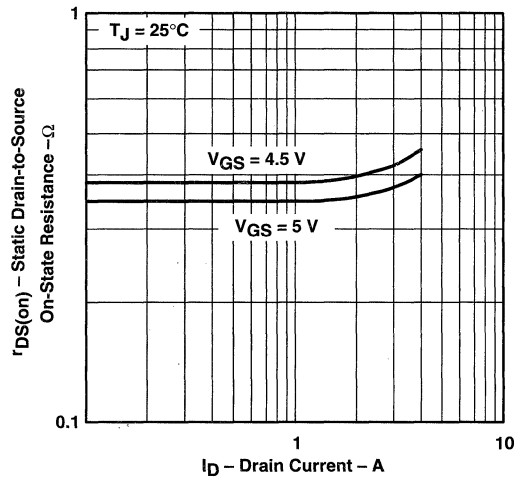


Figure 7

DRAIN CURRENT  
 vs  
 DRAIN-TO-SOURCE VOLTAGE

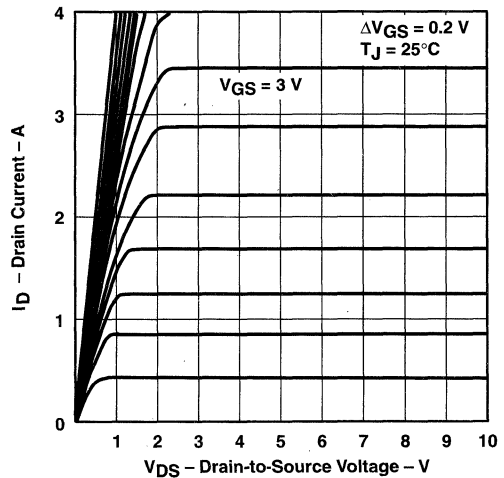


Figure 8

**TPIC1321L**  
**3-HALF H-BRIDGE GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

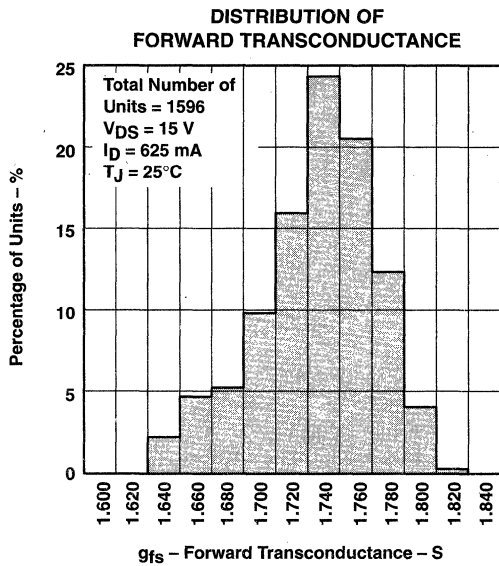


Figure 9

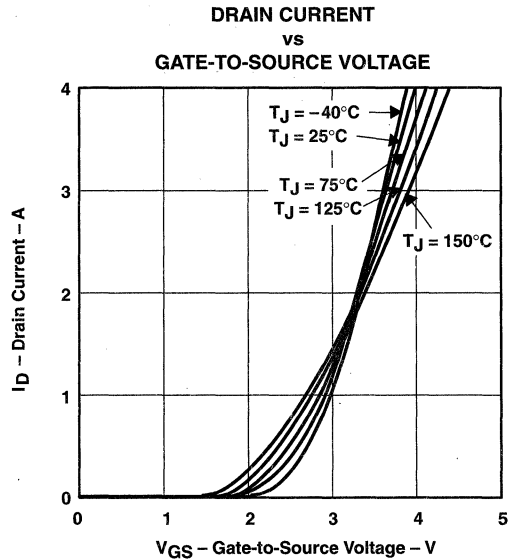


Figure 10

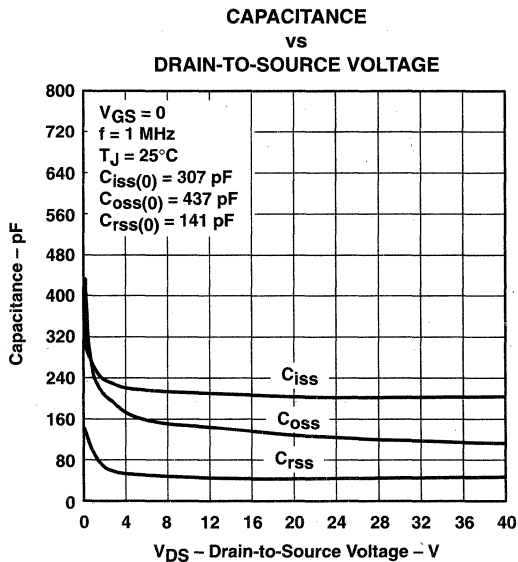


Figure 11

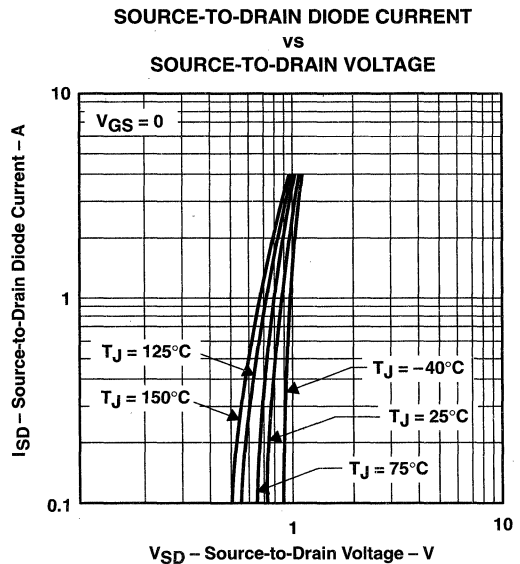


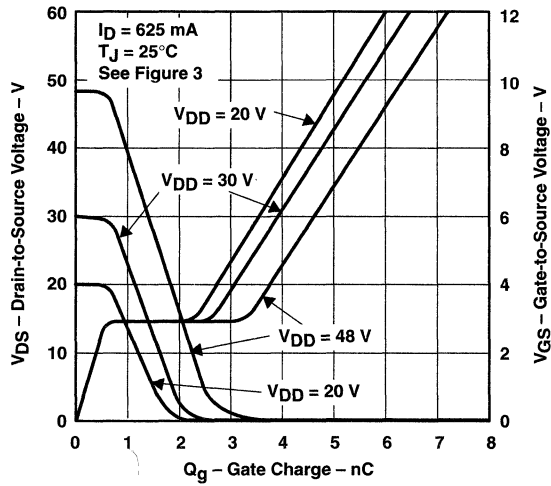
Figure 12



**TYPICAL CHARACTERISTICS**

**DRAIN-TO-SOURCE VOLTAGE AND**  
**GATE-TO-SOURCE VOLTAGE**

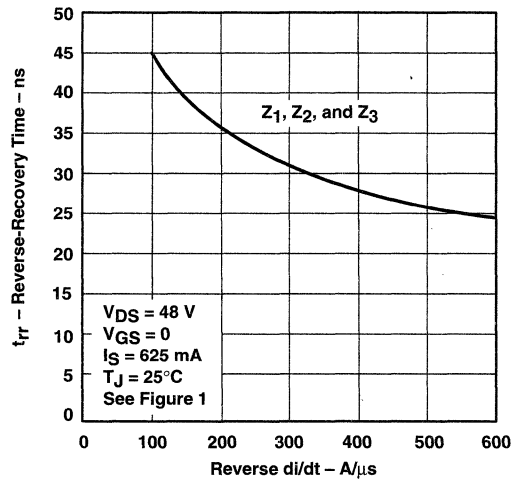
vs  
**GATE CHARGE**



**Figure 13**

**REVERSE-RECOVERY TIME**

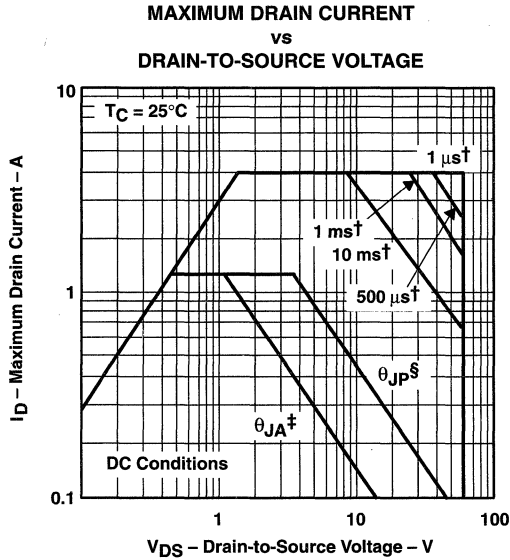
vs  
**REVERSE  $di/dt$**



**Figure 14**



THERMAL INFORMATION



$^\dagger$  Less than 2% duty cycle  
 $^\ddagger$  Device mounted on FR4 printed-circuit board with no heatsink.  
 $^\S$  Device mounted in intimate contact with infinite heatsink.

Figure 15

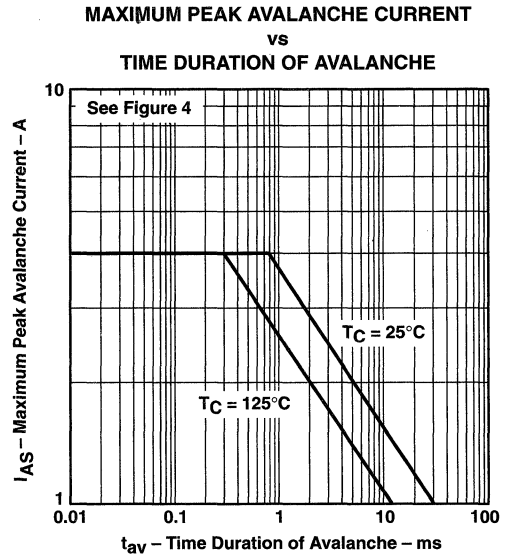
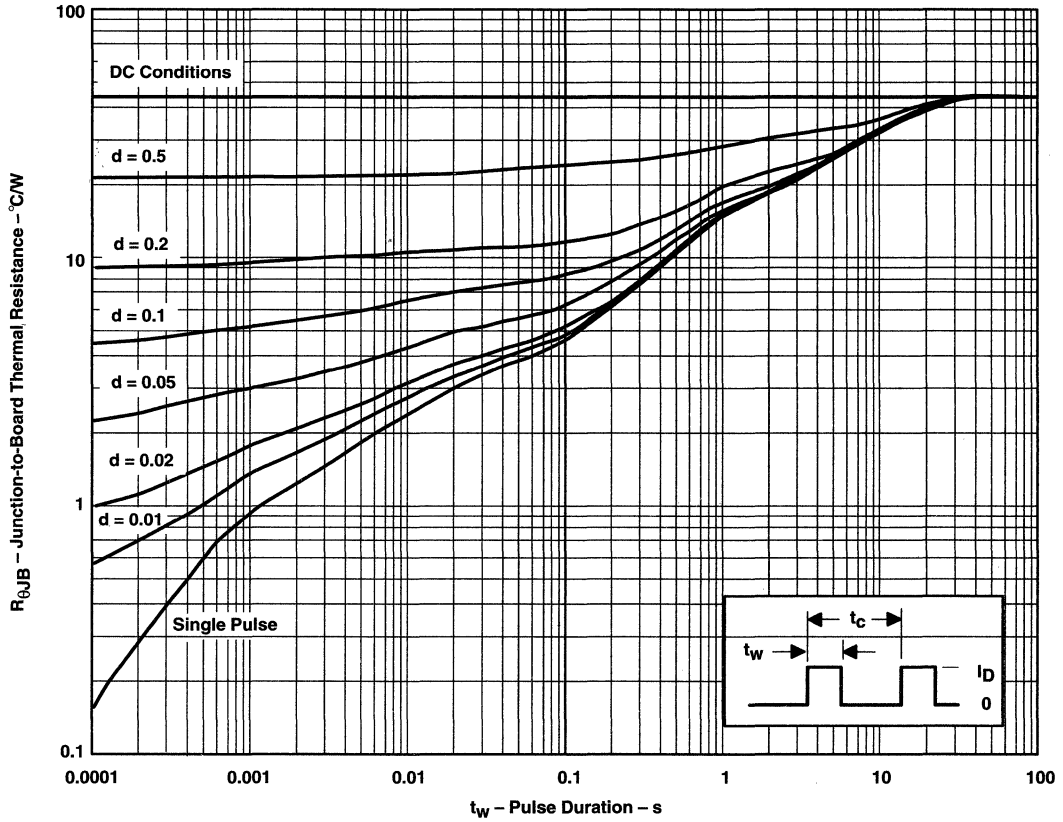


Figure 16

THERMAL INFORMATION

DW PACKAGE†  
 JUNCTION-TO-BOARD THERMAL RESISTANCE  
 vs  
 PULSE DURATION



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.  
 NOTE A:  $Z_{\theta B}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17



# TPIC1501A QUAD AND HEX POWER DMOS ARRAY

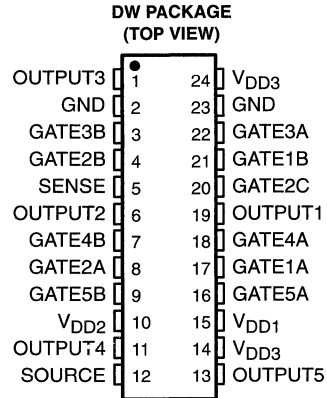
SLIS046 – MAY 1995

- **Low  $r_{DS(on)}$ :**  
100 m $\Omega$  Typ (Full H-Bridge)  
400 m $\Omega$  Typ (Triple Half H-Bridge)
- **Pulsed Current:**  
12 A (Full H-Bridge)  
6 A (Triple Half H-Bridge)
- **Matched Sense Transistor for Class A-B Linear Operation**
- **Fast Commutation Speed**

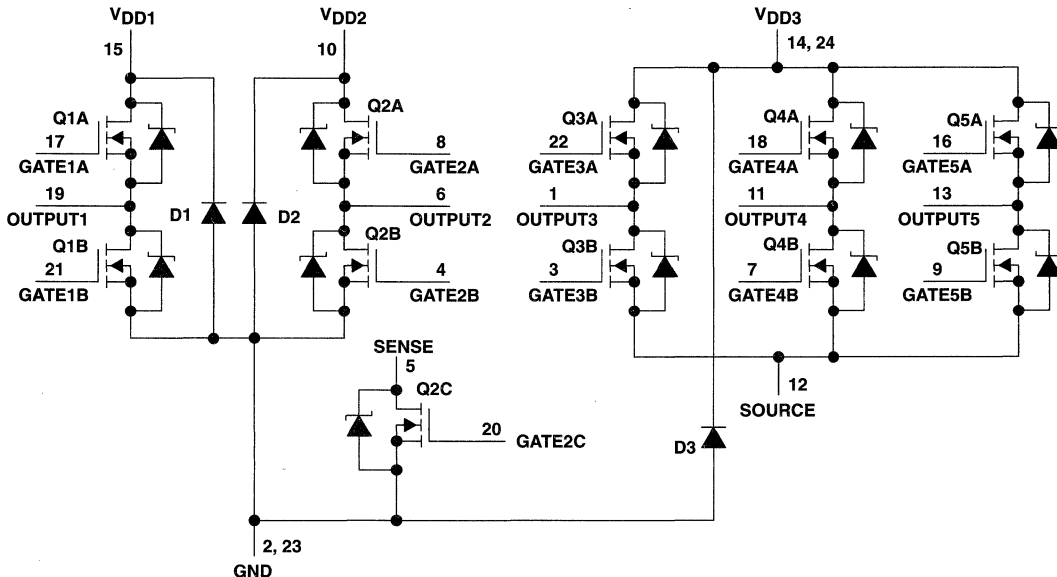
## description

The TPIC1501 is a monolithic power DMOS array that consists of ten electrically isolated N-channel enhancement-mode power DMOS transistors, four of which are configured as a full H-bridge and six as a triple half H-bridge. The lower stage of the full H-bridge is provided with an integrated sense-FET to allow biasing of the bridge in class A-B operation.

The TPIC1501 is offered in a 24-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



## schematic



- NOTES: A. Pins 2 and 23 must be externally connected.  
B. Pins 14 and 24 must be externally connected.  
C. No terminal may be taken greater than 0.5 V below GND.

PRODUCT PREVIEW

PRODUCT PREVIEW information concerns products in the formative or design phase of development. Characteristic data and other specifications are design goals. Texas Instruments reserves the right to change or discontinue these products without notice.

 **TEXAS  
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# TPIC1501A QUAD AND HEX POWER DMOS ARRAY

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## absolute maximum ratings, $T_C = 25^\circ\text{C}$ (unless otherwise noted)<sup>†</sup>

Supply-to-GND voltage .....	20 V
Source-to-GND voltage (Q3A, Q4A, Q5A) .....	20 V
Output-to-GND voltage .....	20 V
Sense-to-GND voltage .....	20 V
Gate-to-source voltage range, $V_{GS}$ (Q1A, Q1B, Q2A, Q2B, Q3A, Q3B, Q4A, Q4B, Q5A, Q5B) .....	$\pm 20$ V
Gate-to-source voltage range, $V_{GS}$ (Q2C) .....	-0.7 V to 6 V
Continuous drain current, each output (Q1A, Q1B, Q2A, Q2B) .....	3 A
Continuous drain current, each output (Q3A, Q3B, Q4A, Q4B, Q5A, Q5B) .....	1.5 A
Continuous drain current (Q2C) .....	15 mA
Continuous source-to-drain diode current (Q1A, Q1B, Q2A, Q2B) .....	3 A
Continuous source-to-drain diode current (Q3A, Q3B, Q4A, Q4B, Q5A, Q5B) .....	1.5 A
Continuous source-to-drain diode current (Q2C) .....	15 mA
Pulsed drain current, each output, $I_{max}$ (Q1A, Q1B, Q2A, Q2B) (see Note 1 and Figure 24) .....	12 A
Pulsed drain current, each output, $I_{max}$ (Q3A, Q3B, Q4A, Q4B, Q5A, Q5B) (see Note 1 and Figure 25) .....	6 A
Pulsed drain current, $I_{max}$ (Q2C) (see Note 1) .....	60 mA
Continuous total dissipation, $T_C = 70^\circ\text{C}$ (see Note 2 and Figures 24 and 25) .....	2.86 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

<sup>†</sup> 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. Pulse duration = 10 ms, duty cycle = 2%
  2. Package mounted in intimate contact with infinite heatsink.

PRODUCT PREVIEW



**TPIC1501A**  
**QUAD AND HEX POWER DMOS ARRAY**

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**electrical characteristics (Q1A, Q1B, Q2A, Q2B),  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	20			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$ ,	1.4	1.7	2.1	V
		$I_D = 5 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.65	1.95	2.35	
$V_{GS(th)match}$	Gate-to-source threshold voltage matching	$I_D = 5 \text{ mA}$ ,	$V_{DS} = V_{GS}$			40	mV
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage	Drain-to-GND current = 250 $\mu\text{A}$ (D1, D2)		20			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 2 \text{ A}$ ,	$V_{GS} = 10 \text{ V}$ ,			0.24	V
		See Notes 3 and 4					
$V_F$	Forward on-state voltage, GND-to- $V_{DD1}$ , GND-to- $V_{DD2}$	$I_D = 3 \text{ A}$ (D1, D2) See Notes 3 and 4			1.8		V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 2 \text{ A}$ , $V_{GS} = 0$ , See Notes 3 and 4 and Figure 19			0.85	1.05	V
		$I_S = 3 \text{ A}$ , $V_{GS} = 0$ , See Notes 3 and 4 and Figure 19			0.9	1.1	
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 16 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, $V_{DD1}$ -to-GND, $V_{DD2}$ -to-GND, gate shorted to source	$V_{DGND} = 16 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 2 \text{ A}$ , See Notes 3 and 4 and Figure 9	$T_C = 25^\circ\text{C}$		0.1	0.12	$\Omega$
			$T_C = 125^\circ\text{C}$		0.14	0.18	
			$T_C = 25^\circ\text{C}$		0.1	0.12	
			$T_C = 125^\circ\text{C}$		0.14	0.18	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 3 and 4	$I_D = 1 \text{ A}$ ,		1.5	2.5	S
			$I_D = 1.5 \text{ A}$ ,		2	3	
		See Notes 3 and 4 and Figure 13					
$C_{iss}$	Short-circuit input capacitance, common source				300		pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 10 \text{ V}$ , $f = 1 \text{ MHz}$ ,	$V_{GS} = 0$ , See Figure 17		225		
$C_{rss}$	Short-circuit reverse transfer capacitance, common source				160		
$\alpha_S$	Sense-FET drain current ratio	$V_{DS} = 6 \text{ V}$ ,	$I_{D(Q2B)} = 5 \text{ mA}$	100	150	200	

NOTES: 3. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

PRODUCT PREVIEW



# TPIC1501A QUAD AND HEX POWER DMOS ARRAY

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## source-to-drain diode characteristics (Q1A, Q2A), $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 1.5\text{ A}$ , $V_{DS} = 16\text{ V}$ , See Figures 1 and 23	$V_{GS} = 0$ , $di/dt = 100\text{ A}/\mu\text{s}$ ,		70		ns
$Q_{RR}$	Total diode charge				90		nC
$t_{rr}$	Reverse-recovery time	$I_S = 2\text{ A}$ , $V_{DS} = 16\text{ V}$ ,	$V_{GS} = 0$ , $di/dt = 100\text{ A}/\mu\text{s}$ ,		75		ns
$Q_{RR}$	Total diode charge				110		nC

## resistive-load switching characteristics (Q1A, Q1B, Q2A, Q2B), $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 16\text{ V}$ , $R_L = 16\ \Omega$ , $t_{dis} = 10\text{ ns}$ , See Figure 3	$t_{en} = 10\text{ ns}$ ,		20		ns	
$t_{d(off)}$	Turn-off delay time				30			
$t_r$	Rise time				15			
$t_f$	Fall time				25			
$Q_g$	Total gate charge	$V_{DS} = 16\text{ V}$ , See Figure 4	$I_D = 1.5\text{ A}$ ,	$V_{GS} = 10\text{ V}$ ,		5.6	7	nC
$Q_{gs(th)}$	Threshold gate-to-source charge					0.8	1	
$Q_{gd}$	Gate-to-drain charge					1.2	1.5	
$L_D$	Internal drain inductance				5		nH	
$L_S$	Internal source inductance				5			
$R_g$	Internal gate resistance				0.25			$\Omega$

PRODUCT PREVIEW



**TPIC1501A**  
**QUAD AND HEX POWER DMOS ARRAY**

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**electrical characteristics (Q3A, Q3B, Q4A, Q4B, Q5A, Q5B),  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	20			V	
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$ ,	1.4	1.7	2.1	V	
		See Figure 6						
		$I_D = 5 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.65	1.95	2.35		
$V_{GS(th)match}$	Gate-to-source threshold voltage matching	$I_D = 5 \text{ mA}$ ,	$V_{DS} = V_{GS}$			40	mV	
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage	Drain-to-GND current = $250 \mu\text{A}$ (D3)		20			V	
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.5 \text{ A}$ ,	$V_{GS} = 10 \text{ V}$ ,			0.675	V	
		See Notes 3 and 4						
$V_F$	Forward on-state voltage, GND-to- $V_{DD3}$	$I_D = 1.5 \text{ A}$ (D3)			1.7		V	
		See Notes 3 and 4						
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.5 \text{ A}$ ,	$V_{GS} = 0$		1	1.2	V	
		See Notes 3 and 4 and Figure 20						
		$I_S = 2 \text{ A}$ ,	$V_{GS} = 0$		1.1	1.3		
		See Notes 3 and 4 and Figure 20						
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 16 \text{ V}$ ,	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$			0.5		10
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA	
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA	
$I_{lkg}$	Leakage current, $V_{DD3}$ -to-GND, gate shorted to source	$V_{DGND} = 16 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$			0.5		10
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ ,	$I_D = 0.3 \text{ A}$ ,	See Notes 3 and 4 and Figures 8 and 10	$T_C = 25^\circ\text{C}$	0.35	0.39	$\Omega$
					$T_C = 90^\circ\text{C}$	0.45	0.5	
					$T_C = 125^\circ\text{C}$	0.50	0.56	
					$T_C = 25^\circ\text{C}$	0.4	0.45	
					$T_C = 125^\circ\text{C}$	0.56	0.65	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ ,	$I_D = 500 \text{ mA}$ ,		0.3	0.8	S	
			See Notes 3 and 4 and Figure 14					
		$V_{DS} = 10 \text{ V}$ ,	$I_D = 750 \text{ mA}$ ,		0.4	0.9		
		See Notes 3 and 4						
$C_{iss}$	Short-circuit input capacitance, common source				98		pF	
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 10 \text{ V}$ ,	$V_{GS} = 0$ ,	See Figure 18	98			
$C_{rss}$	Short-circuit reverse transfer capacitance, common source				$f = 1 \text{ MHz}$ ,			65

NOTES: 3: Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

4: These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**PRODUCT PREVIEW**





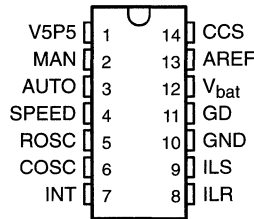


# TPIC2101 DC BRUSH MOTOR CONTROLLER

SLIS060 – OCTOBER 1995

- 0 V to 16 V, 50 mA Max PWM Gate Drive Output
- Dual Speed Command Input Capability
- Effective Motor Voltage Adjustment
- 100% Duty Cycle Capability
- Low Current (<200  $\mu$ A) Sleep State
- Built-in Soft Start
- Over/Under Voltage Protection
- Over Current Protection of External FET/IGBT

D or N PACKAGE  
(TOP VIEW)



## description

The TPIC2101 is a monolithic integrated control circuit designed for direct current (dc) brush motor control that generates a user-adjustable, fixed-frequency, variable duty cycle, pulse width modulated (PWM) signal primarily to control rotor speed of a permanent magnet dc motor. The TPIC2101 can also be used to control power to other loads such as solenoids and incandescent bulbs. This device drives the gate of an external, low side NMOS power transistor to provide PWM controlled power to a motor or other loads. Inductive current from motor or solenoid loads during PWM off-time is recirculated through an external diode.

The TPIC2101 accepts a 0% to 100% PWM signal (auto mode) or a 0 V to 2.2 V differential voltage (manual mode), and internally engages the correct operating mode to accept the input type.

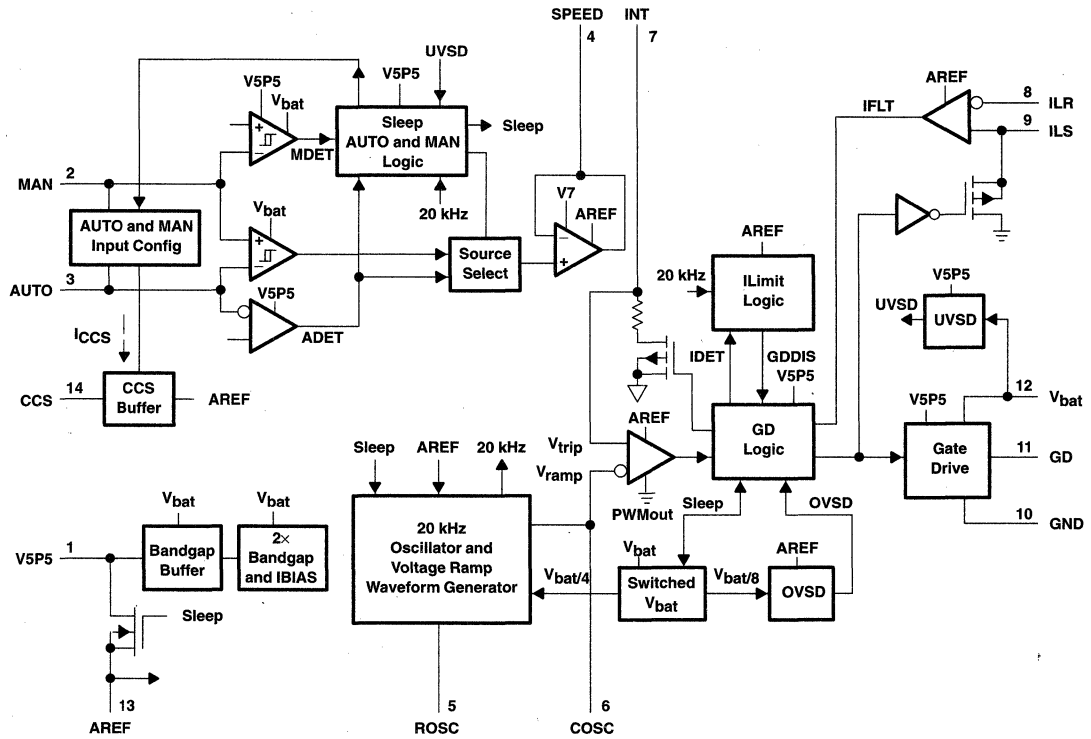
The device operates in a sleep state, a run state, or a fault state. In the sleep state the gate-drive (GD) terminal is held low and the overall current draw is less than 200  $\mu$ A. The normal operating mode of the device is in the run state and is initiated by any speed command. When the device detects an overvoltage or current fault, it enters the fault state.

The TPIC2101 is offered in a 14-terminal plastic DIP (N) package, and a SOIC (D) package, and is characterized for operation over the operating free-air temperature range of  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$ .

# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## functional block diagram



NOTE A. For correct operation, no terminal may be taken below GND.

# TPIC2101 DC BRUSH MOTOR CONTROLLER

SLIS060 – OCTOBER 1995

## Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
V5P5	1	O	5.5 V supply voltage. V5P5 is a regulated voltage supply from $V_{bat}$ , internally switched to AREF during the run state. This requires a 4.7 $\mu$ F tantalum capacitor from V5P5 to GND for stability.
MAN	2	I	Manual control input. MAN is an active high (greater than 5.5 V asserts the manual mode) input that serves as a positive differential input (0-2.3 V full range) for the manual mode. In man mode, $I_{man}$ is approx. $20 \times I_{CCS}$ .
AUTO	3	I	PWM control input. AUTO is an active low input that remains active if pulsed every 2048 counts of the oscillator frequency. It also serves as a negative differential input for the manual mode. In auto mode, $I_{auto}$ is approx. $13 \times I_{CCS}$ pullup, $I_{auto}$ is approx. $20 \times I_{CCS}$ pulldown in man mode.
SPEED	4	O	Integrator output. SPEED is an integrator output with a required minimum resistance between SPEED and INT terminals of 20 k $\Omega$ (typically 1 second RC time constant, or as required for soft start).
ROSC	5	O	Oscillator resistor output. ROSC has an external resistor connected to ground which determines the constant charging current of COSC. The IC forces a voltage of $V_{bat}/4$ in run state.
COSC	6	O	Oscillator capacitor output. COSC has an external capacitor connected to ground which determines (with ROSC) switching frequency. $f(osc) = 2/(ROSC \times COSC)$
INT	7	I	Integrator input. INT is an input from an integrator that requires a 4.7 $\mu$ F capacitor and a 20 k minimum resistance between the SPEED and INT terminals.
ILR	8	I	Current limit reference. ILR is an input from a resistor divider off AREF.
ILS	9	I	Current limit sense. ILS senses drain voltage of external FET. ILS trips within $\pm 10$ mV of ILR.
GND	10		Ground terminal
GD	11	O	Gate drive output. GD, PWM output, 0- $V_{bat}$ voltage, provides a 0- $V_{bat}$ PWM output pre-drive for an external FET.
$V_{bat}$	12	I	Positive power input.
AREF	13	O	5.5 V reference voltage. AREF is a 5.5 V reference voltage switched from V5P5 during the run state. AREF is used as a reference for ILR in current limit detection and is capable of sourcing 2 mA of current.
CCS	14		Constant current sink. $I_{CCS}$ equals $AREF/(2 \times R_{CCS})$ . Requires an external resistor.

### recommended external components for auto and manual modes (see Figures 2 and 4)

TERMINAL NAME	NO.	DESCRIPTION
V5P5	1	Capacitor – 4.7 $\mu$ F tantalum
MAN	2	Capacitor – 0.1 $\mu$ F
MAN	2	Resistor – 499 $\Omega$ , 1%, 100 ppm
AUTO	3	Capacitor – 0.47 $\mu$ F
AUTO	3	Resistor – 499 $\Omega$ , 1%, 100 ppm
SPEED	4	Resistor – 100 k $\Omega$ , 1%, 100 ppm to INT terminal, (minimum 20 k $\Omega$ )
ROSC	5	Resistor – 45.3 k $\Omega$
COSC	6	Capacitor – 2200 pF
INT	7	Capacitor – 4.7 $\mu$ F
CCS	14	Resistor – 27.4 k $\Omega$ , 1%, 100 ppm

# TPIC2101

## DC BRUSH MOTOR CONTROLLER

SLIS060 – OCTOBER 1995

### detailed description

The TPIC2101 is an integrated circuit that generates a fixed frequency, variable duty cycle PWM signal to control the rotor speed of a permanent-magnet dc motor. This section provides a functional description of the device.

### dual command speed input capability

The TPIC2101 is user configurable to either auto or manual mode, and can sense either configuration internal to the IC. In automatic mode, the speed-command-signal is an open-collector PWM signal on the AUTO terminal, and the MAN terminal is floating. In manual mode, the speed-command-signal is a variable resistance across the AUTO and MAN terminals with the MAN terminal connected to  $V_{bat}$ .

### sleep, run, and fault states

The TPIC2101 operates in a sleep state, a run state, or a fault state. In the auto mode, a zero-speed input initiates the sleep state. In the manual mode, an open-circuit at the AUTO and MAN terminals initiates the sleep state. The device will also be in the sleep state during fault conditions. In the sleep state, the gate drive terminal (GD) is held low and the overall current draw is less than 200  $\mu A$ . Any speed command initiates the run state, which is the normal operating state of the device. The fault state is entered only when the device detects an overvoltage or current fault. Fault state is exited either by removal of the overvoltage condition (exiting to run state) or by resetting a current fault by entering the sleep state.

### speed command adjustment

The device adjusts the GD terminal PWM signal with changes in  $V_{bat}$  to keep the effective motor voltage constant. The effective motor voltage is defined to be the product of the GD terminal PWM rate and the voltage of  $V_{bat}$ . Figure 1 shows motor voltage as a function of input speed command in the automatic mode for various battery voltages.  $PWM_{in}$  is described as the duty cycle of the PWM signal at the AUTO terminal.

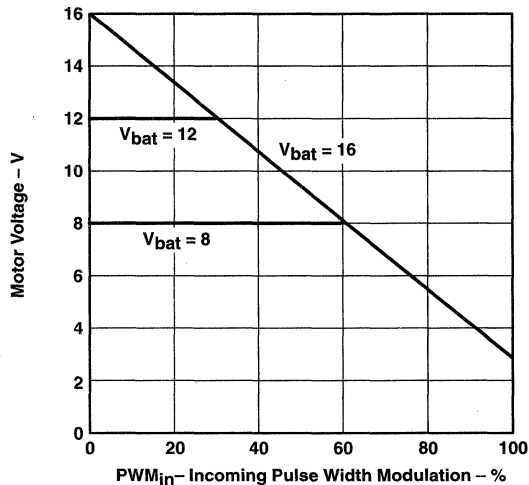


Figure 1. Motor Voltage vs. Incoming PWM for Various Battery Voltages

### over/under voltage protection

The IC enters the fault state if  $V_{bat}$  rises above over-voltage shutdown ( $V_{OV}$  typically equals 18.5 V). If  $V_{bat}$  falls below the under-voltage shutdown ( $V_{UV}$  typically equals 7.5 volts) the IC enters sleep state. Hysteresis assures that the device will not toggle into and out of sleep state or fault condition.

**current limit protection**

Current through the motor is limited by lowering the GD terminal PWM when a high current situation occurs. If the condition persists, the device shuts off the gate drive (GD terminal) until the circuit is reset externally by entering the sleep state.

**theory of operation**

This section explains the normal circuit operation for the automatic and manual states.

**power supply and oscillator**

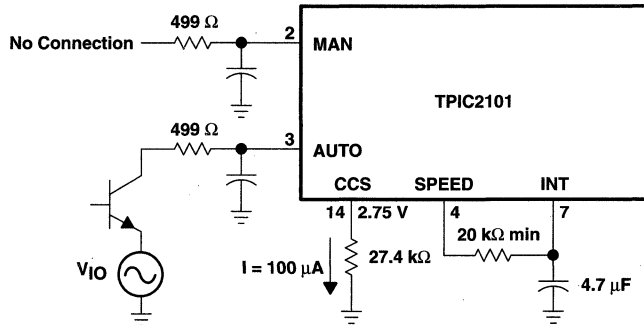
Positive voltage is supplied to the integrated circuit on the  $V_{bat}$  terminal, ground is the GND terminal. The IC steps down the  $V_{bat}$  supply to the regulated 5.5 V supply at the V5P5 terminal. AREF is shorted to V5P5 in run state and disconnected when the IC is in sleep state. Two terminal connections (COSC and ROSC) are provided to control an internal oscillator. The oscillator freq,  $f_{(osc)}$ , is defined by the following equation:

$$f_{(osc)} = \frac{2}{ROSC \times COSC}$$

Nominal oscillator frequency is 20-kHz based on the recommended components.

**automatic mode signal decoding**

In automatic state, a high-to-low signal transition on the AUTO terminal (open collector) will wake the device from the sleep state into the run state. The speed command information is contained in the duty cycle of a 100 Hz PWM signal on the same terminal. The speed information is inverted, i.e. a signal that is 10% high commands a faster speed than a 20% high signal. In automatic mode the MAN terminal is floating. The device is capable of rejecting  $\pm 2$  V of ground offset  $V_{IO}$  between the open-collector switching transistor and the GND terminal without affecting the output duty cycle. Two terminals are provided for an RC integrator (SPEED and INT) to average the incoming PWM signal for use as a PWM comparator input. Figure 2 illustrates the automatic state connections.



**Figure 2. Automatic Mode Connections**

# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## automatic mode signal decoding (continued)

The device enters the sleep state if the PWM signal on the AUTO terminal is absent (the AUTO terminal remains high or low) for 2048 clock cycles of the 20 KHz oscillator. An internal 1 mA pull-up resistor is provided for the AUTO terminal when in the auto mode. This pull-up resistor is not present in the manual mode or during sleep state.

The device adjusts the output PWM duty cycle to keep the effective motor voltage constant with changing battery voltages ( $V_{bat}$ ) as per the equation:

$$PWM_{out} = \frac{(2.88 + 13.12(1 - \text{Input Duty Cycle}))}{V_{bat}} \times 100\%$$

Figure 3 illustrates this transfer curve with various battery voltages.

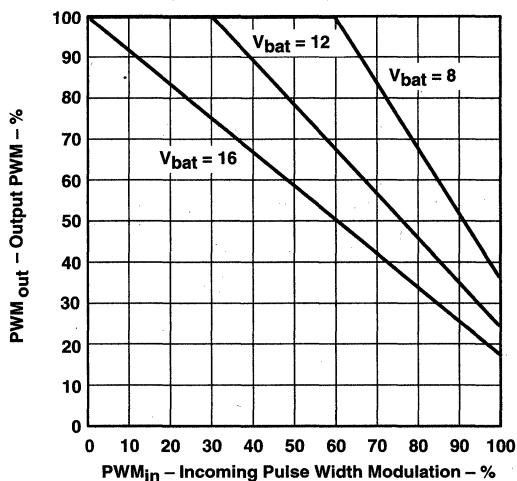


Figure 3. Output PWM vs. Incoming PWM for Various Battery Voltages

The allowable automatic mode PWM<sub>out</sub> variation is  $\pm 7\%$  over all operating conditions as indicated in the AC characteristics Table.

## manual mode speed signal decoding

In manual mode, a high input (>5.5V) on the MAN terminal changes the state of the device from sleep to run. While in the run state the device senses the resistance between the MAN and AUTO terminals by turning on a 2 mA current sink to each terminal. The MAN and AUTO current sinks are multiplied 20 X from the CCS current. This 2 mA current sink creates a 1 V drop across each 0.5 k $\Omega$  resistor and a 0 to 2.2 V differential across the 0 to 1 k $\Omega$  potentiometer (and thus across the 2 terminals). The SPEED and INT terminals should be utilized as in the proceeding section as a low-pass filter. When the connection to the MAN terminal is opened, the device enters the sleep state. In addition, the device is capable of rejecting up to 2.2 V of source voltage offset ( $V_{IO}$ ), as indicated in Figure 4.

manual mode speed signal decoding (continued)

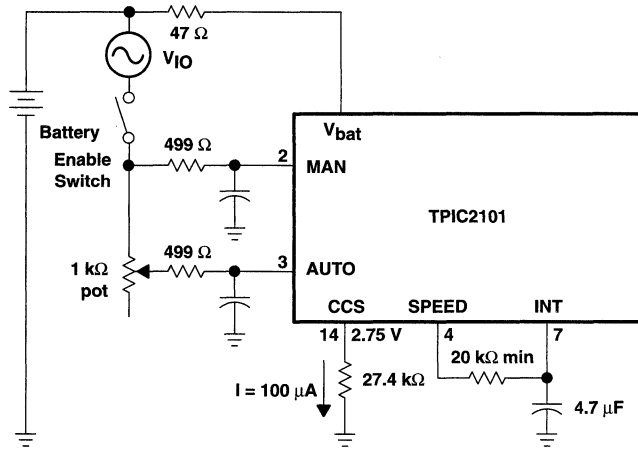


Figure 4. Manual Mode Connections

As in the automatic mode, the device will adjust the GD terminal PWM duty cycle to keep the effective motor voltage constant with changing battery voltages ( $V_{bat}$ ). The transfer equation for the manual mode is:

$$PWM_{out} = \frac{(2.88 + 6.56(V_{MAN} - V_{AUTO}))}{V_{bat}} \times 100\%$$

Figure 5 shows the output characteristic for various source voltages.

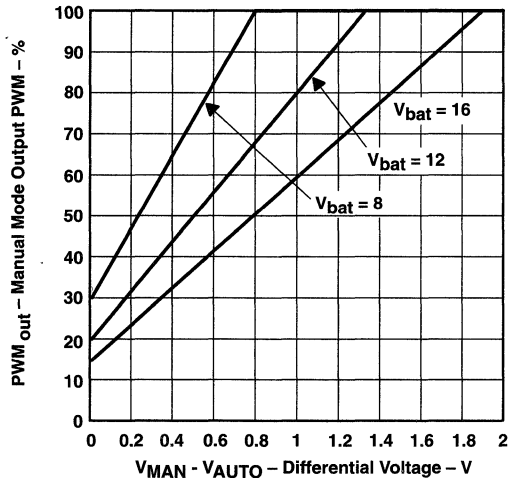


Figure 5. Manual Mode Input Signal vs. Output PWM

The allowable manual mode  $PWM_{out}$  variation is  $\pm 7\%$  over all operating conditions as indicated in the AC characteristics table.



# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## over/under voltage operating

The TPIC2101 detects an over or under voltage condition (on the  $V_{bat}$  terminal) and turns off the gate drive circuit. The device remains in this condition until the supply voltage returns to normal operating voltage. Hysteresis assures that the over/under voltage condition does not toggle off and on near the threshold. The INT terminal pulls toward GND through an internal impedance of less than  $500\ \Omega$  during the over-voltage condition or during sleep state. This ensures a slow ramp up of the GD terminal PWM when the  $V_{bat}$  voltage returns to the operating range.

## current limit operation

An over-current condition is detected if the ILS terminal is higher than the ILR terminal while the gate drive (GD terminal) is high. This condition activates a closed-loop control, causing the INT terminal to be pulled low (through an internal resistance less than  $500\ \Omega$ ) lowering the commanded duty cycle to close the loop.

## current fault operation

During a window of 8192 clock cycles, a latch is set if at least once during the window, a current limit condition is detected. If a current limit condition is set for eight consecutive 8192 clock cycle windows, the gate drive (GD terminal) will be shut off for a disable period of 65536 clock cycles. During the disable period, the INT terminal is pulled to GND through an internal resistance of less than  $500\ \Omega$ . After the disable period is completed, an internal restart is attempted. If the current limit is present again, as described above, for 8 consecutive windows, the GD and INT terminals are again pulled to GND and the device remains in this current fault state until the device is cycled through a sleep state to run state. However, if the current limit condition is not present during any of the eight 8192 clock cycle windows, the latches for the 8 count window timer and the two cycle shutdown/restart are reset. See timing diagrams, Figures 6, 7, and 8.

## absolute maximum ratings over the operating free-air temperature range (unless otherwise noted)<sup>†</sup>

Supply voltage range, $V_{bat}$ <sup>‡</sup>	-0.3 V to 40 V
Input voltage range, MAN, AUTO	-0.3 V to 40 V
Input voltage range, INT CCS, ILR	-0.3 V to 7 V
Continuous gate drive output current, $I_{GD}$	$\pm 50$ mA
Continuous speed output current, $I_{O(SPEED)}$	$\pm 1$ mA
Continuous output current, $I_{O(V5P5)}$ , $I_{O(AREF)}$	20 mA
Continuous ROSC output Current, $I_{O(ROSC)}$	1 mA
Continuous output current, $I_{O(CCS)}$	500 $\mu$ A
Thermal Resistance, junction to ambient, $R_{\theta JA}$ : D package	131°C/W
N package	78°C/W
Operating free-air temperature range, $T_A$	-40°C to 105°C
Maximum junction temperature, $T_{JM}$	150°C
Storage temperature range, $T_{stg}$	-65°C to 150°C

<sup>†</sup> 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.

<sup>‡</sup> Under load dump conditions, the voltage on  $V_{bat}$  can reach 40 V within 1 ms.



# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{bat}$	8	12	16	V
AREF Input current $I_{(AREF)}$	0		2	mA
Input voltage, $V_{I(MAN)}$ , $V_{I(AUTO)}$ (manual mode)	6		16	V
Differential voltage, $V_{I(MAN)} - V_{I(AUTO)}$	0		2.2	V
Input voltage, $V_{I(AUTO)}$ (auto mode)	0		5.5	V
$V_I$ , ILR, ILS	0.5		2.75	V
Output resistance, input resistance, $R_{(CCS)}$	27.2	27.5	27.8	k $\Omega$
Output Resistance, $ROSC$ , $r_o$	20		100	k $\Omega$
Output Capacitance, $CO$ , $C_O$	1		5	nF
Gate drive frequency $f = 2/(ROSC \times CO)$ , $f_{(GD)}$		20		kHz
Gate drive output capacitance, $CO_{(GD)}$			3300	pF
Operating free-air temperature, $T_A$	-40		105	$^{\circ}C$

# TPIC2101

## DC BRUSH MOTOR CONTROLLER

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### electrical characteristics, $V_{bat} = 8\text{ V to }16\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
$I_{bat}$	Supply current (average), $V_{bat}$	$V_{bat} = 16\text{ V}$ , GD open, $f(\text{osc}) = 20\text{ kHz}$ , $MAN = AUTO = V_{bat}$		4	10	mA
		$V_{bat} = 16\text{ V}$ , GD open, $f(\text{osc}) = 20\text{ kHz}$ , MAN open, Auto mode, $AUTO = 99\% \text{ PWM}_{in}$		2	10	mA
$I_{bat(Q)}$	Quiescent current (sleep state), $V_{bat}$	$V_{bat} = 13\text{ V}$ , AUTO and MAN open		150	200	$\mu\text{A}$
		$V_{bat} = 13\text{ V}$ , AUTO shorted to MAN, floating		165	200	$\mu\text{A}$
$V_{(AREF)}$	Voltage supply regulation, AREF	$I_{(AREF)} = 0 - 2\text{ mA}$ , $MAN = AUTO = V_{bat}$	5.225	5.5	5.775	V
$V_{IO}$	Input offset voltage, current limit comparator, ILS, ILR	AUTO or MAN mode, ILS, ILR common mode, Voltage range 0.5 – 2.75 V, $V_{int} = 4.5\text{ V}$ , Detect $I_{(int)} > 100\text{ }\mu\text{A}$			10	mV
$I_{IB}$	Input bias current, current limit comparator, ILS, ILR†	ILS, ILR common mode, Voltage range 0.5 – 2.75 V			250	nA
$I_{IO}$	Input offset current, current limit comparator, ILS, ILR†	ILS, ILR common mode, Voltage range 0.5 – 2.75 V			100	nA
$I_{OL(CLS)}$	Pull-down current, ILS terminal blanking, ILS	ILS = 100 mV, GD commanded low	250	360		$\mu\text{A}$
$V_{IL(AUTO)}$	Automatic mode low level input voltage, AUTO	MAN open, AUTO mode, Lower $V_{I(AUTO)}$ until $V_{I(SPEED)} > 2.4\text{ V}$	2.7	3	3.3	V
$V_{IH(AUTO)}$	Automatic mode high level input voltage, AUTO	MAN open, AUTO mode, Raise $V_{I(AUTO)}$ until $V_{I(SPEED)} < 2.4\text{ V}$	3.6	4	4.4	V
$I_{I(AUTO)}$	Input current, automatic mode, AUTO	MAN open, Auto mode, $V_{I(AUTO)} = 0\text{ V}$	-1		-10	mA
$I_{I(AUTOQ)}$	Input current, auto sleep mode, AUTO	MAN open, Sleep state, $V_{I(AUTO)} = 0\text{ V}$	-40	-80		$\mu\text{A}$
$V_{IH(MAN)}$	High level input voltage, manual mode, MAN	$V_{bat} = 9\text{ V to }16\text{ V}$ , $V_{IH(MAN)} = V_{IH(AUTO)}$ , Raise $V_{(MAN)}$ until $V_{I(AREF)} > 2.5\text{ V}$	5	5.5	6	V
$V_{IL(MAN)}$	Low level input voltage, manual mode, MAN	$V_{I(MAN)} = V_{I(AUTO)}$ , Lower $V_{I(MAN)}$ until $V_{I(AREF)} < 2.5\text{ V}$	2.3	2.5	2.7	V
$V_{ID(MAN)}$	Input voltage, manual mode high differential (high speed command), MAN-AUTO	$V_{bat} = 16\text{ V}$ , $V_{bat} - 3.5\text{ V} < MAN < V_{bat}$	1.7		2.3	V

† Indicates electrical parameter not tested in production.



# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## electrical characteristics, $V_{bat} = 8\text{ V to }16\text{ V}$ , $T_A = 25^\circ\text{C}$ (continued)

PARAMETER		TEST CONDITION		MIN	TYP	MAX	UNIT
$V_{ID(low)}$	Input voltage, manual mode low differential (low speed command), MAN-AUTO	$V_{bat} - 3.5\text{ V} < \text{MAN} < V_{bat} + \Delta\text{V}$ where " $\Delta$ " is the lesser of 2 V and $16\text{ V} - V_{bat}$ . $\text{PWM}_{out} @ V_{(diff)} = 0.2\text{ V} \geq \text{PWM}_{out} @ V_{(DIFF)} = 0\text{ V}$				0.2	V
$I_{I(MAN)}$ $I_{I(AUTO)}$	Input currents, auto and manual mode, MAN, AUTO	$V_{bat} - 3.5\text{ V} < \text{MAN} < V_{bat} + \Delta\text{V}$ where " $\Delta$ " is the lesser of 2 V and $16\text{ V} - V_{bat}$ . MAN - AUTO = 0 V to 2 V, $R_{(CSS)} = 27.5\text{ k}\Omega$ to GND		1.70	2	2.30	mA
$I_{I(MANRATIO)}$	Input current, manual mode matching ratio, MAN, AUTO	$V_{bat} - 3.5\text{ V} < \text{MAN} < V_{bat} + \Delta\text{V}$ where " $\Delta$ " is the lesser of 2 V and $16\text{ V} - V_{bat}$ . MAN - AUTO = 0 V to 2 V, $R_{CSS} = 27.5\text{ k}\Omega$ to GND		-7		7	%
$I_{I(MAN(a))}$	Input current, man terminal auto mode, MAN	Auto mode,	MAN = 2.2 V	5	10	15	$\mu\text{A}$
$I_{I(MANQ)}$	Input current, man terminal sleep mode, MAN	Sleep state,	MAN = 2.2 V	5	10	15	$\mu\text{A}$
$V_{(CCS)}$	Constant current sink voltage regulation, CCS	Auto or Man mode,	$I_{(CCS)} = -100\text{ }\mu\text{A}$	2.58	2.78	2.92	V
$V_{(OV)}$	Over voltage shutdown, $V_{bat}$	$V_{bat}$ rising from 16 V, Detect $I_{(INT)} > 100\text{ }\mu\text{A}$	INT = 1 V,	17	18.5	20	V
$V_{hys(OV)}$	Hysteresis, over voltage, $V_{bat}$	$V_{bat}$ rising from 20.1 V, Detect $I_{(INT)} < 100\text{ }\mu\text{A}$	INT = 1 V,	0.5	0.8	0.99	V
$V_{IT-(UVLO)}$	Under voltage shutdown negative going threshold voltage, $V_{bat}$	MAN = $V_{bat}$ . Detect AREF < 2.5 V	$V_{bat}$ falling from 9 V,	7	7.5	8	V
$V_{IT+(UVHI)}$	Under voltage shutdown positive going threshold voltage, $V_{bat}$	MAN = $V_{bat}$ . Detect AREF > 2.5 V	$V_{bat}$ rising from 6.9 V,	8	8.5	9	V
$V_{hys(UV)}$	Hysteresis, under voltage, $V_{bat}$	$V_{(UVHI)} - V_{(UVLO)}$		0.5	1		V
$V_{OH(GD)}$	High level output voltage, gate drive, GD	$I_{GD} = -50\text{ mA}$ , Run state	INT = 4.5 V,	$V_{bat} - 3$		$V_{bat}$	V
		$I_{GD} = -2\text{ mA}$ , Run state	INT = 4.5 V,	$V_{bat} - 0.2$		$V_{bat}$	V
$V_{OL(GD)}$	Low level output voltage, gate drive, GD	Run state, $V_{I(INT)} = 0\text{ V}$ ,	$I_{GR} = 50\text{ mA}$ , $V_{COSC} = 1\text{ V}$			3.5	V
		Run state, INT = 0 V,	$I_{GD} = 2\text{ mA}$ , $V_{COSC} = 1\text{ V}$			0.75	V
$V_{GD(SL)}$	Gate voltage, sleep-state, GD	Sleep state,	$I_{GD} = 2\text{ mA}$		0.03	0.75	V
$I_{(GDP)}$	Pulldown current, gate drive passive, GD	$V_{bat}$ open,	$V_{GD} = 0.75\text{ V}$	7.5	20		$\mu\text{A}$
$I_{(INT)}$	Pulldown current, INT	Run state, $V_{I(INT)} = 1\text{ V}$	$V_{ILS} > V_{ILR}$ ,	2	3		mA

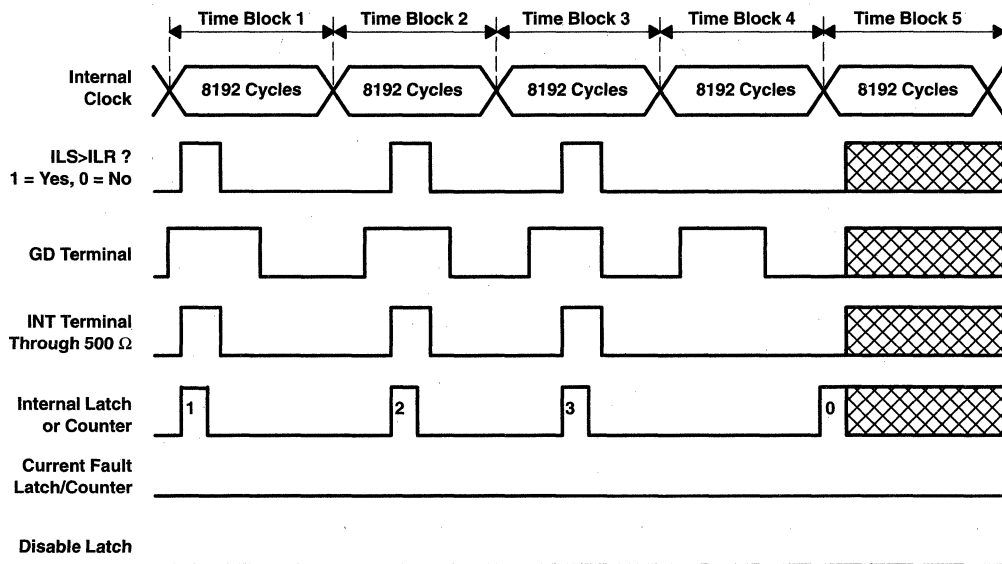
# TPIC2101 DC BRUSH MOTOR CONTROLLER

SLIS060 – OCTOBER 1995

switching characteristics,  $V_{bat} = 8\text{ V to }16\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_r$	Rise time $V_{bat} = 16\text{ V}$ , Load = 3300 pF, ROSC = 45.3 k $\Omega$ , COSC = 2200 pF			1	$\mu\text{s}$
$t_f$	Fall time $V_{bat} = 16\text{ V}$ , Load = 3300 pF, ROSC = 45.3 k $\Omega$ , COSC = 2200 pF			0.8	$\mu\text{s}$
	Output PWM absolute accuracy to spec equation $16 > V_{bat} > 9$ Manual and automatic modes GD open, Measure at GD = $0.5 \times V_{bat}$ @ 20 kHz	-7%		7%	
$f_{(osc)}$	Oscillator frequency ROSC = 45.3 k $\Omega$ , COSC = 2200 pF	19	20	21	kHz
	Minimum speed pedestal MAN = AUTO = $V_{bat} = 16$	15		21	%DC
	$V_{bat} = 16$ , MAN floating, AUTO @ 99% duty cycle	15		21	%DC

## PARAMETER MEASUREMENT INFORMATION



No Current Limit Condition Present in Time Block 4.  
Internal Counter or Latch Set to zero. Current Limit  
Condition Not Present For Eight Consecutive 8192 Cycles.  
No Disable Period.

Figure 6. Current Fault Timing Diagram, Normal State

PARAMETER MEASUREMENT INFORMATION

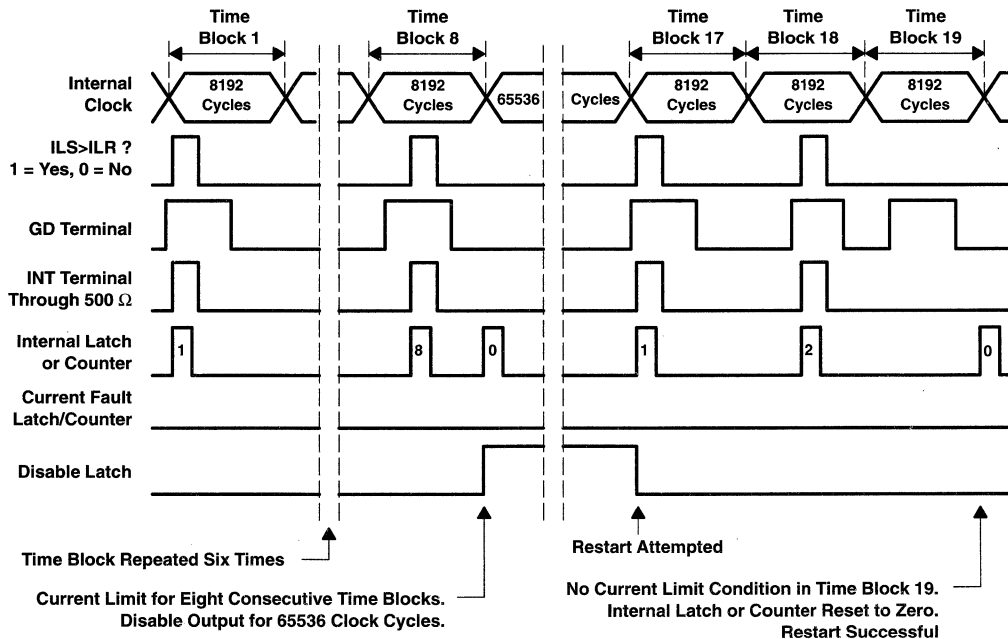
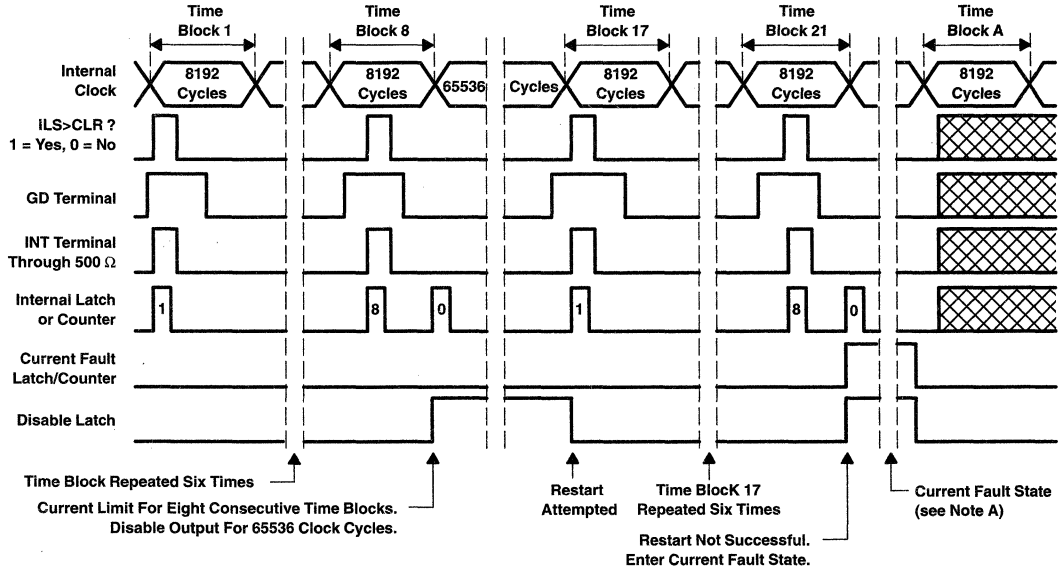


Figure 7. Current Fault Timing Diagram, Over-Current Limit Condition

# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## PARAMETER MEASUREMENT INFORMATION



NOTE A. The integrated circuit remains in this state until cycled through the sleep state into the run state. Timing resumes as shown in time block A at right.

Figure 8. Over-Current Fault State Timing Diagram 3

TYPICAL CHARACTERISTICS

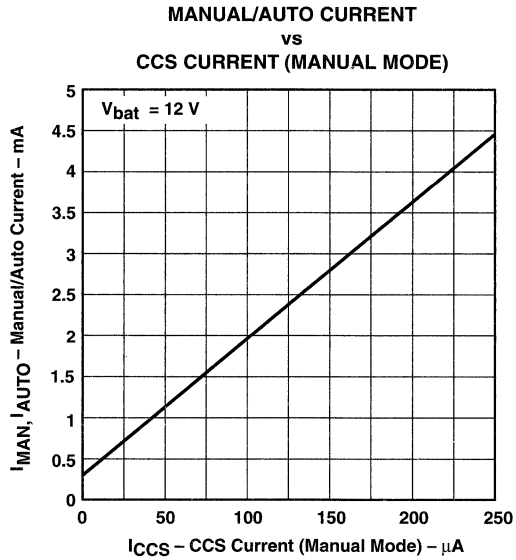


Figure 9

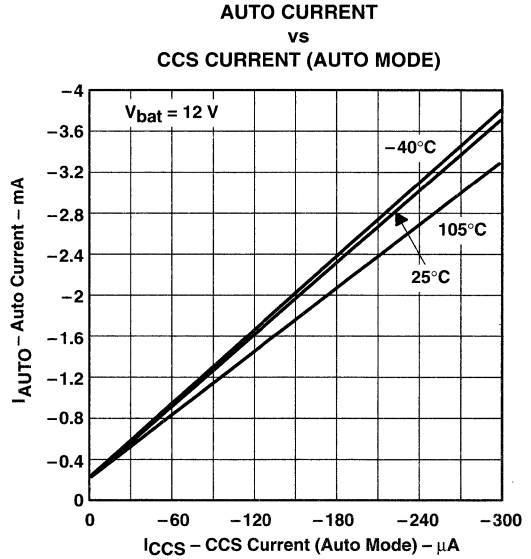


Figure 10

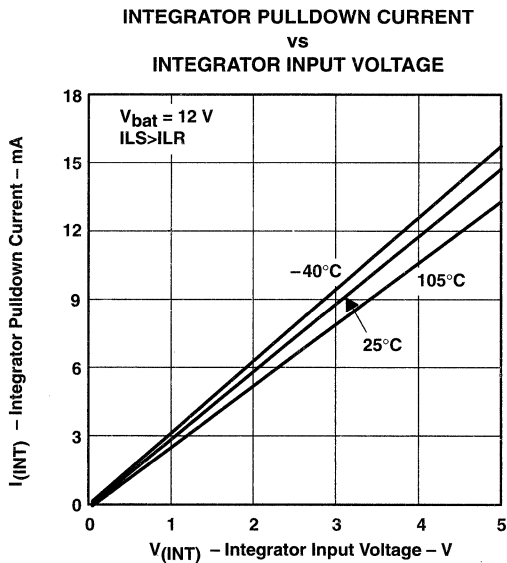


Figure 11

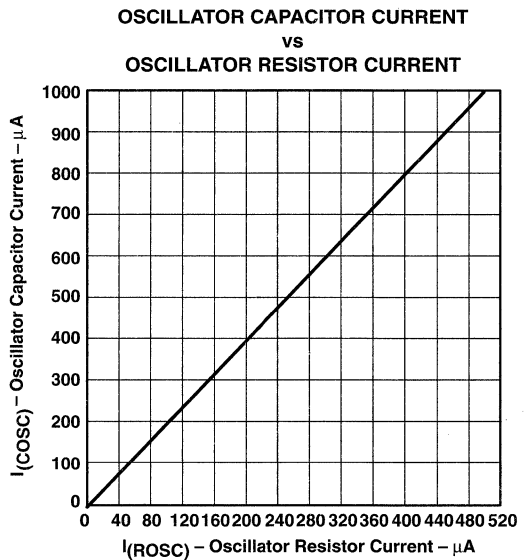


Figure 12



# TPIC2101 DC BRUSH MOTOR CONTROLLER

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## TYPICAL CHARACTERISTICS

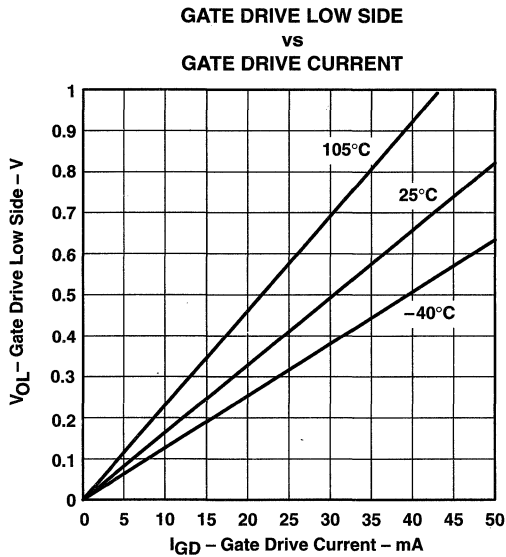


Figure 13

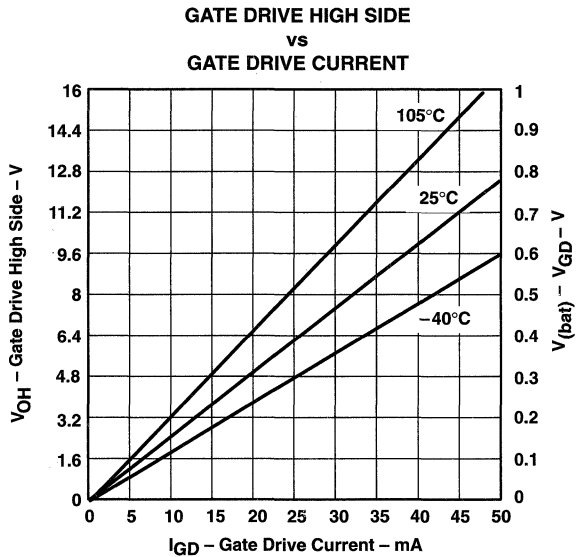


Figure 14

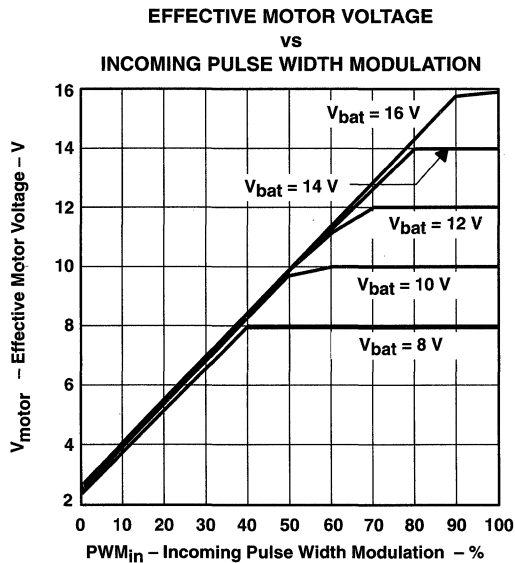


Figure 15

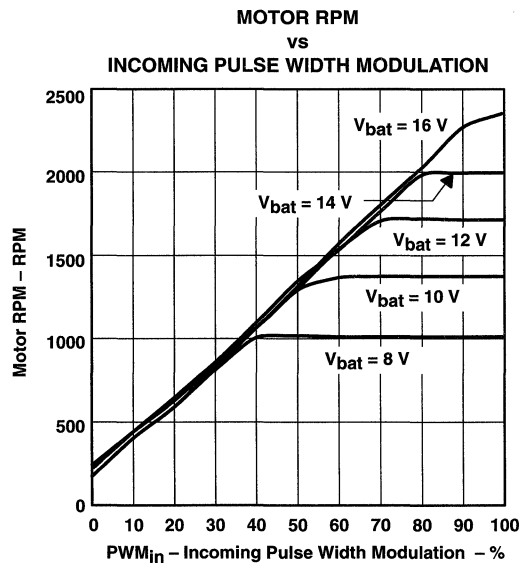


Figure 16

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE V5P5  
vs  
INPUT VOLTAGE AT  $V_{bat}$

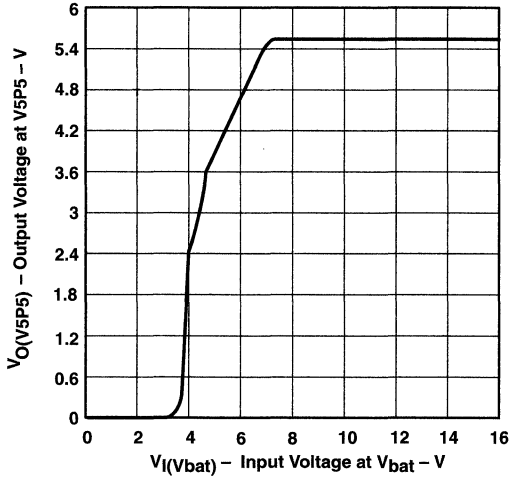


Figure 17

OUTPUT VOLTAGE AT V5P5  
vs  
AMBIENT TEMPERATURE

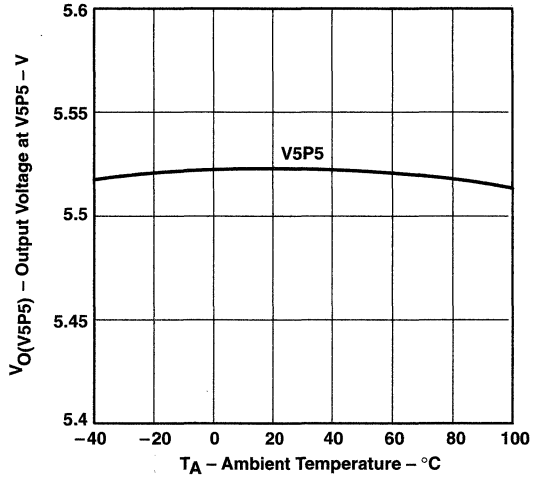


Figure 18

OUTPUT VOLTAGE AT V5P5  
vs  
V5P5 OUTPUT CURRENT

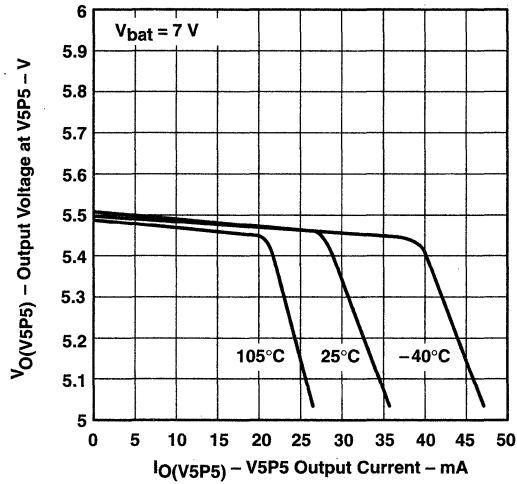


Figure 19



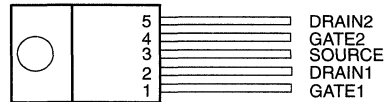
# TPIC2202

## 2-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS017 – SEPTEMBER 1992

- Two 7.5-A Independent Output Channels, Continuous Current Per Channel
- Low  $r_{DS(on)}$  . . . 0.09  $\Omega$  Typical
- Output Voltage . . . 60 V
- Pulsed Current . . . 15 A Per Channel
- Avalanche Energy . . . 120 mJ

KC PACKAGE  
(TOP VIEW)

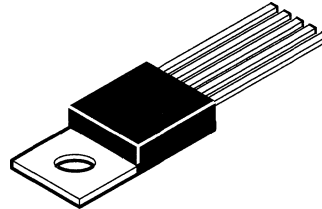
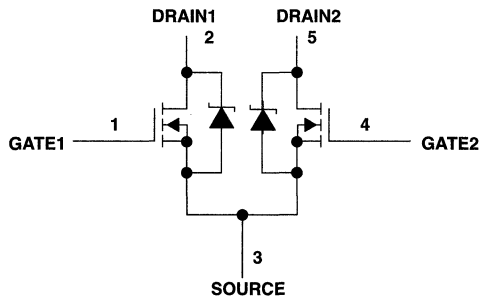


The tab is electrically connected to SOURCE.

### description

The TPIC2202 is a monolithic power DMOS array that consists of two independent N-channel enhancement-mode DMOS transistors connected in a common-source configuration with open drains.

### schematic



### absolute maximum ratings over operating case temperature range (unless otherwise noted)

Drain-source voltage, $V_{DS}$ .....	60 V
Gate-source voltage, $V_{GS}$ .....	$\pm 20$ V
Continuous source-drain diode current .....	7.5 A
Pulsed drain current, each output, all outputs on, $I_D$ (see Note 1) .....	15 A
Continuous drain current, each output, all outputs on .....	7.5 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4) .....	120 mJ
Continuous power dissipation at (or below) $T_A = 25^\circ\text{C}$ (see Note 2) .....	2 W
Continuous power dissipation at (or below) $T_C = 75^\circ\text{C}$ , all outputs on (see Note 2) .....	31 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

- NOTES: 1. Pulse duration = 10 ms, duty cycle = 6%
2. For operation above  $25^\circ\text{C}$  free-air temperature, derate linearly at the rate of  $16\text{ mW}/^\circ\text{C}$ . For operation above  $75^\circ\text{C}$  case temperature, and with all outputs conducting, derate linearly at the rate of  $0.42\text{ W}/^\circ\text{C}$ . To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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# TPIC2202

## 2-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS017 – SEPTEMBER 1992

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DS}$ Drain-source breakdown voltage	$I_D = 1 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{TGS}$ Gate-source threshold voltage	$I_D = 1 \text{mA}$ , $V_{DS} = V_{GS}$	1.2	1.75	2.4	V
$V_{DS(on)}$ Drain-source on-state voltage	$I_D = 7.5 \text{A}$ , $V_{GS} = 15 \text{V}$ , See Notes 3 and 4		0.68	0.94	V
$I_{DSS}$ Zero-gate-voltage drain current	$V_{DS} = 48 \text{V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.07	1	$\mu\text{A}$
		$T_C = 125^\circ\text{C}$	1.3	10	
$I_{GSSF}$ Forward gate current, drain short circuited to source	$V_{GS} = 20 \text{V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$ Reverse gate current, drain short circuited to source	$V_{GS} = -20 \text{V}$ , $V_{DS} = 0$		10	100	nA
$r_{DS(on)}$ Static drain-source on-state resistance	$V_{GS} = 15 \text{V}$ , $I_D = 7.5 \text{A}$ , See Notes 3 and 4 and Figures 5 and 6	$T_C = 25^\circ\text{C}$	0.09	0.125	$\Omega$
		$T_C = 125^\circ\text{C}$	0.15	0.21	
$g_{fs}$ Forward transconductance	$V_{DS} = 15 \text{V}$ , $I_D = 5 \text{A}$ , See Notes 3 and 4	2.5	4.7		S
$C_{iss}$ Short-circuit input capacitance, common source	$V_{DS} = 25 \text{V}$ , $V_{GS} = 0$ , $f = 300 \text{kHz}$		490		pF
$C_{oss}$ Short-circuit output capacitance, common source			285		
$C_{rss}$ Short-circuit reverse transfer capacitance, common source			90		

NOTES: 3. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{SD}$ Forward on voltage	$I_S = 7.5 \text{A}$ , $V_{GS} = 0$ , $di/dt = 100 \text{A}/\mu\text{s}$ , $V_{DS} = 48 \text{V}$ , See Figure 1		0.8	1.3	V
$t_{rr}$ Reverse recovery time			200		ns
$Q_{RR}$ Total source-drain diode charge			1.5		

### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

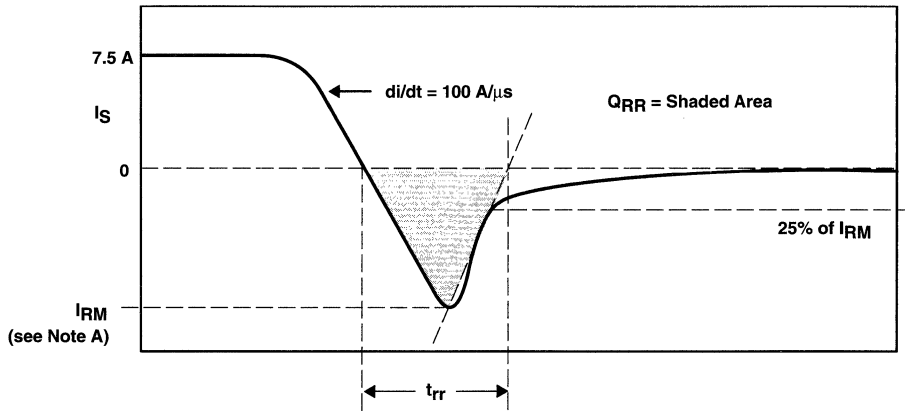
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25 \text{V}$ , $R_L = 6.7 \Omega$ , $t_{en} = 10 \text{ns}$ , $t_{dis} = 10 \text{ns}$ , See Figure 2		12		ns
$t_{d(off)}$ Turn-off delay time			100		
$t_r$ Rise time			43		
$t_f$ Fall time			5		
$Q_g$ Total gate charge	$V_{DD} = 48 \text{V}$ , $I_D = 2.5 \text{A}$ , $V_{GS} = 10 \text{V}$ , See Figure 3		13.6	18	nC
$Q_{gs}$ Gate-source charge			8.3	11	
$Q_{gd}$ Gate-drain charge			5.3	7	
$L_D$ Internal drain inductance			7		nH
$L_S$ Internal source inductance			7		

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power		62.5		$^\circ\text{C}/\text{W}$
$R_{\theta JC}$ Junction-to-case thermal resistance	All outputs with equal power		2.4		$^\circ\text{C}/\text{W}$
	One output dissipating power		3.3		$^\circ\text{C}/\text{W}$



PARAMETER MEASUREMENT INFORMATION



NOTE A:  $I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveforms of Source-Drain Diode

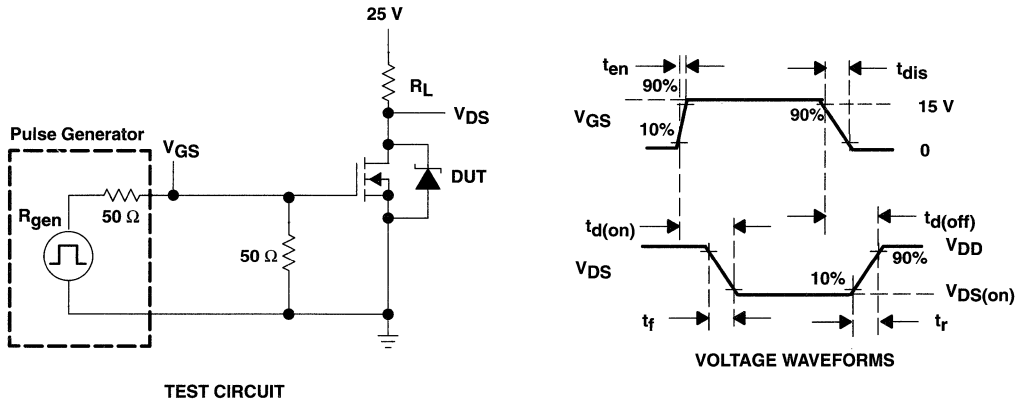


Figure 2. Test Circuit and Voltage Waveforms, Resistive Switching

# TPIC2202 2-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS017 – SEPTEMBER 1992

## PARAMETER MEASUREMENT INFORMATION

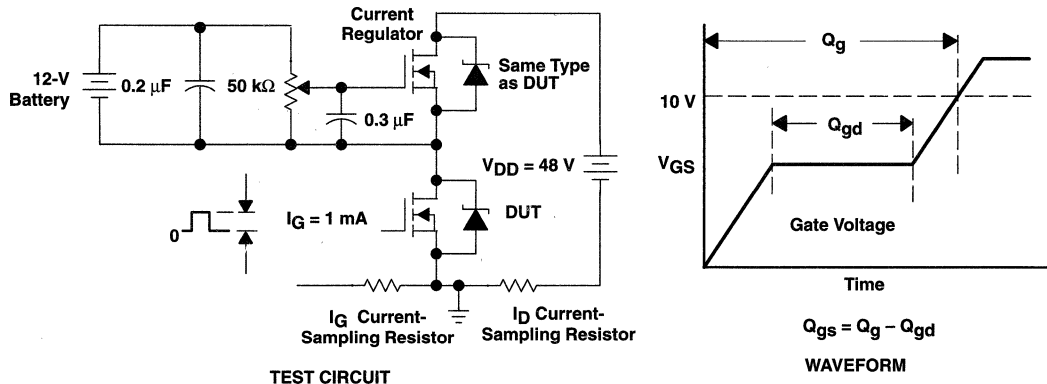
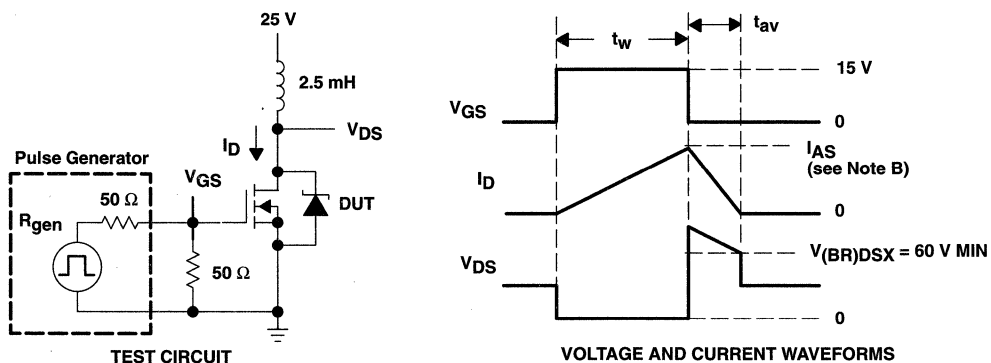


Figure 3. Gate Charge Test Circuit and Waveform



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 7.5$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 120 \text{ mJ min.}$$

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
CASE TEMPERATURE

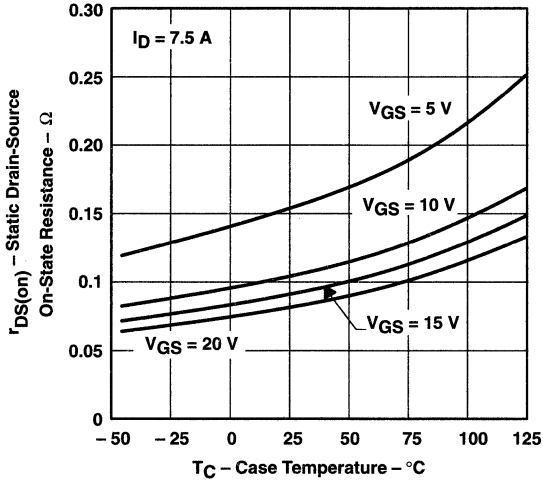


Figure 5

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

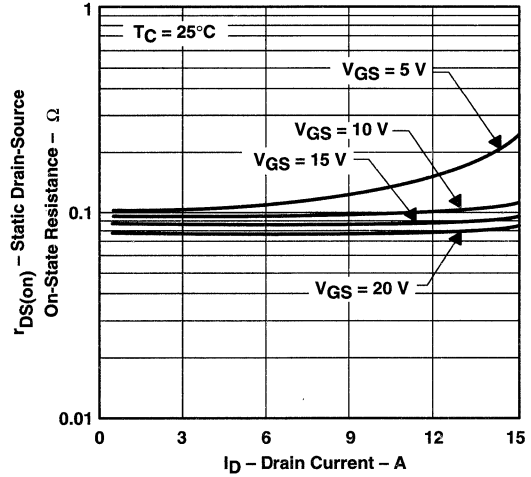


Figure 6

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

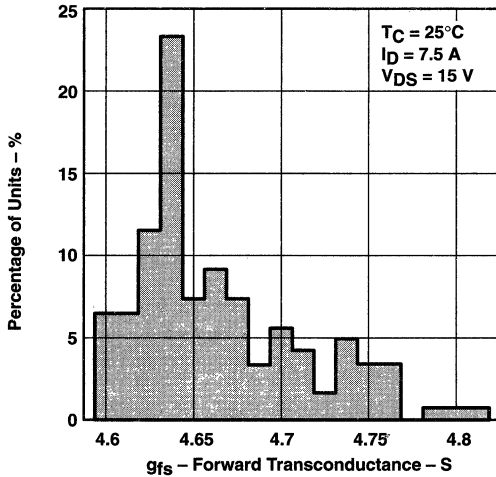


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

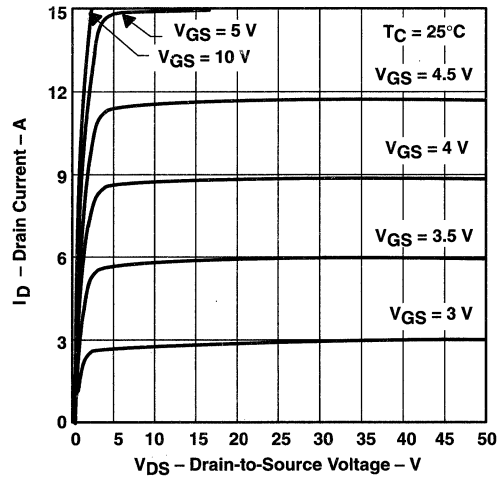


Figure 8



# TPIC2202 2-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS017 – SEPTEMBER 1992

## TYPICAL CHARACTERISTICS

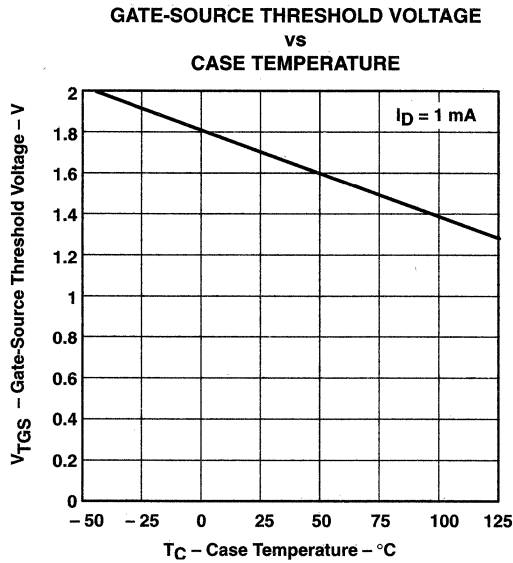


Figure 9

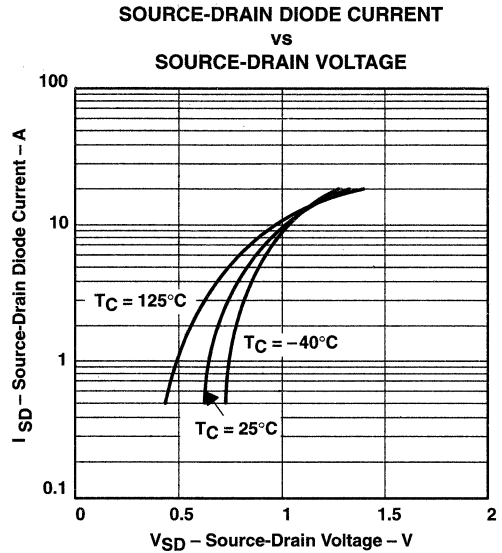


Figure 10

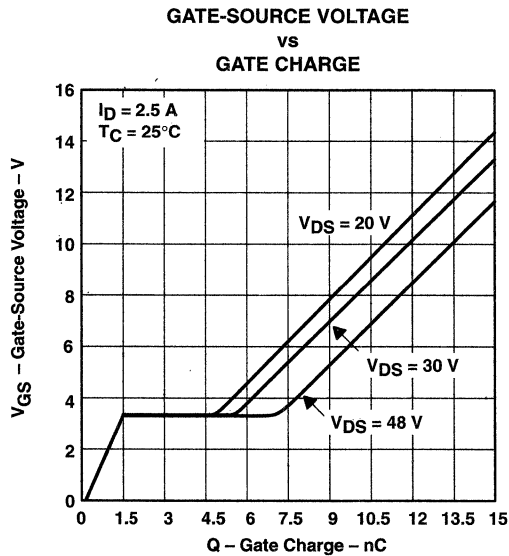


Figure 11

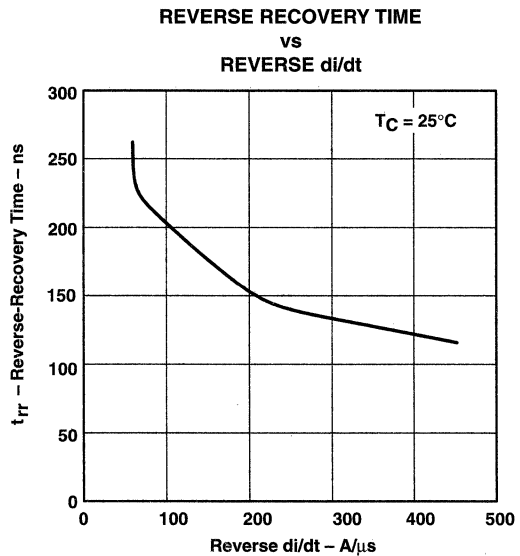
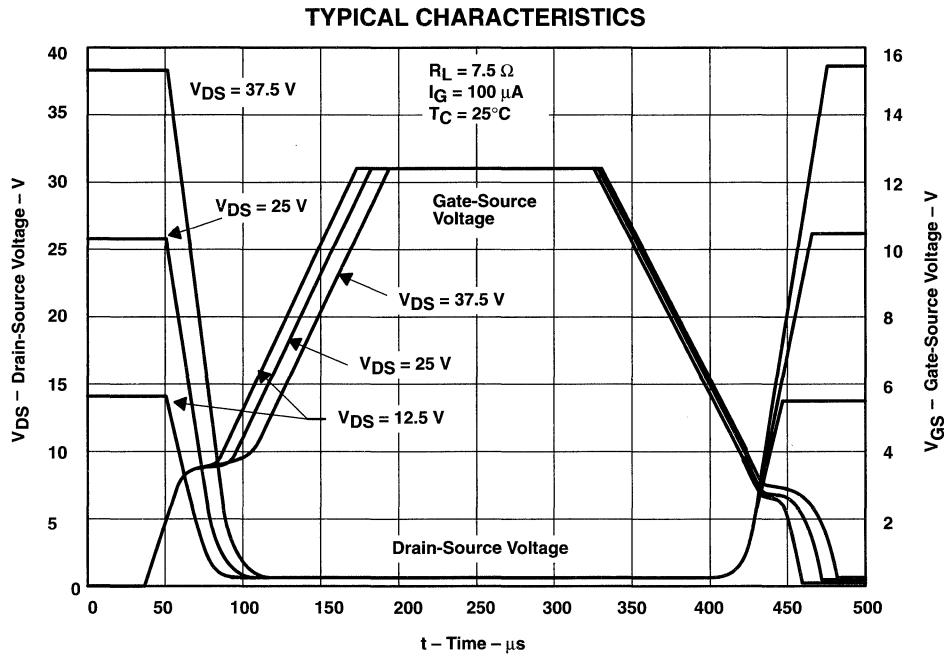


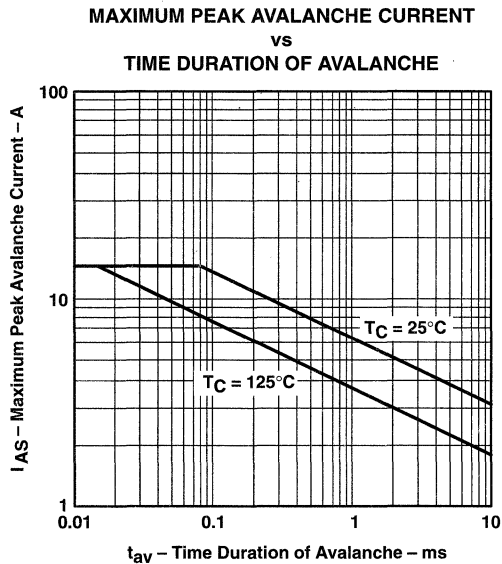
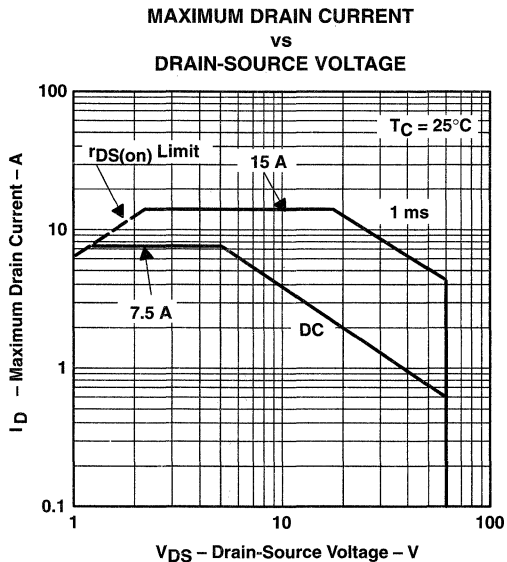
Figure 12



**TPIC2202**  
**2-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

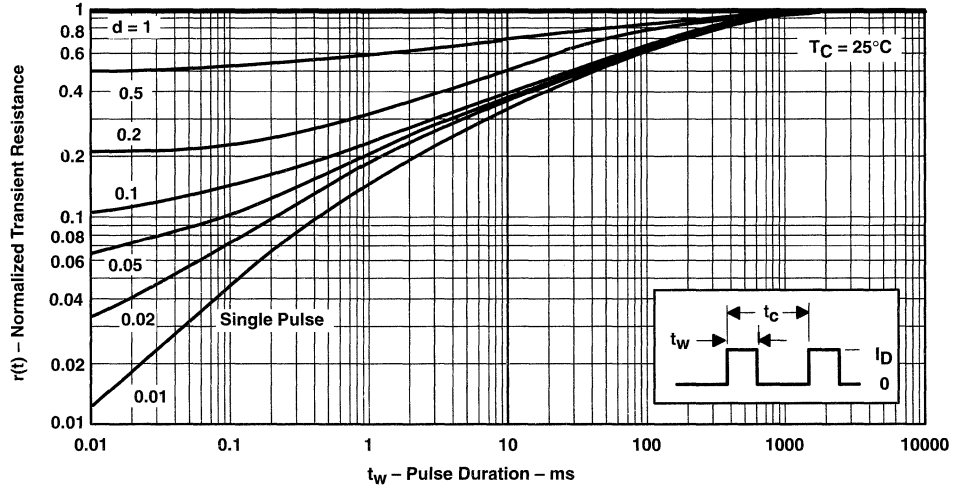
SLIS017 – SEPTEMBER 1992

**THERMAL INFORMATION**



THERMAL INFORMATION

NORMALIZED TRANSIENT THERMAL IMPEDANCE  
vs  
SQUARE-WAVE PULSE DURATION



NOTES:  $Z_{\theta JC}(t) = r(t) R_{\theta JC}$   
 $t_w$  = pulse duration  
 $t_c$  = period  
 $d$  = duty cycle =  $t_w/t_c$

Figure 16



# TPIC2301

## 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

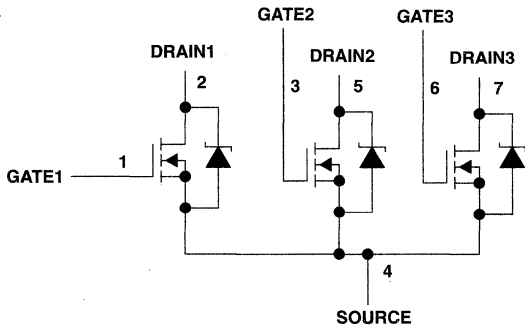
SLIS018 – SEPTEMBER 1992

- Three 7.5-A Independent Output Channels, Continuous Current Per Channel
- Low  $r_{DS(on)}$  . . . 0.09  $\Omega$  Typical
- Output Voltage . . . 60 V
- Pulsed Current . . . 15 A Per Channel
- Avalanche Energy . . . 120 mJ

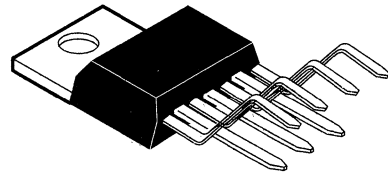
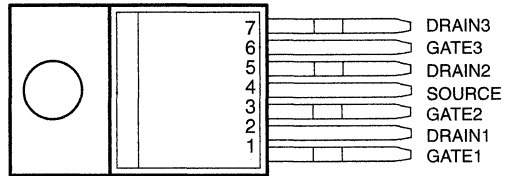
### description

The TPIC2301 is a monolithic power DMOS array that consists of three independent N-channel enhancement-mode DMOS transistors connected in a common-source configuration with open drains.

### schematic



KV PACKAGE  
(TOP VIEW)



The tab is electrically connected to SOURCE.

### absolute maximum ratings over operating case temperature range (unless otherwise noted)

Drain-source voltage, $V_{DS}$ . . . . .	60 V
Gate-source voltage, $V_{GS}$ . . . . .	$\pm 20$ V
Continuous source-drain diode current . . . . .	7.5 A
Pulsed drain current, each output, all outputs on, $I_D$ (see Note 1) . . . . .	15 A
Continuous drain current, each output, all outputs on . . . . .	7.5 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4) . . . . .	120 mJ
Continuous power dissipation at (or below) $T_A = 25^\circ\text{C}$ (see Note 2) . . . . .	2 W
Continuous power dissipation at (or below) $T_C = 75^\circ\text{C}$ , all outputs on (see Note 2) . . . . .	50 W
Operating virtual junction temperature range, $T_J$ . . . . .	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ . . . . .	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ . . . . .	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	$260^\circ\text{C}$

- NOTES: 1. Pulse duration = 10 ms, duty cycle = 6%
2. For operation above  $25^\circ\text{C}$  free-air temperature, derate linearly at the rate of 16 mW/ $^\circ\text{C}$ . For operation above  $75^\circ\text{C}$  case temperature, and with all outputs conducting, derate linearly at the rate of 0.66 W/ $^\circ\text{C}$ . To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

# TPIC2301

## 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS018 – SEPTEMBER 1992

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DS}$ Drain-source breakdown voltage	$I_D = 1 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{TGS}$ Gate-source threshold voltage	$I_D = 1 \text{ mA}$ , $V_{DS} = V_{GS}$	1.2	1.75	2.4	V
$V_{DS(on)}$ Drain-source on-state voltage	$I_D = 7.5 \text{ A}$ , $V_{GS} = 15 \text{ V}$ , See Notes 3 and 4		0.68	0.94	V
$I_{DSS}$ Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.07	1	$\mu\text{A}$
		$T_C = 125^\circ\text{C}$	1.3	10	
$I_{GSSF}$ Forward gate current, drain short circuited to source	$V_{GS} = 20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$ Reverse gate current, drain short circuited to source	$V_{GS} = -20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$r_{DS(on)}$ Static drain-source on-state resistance	$V_{GS} = 15 \text{ V}$ , $I_D = 7.5 \text{ A}$ , See Notes 3 and 4 and Figures 5 and 6	$T_C = 25^\circ\text{C}$	0.09	0.125	$\Omega$
		$T_C = 125^\circ\text{C}$	0.15	0.21	
$g_{fs}$ Forward transconductance	$V_{DS} = 15 \text{ V}$ , $I_D = 5 \text{ A}$ , See Notes 3 and 4	3.3	4.7		S
$C_{iss}$ Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $V_{GS} = 0$ , $f = 300 \text{ kHz}$		490		$\mu\text{F}$
$C_{oss}$ Short-circuit output capacitance, common source			285		
$C_{rss}$ Short-circuit reverse transfer capacitance, common source			90		

NOTES: 3. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{SD}$ Forward on voltage	$I_S = 7.5 \text{ A}$ , $V_{GS} = 0$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , $V_{DS} = 48 \text{ V}$ , See Figure 1		0.8	1.3	V
$t_{rr}$ Reverse recovery time			200		ns
$Q_{RR}$ Total source-drain diode charge				1.5	

### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

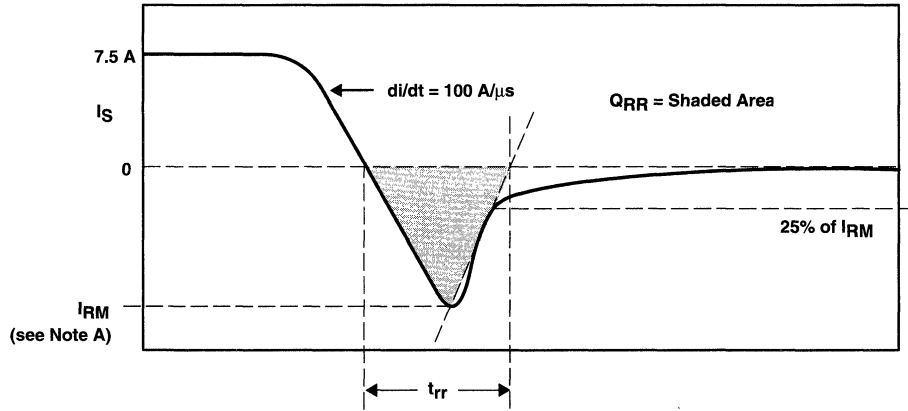
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25 \text{ V}$ , $R_L = 6.7 \Omega$ , $t_{en} = 10 \text{ ns}$ , $t_{dis} = 10 \text{ ns}$ , See Figure 2		12		ns
$t_{d(off)}$ Turn-off delay time			100		
$t_r$ Rise time			43		
$t_f$ Fall time			5		
$Q_g$ Total gate charge	$V_{DS} = 48 \text{ V}$ , $I_D = 2.5 \text{ A}$ , $V_{GS} = 10 \text{ V}$ , See Figure 3		13.6	18	nC
$Q_{gs}$ Gate-source charge			8.3	11	
$Q_{gd}$ Gate-drain charge			5.3	7	
$L_D$ Internal drain inductance			7		nH
$L_S$ Internal source inductance			7		

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power			62.5	$^\circ\text{C}/\text{W}$
$R_{\theta JC}$ Junction-to-case thermal resistance	All outputs with equal power			1.5	$^\circ\text{C}/\text{W}$
	One output dissipating power			3.3	$^\circ\text{C}/\text{W}$



PARAMETER MEASUREMENT INFORMATION



NOTE A:  $I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveforms of Source-Drain Diode

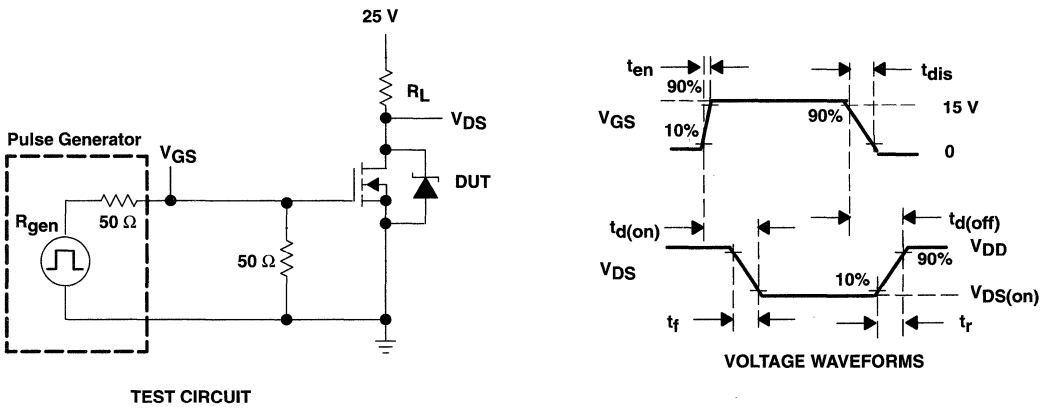


Figure 2. Resistive Switching



# TPIC2301 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS018 – SEPTEMBER 1992

## PARAMETER MEASUREMENT INFORMATION

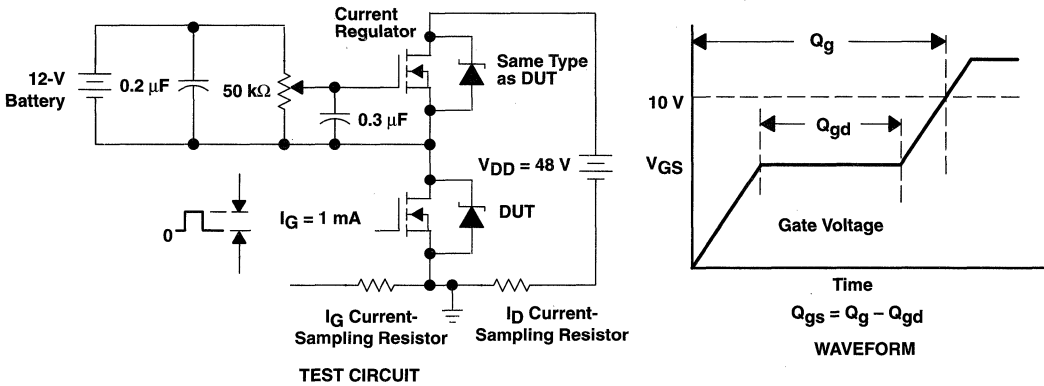
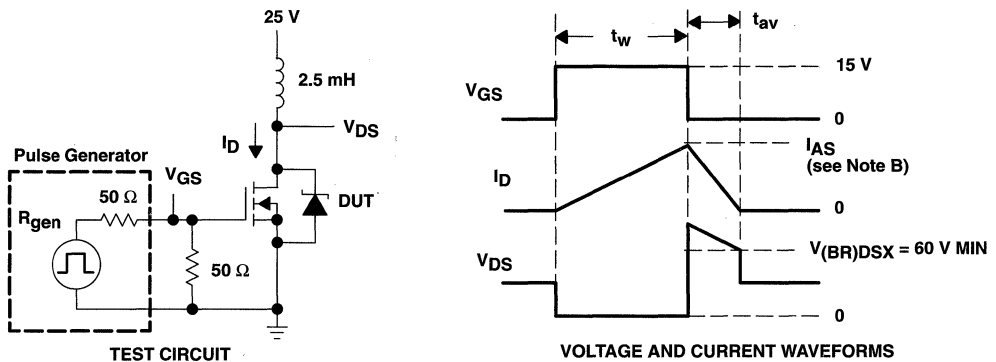


Figure 3. Gate-Charge Test Circuit and Waveform



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 7.5$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 120 \text{ mJ min.}$$

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
CASE TEMPERATURE

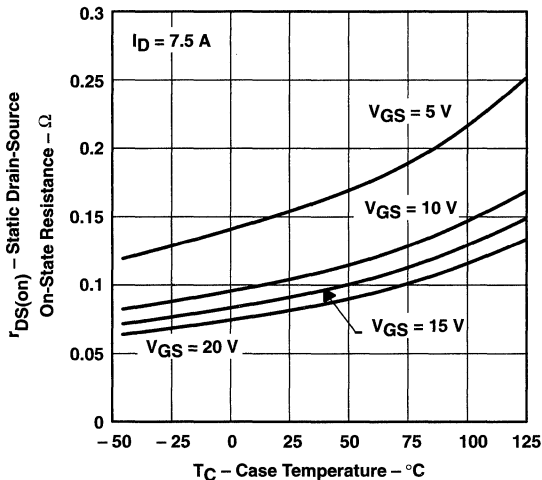


Figure 5

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

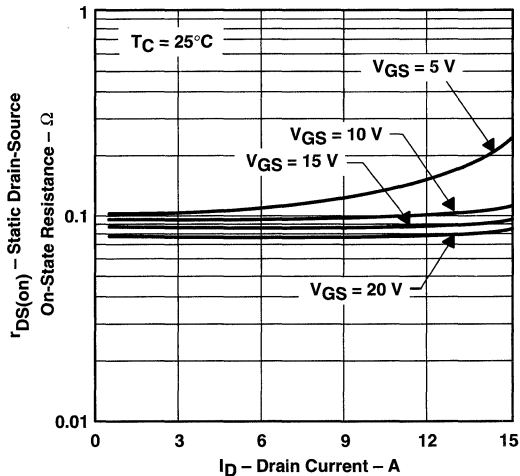


Figure 6

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

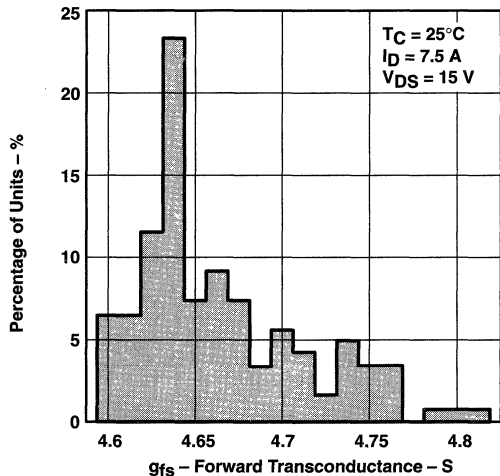


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

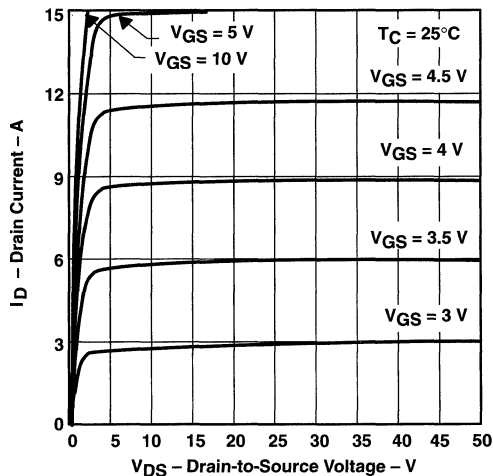
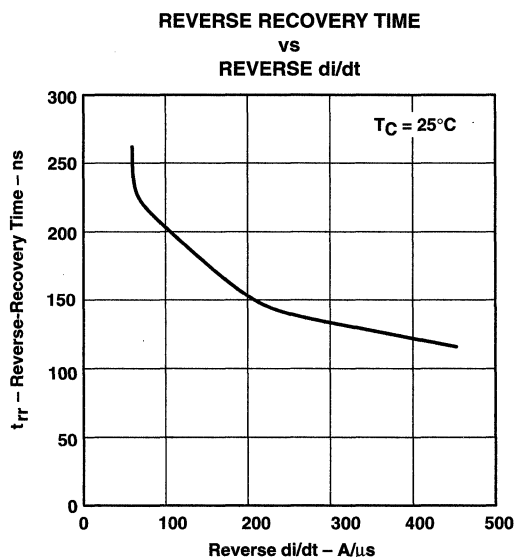
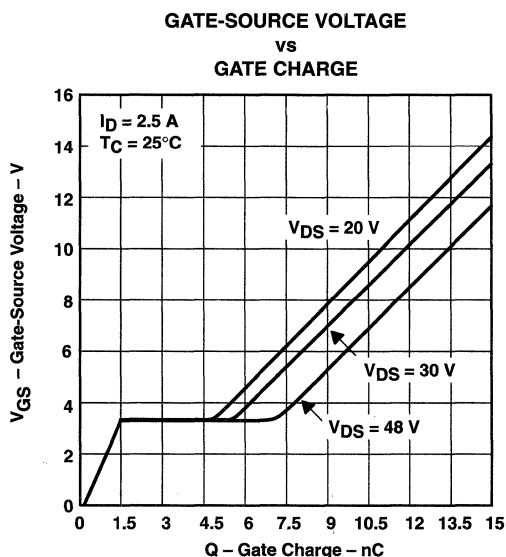
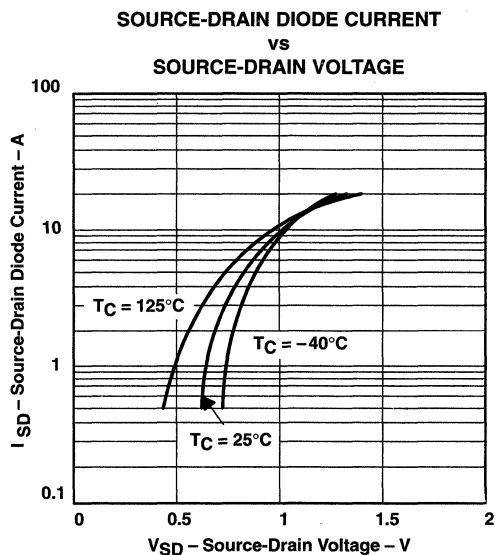
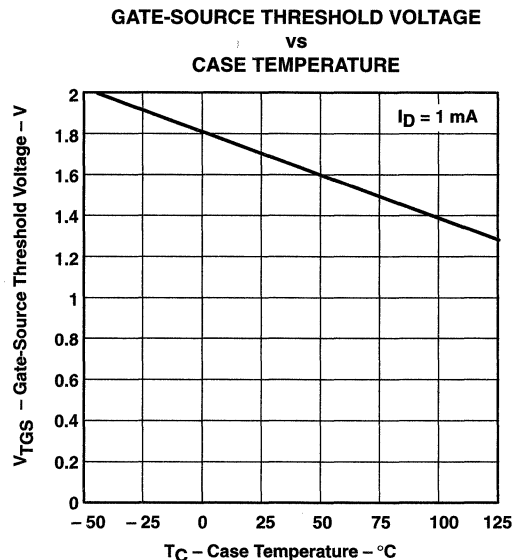


Figure 8

# TPIC2301 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS018 – SEPTEMBER 1992

## TYPICAL CHARACTERISTICS



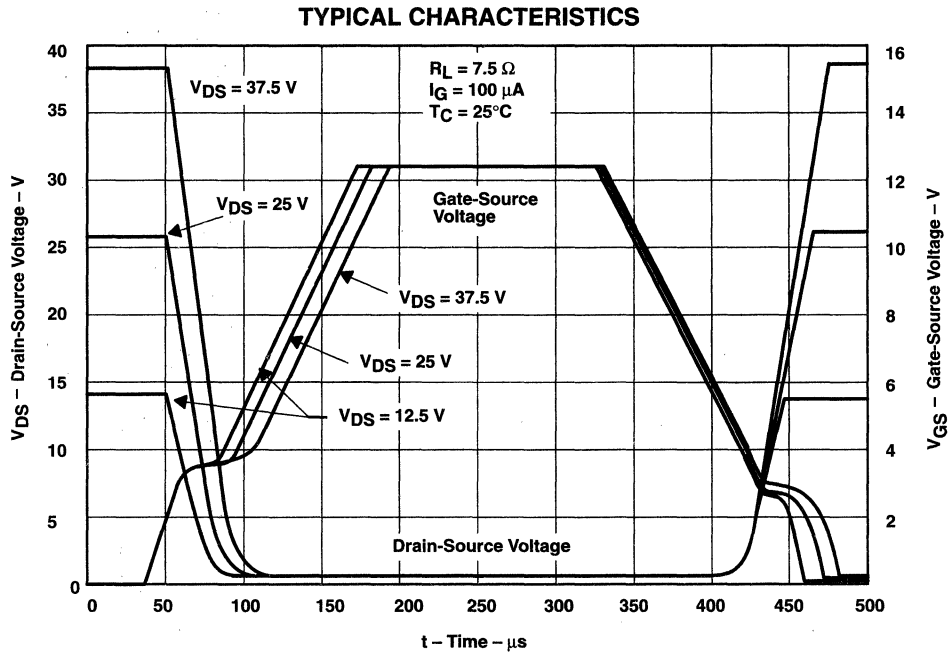
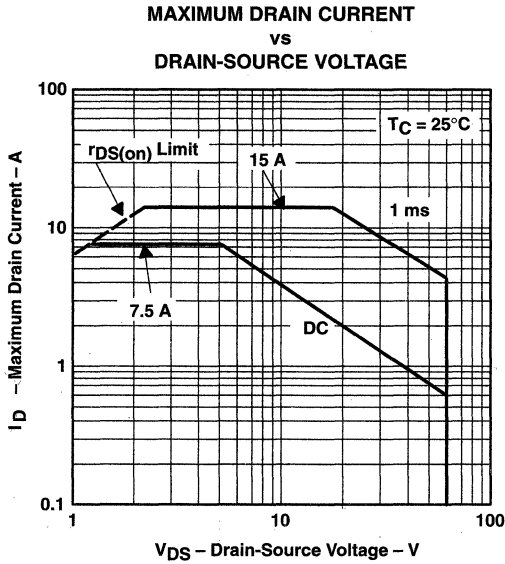


Figure 13. Resistive Switching Waveforms

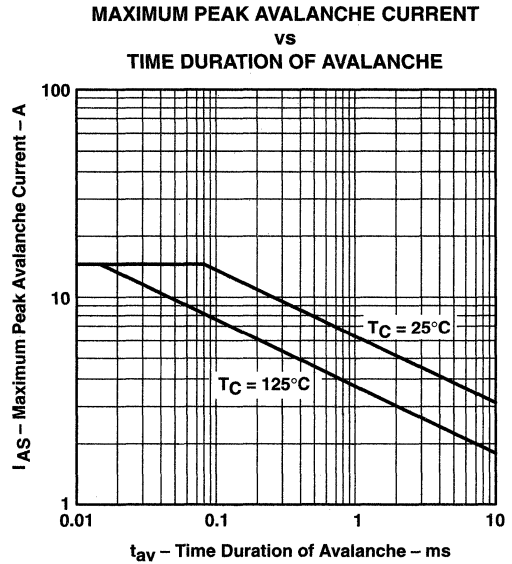
**TPIC2301**  
**3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

SLIS018 – SEPTEMBER 1992

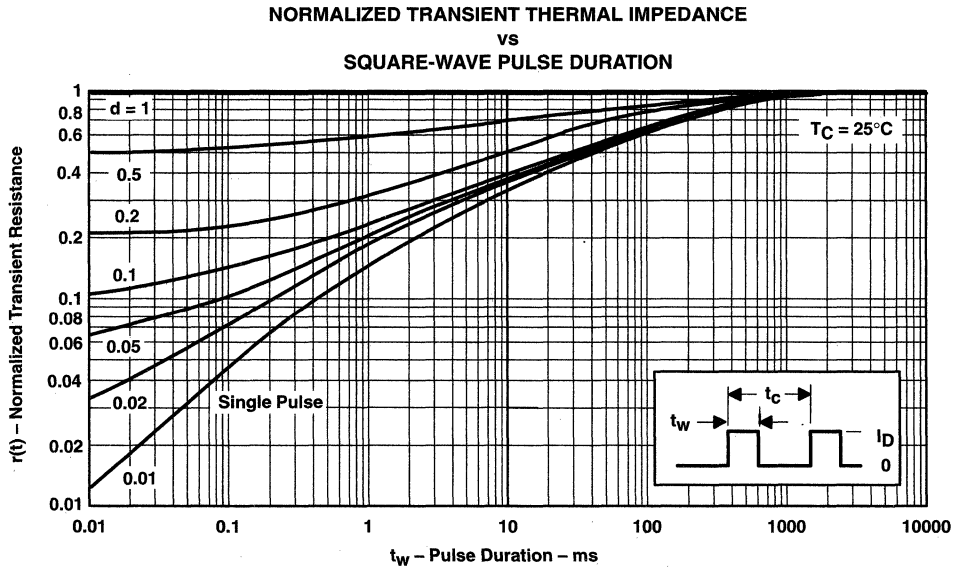
**THERMAL INFORMATION**



**Figure 14**



**Figure 15**



NOTES:  $Z_{\theta JC}(t) = r(t) R_{\theta JC}$   
 $t_w$  = pulse duration  
 $t_c$  = period  
 $d$  = duty cycle =  $t_w/t_c$

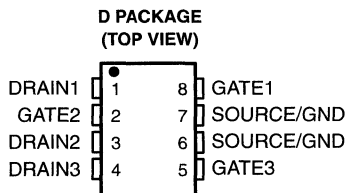
**Figure 16**

# TPIC2302

## 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS028B – APRIL 1994 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 5 A Per Channel
- Fast Commutation Speed

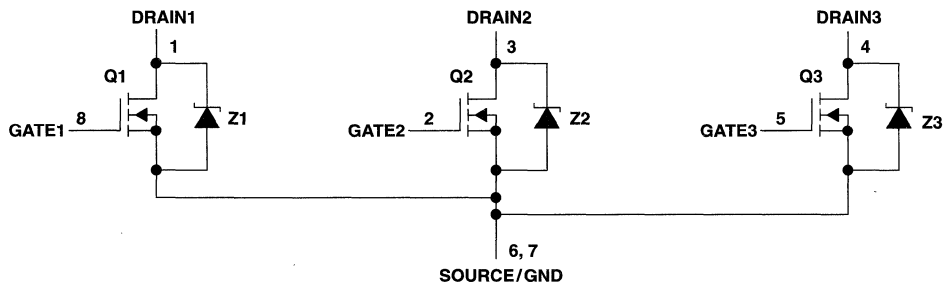


### description

The TPIC2302 is a monolithic power DMOS array that consists of three electrically isolated N-channel enhancement-mode DMOS transistors configured with a common source and open drains. The TPIC2302 is offered in a standard 8-pin small-outline surface-mount (D) package.

The TPIC2302 is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



### absolute maximum ratings over operating case temperature range (unless otherwise noted)<sup>†</sup>

Drain-to-source voltage, $V_{DS}$ . . . . .	60 V
Gate-to-source voltage, $V_{GS}$ . . . . .	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$ . . . . .	1 A
Pulsed drain current, each output, $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 6) . . . . .	5 A
Single-pulse avalanche energy, $T_C = 25^{\circ}\text{C}$ , $E_{AS}$ (see Figures 4 and 16) . . . . .	9 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$ . . . . .	0.95 W
Operating virtual junction temperature range, $T_J$ . . . . .	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$ . . . . .	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range, $T_{stg}$ . . . . .	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	$260^{\circ}\text{C}$

<sup>†</sup> 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

# TPIC2302

## 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , $V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3		0.4	0.475	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3), See Notes 2 and 3		0.9	1.1	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$		0.05	1	$\mu\text{A}$
				0.5	10	
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_R = 48 \text{ V}$		0.05	1	$\mu\text{A}$
				0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.4	0.475	$\Omega$
			$T_C = 125^\circ\text{C}$	0.63	0.7	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 2 and 3	$I_D = 0.5 \text{ A}$	0.85	1.02	S
$C_{iSS}$	Short-circuit input capacitance, common source			115	145	pF
$C_{oSS}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$	$V_{GS} = 0$	60	75	
$C_{rSS}$	Short-circuit reverse-transfer capacitance, common source			30	40	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum, pulse duration  $\leq 5 \text{ ms}$ .  
3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , See Figure 1		65		ns
$Q_{RR}$	Total diode charge			0.03		$\mu\text{C}$



# TPIC2302

## 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

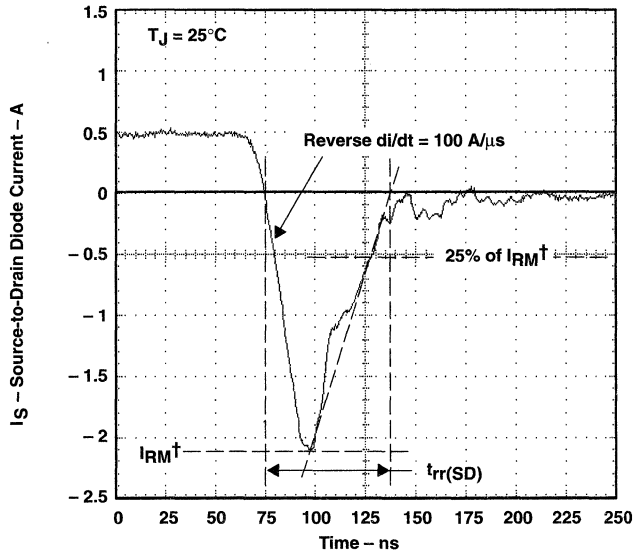
PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2				21	42	ns
$t_{d(off)}$	Turn-off delay time					20	40	
$t_{r2}$	Rise time					5	10	
$t_{f2}$	Fall time					13	26	
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3	$I_D = 0.5\text{ A}$ ,	$V_{GS} = 10\text{ V}$ ,		3.1	3.8	nC
$Q_{gs(th)}$	Threshold gate-to-source charge					0.4	0.5	
$Q_{gd}$	Gate-to-drain charge					1.3	1.6	
$L_D$	Internal drain inductance					5		
$L_S$	Internal source inductance				5		nH	
$R_g$	Internal gate resistance				0.25			$\Omega$

### thermal resistance

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	All outputs with equal power,	See Note 4			130		$^\circ\text{C/W}$
$R_{\theta JP}$	Junction-to-pin thermal resistance					44		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

### PARAMETER MEASUREMENT INFORMATION



$^\dagger I_{RM}$  = maximum recovery current

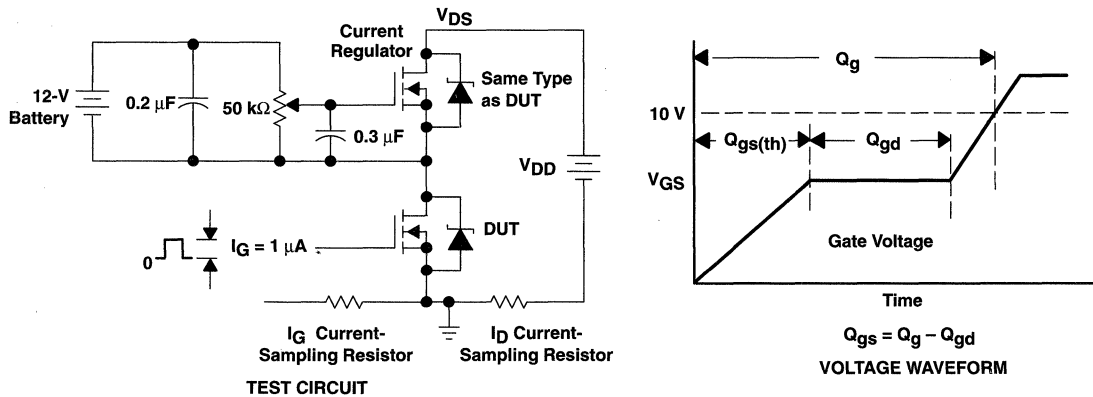
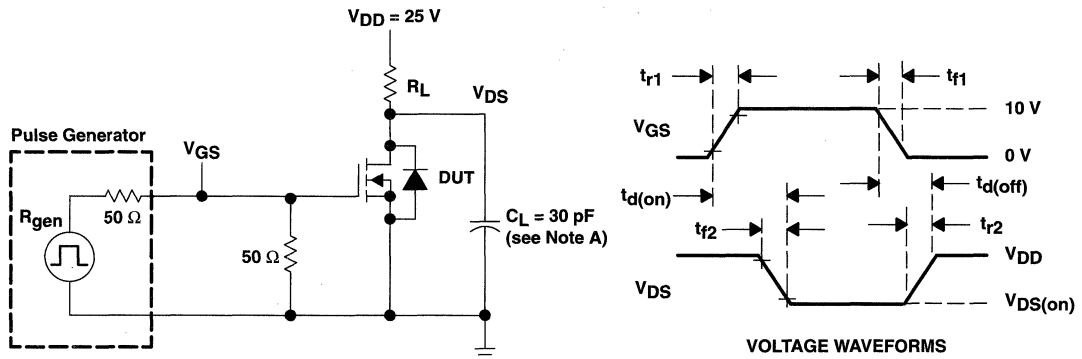
**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**



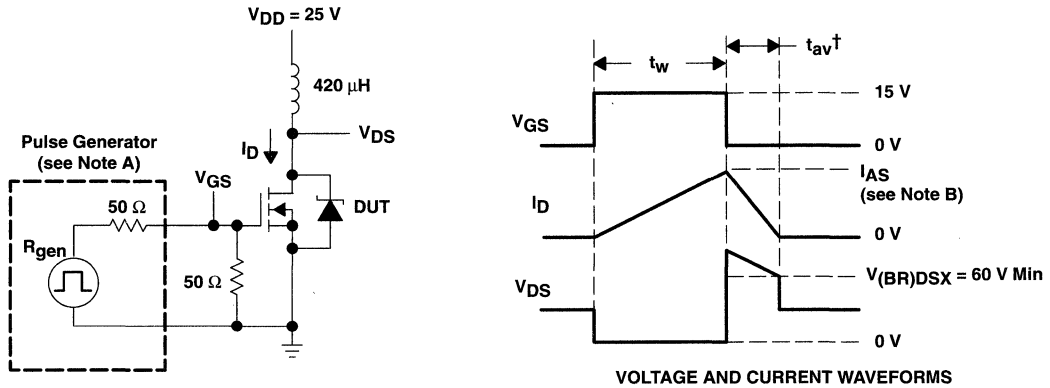
# TPIC2302 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

† Non-JEDEC symbol for avalanche time

NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .

B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 5$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 9 \text{ mJ, where } t_{av} = \text{avalanche time.}$$

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

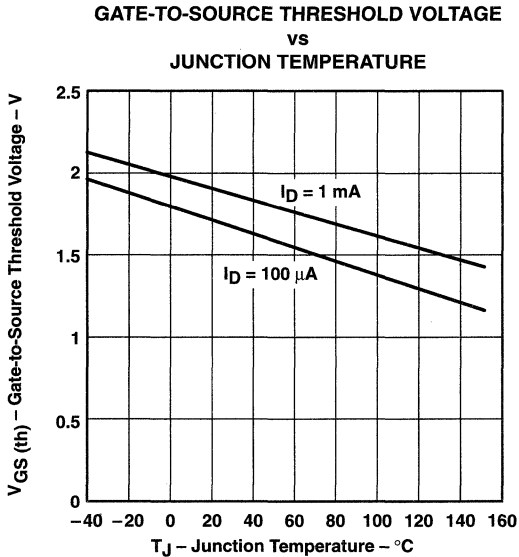


Figure 5

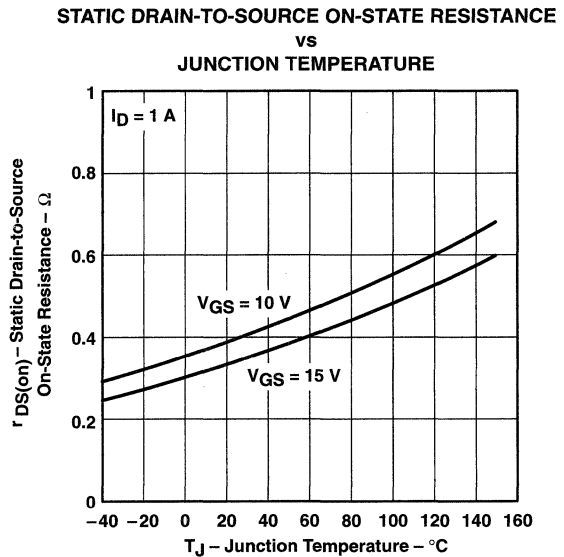


Figure 6

# TPIC2302 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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## TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

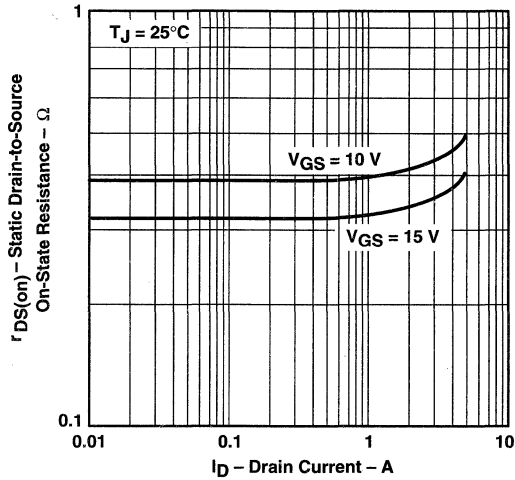


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

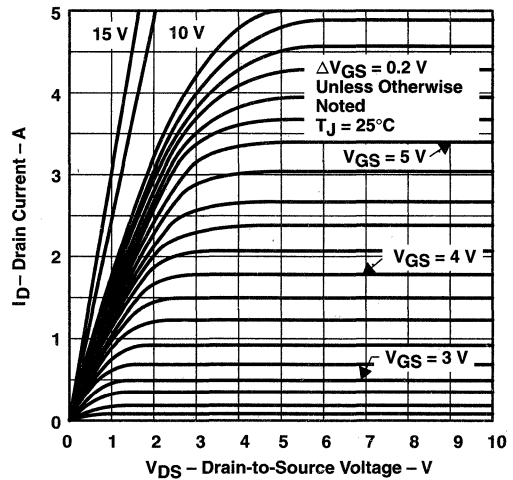


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

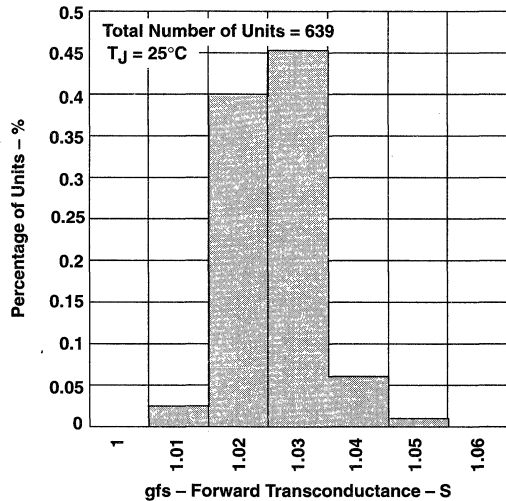


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

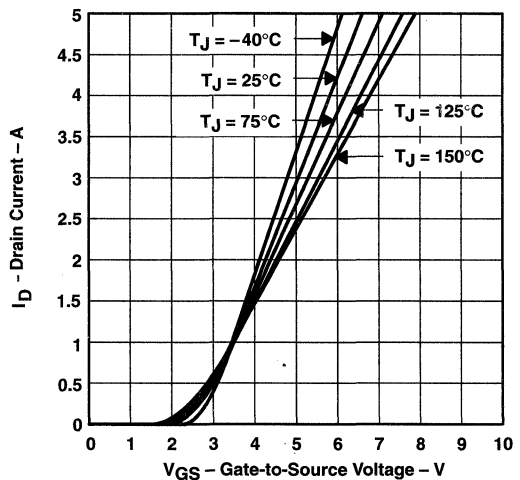


Figure 10

**TPIC2302**  
**3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

**CAPACITANCE  
vs  
DRAIN-TO-SOURCE VOLTAGE**

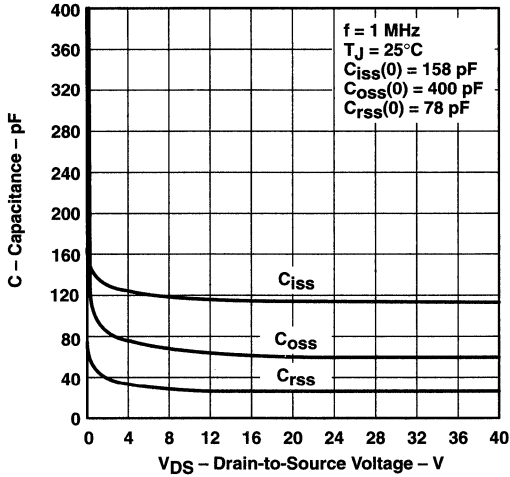


Figure 11

**SOURCE-TO-DRAIN DIODE CURRENT  
vs  
SOURCE-TO-DRAIN VOLTAGE**

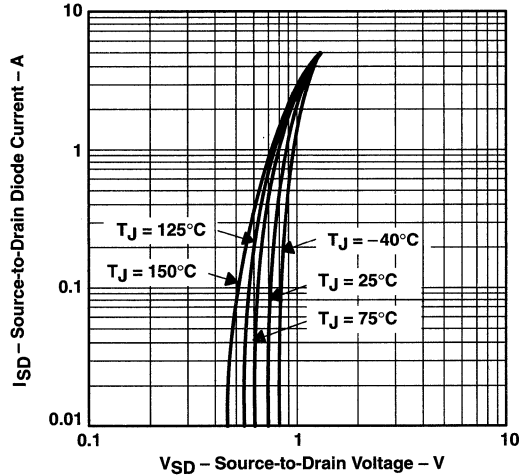


Figure 12

**DRAIN-TO-SOURCE VOLTAGE AND  
GATE-TO-SOURCE VOLTAGE  
vs  
GATE CHARGE**

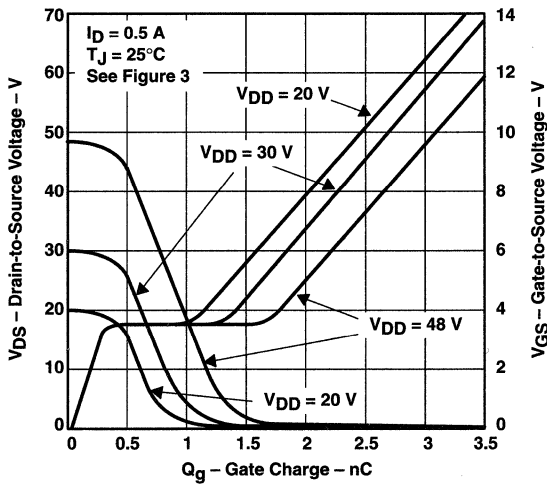


Figure 13

**REVERSE-RECOVERY TIME  
vs  
REVERSE di/dt**

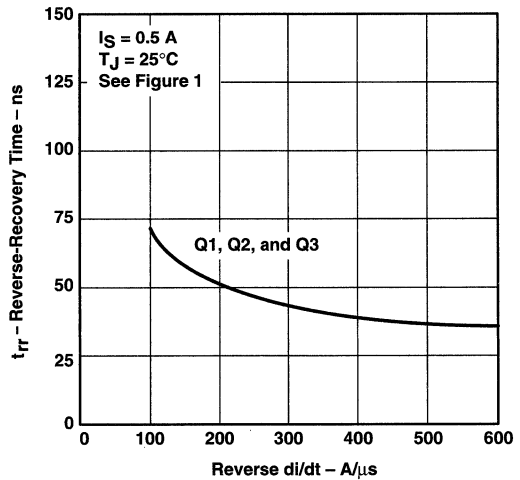
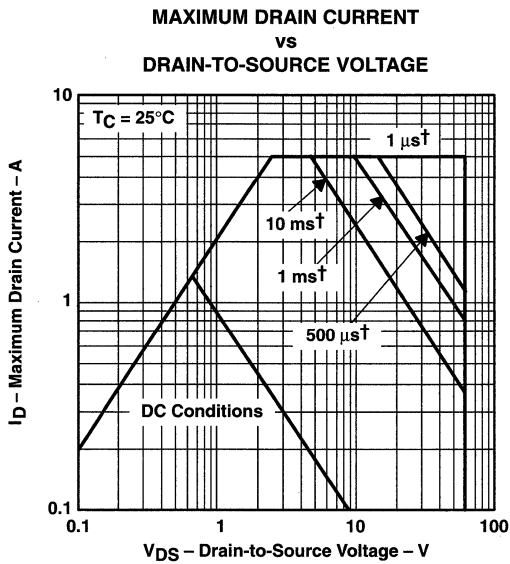


Figure 14

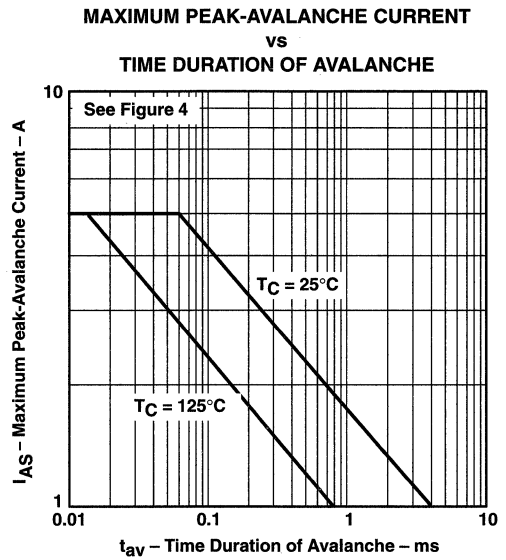
# TPIC2302 3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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## THERMAL INFORMATION



† Less than 0.1 duty cycle

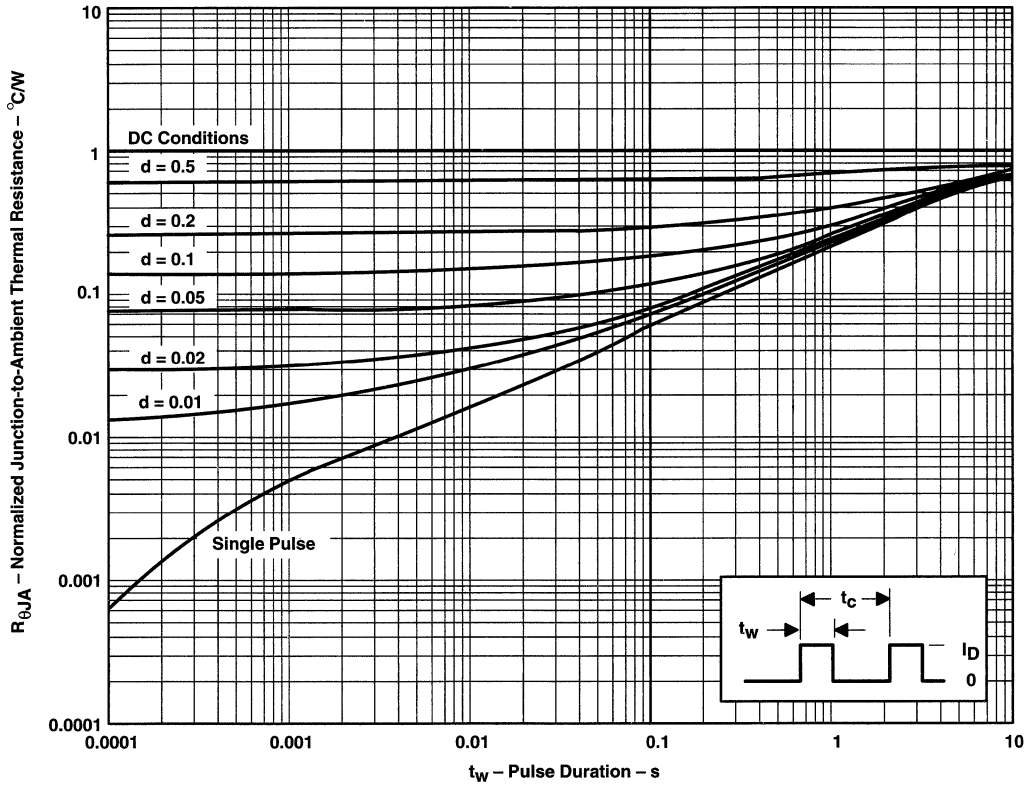


**TPIC2302**  
**3-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**D PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**VS**  
**PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heat sink

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17

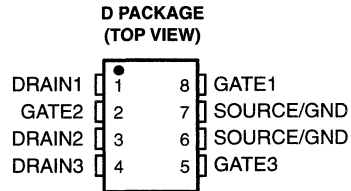


# TPIC2322L

## 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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- Low  $r_{DS(on)}$  . . . 0.6  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 2.25 A Per Channel
- Fast Commutation Speed
- Direct Logic-Level Interface

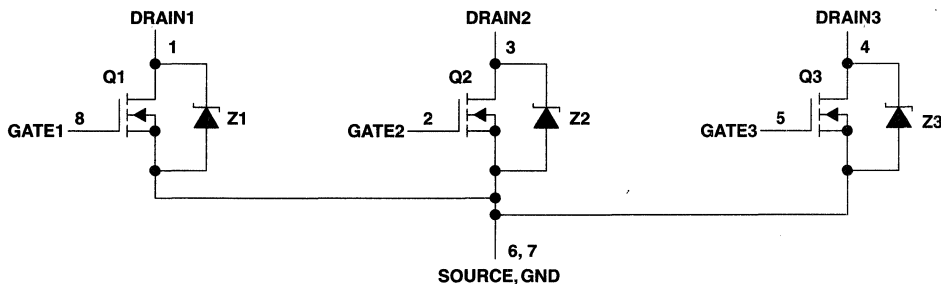


### description

The TPIC2322L is a monolithic logic-level power DMOS array that consists of three electrically isolated N-channel enhancement-mode DMOS transistors configured with a common source and open drains.

The TPIC2322L is offered in a standard eight-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$ .....	60 V
Gate-to-GND voltage .....	100 V
Drain-to-GND voltage .....	100 V
Gate-to-source voltage, $V_{GS}$ .....	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$ .....	0.75 A
Continuous source-to-drain diode current, $T_C = 25^{\circ}\text{C}$ .....	0.75 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 15) .....	2.25 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^{\circ}\text{C}$ (see Figure 4) .....	30.4 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$ (see Figure 15) .....	0.95 W
Operating virtual junction temperature range, $T_J$ .....	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$ .....	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range .....	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^{\circ}\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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# TPIC2322L

## 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ , $V_{GS} = 0$	60			V	
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	1.5	1.85	2.2	V	
$V_{(BR)}$	Reverse drain to GND breakdown voltage	Drain to GND current = $250 \mu\text{A}$	100			V	
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 0.75 \text{ A}$ , See Notes 2 and 3		0.45	0.53	V	
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 0.75 \text{ A}$ , See Notes 2 and 3 and Figure 12		0.85	1	V	
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA	
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA	
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 0.75 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$		0.6	0.7	$\Omega$
			$T_C = 125^\circ\text{C}$		0.94	1	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , $I_D = 0.5 \text{ A}$ , See Notes 2 and 3 and Figure 9	0.75	0.9		S	
$C_{iSS}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ , $V_{GS} = 0$ , See Figure 11		115	145	pF	
$C_{oSS}$	Short-circuit output capacitance, common source			60	75		
$C_{rSS}$	Short-circuit reverse transfer capacitance, common source			30	40		

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$ (see schematic diagram)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_F = 0.375 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , See Figures 1 and 14		85		ns
$Q_{RR}$	Total diode charge			0.19		$\mu\text{C}$



# TPIC2322L

## 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 67\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		21	42	ns
$t_{d(off)}$ Turn-off delay time			26	52	
$t_r$ Rise time			14	28	
$t_f$ Fall time			13	26	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.375\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		1.8	2.3	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.4	0.5	
$Q_{gd}$ Gate-to-drain charge			1.1	1.4	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance, See Note 4	All outputs with equal power		130		$^\circ\text{C}/\text{W}$
$R_{\theta JP}$ Junction-to-pin thermal resistance			44		$^\circ\text{C}/\text{W}$

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink.

### PARAMETER MEASUREMENT INFORMATION

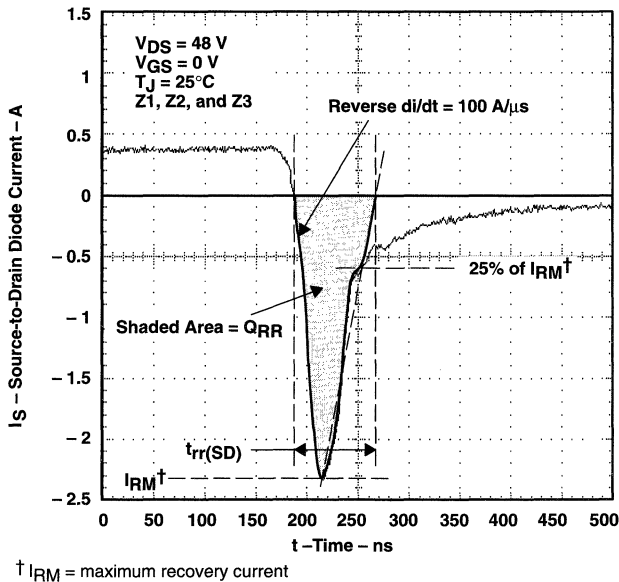
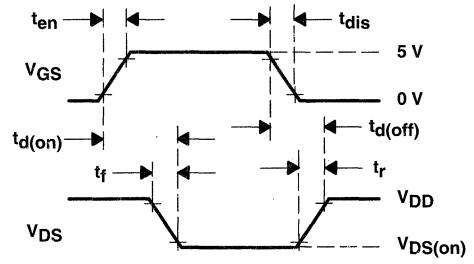
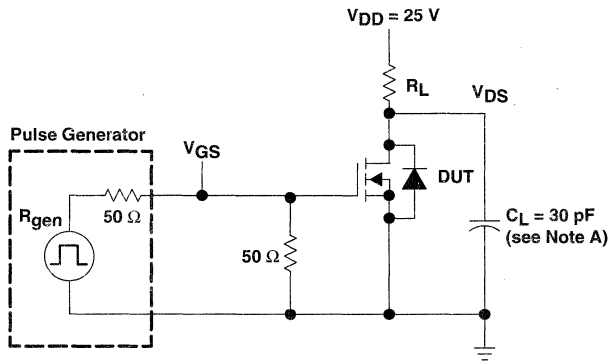


Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode

# TPIC2322L 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION

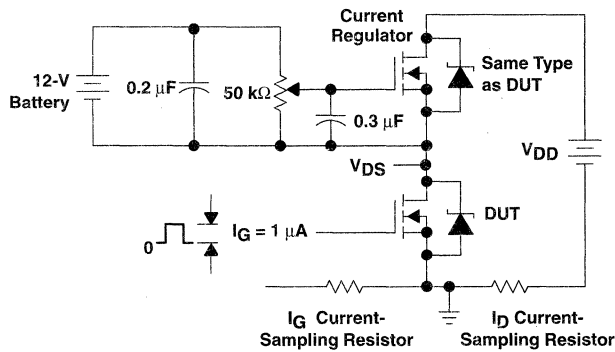


VOLTAGE WAVEFORMS

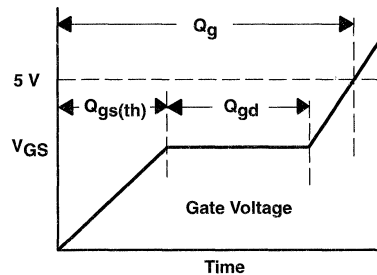
### TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



### TEST CIRCUIT



VOLTAGE WAVEFORM

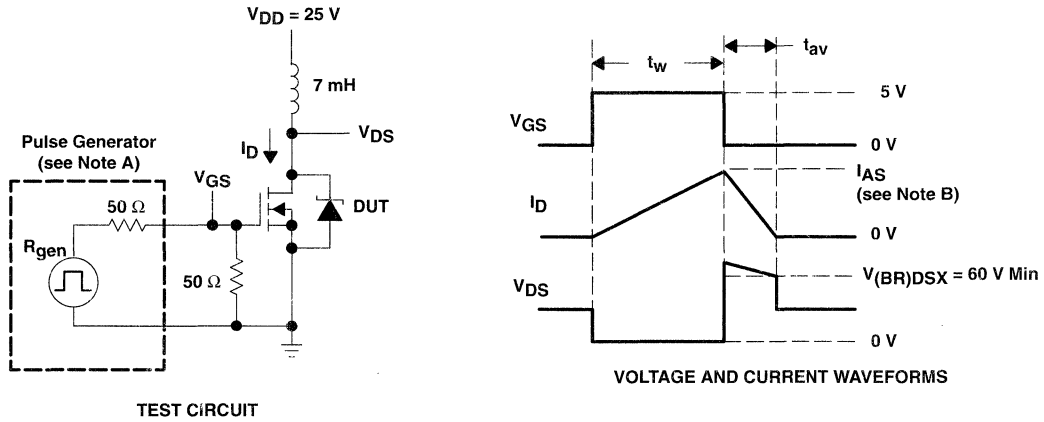
Figure 3. Gate-Charge Test Circuit and Voltage Waveform

# TPIC2322L

## 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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### PARAMETER MEASUREMENT INFORMATION

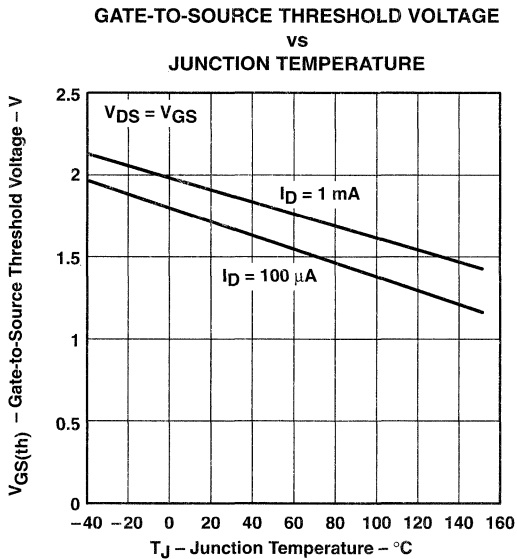


NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 2.25$  A.

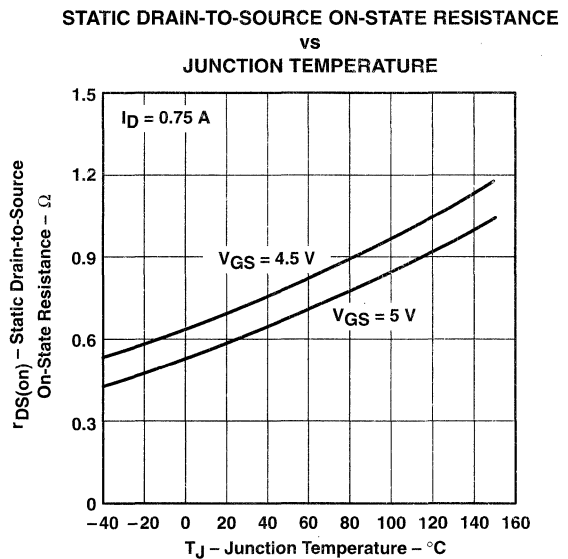
Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 30.4$  mJ.

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

### TYPICAL CHARACTERISTICS



**Figure 5**



**Figure 6**

# TPIC2322L 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

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## TYPICAL CHARACTERISTICS

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT**

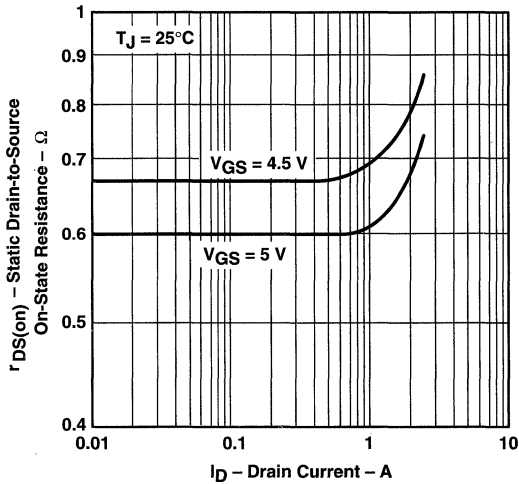


Figure 7

**DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE**

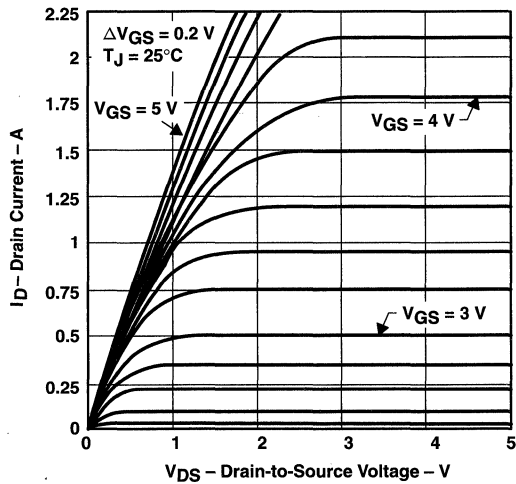


Figure 8

**DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE**

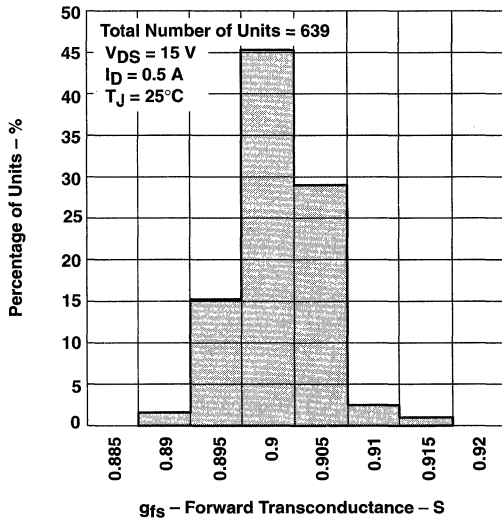


Figure 9

**DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE**

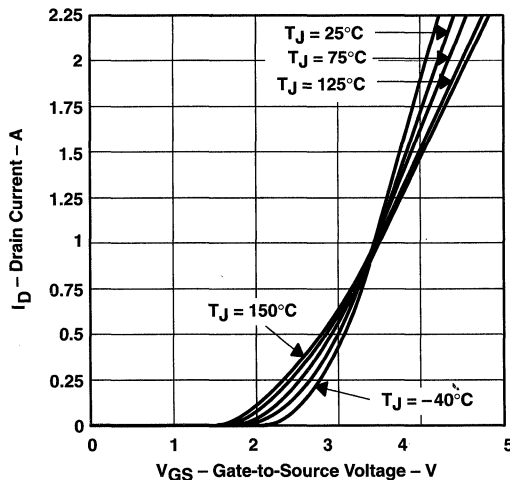


Figure 10

# TPIC2322L

## 3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY

SLIS036A – JUNE 1994 – REVISED OCTOBER 1994

### TYPICAL CHARACTERISTICS

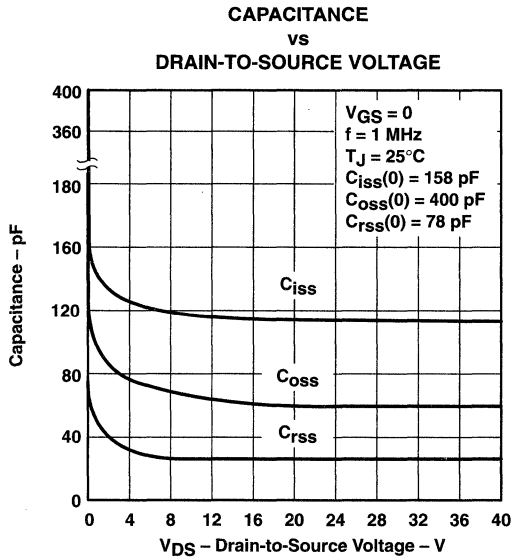


Figure 11

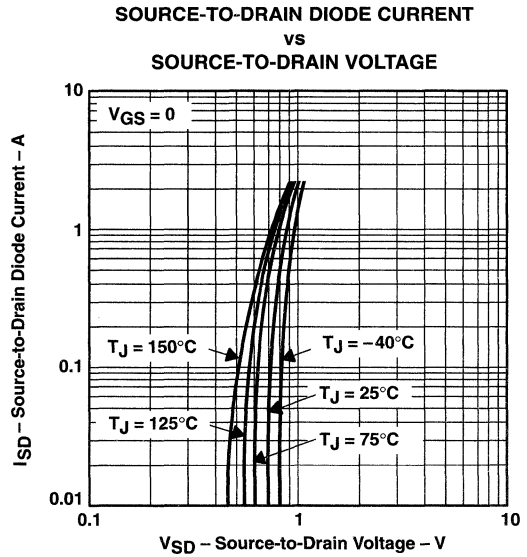


Figure 12

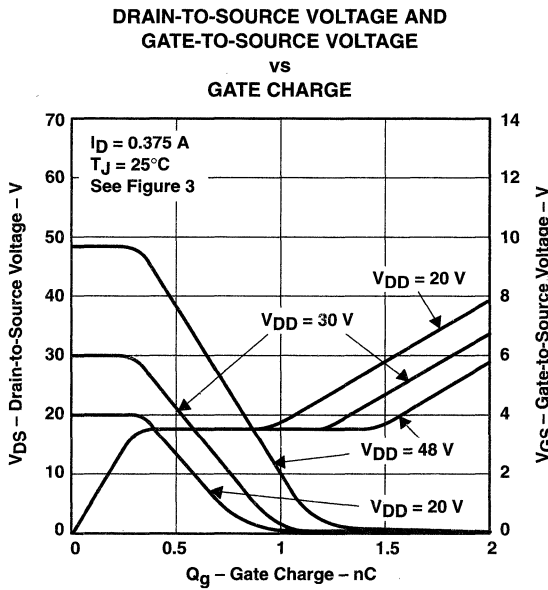


Figure 13

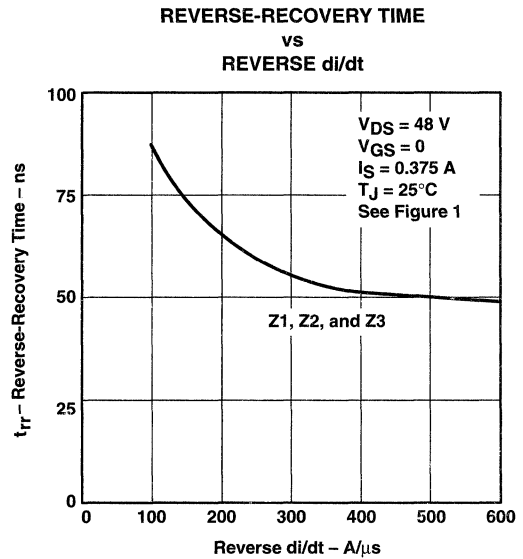


Figure 14

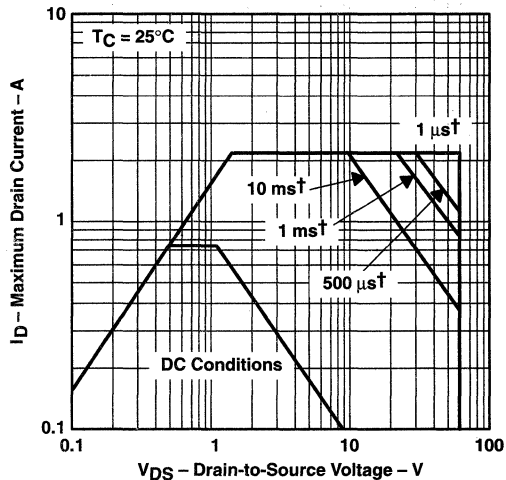


**TPIC2322L**  
**3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY**

SLIS036A – JUNE 1994 – REVISED OCTOBER 1994

**THERMAL INFORMATION**

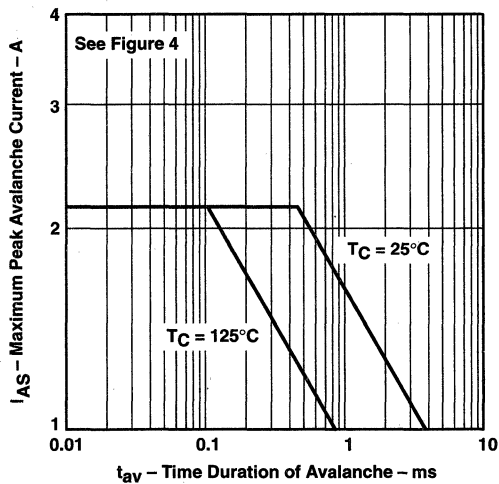
**MAXIMUM DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



† Less than 2% duty cycle

**Figure 15**

**MAXIMUM PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



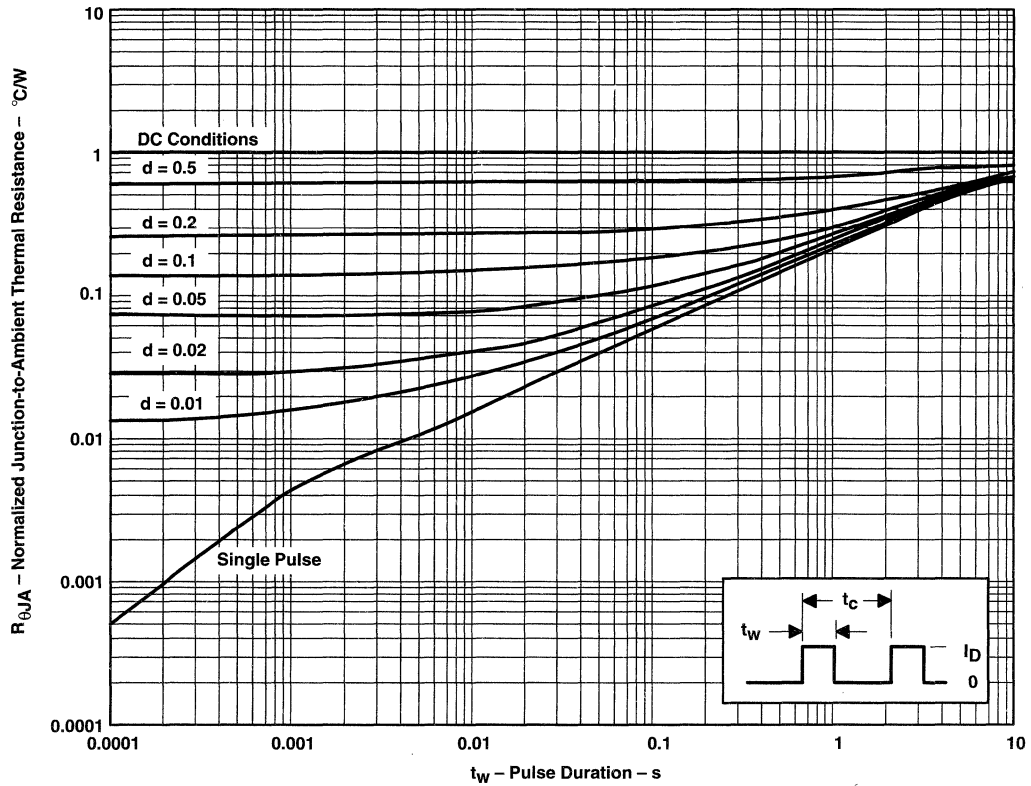
**Figure 16**

**TPIC2322L**  
**3-CHANNEL COMMON-SOURCE LOGIC-LEVEL POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**D PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heat sink.

- NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17





# TPIC2603 6-CHANNEL SERIAL INTERFACE LOW-SIDE DRIVER

SLIS056 – DECEMBER 1995

- Serial Control With Diagnostics
- Six Power DMOS Transistor Outputs of 350 mA Continuous Current
- Internal 60-V Inductive Load Clamp
- Independent ON-State Shorted-Load/Short-to-Battery Fault Detection on All Drain Terminals
- Independent OFF-State Open-Load Fault Sense on All Drain Terminals
- Transition of Drain Outputs to Low Duty Cycle PWM Mode for Over-Current Condition
- Over-Battery-Voltage-Lockout Protection
- Over-Temperature Fault Sense and Reporting
- Fault Diagnostics Returned Through Serial Output Terminal
- Internal Power-On Reset of Registers
- CMOS Compatible Inputs With Hysteresis

## description

The TPIC2603 is a monolithic low-side driver which provides serial interface and diagnostics to control six on-board power DMOS switches. Each channel has independent OFF-state open-load sense, ON-state shorted-load/short-to-battery protection, over-battery-voltage protection, and over-temperature sense with fault status reported through the serial interface. The device also provides inductive voltage transient protection for each drain output. The TPIC2603 can be used to drive inductive and resistive loads such as relays, valves, and lamps.

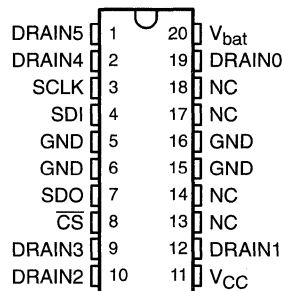
Serial data input (SDI) is transferred through the serial register when  $\overline{CS}$  is low on low-to-high transitions of the serial clock (SCLK). Each string of data must consist of 8 or 16 bits of data. A logic high input data bit will turn the respective output channel ON and a logic low data bit will turn it OFF.  $\overline{CS}$  must be transitioned high after all of the serial data has been clocked into the device. A low-to-high transition of  $\overline{CS}$  will transfer the last six bits of serial data to the output buffer, 3-state the serial data out (SDO) terminal, and re-enable the fault register. Fault data for the device is sent out the SDO terminal. The first bit of the shift register is exclusively OR'ed with the fault registers. When a fault exists, the SDI data is inverted as it is transferred out of SDO. Fault data consists of fault flags for over-temperature (bit 6) and shorted/open-load (bits 0-5) for each of the six output channels. Fault register bits are set or cleared asynchronously, when  $\overline{CS}$  is high to reflect the current state of the hardware. The fault must be present when  $\overline{CS}$  is transitioned from high to low to be captured and reported in the serial fault data. New faults cannot be captured in the serial register when  $\overline{CS}$  is low.

If an over-current or shorted-load fault occurs, the channel will transition into a low duty cycle pulse-width-modulated (PWM) signal as long as the fault is present. More detail on fault detection operation is presented in the device operation section of this data sheet.

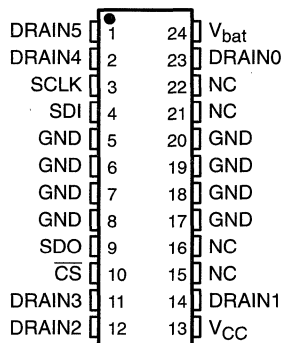
The TPIC2603 provides pull-down resistors on all active-high inputs except SCLK. A pull-up resistor is used on  $\overline{CS}$ .

The TPIC2603 is characterized for operation over the operating case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

NE PACKAGE  
(TOP VIEW)



DW PACKAGE  
(TOP VIEW)



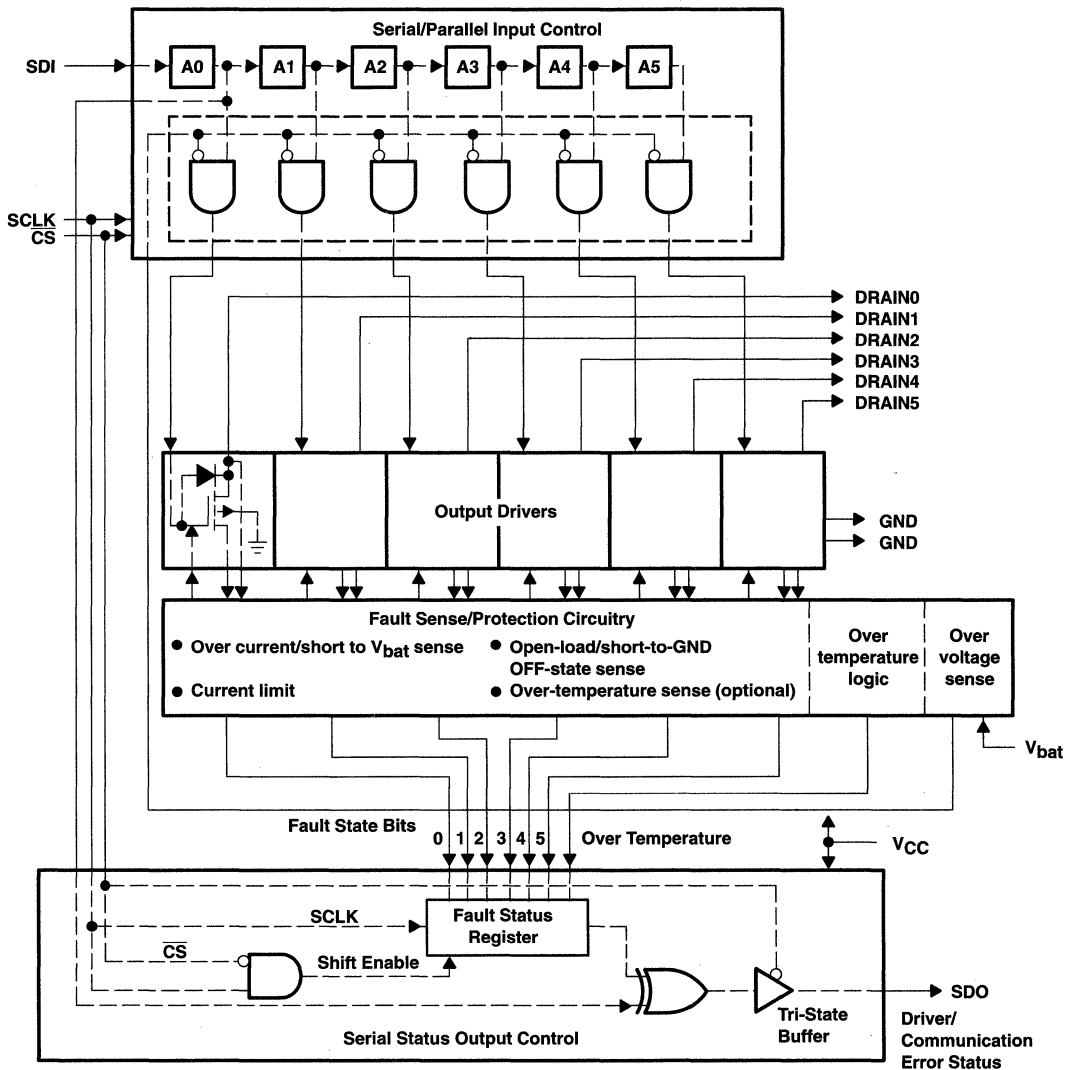
NC – No internal connection

PRODUCT PREVIEW

# TPIC2603 6-CHANNEL SERIAL INTERFACE LOW-SIDE DRIVER

SLIS056 – DECEMBER 1995

## functional block diagram



PRODUCT PREVIEW

# TPIC2603

## 6-CHANNEL SERIAL INTERFACE LOW-SIDE DRIVER

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### Terminal Functions

TERMINAL NAME	NO.†	I/O	DESCRIPTION
CS	8 (10)	I	Chip select. CS is an active-low input. Serial communication is enabled by pulling the CS terminal low. The CS input should only be transitioned when SCLK is low. CS has an internal active pull-up and requires CMOS logic level inputs.
DRAIN0 DRAIN1 DRAIN2 DRAIN3 DRAIN4 DRAIN5	19 (23) 12 (14) 10 (12) 9 (11) 2 (2) 1 (1)	O	FET drain outputs. These terminals pull current through the low-side switched loads. They are actively clamped at the peak clamping voltage as defined in the electrical characteristics section of this data sheet.
GND	5, 6, 15, 16 (5, 6, 7, 8, 17, 18, 19, 20)		Ground. These terminals provide circuit ground for the device.
SCLK	3 (3)	I	Serial clock. SCLK clocks the shift register. Serial data is transferred into the serial data input (SDI) port and serial fault data is transferred out of the serial data output (SDO) port of the device on the rising edges of SCLK.
SDI	4 (4)	I	Serial data input. SDI receives serial data from the control device. The serial data transmitted on this terminal is an 8-bit (or 16-bit) control byte with the most significant bit (MSB) being transferred first. The input has an internal active pull-down and requires CMOS logic level inputs. See Figures 2 and 4 for input protocol.
SDO	7 (9)	O	Serial data output. This 3-state output transfers fault data to the control device. The output will remain 3-stated unless the device is selected by a low on chip select (CS). See Figures 3 and 4 for fault protocol.
V <sub>bat</sub>	20 (24)		Battery voltage. The output drivers will operate at the battery voltage (V <sub>bat</sub> ) levels as low as 5.5-V. This supply is provided for over-voltage shutdown protection and for added gate-drive capabilities.
V <sub>CC</sub>	11 (13)		Supply voltage. V <sub>CC</sub> is connected to the 5-V power supply voltage. The output driver will be able to turn ON at V <sub>CC</sub> levels as low as 4.5 V.

† Terminal numbers listed in parenthesis are for the 24-pin DW package.

### absolute maximum ratings over the recommended operating case temperature range (unless otherwise noted)‡

Logic supply voltage range, V <sub>CC</sub> (see Note 1)	–0.3 V to 7 V
Battery supply voltage range, V <sub>bat</sub>	–1.5 V to 60 V
Logic input voltage range, V <sub>I</sub>	–0.3 V to 7 V
Power DMOS drain-to-source voltage, V <sub>DS</sub> (see Note 2)	70 V
Continuous drain current, each output, all outputs on, I <sub>DN</sub> , T <sub>C</sub> = 25°C	350 mA
Pulsed drain current, single output, T <sub>A</sub> = 25°C (see Note 3)	2.25 A
Single-pulse avalanche energy, E <sub>AS</sub> (see Figure 14)	100 mJ
Operating virtual junction temperature range, T <sub>J</sub>	–40°C to 150°C
Storage temperature range, T <sub>stg</sub>	–55°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 are with respect to GND.
  2. Each power DMOS source is internally connected to GND.
  3. Pulse duration ≤ 100 μs and duty cycle ≤ 2%.

PRODUCT PREVIEW



# TPIC2603

## 6-CHANNEL SERIAL INTERFACE LOW-SIDE DRIVER

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### recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5	5.5	V
Battery supply voltage, $V_{bat}$	5.5	12	25	V
High-level input voltage, $V_{IH}$	$0.7 V_{CC}$		$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	$0.3 V_{CC}$		V
Operating case temperature, $T_C$	-40		125	°C

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT		
$V_{bat}$	Battery supply voltage	Normal operation		5.5	25	V	
$I_{bat}$	Battery supply current	$V_{CC} = 5\text{ V}$			5	mA	
		$V_{CC} = 0\text{ V}$			50	$\mu\text{A}$	
$V_{CC}$	Logic supply voltage	4.5		5.5	V		
$I_{CC}$	Logic supply current	All outputs off, $V_{bat} = 5.5\text{ V}$			5	mA	
$V_{turnon}$	$V_{CC}$ turn-on voltage (logic operational)	$V_{bat} = 5.5\text{ V}$ , Check output functionality			4.5	V	
$V_{(OV)}$	Over-battery voltage shutdown	Gate disabled		30	38	V	
$V_{hys(ov)}$	Over-battery voltage reset hysteresis			0.4	2	V	
$r_{DS(on)}$	Drain-to-source on-state resistance	$V_{bat} = 13\text{ V}$	$I_O = 0.35\text{ A}$ , $T_C = 25^\circ\text{C}$	0.7	1	$\Omega$	
		$V_{bat} = 5.5\text{ V}$		1.7	2.3		
		$V_{bat} = 13\text{ V}$	$I_O = 0.35\text{ A}$ , $T_C = 125^\circ\text{C}$	1.2			
		$V_{bat} = 5.5\text{ V}$		2.7			
$I_L$	On-state current limit	0.8		5	A		
$I_{TM(ov)}$	Over-current sense	0.8		3	A		
$I_{CS}$	Input pull-up current	$\text{GND} < V_I < 0.7 V_{CC} - \overline{\text{CS}}$		-5	-10	-50	$\mu\text{A}$
$I_{IL}$	Input pull-down current	$0.3 V_{CC} < V_I < V_{CC}$ , All other inputs		2.5	10	25	$\mu\text{A}$
$I_{DSX}$	Off-state drain current	$V_{load} = V_{bat} = 14.5\text{ V}$		20	40	80	$\mu\text{A}$
$I_{O(sleep)}$	Output current, sleep-state	$V_{bat} < 0.5\text{ V}$ , $V_{CC} < 0.5\text{ V}$ , Load = 14 V				50	$\mu\text{A}$
$V_{OH}$	High-level serial output voltage	$I_O = 1\text{ mA}$		$0.8 V_{CC}$			V
$V_{OL}$	Low-level serial output voltage	$I_O = 1\text{ mA}$			0.2	0.4	V
$I_{oz}$	Output current, SDO 3-state	$V_{CC} = 5.5\text{ V to } 0\text{ V}$		-10	1	10	$\mu\text{A}$
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	dc < 1%, $t_w = 100\ \mu\text{s}$ , $I_O = 20\text{ mA}$		52	58	68	V
$T_{(limit)}$	Thermal flag	150	170	185			°C
$T_{(hyst)}$	Thermal flag hysteresis	5	10	15			°C
$V_{(open)}$	Open load detection voltage	$0.3 V_{CC}$		$0.7 V_{CC}$			V

PRODUCT PREVIEW



**TPIC2603**  
**6-CHANNEL SERIAL INTERFACE LOW-SIDE DRIVER**

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**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$t_w$	Clock cycle period pulse duration SCLK		250	555	ns	
$t_{wH}(\text{SCLK})$	Pulse duration SCLK high		100	248	ns	
$t_{wL}(\text{SCLK})$	Pulse duration SCLK low		100	248	ns	
$t_{pd1}$	Propagation delay from falling edge of $\overline{\text{CS}}$ to SDO valid		150	300	ns	
$t_{pd2}$	Propagation delay from rising edge of $\overline{\text{CS}}$ to SDO 3-state	$\overline{\text{CS}} = 2\text{ V}$ to SDO 3-state	150	200	ns	
$t_{pd3}$	Propagation delay from SCLK to SDO	$\overline{\text{CS}} < 0.8\text{ V}$	80	172	ns	
$t_r(\text{SDO})$	Rise time of SDO	$C_{load} = 200\text{ pF}$	30	50	ns	
$t_f(\text{SDO})$	Fall time of SDO	$C_{load} = 200\text{ pF}$	30	50	ns	
$t_{stb}$	Short-to-battery/shorted-load/open-load deglitch time	See Figures 5 and 6	25	70	100	$\mu\text{s}$
$t_{d(on)}$	Turn-on delay time, rising edge of $\overline{\text{CS}}$ to drain	$V_{bat} = 14\text{ V}$ , $R_{load} = 30\ \Omega$	0.4	5	10	$\mu\text{s}$
$t_{d(off)}$	Turn-off delay time, rising edge of $\overline{\text{CS}}$ to drain		0.4	5	15	
$t_r(\text{drain})$	Rise time of drain terminal		0.4	5	10	
$t_f(\text{drain})$	Fall time of drain terminal		0.4	5	10	
$f(\text{SCLK})$	Serial clock frequency		1.8	4	MHz	
$t_{cyc}(\text{ref})$	Short-to-battery sense cycle time	See Figure 5	1.6	4	6.4	ms
$t_{wsense}$	Short-to-battery sense pulse duration	See Figure 5	25	70	100	$\mu\text{s}$
$t_{su1}$	Setup to/from the fall edge of $\overline{\text{CS}}$ to the rising edge of SCLK	See Figure 1	150	200	ns	
$t_{su}(\text{SDI})$	Setup time, SDI to SCLK	See Figure 1	25	55	ns	
$t_h(\text{SDI})$	Hold time, SDI after SCLK	See Figure 1	10	55	ns	

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance			50	$^\circ\text{C}$
$R_{\theta JC}$	Junction-to-case thermal resistance			10	$^\circ\text{C}$

**PRODUCT PREVIEW**



# TPIC2701

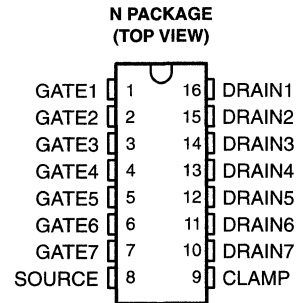
## 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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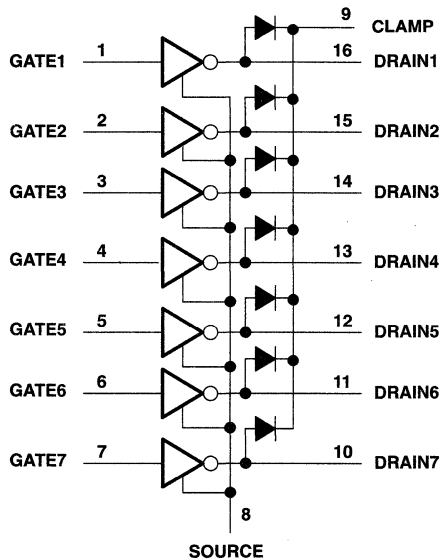
- Seven 0.5-A Independent Output Channels
- Integrated Clamp Diode With Each Output
- Low  $r_{DS(on)}$  . . . 0.5  $\Omega$  Typical
- Output Voltage . . . 60 V
- Pulsed Current . . . 3 A Per Channel
- Avalanche Energy . . . 22 mJ

### description

The TPIC2701 is a monolithic power DMOS transistor array that consists of seven independent N-channel enhancement-mode DMOS transistors connected in a common-source configuration with open drains. The TPIC2701 is pin-for-pin functionally compatible with the Texas Instruments ULN2001A through ULN2004A.



### logic diagram



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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# TPIC2701

## 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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### absolute maximum ratings over operating case temperature range (unless otherwise noted)

Drain-source voltage, $V_{DS}$	60 V
Gate-source voltage, $V_{GS}$	$\pm 20$ V
Clamp-drain voltage, $V_{CD}$	60 V
Continuous source-drain diode current	0.5 A
Pulsed drain current, each output, $I_D$ (see Note 1 and Figure 17)	3 A
Pulsed clamp current, $I_{CL}$ (see Note 1 and Figure 18)	3 A
Continuous drain current, each output, all outputs on	0.5 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	22 mJ
Continuous total dissipation at (or below) $T_A = 25^\circ\text{C}$ (see Note 2)	1.4 W
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

- NOTES: 1. Pulse duration = 10 ms, duty cycle = 6%.  
 2. For operation above  $25^\circ\text{C}$  free-air temperature, derate linearly at the rate of 11 mW/ $^\circ\text{C}$ . To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded.

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DS}$	Drain-source breakdown voltage	$I_D = 1 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{TGS}$	Gate-source threshold voltage	$I_D = 1 \text{ mA}$ , $V_{DS} = V_{GS}$	1.2	1.75	2.4	V
$V_{DS(on)}$	Drain-source on-state voltage	$I_D = 0.5 \text{ A}$ , $V_{GS} = 15 \text{ V}$ , See Notes 3 and 4		0.25	0.4	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{GS} = -20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$r_{DS(on)}$	Forward drain-source on-state resistance	$V_{GS} = 15 \text{ V}$ , $I_D = 0.5 \text{ A}$ , See Notes 3 and 4 and Figures 5 and 6	$T_C = 25^\circ\text{C}$	0.5	0.8	$\Omega$
			$T_C = 125^\circ\text{C}$	0.8	1.3	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , $I_D = 0.5 \text{ A}$ , See Notes 3 and 4	0.5	0.8		S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $V_{GS} = 0$ , $f = 300 \text{ kHz}$		105		pF
$C_{oss}$	Short-circuit output capacitance, common source			65		
$C_{rss}$	Short-circuit reverse transfer capacitance, common source			15		

- NOTES: 3. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts with a single output transistor conducting.

### source-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{SD}$	Forward on voltage	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$		0.9	1.4	V
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ , $di/dt = 25 \text{ A}/\mu\text{s}$ , See Figure 1		165		ns
$Q_{RR}$	Total source-drain diode charge			250		nC



# TPIC2701

## 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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### clamp diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_F$ Forward on-voltage	$I_F = 0.5 \text{ A}$		1	1.5	V
$V_{BR}$ Breakdown voltage	$I_R = 1 \mu\text{A}$	60			V
$I_R$ Reverse leakage current	$V_R = 48 \text{ V}$		0.05	1	$\mu\text{A}$
$t_{rr}(\text{CD})$ Reverse-recovery time	$I_F = 0.1 \text{ A}$ , $di/dt = 25 \text{ A}/\mu\text{s}$ , $V_{CD} = 48 \text{ V}$ , See Figure 1		90		ns
$Q_{RR}$ Total source-drain diode charge			100		nC

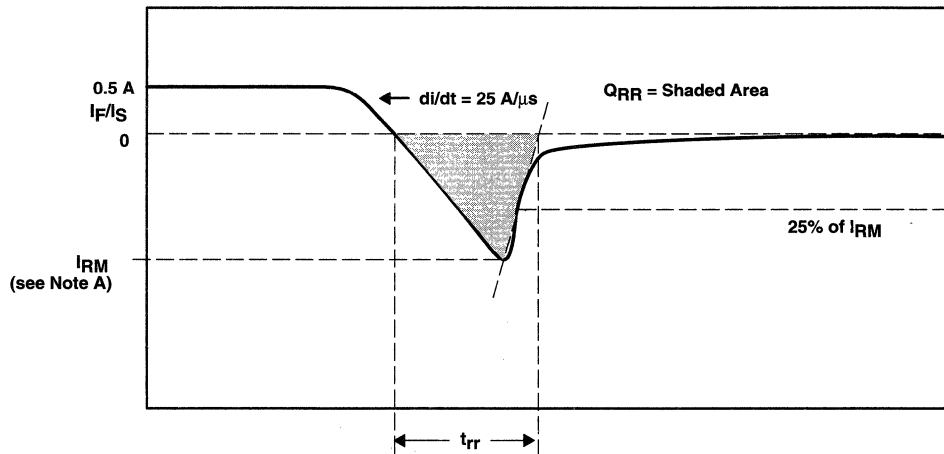
### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(\text{on})}$ Turn-on delay time			10		ns
$t_{d(\text{off})}$ Turn-off delay time	$V_{DD} = 25 \text{ V}$ , $R_L = 100 \Omega$ , $t_{\text{en}} = 10 \text{ ns}$ , $t_{\text{dis}} = 10 \text{ ns}$ , See Figure 2		30		
$t_r$ Rise time			15		
$t_f$ Fall time			5		
$Q_g$ Total gate charge			2.8	3.6	nC
$Q_{gs}$ Gate-source charge	$V_{DS} = 48 \text{ V}$ , $I_D = 0.25 \text{ A}$ , $V_{GS} = 10 \text{ V}$ , See Figure 3		1.6	2	
$Q_{gd}$ Gate-drain charge			1.2	1.6	

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power			90	$^\circ\text{C}/\text{W}$

### PARAMETER MEASUREMENT INFORMATION



NOTE A:  $I_{RM}$  = maximum recovery current

**Figure 1. Reverse-Recovery-Current Waveforms of Source-Drain and Clamp Diodes**

# TPIC2701 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION

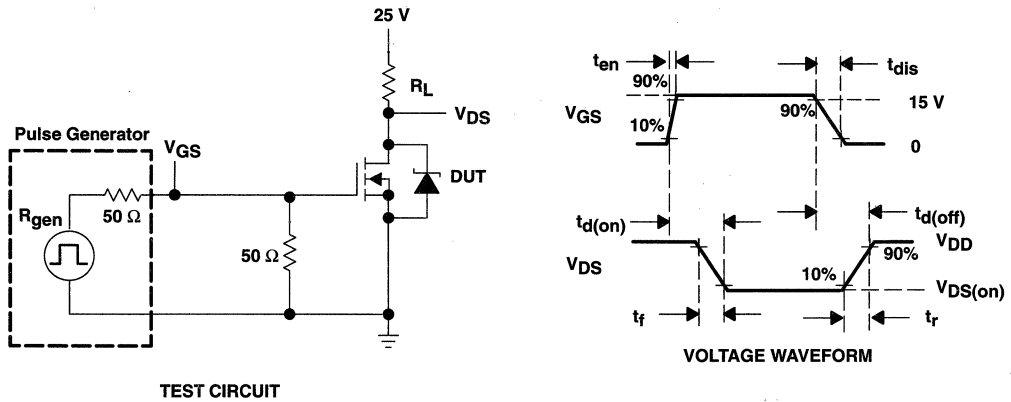


Figure 2. Resistive Switching

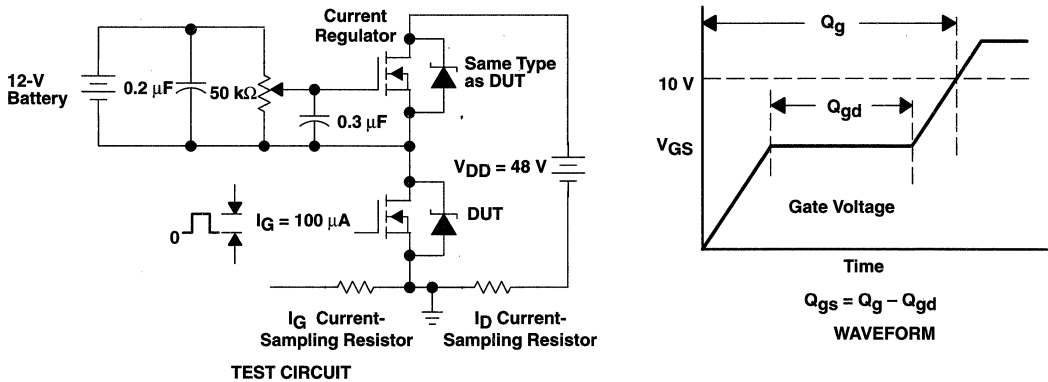
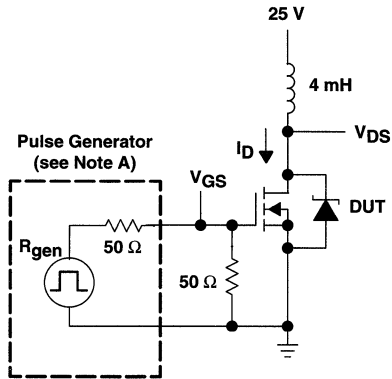


Figure 3. Gate Charge Test Circuit and Waveform

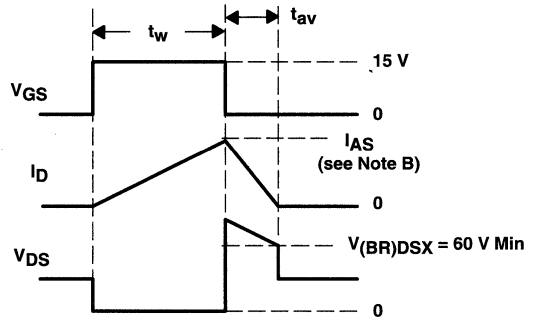
**TPIC2701**  
**7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

SLIS019 – SEPTEMBER 1992 – REVISED OCTOBER 1992

**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**



**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 2.5 \text{ A}$ .

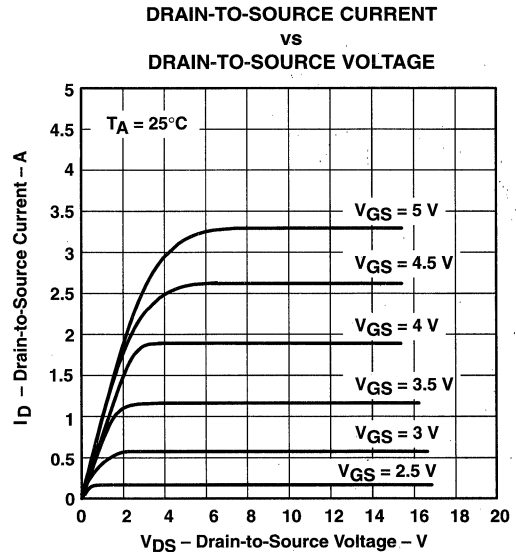
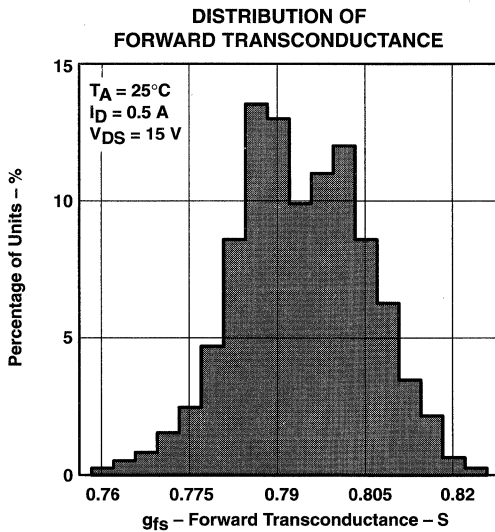
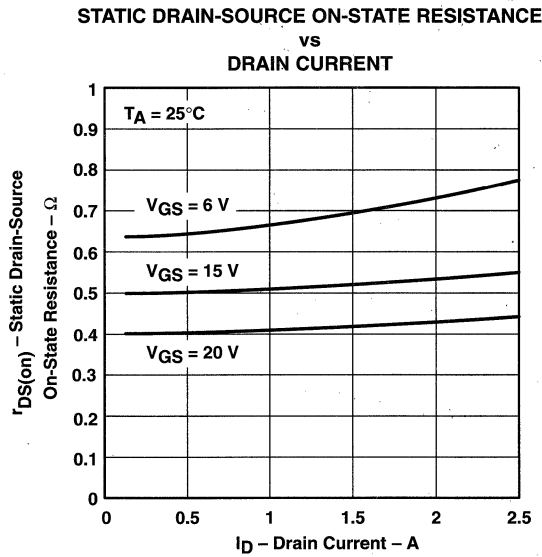
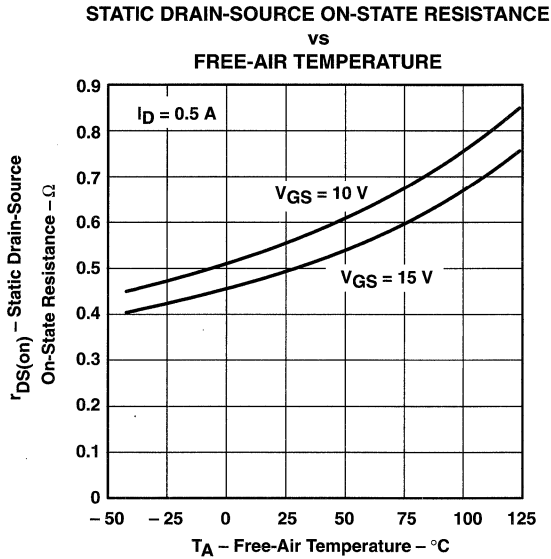
Energy test level is defined as 
$$E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 22 \text{ mJ min.}$$

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

# TPIC2701 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS019 – SEPTEMBER 1992 – REVISED OCTOBER 1992

## TYPICAL CHARACTERISTICS



**TYPICAL CHARACTERISTICS**

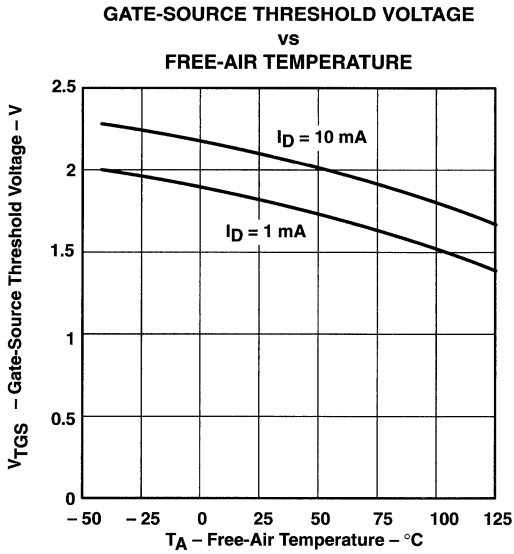


Figure 9

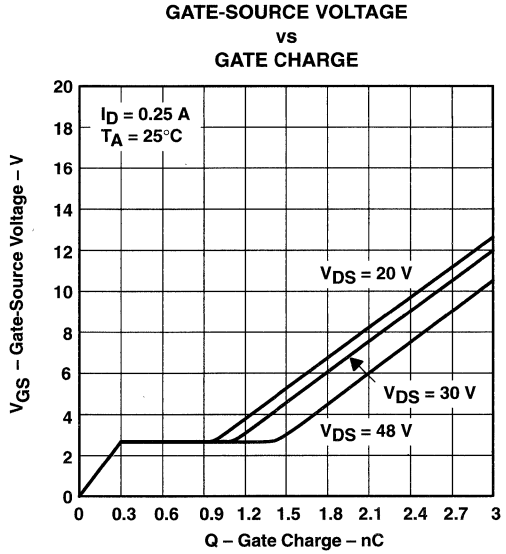


Figure 10

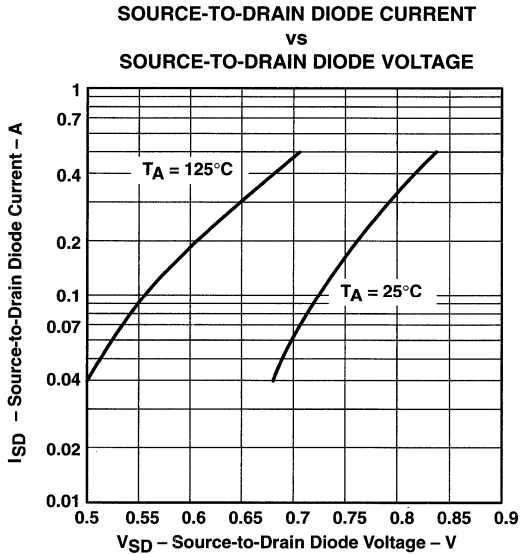


Figure 11

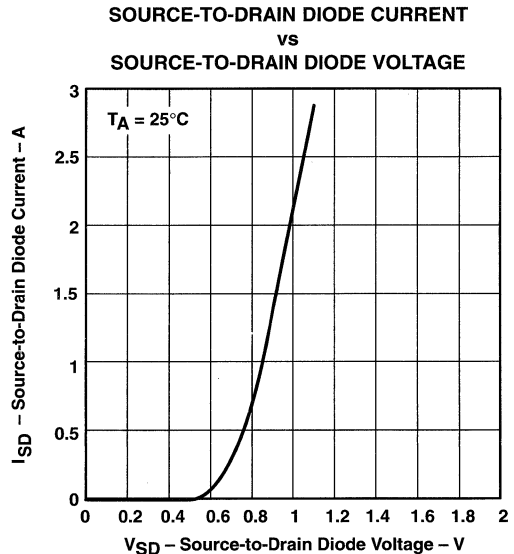
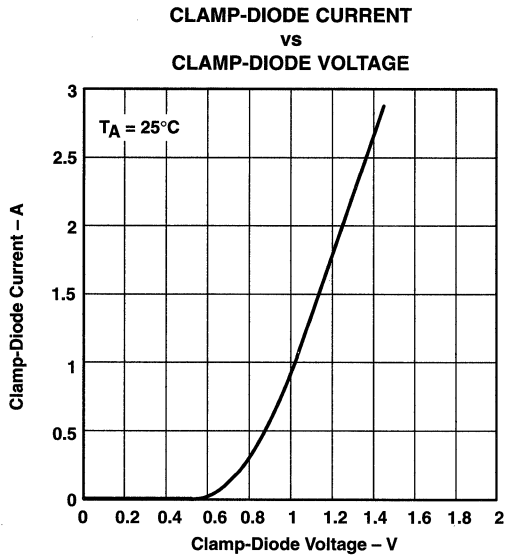


Figure 12

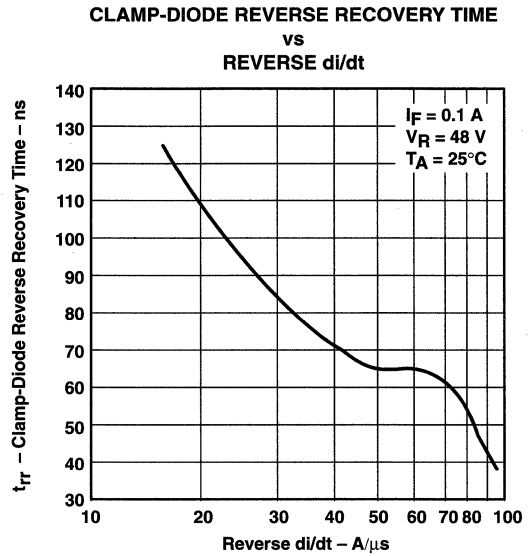
**TPIC2701**  
**7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY**

SLIS019 – SEPTEMBER 1992 – REVISED OCTOBER 1992

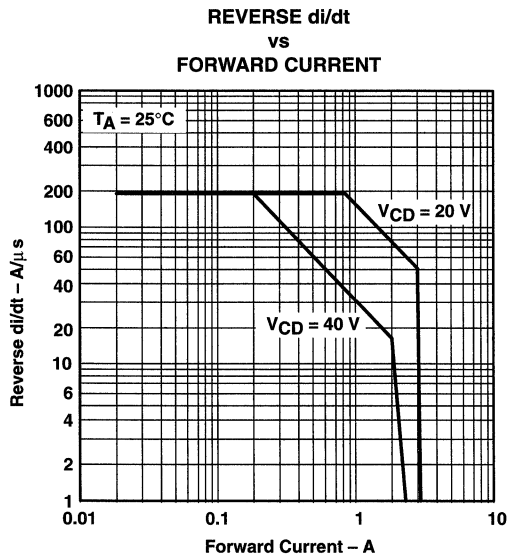
**TYPICAL CHARACTERISTICS**



**Figure 13**



**Figure 14**



NOTE :  $V_{CD} = V_{clamp} - V_{drain}$

**Figure 15**

TPIC2701  
7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS019 – SEPTEMBER 1992 – REVISED OCTOBER 1992

TYPICAL CHARACTERISTICS

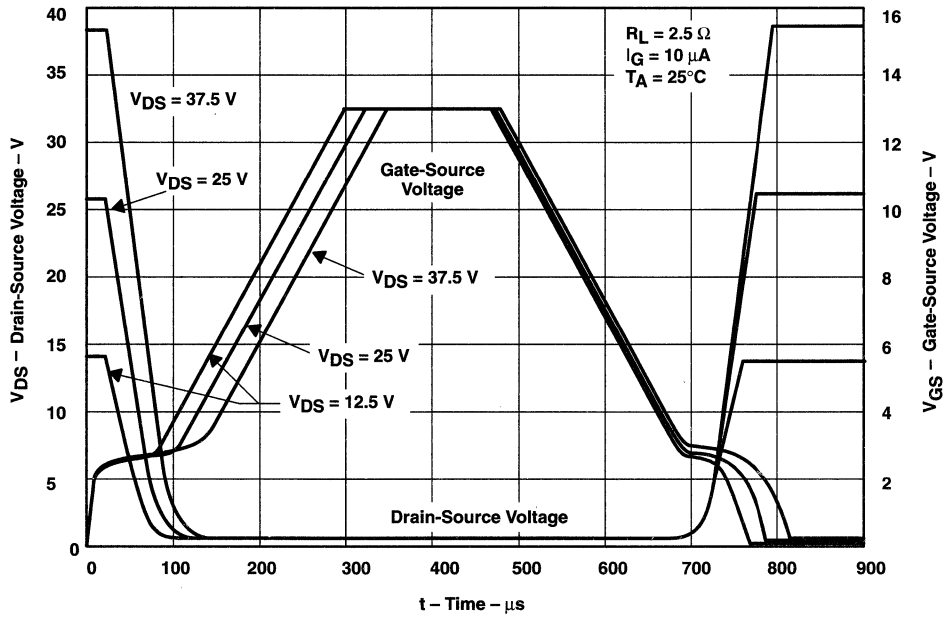


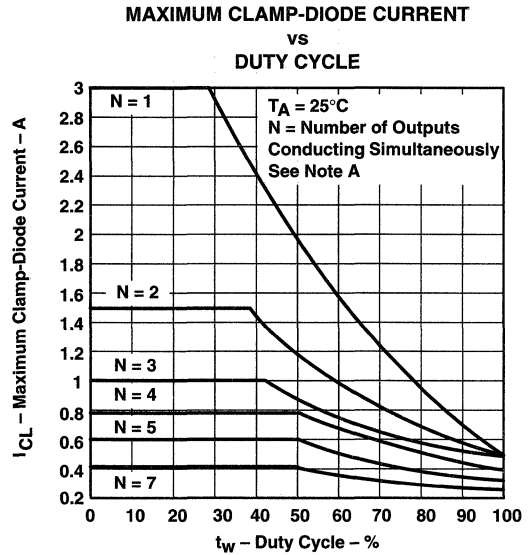
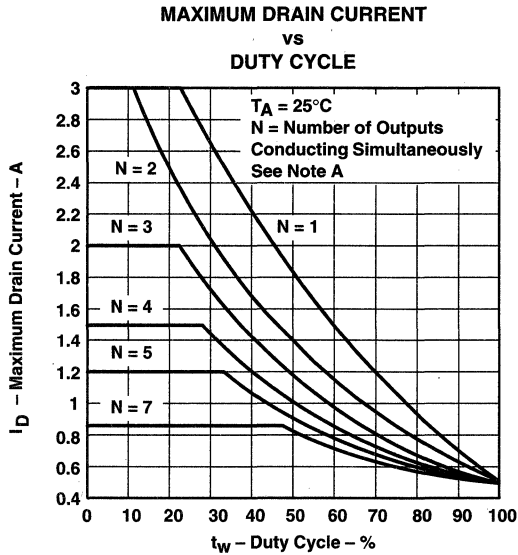
Figure 16. Resistive Switching Waveforms



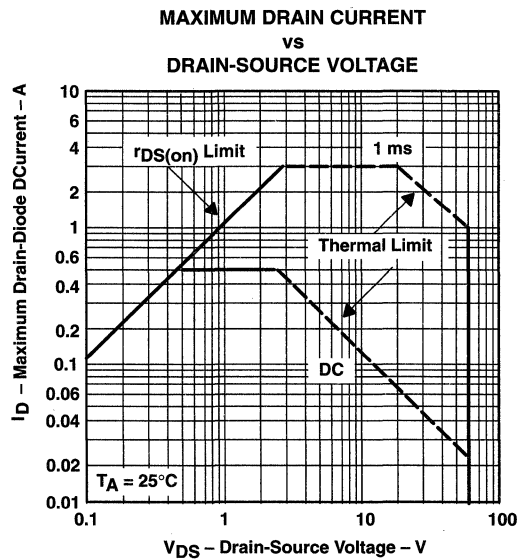
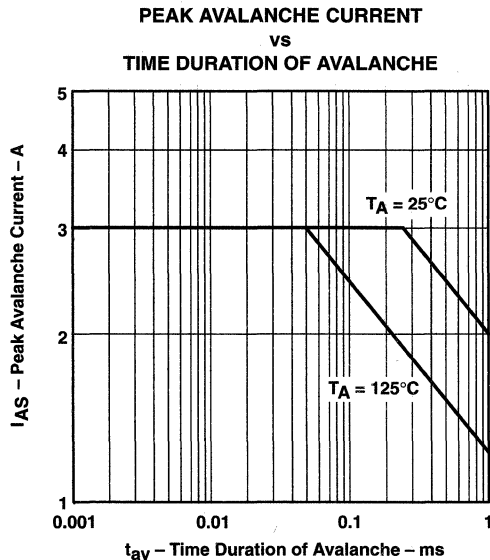
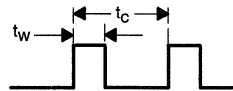
# TPIC2701 7-CHANNEL COMMON-SOURCE POWER DMOS ARRAY

SLIS019 – SEPTEMBER 1992 – REVISED OCTOBER 1992

## THERMAL INFORMATION



NOTE A: For Figures 17 and 18,  $d = t_w/t_c = 10 \text{ ms} / t_c$ , where  $t_w$  and  $t_c$  are defined by the following:



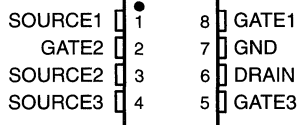
# TPIC3302

## 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 5 A Per Channel
- Fast Commutation Speed

**D PACKAGE  
(TOP VIEW)**

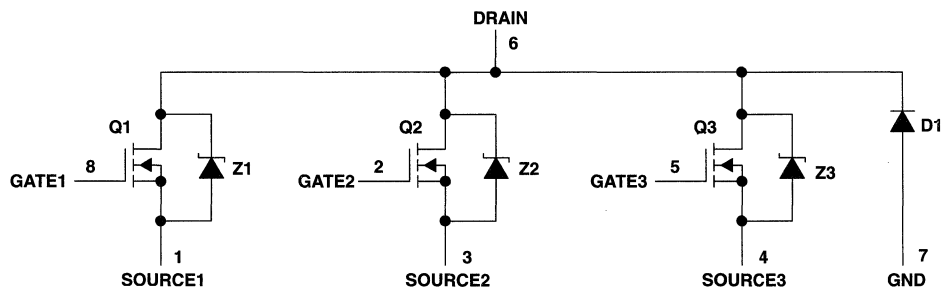


### description

The TPIC3302 is a monolithic power DMOS array that consists of three electrically isolated N-channel enhancement-mode DMOS transistors configured with a common drain and open sources. The TPIC3302 is offered in a standard eight-pin small-outline surface-mount (D) package.

The TPIC3302 is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



### absolute maximum ratings over operating case temperature range (unless otherwise noted)<sup>†</sup>

Drain-to-source voltage, $V_{DS}$ . . . . .	60 V
Source-to-GND voltage . . . . .	100 V
Drain-to-GND voltage . . . . .	100 V
Gate-to-source voltage, $V_{GS}$ . . . . .	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$ . . . . .	1 A
Continuous source-to-drain diode current . . . . .	1 A
Pulsed drain current, each output, $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 6) . . . . .	5 A
Single-pulse avalanche energy, $T_C = 25^{\circ}\text{C}$ , $E_{AS}$ (see Figure 4) . . . . .	9 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$ . . . . .	0.95 W
Operating virtual junction temperature range, $T_J$ . . . . .	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$ . . . . .	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range, $T_{stg}$ . . . . .	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	$260^{\circ}\text{C}$

<sup>†</sup> 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

# TPIC3302

## 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.4	0.475	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$ , See Notes 2 and 3			2		V
$V_F(SD)$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 0$ ,		0.9	1.1	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_R = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.4	0.475		$\Omega$
			$T_C = 125^\circ\text{C}$	0.63	0.7		
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 2 and 3	$I_D = 0.5 \text{ A}$ ,	0.85	1.02		S
$C_{iss}$	Short-circuit input capacitance, common source				115	145	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ ,	$V_{GS} = 0$ ,		60	75	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source	$f = 1 \text{ MHz}$			30	40	

- NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum, pulse duration  $\leq 5 \text{ ms}$ .  
3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ ,	$V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ ,		35		ns
$Q_{RR}$	Total diode charge	$di/dt = 100 \text{ A}/\mu\text{s}$ ,	See Figure 1		0.03		$\mu\text{C}$

### GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$ (see schematic, D1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_F = 0.5 \text{ A}$ ,	$V_{DS} = 48 \text{ V}$ ,		90		ns
$Q_{RR}$	Total diode charge	$di/dt = 100 \text{ A}/\mu\text{s}$ ,	See Figure 1		0.2		$\mu\text{C}$

# TPIC3302

## 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

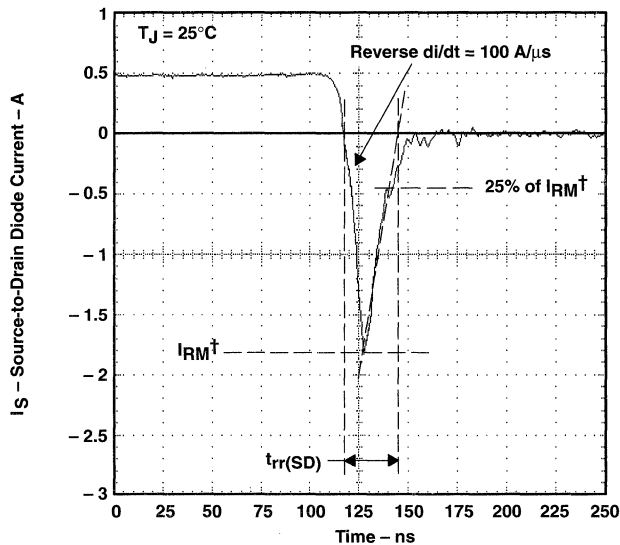
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		21	42	ns
$t_{d(off)}$ Turn-off delay time			20	40	
$t_r$ Rise time			5	10	
$t_f$ Fall time			13	26	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.5\text{ A}$ , $V_{GS} = 10\text{ V}$ , See Figure 3		3.1	3.8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.4	0.5	
$Q_{gd}$ Gate-to-drain charge			1.3	1.6	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power, See Note 4		130		$^\circ\text{C/W}$
$R_{\theta JP}$ Junction-to-pin thermal resistance			44		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

### PARAMETER MEASUREMENT INFORMATION



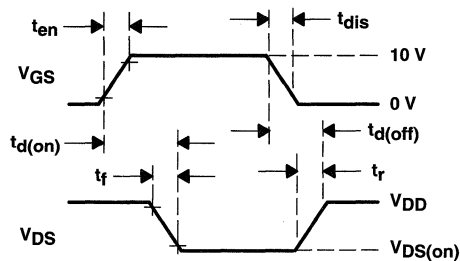
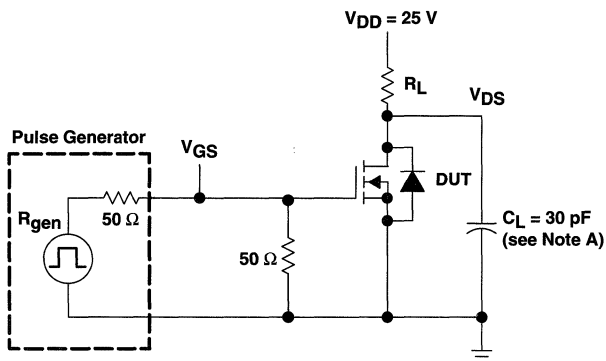
$^\dagger I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode

# TPIC3302 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

## PARAMETER MEASUREMENT INFORMATION

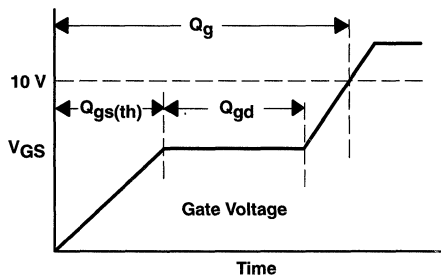
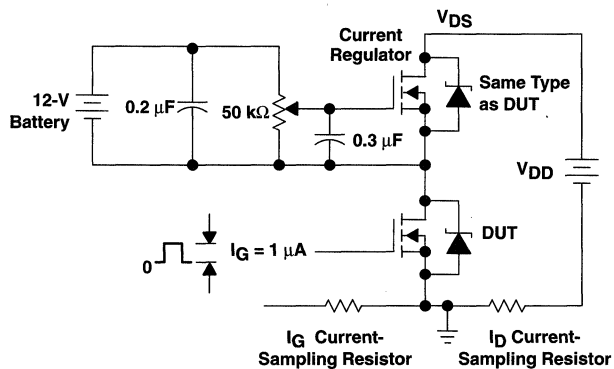


VOLTAGE WAVEFORMS

### TEST CIRCUIT

NOTE A: C<sub>L</sub> includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



VOLTAGE WAVEFORM

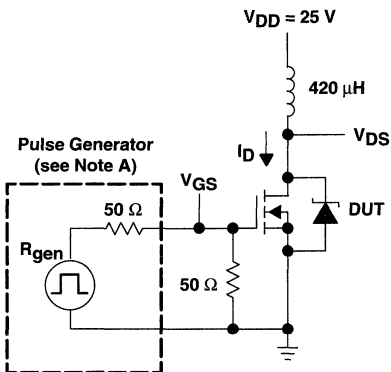
### TEST CIRCUIT

Figure 3. Gate-Charge Test Circuit and Voltage Waveform

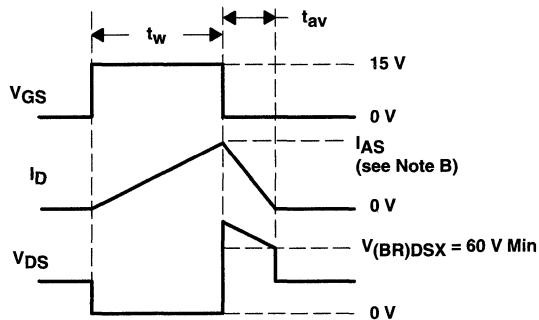
# TPIC3302 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

## PARAMETER MEASUREMENT INFORMATION



**TEST CIRCUIT**



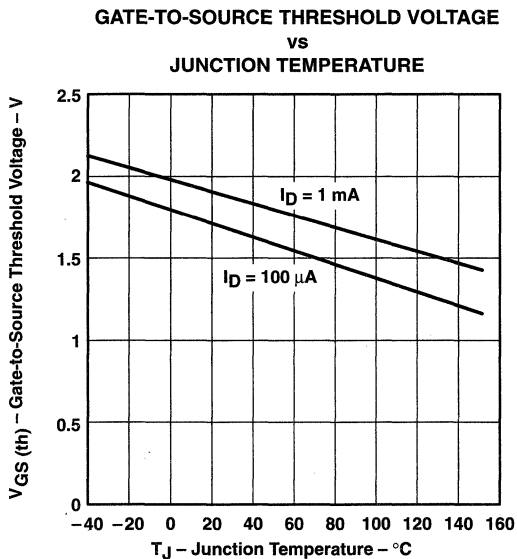
**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 5 \text{ A}$ .

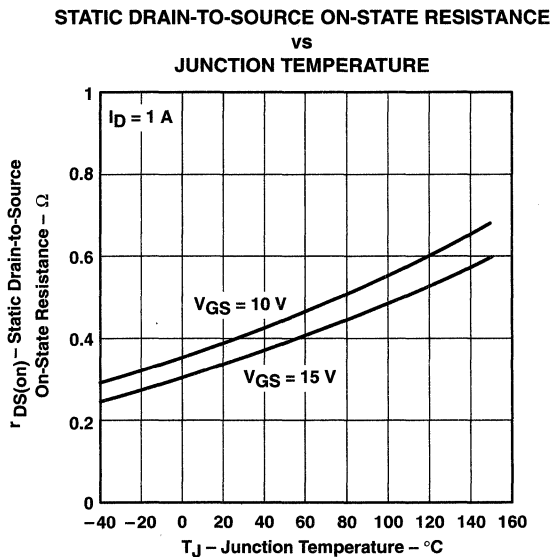
$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 9 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

## TYPICAL CHARACTERISTICS



**Figure 5**



**Figure 6**

# TPIC3302 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

## TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

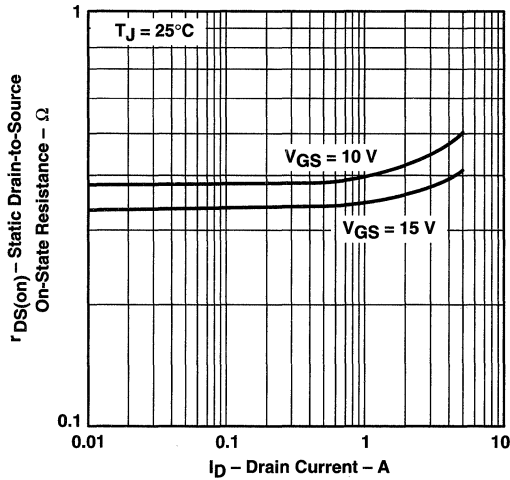


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

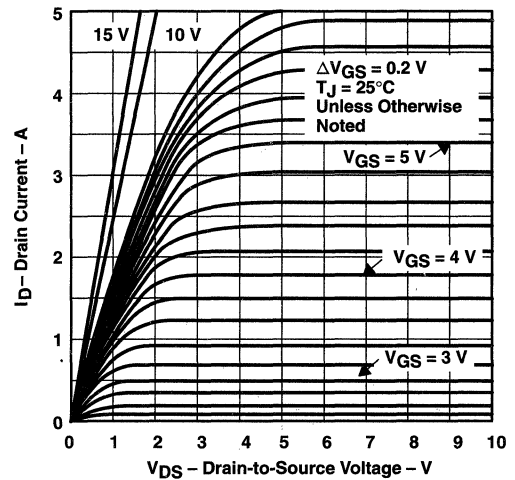


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

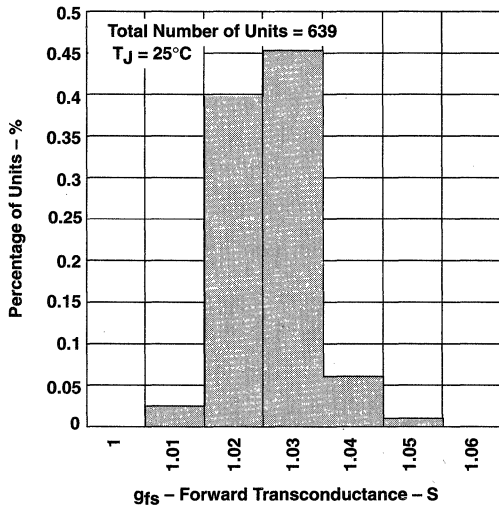


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

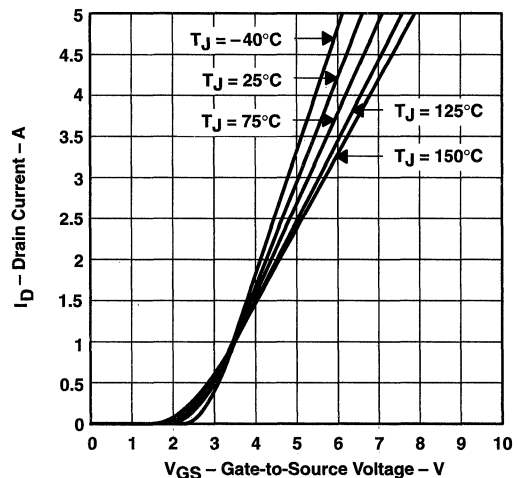


Figure 10

# TPIC3302

## 3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY

SLIS021B – APRIL 1994 – REVISED JULY 1995

### TYPICAL CHARACTERISTICS

**CAPACITANCE  
vs  
DRAIN-TO-SOURCE VOLTAGE**

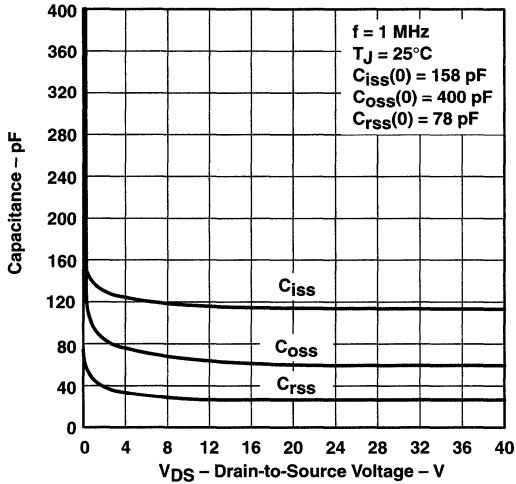


Figure 11

**SOURCE-TO-DRAIN DIODE CURRENT  
vs  
SOURCE-TO-DRAIN VOLTAGE**

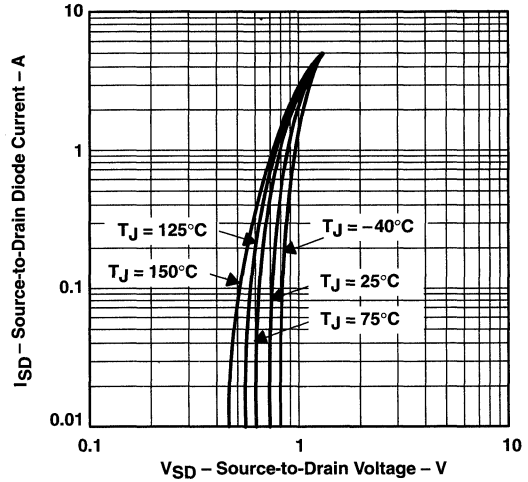


Figure 12

**DRAIN-TO-SOURCE VOLTAGE AND  
GATE-TO-SOURCE VOLTAGE  
vs  
GATE CHARGE**

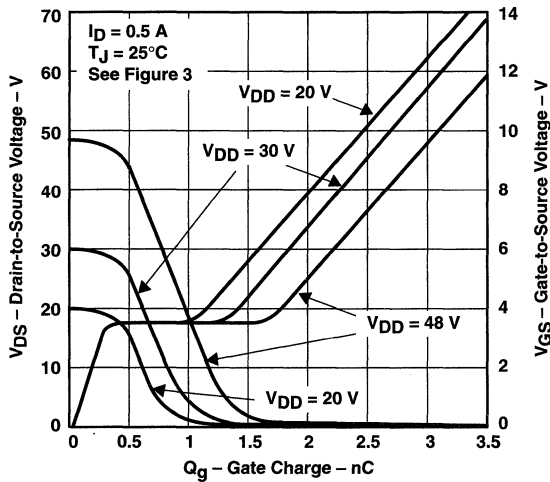


Figure 13

**REVERSE-RECOVERY TIME  
vs  
REVERSE di/dt**

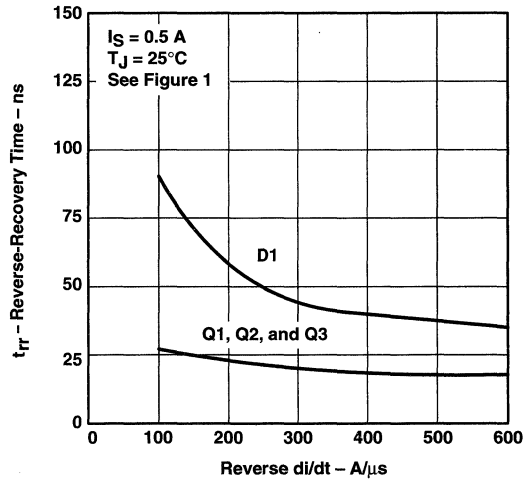


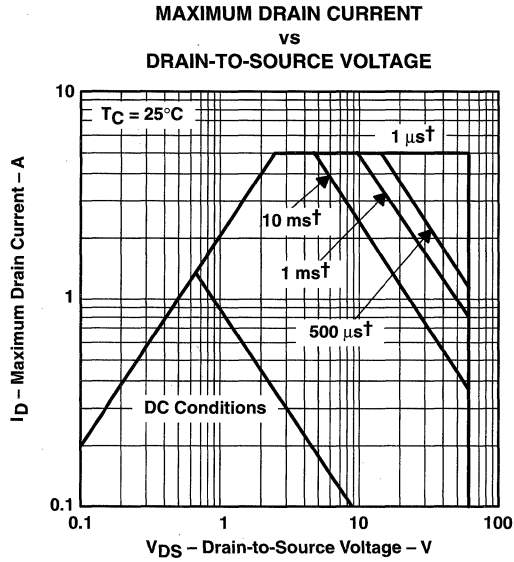
Figure 14



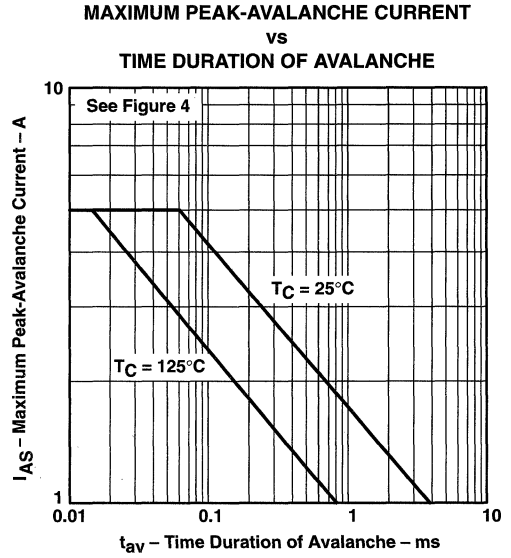
**TPIC3302**  
**3-CHANNEL COMMON-DRAIN POWER DMOS ARRAY**

SLIS021B – APRIL 1994 – REVISED JULY 1995

**THERMAL INFORMATION**

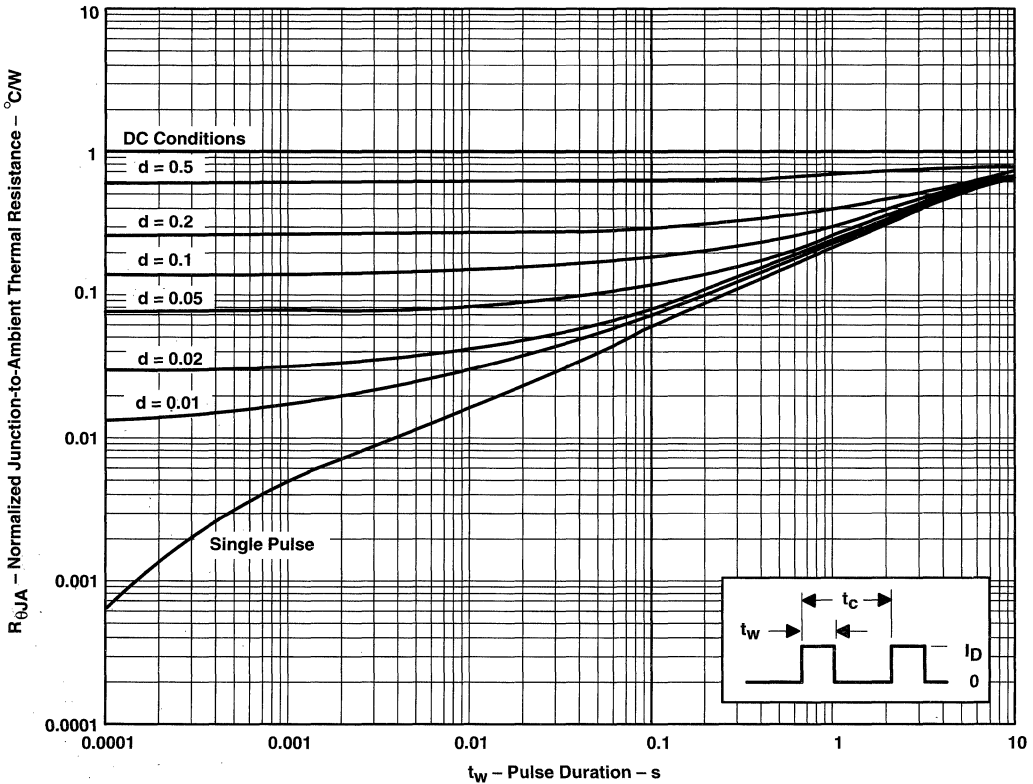


† Less than 0.1 duty cycle



THERMAL INFORMATION

D PACKAGE†  
NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE  
vs  
PULSE DURATION



† Device mounted on FR4 printed-circuit board with no heat sink

NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$

$t_w$  = pulse duration

$t_c$  = cycle time

$d$  = duty cycle =  $t_w/t_c$

Figure 17

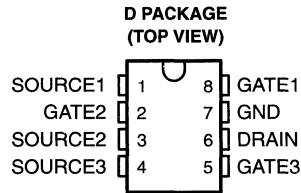


# TPIC3322L

## 3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY

SLIS035B – JUNE 1994 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 0.6  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 2.25 A Per Channel
- Fast Commutation Speed
- Direct Logic-Level Interface

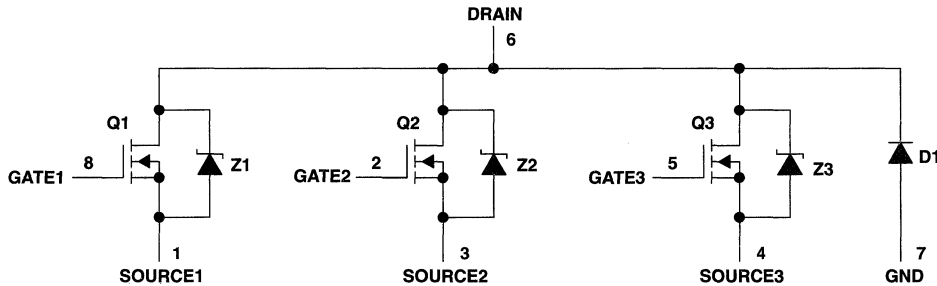


### description

The TPIC3322L is a monolithic logic-level power DMOS transistor array that consists of three isolated N-channel enhancement-mode DMOS transistors configured with a common drain and open sources.

The TPIC3322L is offered in a standard 8-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic diagram



### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$ . . . . .	60 V
Source-to-GND voltage . . . . .	100 V
Drain-to-GND voltage . . . . .	100 V
Gate-to-source voltage, $V_{GS}$ . . . . .	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$ . . . . .	0.75 A
Continuous source-to-drain diode current, $T_C = 25^{\circ}\text{C}$ . . . . .	0.75 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 15) . . . . .	2.25 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^{\circ}\text{C}$ (see Figure 4) . . . . .	19 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$ (see Figure 15) . . . . .	0.95 W
Operating virtual junction temperature range, $T_J$ . . . . .	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$ . . . . .	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range, $T_{stg}$ . . . . .	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	$260^{\circ}\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%.

# TPIC3322L

## 3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 0.75 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 5 \text{ V}$ ,		0.45	0.53	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 0.75 \text{ A}$ , See Notes 2 and 3			1.8		V
$V_F(SD)$	Forward on-state voltage, source-to-drain	$I_S = 0.75 \text{ A}$ , See Notes 2 and 3 and Figure 12	$V_{GS} = 0$ ,		0.85	1	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 0.75 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$		0.6	0.7	$\Omega$
			$T_C = 125^\circ\text{C}$		0.94	1	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 0.5 \text{ A}$ ,		0.75	0.9	S
$C_{iss}$	Short-circuit input capacitance, common source				115	145	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ ,	$V_{GS} = 0$ ,		60	75	
$C_{rSS}$	Short-circuit reverse transfer capacitance, common source	$f = 1 \text{ MHz}$ ,	See Figure 11		30	40	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain and GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 0.375 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , See Figures 1 and 14	$V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ ,	Z1, Z2, Z3	30		ns
				D1	85		
$Q_{RR}$	Total diode charge			Z1, Z2, Z3	0.03		$\mu\text{C}$
				D1	0.19		



# TPIC3322L

## 3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

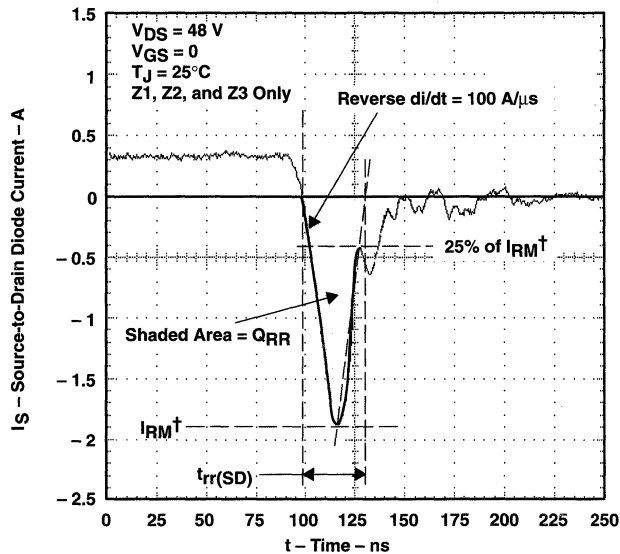
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 67\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2		8	16	ns
$t_{d(off)}$ Turn-off delay time			12	24	
$t_{r2}$ Rise time			14	28	
$t_{f2}$ Fall time			13	26	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.375\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		1.8	2.3	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.4	0.5	
$Q_{gd}$ Gate-to-drain charge			1.1	1.4	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance, See Note 4	All outputs with equal power		130		$^\circ\text{C/W}$
$R_{\theta JC}$ Junction-to-case thermal resistance			44		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink.

### PARAMETER MEASUREMENT INFORMATION



$\dagger I_{RM}$  = maximum recovery current

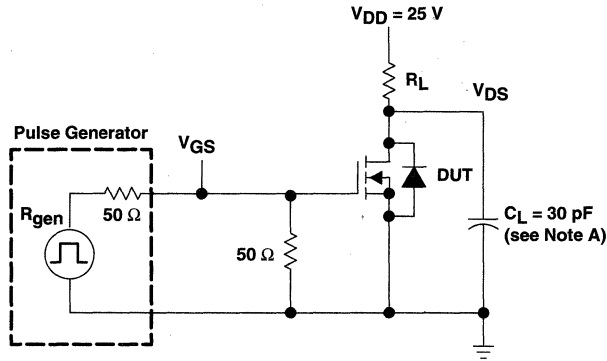
NOTE A. The above waveform represents D1 in shape only.

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode

**TPIC3322L**  
**3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY**

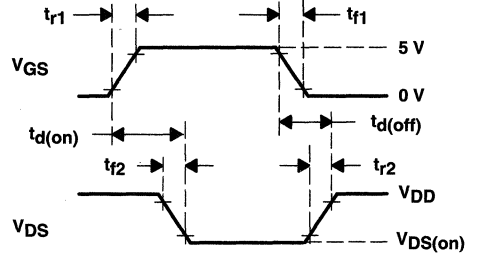
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**PARAMETER MEASUREMENT INFORMATION**



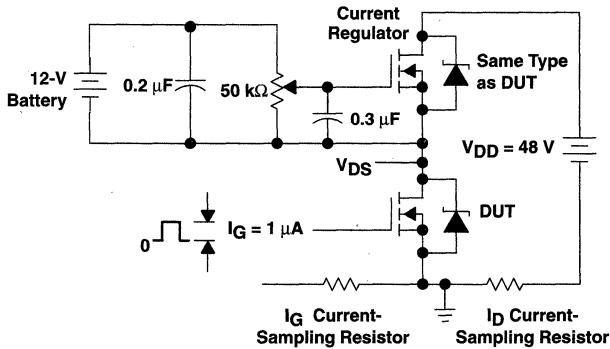
**TEST CIRCUIT**

NOTE A:  $C_L$  includes probe and jig capacitance.

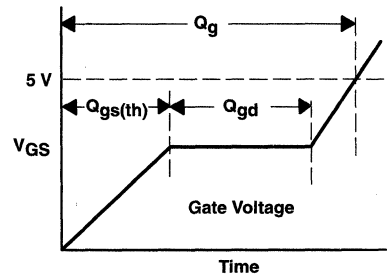


**VOLTAGE WAVEFORMS**

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**



**TEST CIRCUIT**



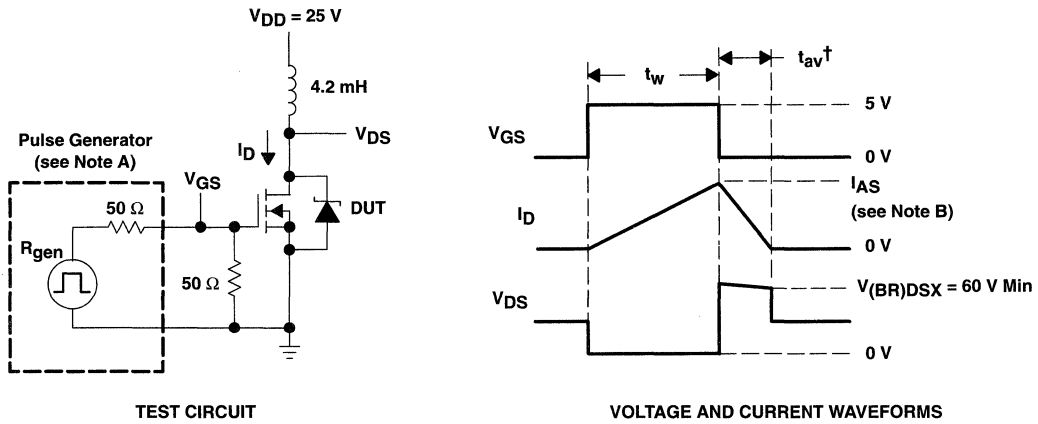
**VOLTAGE WAVEFORM**

**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**

**TPIC3322L**  
**3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY**

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**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**

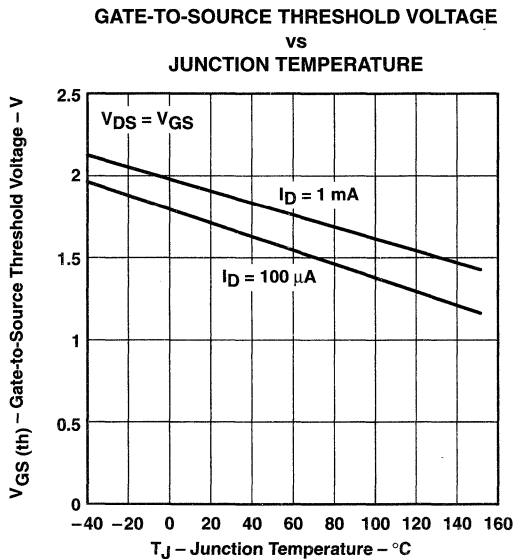
† Non-JEDEC symbol for avalanche time

NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 2.25$  A.

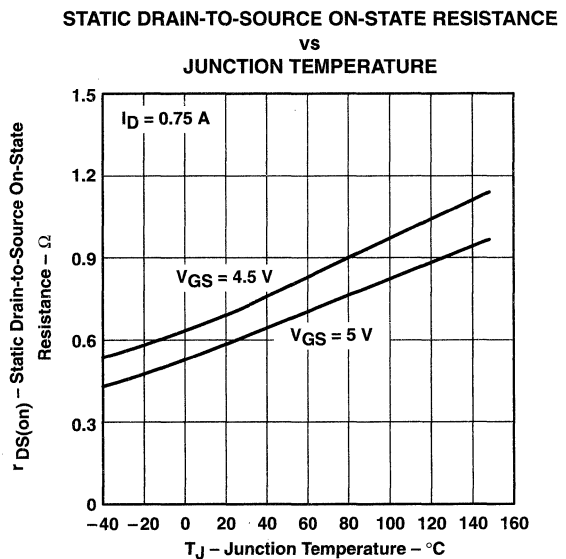
Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 19$  mJ, where  $t_{av}$  = avalanche time.

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**



**Figure 5**



**Figure 6**

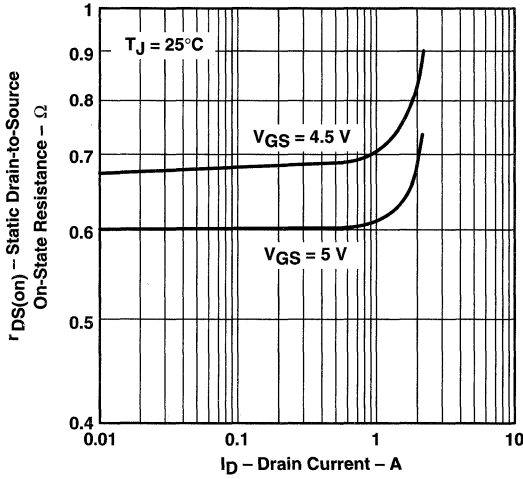


**TPIC3322L**  
**3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY**

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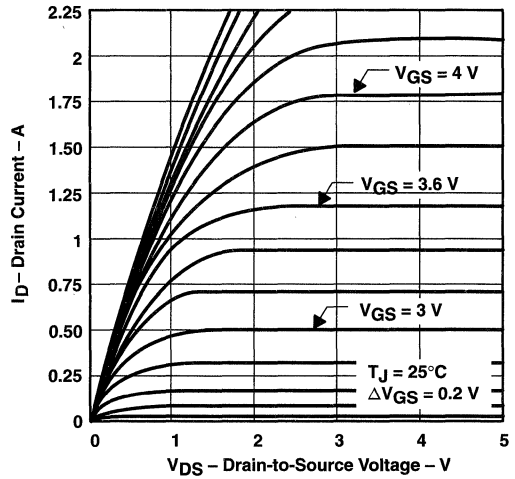
**TYPICAL CHARACTERISTICS**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE vs DRAIN CURRENT**



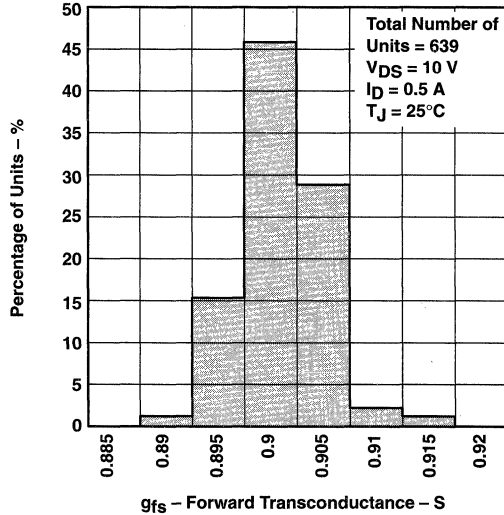
**Figure 7**

**DRAIN CURRENT vs DRAIN-TO-SOURCE VOLTAGE**



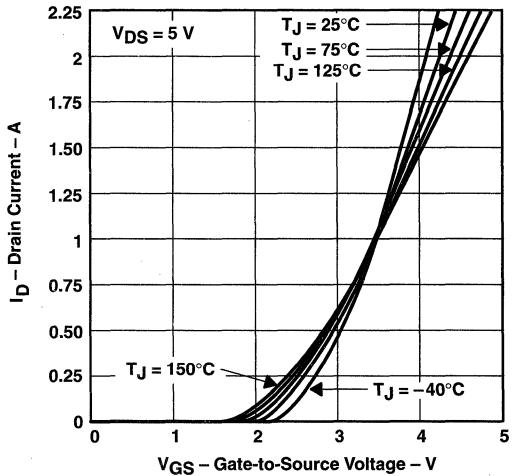
**Figure 8**

**DISTRIBUTION OF FORWARD TRANSCONDUCTANCE**



**Figure 9**

**DRAIN CURRENT vs GATE-TO-SOURCE VOLTAGE**



**Figure 10**

# TPIC3322L

## 3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY

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### TYPICAL CHARACTERISTICS

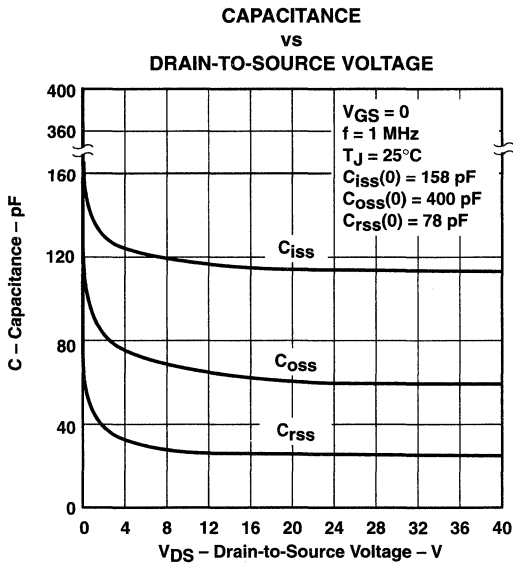


Figure 11

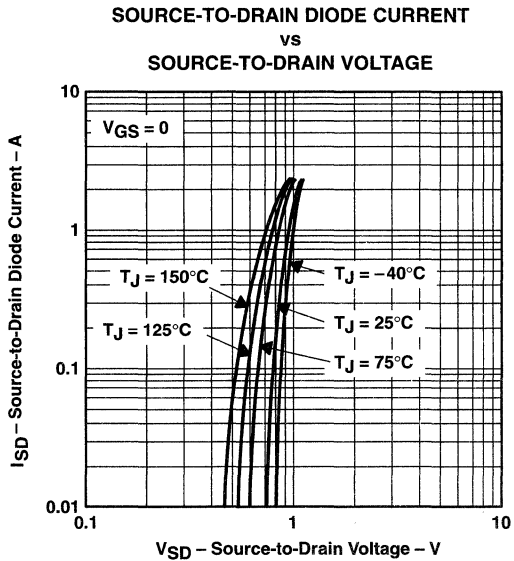


Figure 12

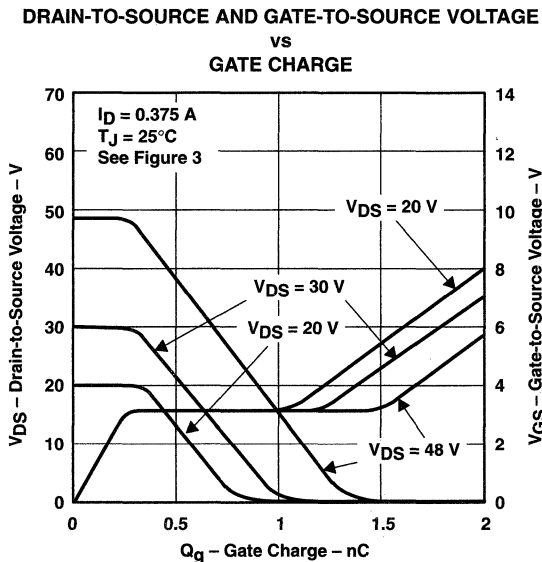


Figure 13

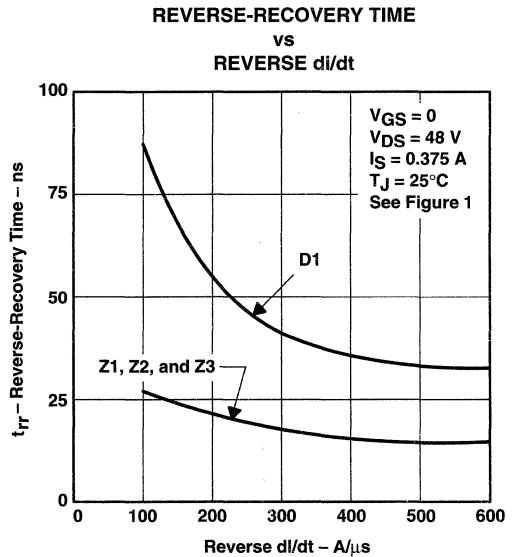
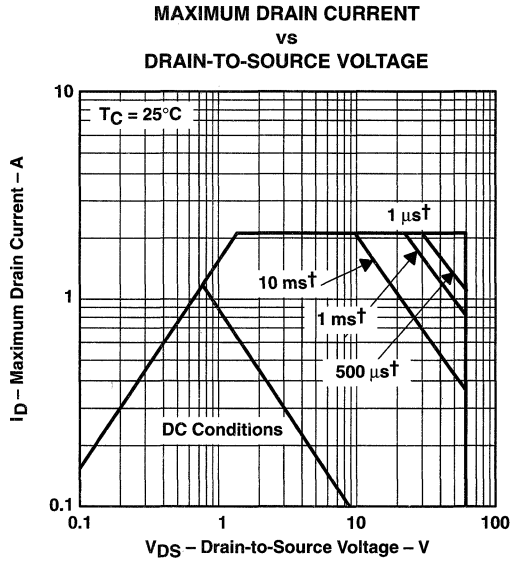


Figure 14

**TPIC3322L**  
**3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY**

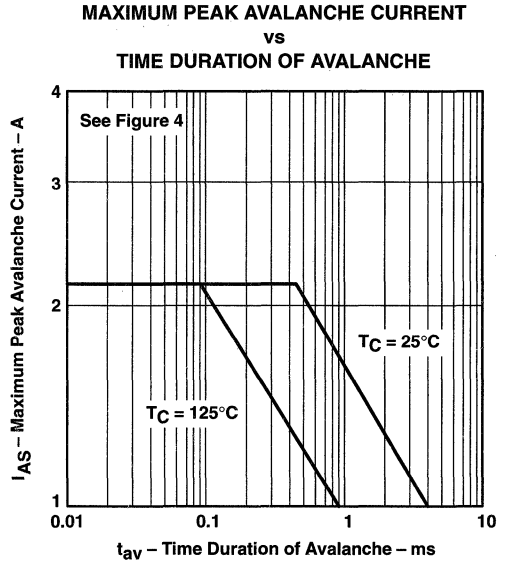
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**THERMAL INFORMATION**



† Less than 2% duty cycle

**Figure 15**



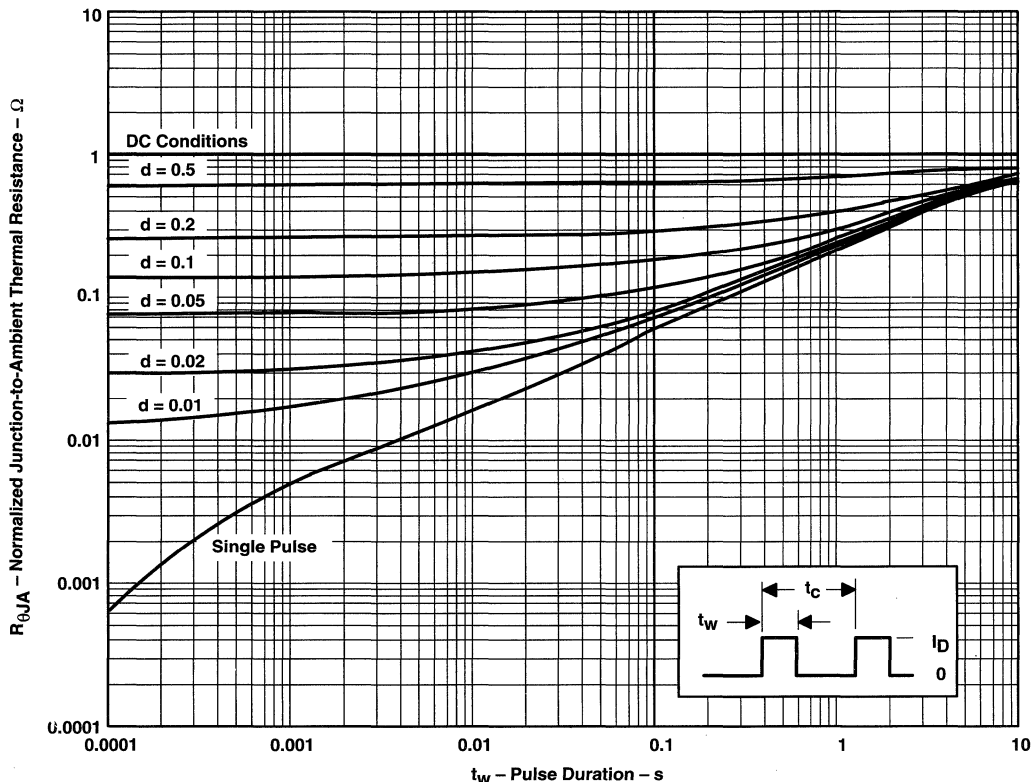
**Figure 16**

**TPIC3322L**  
**3-CHANNEL COMMON-DRAIN LOGIC-LEVEL POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE†  
vs  
PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heat sink.

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$

$t_w$  = pulse duration

$t_c$  = cycle time

$d$  = duty cycle =  $t_w/t_c$

**Figure 17**



# TPIC5201 DUAL POWER DMOS ARRAY

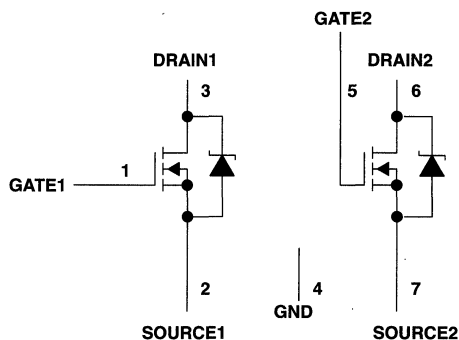
SLIS020 – SEPTEMBER 1992

- Two 7.5-A Independent Output Channels, Continuous Current Per Channel
- Low  $r_{DS(on)}$  ... 0.09  $\Omega$  Typical
- Output Voltage ... 60 V
- Pulsed Current ... 15 A Per Channel
- Avalanche Energy ... 120 mJ

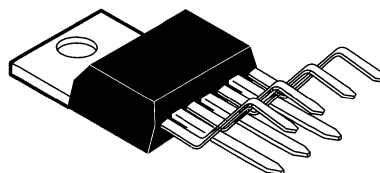
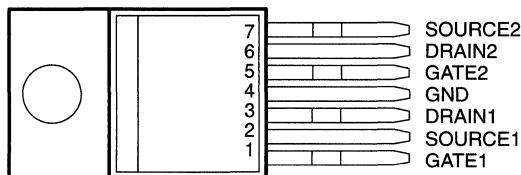
## description

The TPIC5201 is a power monolithic DMOS array that consists of dual independent N-channel enhancement-mode DMOS transistors.

## schematic



KV PACKAGE  
(TOP VIEW)



To ensure correct device operation, the source and the drain of the same transistor cannot simultaneously be taken below GND.

The tab is electrically connected to GND.

## absolute maximum ratings over operating case temperature range (unless otherwise noted)

Drain-source voltage, $V_{DS}$ .....	60 V
Source-GND voltage .....	60 V
Drain-GND voltage .....	60 V
Gate-source voltage, $V_{GS}$ .....	$\pm 20$ V
Continuous source-drain diode current .....	7.5 A
Pulsed drain current, each output, all outputs on, $I_D$ (see Note 1) .....	15 A
Continuous drain current, each output, all outputs on .....	7.5 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4) .....	120 mJ
Continuous power dissipation at (or below) $T_A = 25^\circ\text{C}$ (see Note 2) .....	2 W
Continuous power dissipation at (or below) $T_C = 75^\circ\text{C}$ , all outputs on (see Note 2) .....	31 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

NOTES: 1. Pulse duration = 10 ms, duty cycle = 6%

2. For operation above  $25^\circ\text{C}$  free-air temperature, derate linearly at the rate of 16 mW/ $^\circ\text{C}$ . For operation above  $75^\circ\text{C}$  case temperature, and with all outputs conducting, derate linearly at the rate of 0.42 W/ $^\circ\text{C}$ . To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

 **TEXAS  
INSTRUMENTS**

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# TPIC5201

## DUAL POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DS}$ Drain-source breakdown voltage	$I_D = 1 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{TGS}$ Gate-source threshold voltage	$I_D = 1 \text{ mA}$ , $V_{DS} = V_{GS}$	1.2	1.75	2.4	V
$V_{DS(on)}$ Drain-source on-state voltage	$I_D = 7.5 \text{ A}$ , $V_{GS} = 15 \text{ V}$ , See Notes 3 and 4		0.68	0.94	V
$V_{DSS}$ Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{DS} = 0$	$T_C = 25^\circ\text{C}$	0.07	1	$\mu\text{A}$
		$T_C = 125^\circ\text{C}$	1.3	10	
$I_{GSSF}$ Forward gate current, drain short circuited to source	$V_{GS} = 20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$ Reverse gate current, drain short circuited to source	$V_{GS} = -20 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$r_{DS(on)}$ Static drain-source on-state resistance	$V_{GS} = 15 \text{ V}$ , $I_D = 7.5 \text{ A}$ , See Notes 3 and 4 and Figures 5 and 6	$T_C = 25^\circ\text{C}$	0.09	0.125	$\Omega$
		$T_C = 125^\circ\text{C}$	0.15	0.21	
$g_{fs}$ Forward transconductance	$V_{DS} = 15 \text{ V}$ , $I_D = 5 \text{ A}$ , See Notes 3 and 4	2.5	4.7		S
$C_{iss}$ Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $V_{GS} = 0$ , $f = 300 \text{ kHz}$		490		pF
$C_{oss}$ Short-circuit output capacitance, common source			285		
$C_{rss}$ Short-circuit reverse transfer capacitance, common source			90		

NOTES: 3. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

4. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{SD}$ Forward on voltage	$I_S = 7.5 \text{ A}$ , $V_{GS} = 0$ ,	0.8	1.3		V
$t_{rr}$ Reverse-recovery time	$di/dt = 100 \text{ A}/\mu\text{s}$ , $V_{DS} = 48 \text{ V}$ , See Figure 1		200		ns
$Q_{RR}$ Total source-drain diode charge			1.5		$\mu\text{C}$

### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

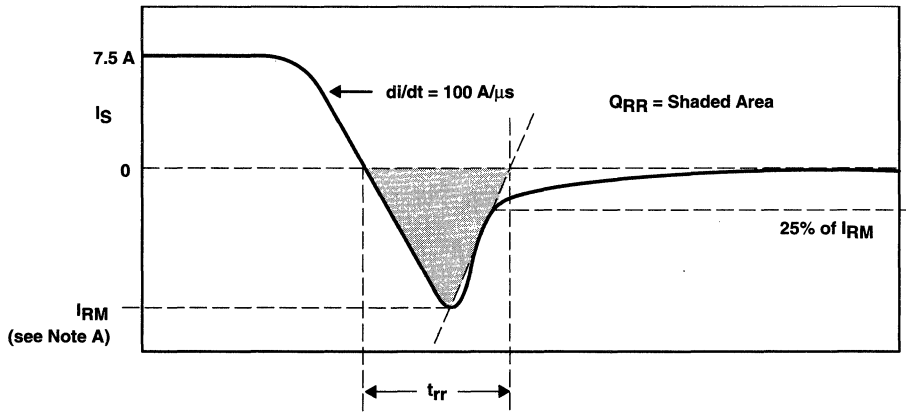
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25 \text{ V}$ , $R_L = 6.7 \Omega$ , $t_{en} = 10 \text{ ns}$ , $t_{dis} = 10 \text{ ns}$ , See Figure 2		12		ns
$t_r$ Rise time			43		
$t_{d(off)}$ Turn-off delay time			100		
$t_f$ Fall time			5		
$Q_g$ Total gate charge	$V_{DD} = 48 \text{ V}$ , $I_D = 2.5 \text{ A}$ , $V_{GS} = 15$ , See Figure 3		13.6	18	nC
$Q_{gs}$ Gate-source charge			8.3	11	
$Q_{gd}$ Gate-drain charge			5.3	7	
$L_D$ Internal drain inductance			7		nH
$L_S$ Internal source inductance			7		

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power			62.5	$^\circ\text{C}/\text{W}$
$R_{\theta JC}$ Junction-to-case thermal resistance	All outputs with equal power			2.4	$^\circ\text{C}/\text{W}$
	One output dissipating power			3.3	$^\circ\text{C}/\text{W}$



PARAMETER MEASUREMENT INFORMATION



NOTE A:  $I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveforms of Source-Drain Diode

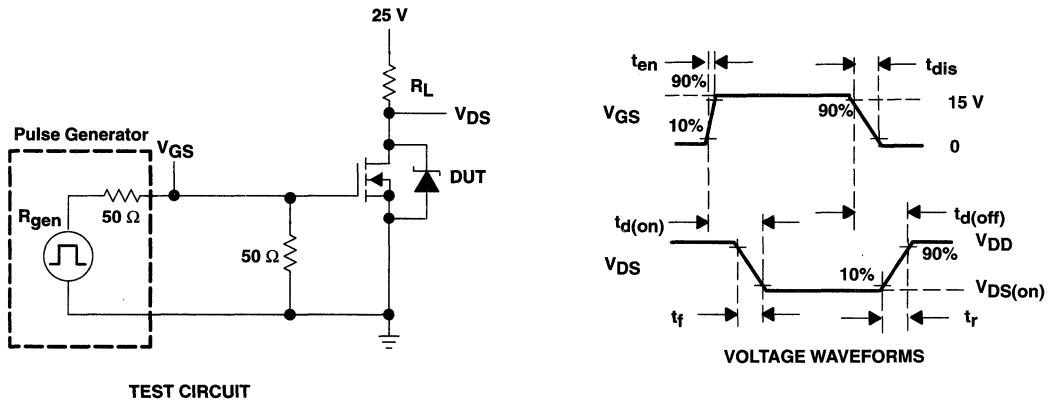


Figure 2. Resistive Switching



# TPIC5201 DUAL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION

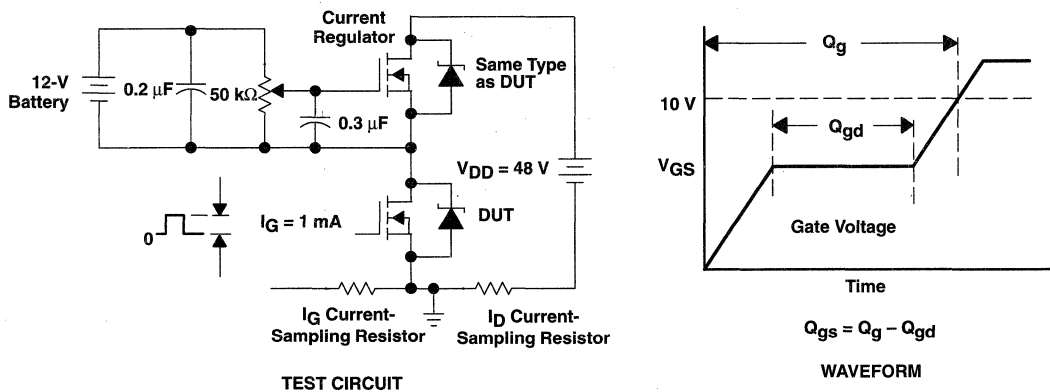
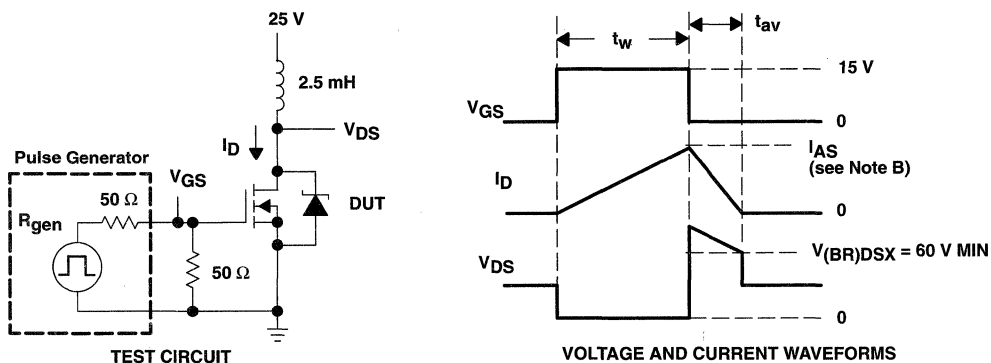


Figure 3. Gate Charge Test Circuit and Waveform



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 7.5$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 120 \text{ mJ min.}$$

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

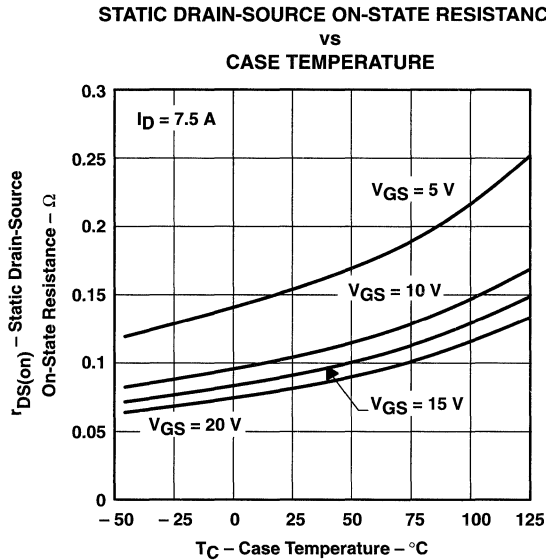


Figure 5

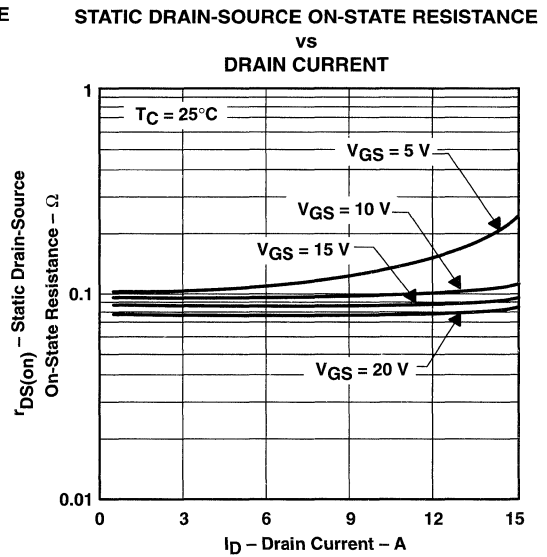


Figure 6

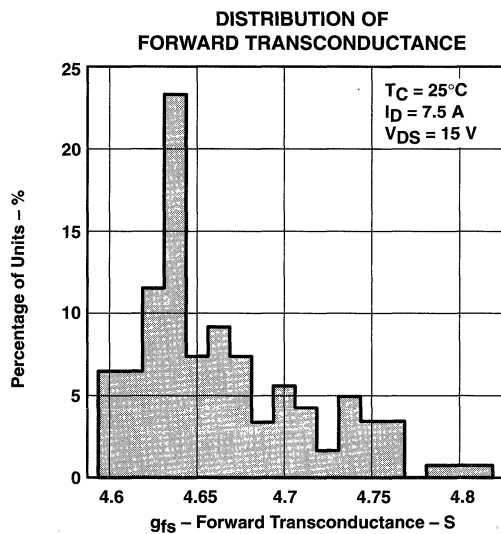


Figure 7

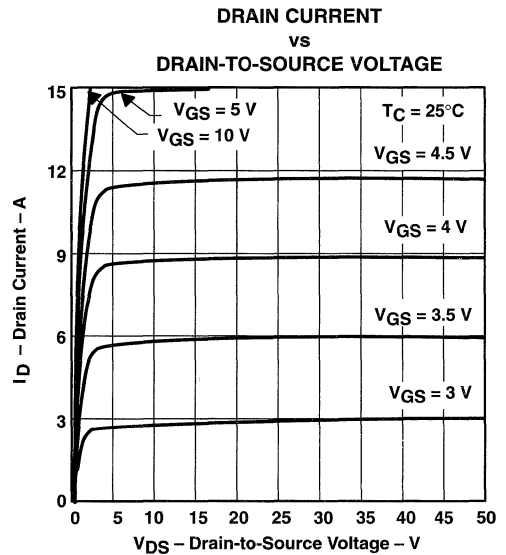


Figure 8

# TPIC5201 DUAL POWER DMOS ARRAY

SLIS020 – SEPTEMBER 1992

## TYPICAL CHARACTERISTICS

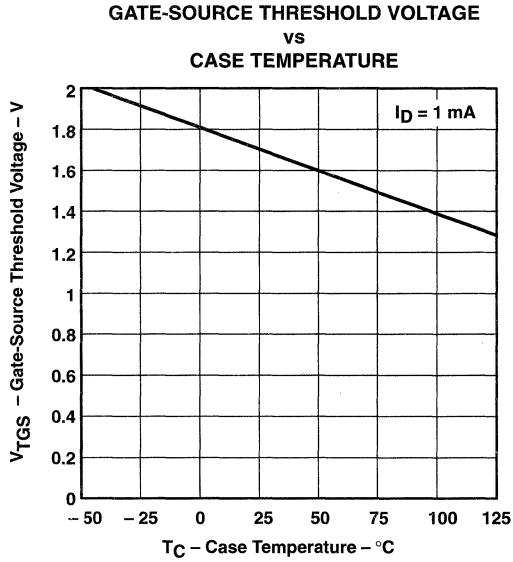


Figure 9

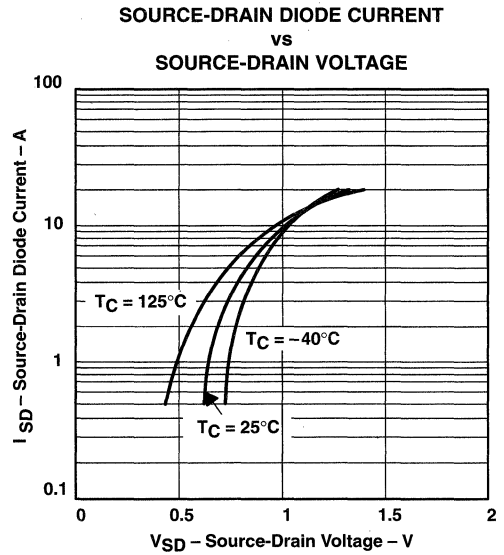


Figure 10

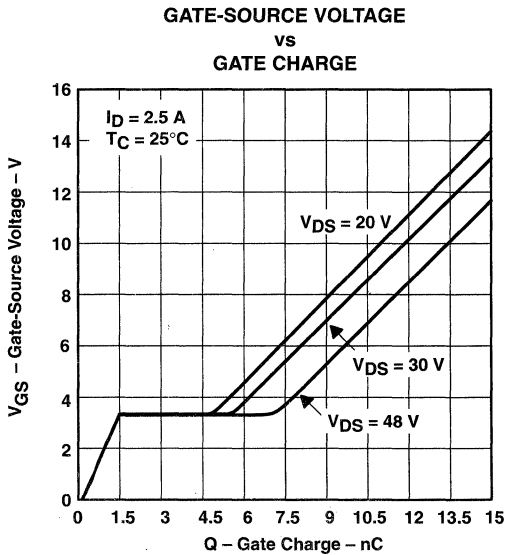


Figure 11

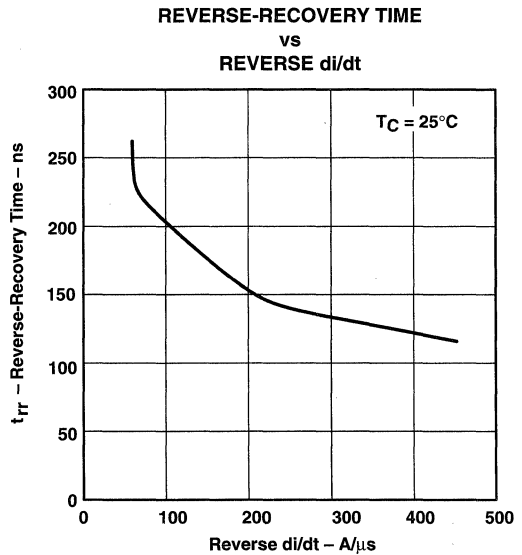


Figure 12

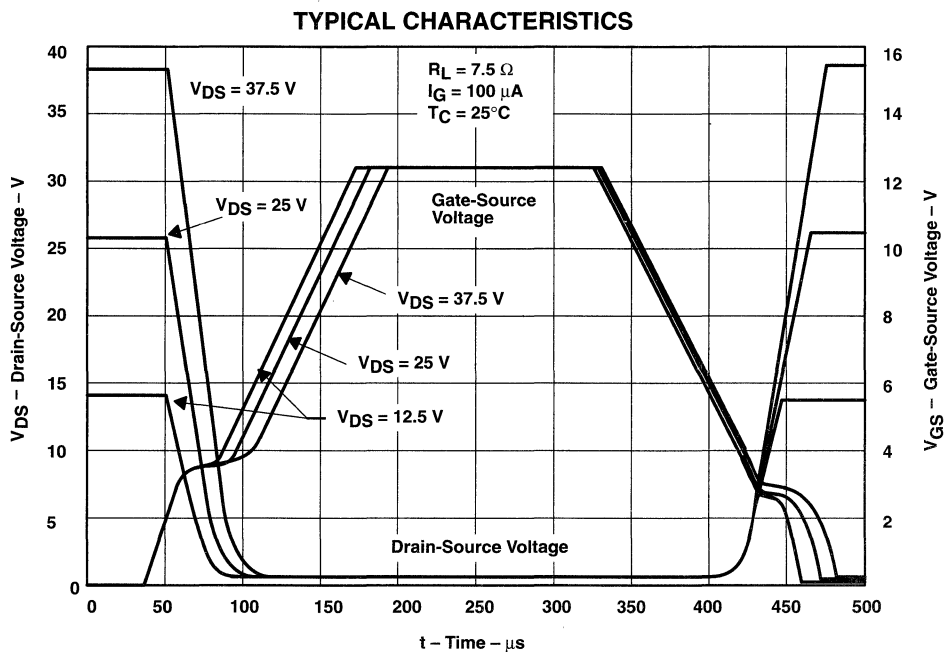


Figure 13. Resistive Switching Waveforms

# TPIC5201 DUAL POWER DMOS ARRAY

SLIS020 – SEPTEMBER 1992

## THERMAL INFORMATION

MAXIMUM DRAIN CURRENT  
vs  
DRAIN-SOURCE VOLTAGE

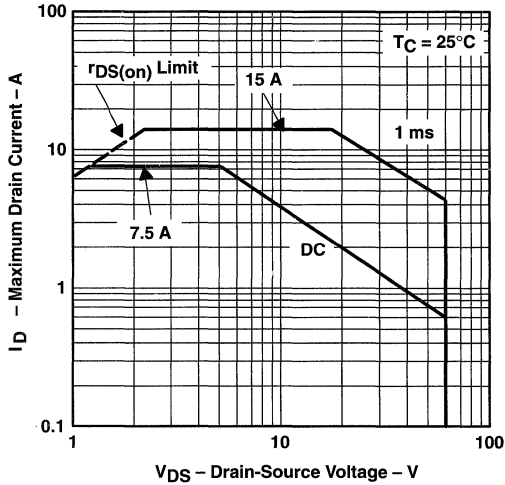


Figure 14

MAXIMUM PEAK AVALANCHE CURRENT  
vs  
TIME DURATION OF AVALANCHE

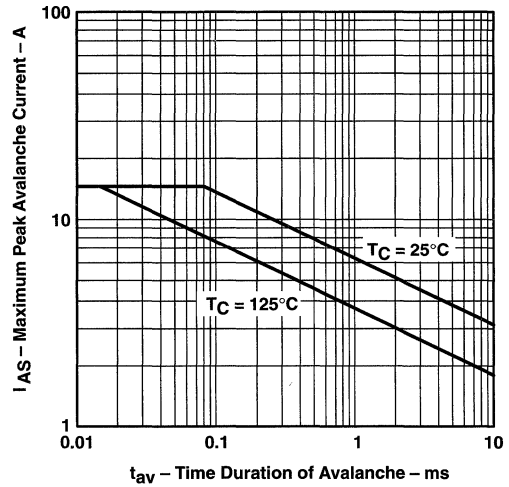
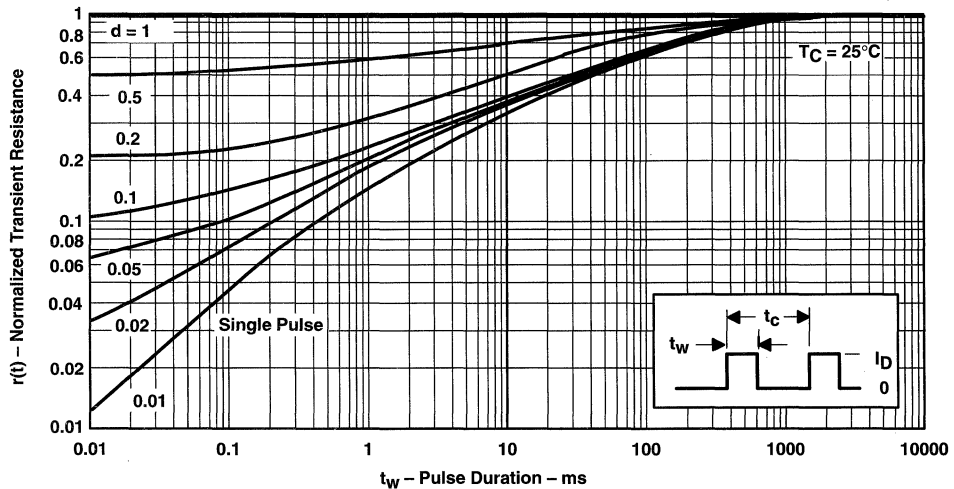


Figure 15

NORMALIZED TRANSIENT THERMAL IMPEDANCE  
vs  
SQUARE-WAVE PULSE DURATION



NOTES:  $Z_{\theta JC}(t) = r(t) R_{\theta JC}$   
 $t_w$  = pulse duration  
 $t_c$  = period  
 $d$  = duty cycle =  $t_w/t_c$

Figure 16

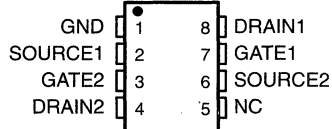
# TPIC5203

## 2-CHANNEL INDEPENDENT GATE-PROTECTED POWER DMOS ARRAY

SLIS040 – SEPTEMBER 1994

- Low  $r_{DS(on)}$  . . . 0.26  $\Omega$  Typ
- High Voltage Output . . . 60 V
- Extended ESD Capability . . . 4000 V
- Pulsed Current . . . 8 A Per Channel
- Fast Commutation Speed

**D PACKAGE  
(TOP VIEW)**



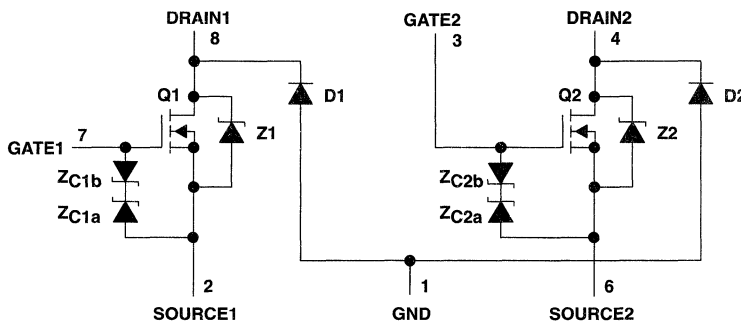
NC – No internal connection

### description

The TPIC5203 is a monolithic gate-protected power DMOS array that consists of two independent electrically isolated N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5203 is offered in a standard eight-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



NOTE: For correct operation, no terminal pin may be taken below GND.

**TPIC5203**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS040 – SEPTEMBER 1994

**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage (Q1, Q2)	100 V
Drain-to-GND voltage (Q1, Q2)	100 V
Gate-to-source voltage range, $V_{GS}$	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$	1.6 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$	1.6 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15)	8 A
Continuous gate-to-source zener diode current, $T_C = 25^\circ\text{C}$	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15, and 16)	21.6 mJ
Continuous total dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15)	962 mW
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC5203**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**  
 SLIS040 – SEPTEMBER 1994

**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	1.5	2.05	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$	18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$	9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = $250 \mu\text{A}$	100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.6 \text{ A}$ , See Notes 2 and 3		0.42	0.5	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.6 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2), See Notes 2 and 3 and Figure 12		1	1.2	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.6 \text{ A}$ (D1, D2), See Notes 2 and 3		5		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ , $V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{kg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1.6 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.26	0.31	$\Omega$
			$T_C = 125^\circ\text{C}$	0.41	0.45	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 800 \text{ mA}$	1.5	1.83	S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ , $V_{GS} = 0$ , See Figure 11		150	275	pF
$C_{oss}$	Short-circuit output capacitance, common source			100	150	
$C_{rss}$	Short-circuit reverse transfer capacitance, common source			40	125	

- NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 800 \text{ mA}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , Z1 and Z2		50	ns
			D1 and D2		265	
$Q_{RR}$	Total diode charge		Z1 and Z2		63	nC
			D1 and D2		1240	



**TPIC5203**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**  
 SLIS040 – SEPTEMBER 1994

**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

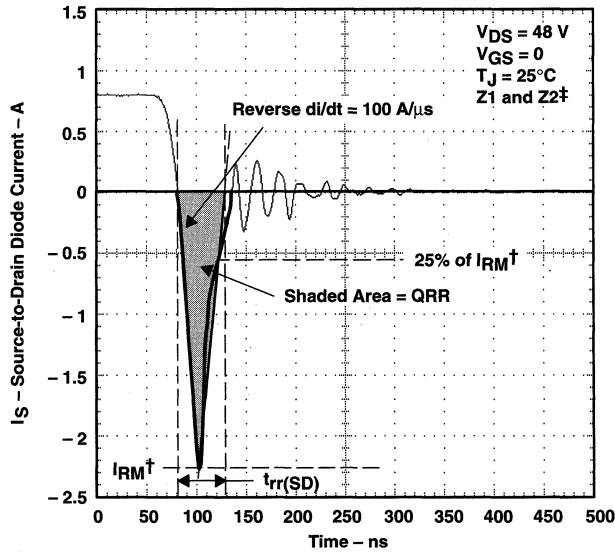
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 30\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		25	50	ns
$t_{d(off)}$ Turn-off delay time			27	50	
$t_r$ Rise time			15	30	
$t_f$ Fall time			7	15	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.8\text{ A}$ , $V_{GS} = 10\text{ V}$ , See Figure 3		4.7	5.9	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.5	0.6	
$Q_{gd}$ Gate-to-drain charge			1.9	2.4	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		130		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		79		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		34		

- NOTES: 4. Package mounted on an FR4 printed-circuit board with no heatsink  
 5. Package mounted on a 24 inch<sup>2</sup>, 4-layer FR4 printed-circuit board  
 6. Package mounted in intimate contact with infinite heatsink  
 7. All outputs with equal power

**PARAMETER MEASUREMENT INFORMATION**



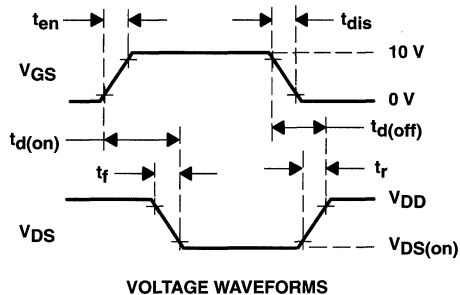
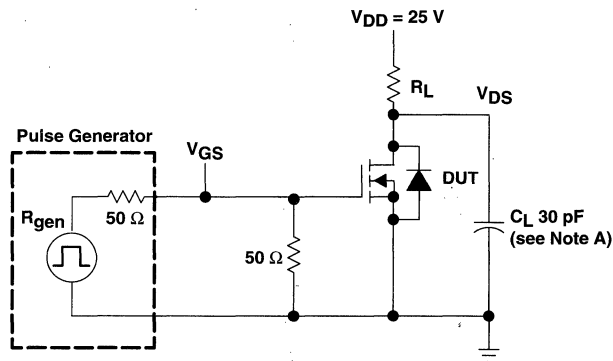
†  $I_{RM}$  = maximum recovery current

‡ The above waveform is representative of D1 and D2 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**



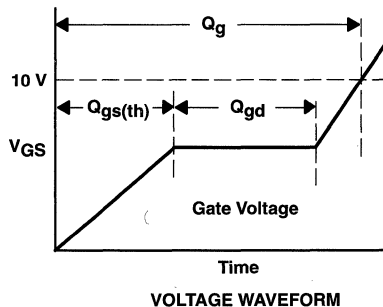
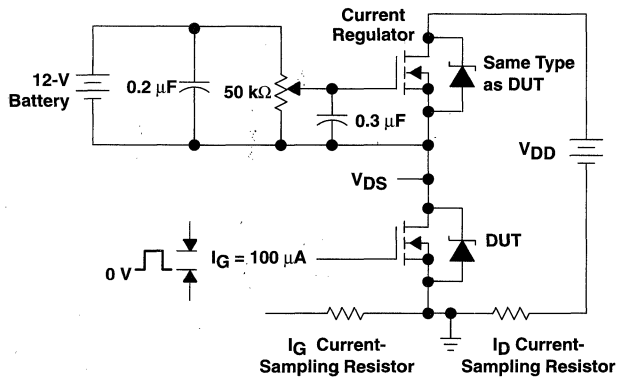
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

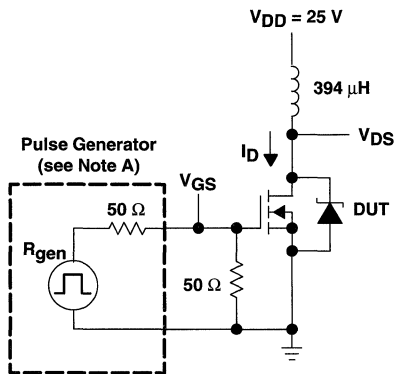
Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



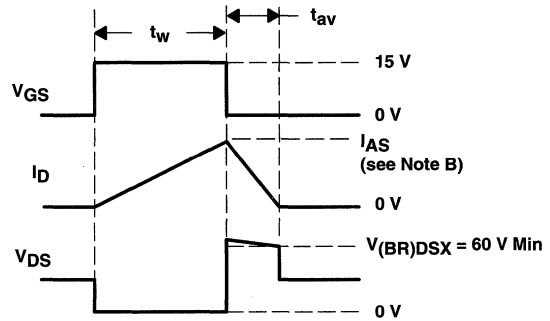
TEST CIRCUIT

Figure 3. Gate-Charge Test Circuit and Voltage Waveform

**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**



**VOLTAGE AND CURRENT WAVEFORMS**

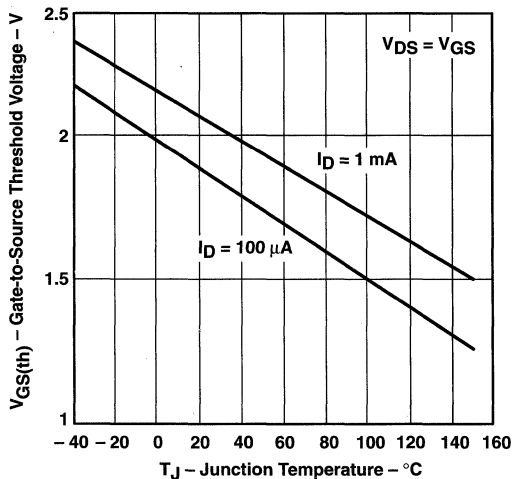
- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 8$  A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 21.6$  mJ.

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

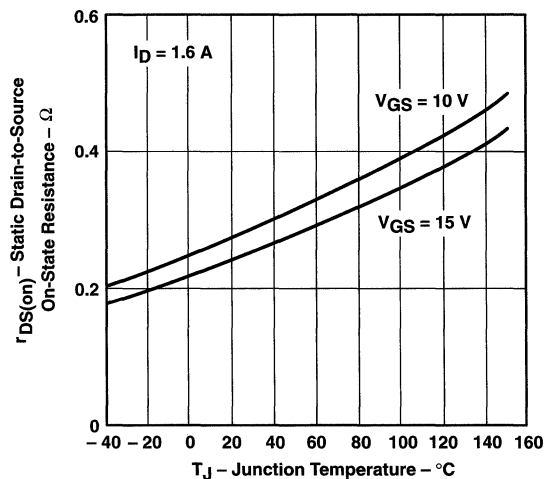
**TYPICAL CHARACTERISTICS**

**GATE-TO-SOURCE THRESHOLD VOLTAGE**  
 vs  
**JUNCTION TEMPERATURE**



**Figure 5**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
 vs  
**JUNCTION TEMPERATURE**



**Figure 6**

TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
 vs  
 DRAIN CURRENT

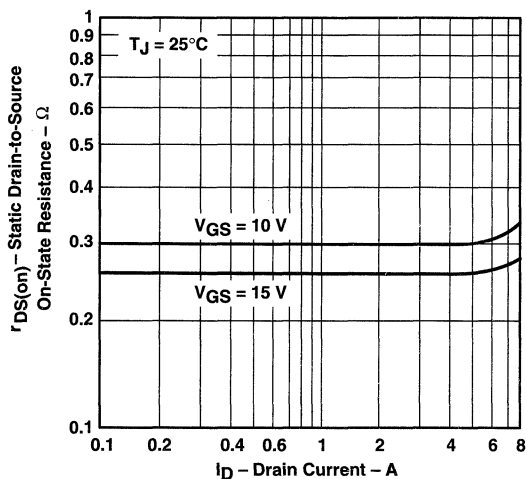


Figure 7

DRAIN CURRENT  
 vs  
 DRAIN-TO-SOURCE VOLTAGE

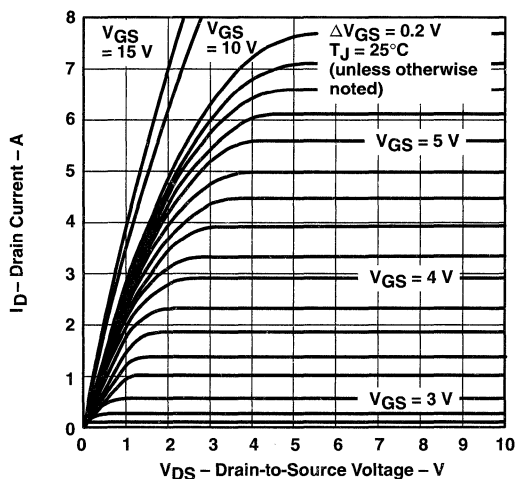


Figure 8

DISTRIBUTION OF  
 FORWARD TRANSCONDUCTANCE

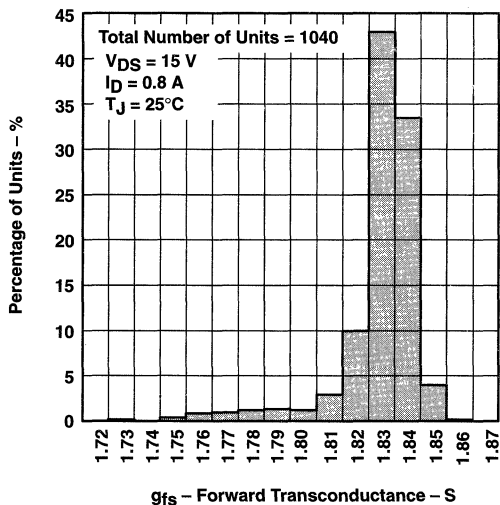


Figure 9

DRAIN CURRENT  
 vs  
 GATE-TO-SOURCE VOLTAGE

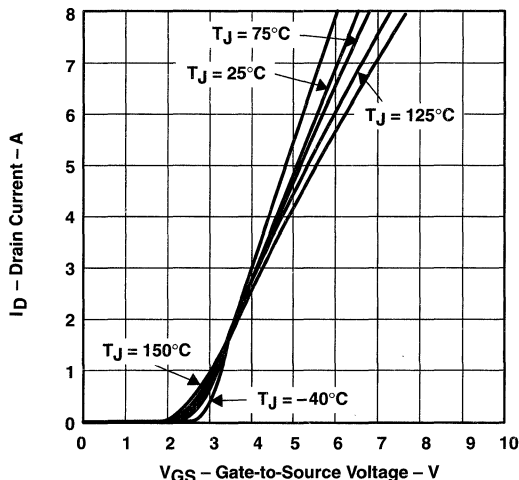
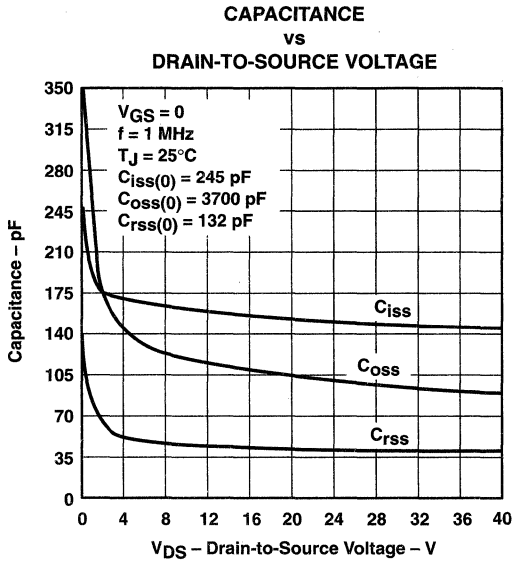
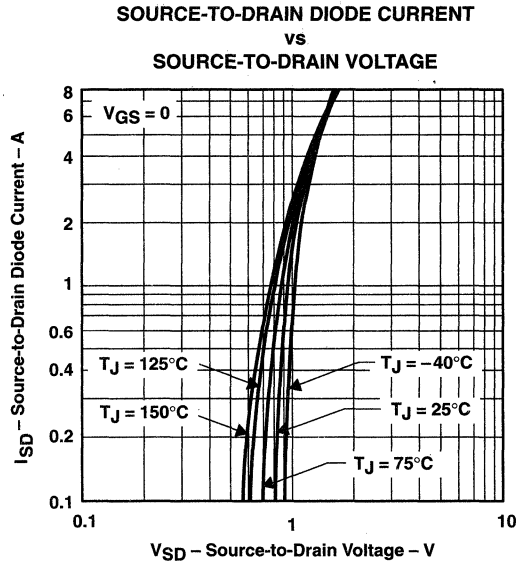


Figure 10

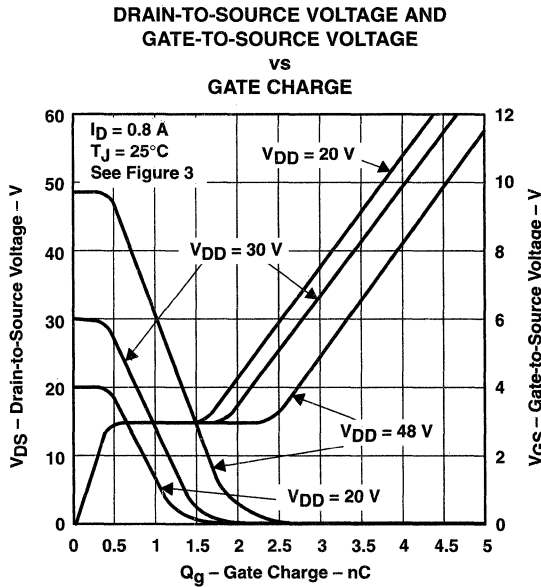
**TYPICAL CHARACTERISTICS**



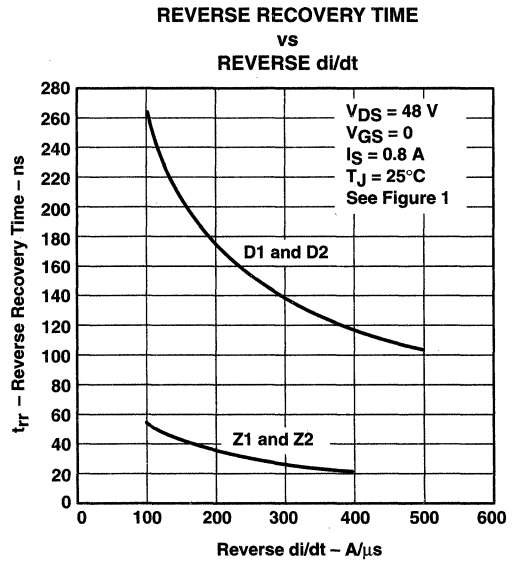
**Figure 11**



**Figure 12**

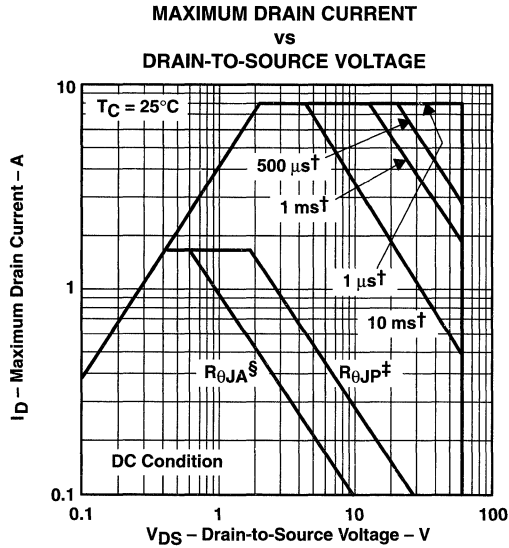


**Figure 13**

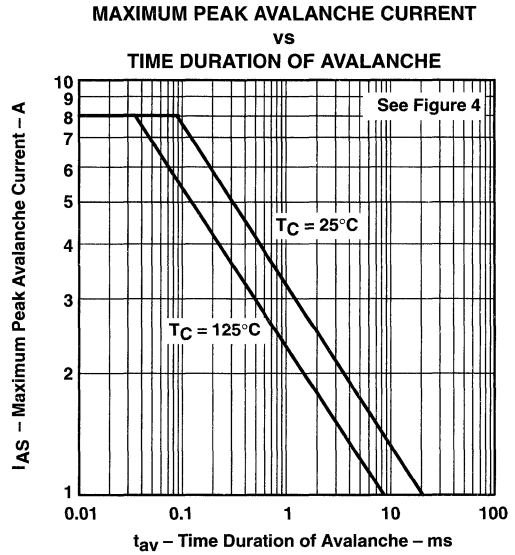


**Figure 14**

**THERMAL INFORMATION**

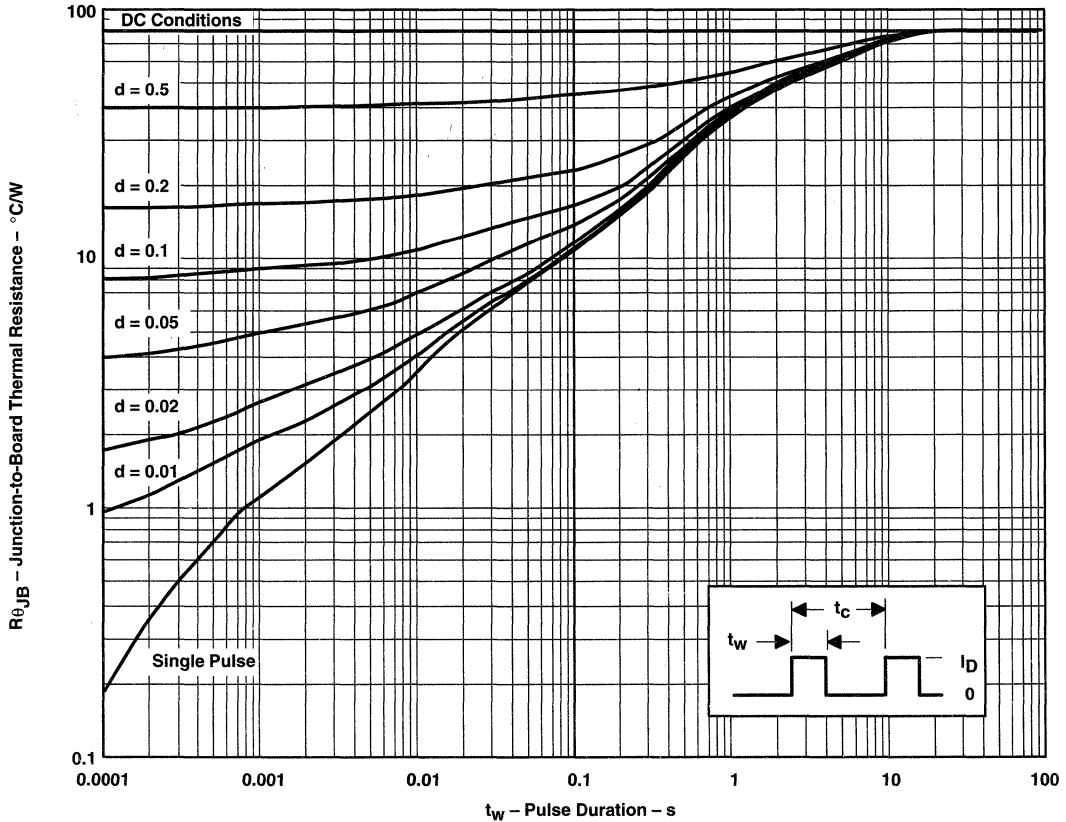


† Less than 2% duty cycle  
 ‡ Device mounted in intimate contact with infinite heatsink.  
 § Device mounted on FR4 printed circuit board with no heatsink.



TPIC5203  
 2-CHANNEL INDEPENDENT GATE-PROTECTED  
 POWER DMOS ARRAY  
 SLIS040 – SEPTEMBER 1994

THERMAL INFORMATION  
 D PACKAGE†  
 JUNCTION-TO-BOARD THERMAL RESISTANCE  
 vs  
 PULSE DURATION



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink

NOTE A.  $Z_{\theta JB}(t) = r(t)R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

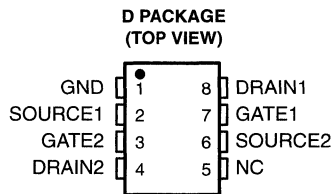
Figure 17

# TPIC5223L

## 2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

SLIS043A – NOVEMBER 1994 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 0.38  $\Omega$  Typ
- Voltage Output . . . 60 V
- Input Protection Circuitry . . . 18 V
- Pulsed Current . . . 3 A Per Channel
- Extended ESD Capability . . . 4000 V
- Direct Logic-Level Interface



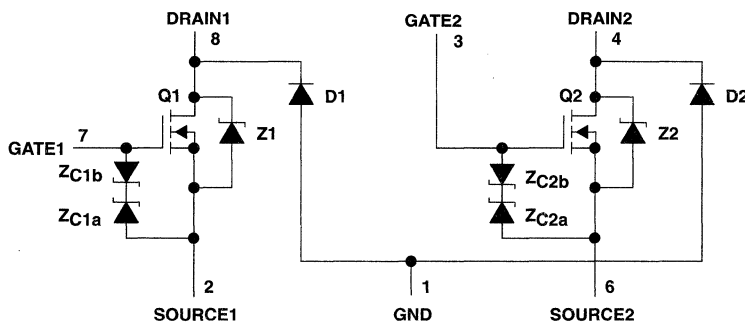
NC – No internal connection

### description

The TPIC5223L is a monolithic gate-protected logic-level power DMOS array that consists of two electrically isolated independent N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5223L is offered in a standard eight-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



NOTE A: For correct operation, no terminal may be taken below GND.



**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

SLIS043A – NOVEMBER 1994 – REVISED SEPTEMBER 1995

**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage .....	100 V
Drain-to-GND voltage .....	100 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	3 A
Continuous gate-to-source zener diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16) .....	108 mJ
Continuous total power dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15) .....	0.95 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

SLIS043A – NOVEMBER 1994 – REVISED SEPTEMBER 1995

**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250\ \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1\ \text{mA}$ , See Figure 5	1.5	2.05	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250\ \mu\text{A}$	18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250\ \mu\text{A}$	9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = $250\ \mu\text{A}$	100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1\ \text{A}$ , See Notes 2 and 3		0.375	0.425	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1\ \text{A}$ , $V_{GS} = 0$ (Z1, Z2), See Notes 2 and 3 and Figure 12		0.85	1.2	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1\ \text{A}$ (D1, D2), See Notes 2 and 3		3		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48\ \text{V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15\ \text{V}$ , $V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5\ \text{V}$ , $V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48\ \text{V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5\ \text{V}$ , $I_D = 1\ \text{A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.38	0.43	$\Omega$
			$T_C = 125^\circ\text{C}$	0.61	0.65	
$g_{fs}$	Forward transconductance	$V_{DS} = 15\ \text{V}$ , $I_D = 500\ \text{mA}$ , See Notes 2 and 3 and Figure 9	1.2	1.49		S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25\ \text{V}$ , $f = 1\ \text{MHz}$ , $V_{GS} = 0$ , See Figure 11		150	190	pF
$C_{oss}$	Short-circuit output capacitance, common source			100	125	
$C_{rss}$	Short-circuit reverse transfer capacitance, common source			40	50	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 500\ \text{mA}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48\ \text{V}$ , $di/dt = 100\ \text{A}/\mu\text{s}$	Z1 and Z2	50	ns
				D1 and D2	210	
$Q_{RR}$	Total diode charge	$I_S = 500\ \text{mA}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48\ \text{V}$ , $di/dt = 100\ \text{A}/\mu\text{s}$	Z1 and Z2	50	nC
				D1 and D2	800	

# TPIC5223L

## 2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

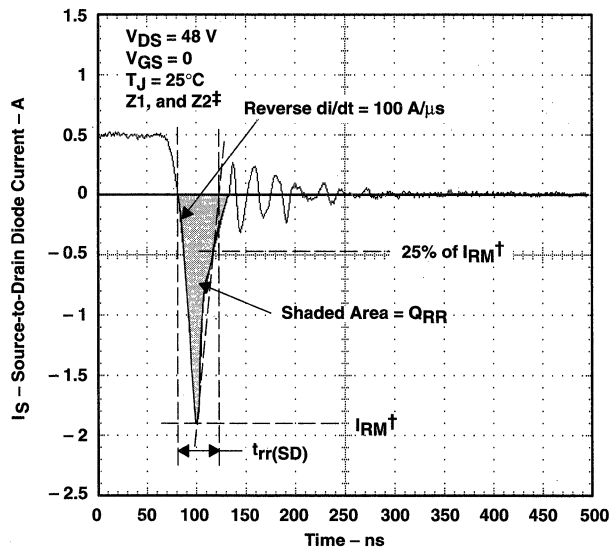
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2		34	70	ns
$t_{d(off)}$ Turn-off delay time			20	40	
$t_{r1}$ Rise time			28	55	
$t_{f2}$ Fall time			15	30	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 500\text{ mA}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		3.1	3.8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.5	0.6	
$Q_{gd}$ Gate-to-drain charge			1.9	2.3	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		130		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		78.6		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		34		

- NOTES:
- Package mounted on an FR4 printed-circuit board with no heatsink.
  - Package mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board.
  - Package mounted in intimate contact with infinite heatsink.
  - All outputs with equal power

### PARAMETER MEASUREMENT INFORMATION



†  $I_{RM}$  = maximum recovery current

‡ The above waveform is representative of D1 and D2 in shape only.

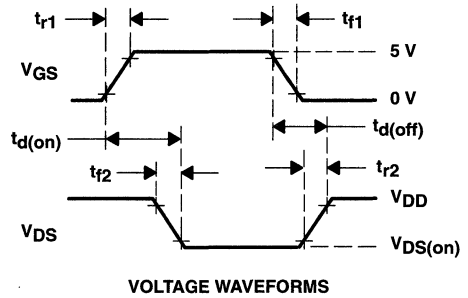
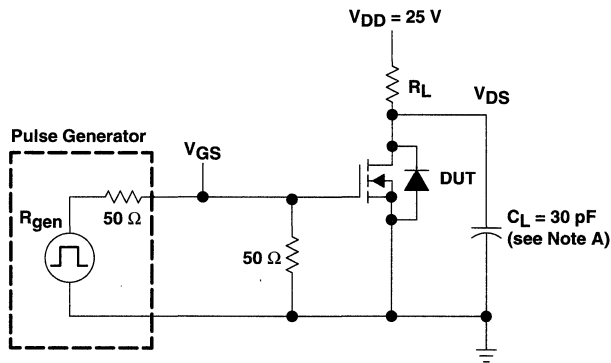
Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode



**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

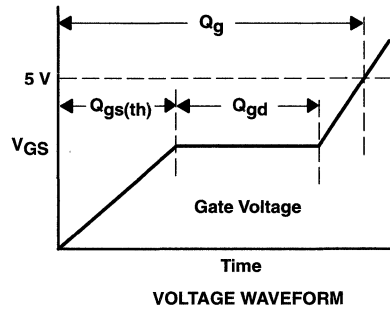
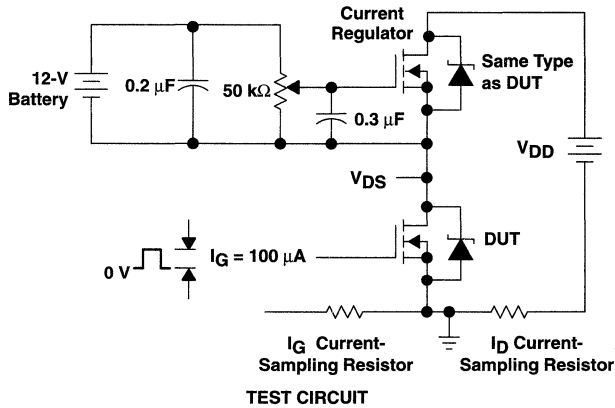
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**PARAMETER MEASUREMENT INFORMATION**



NOTE A:  $C_L$  includes probe and jig capacitance.

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**

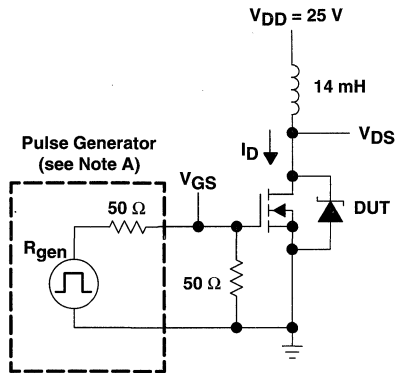


**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**

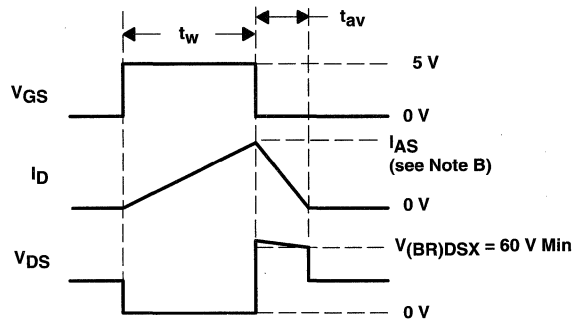
# TPIC5223L 2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 108 \text{ mJ, where } t_{av} = \text{avalanche time.}$$

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

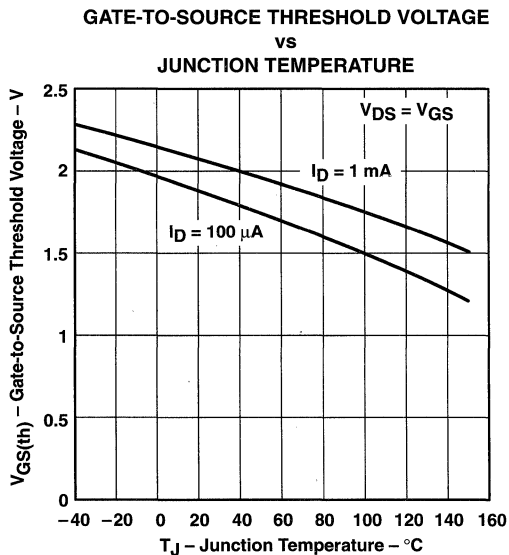


Figure 5

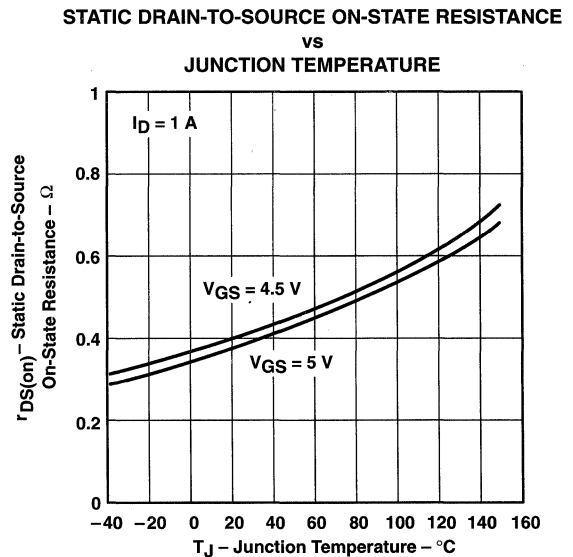


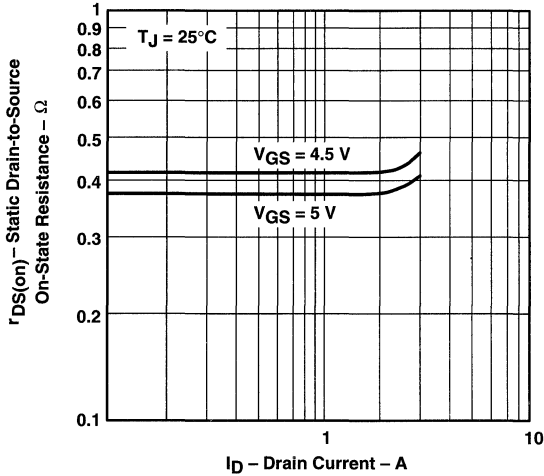
Figure 6

**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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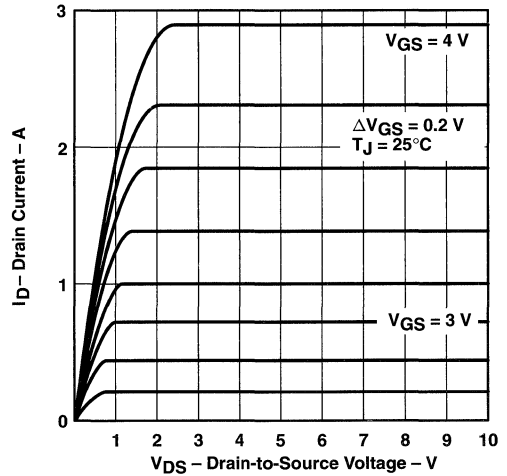
**TYPICAL CHARACTERISTICS**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**DRAIN CURRENT**



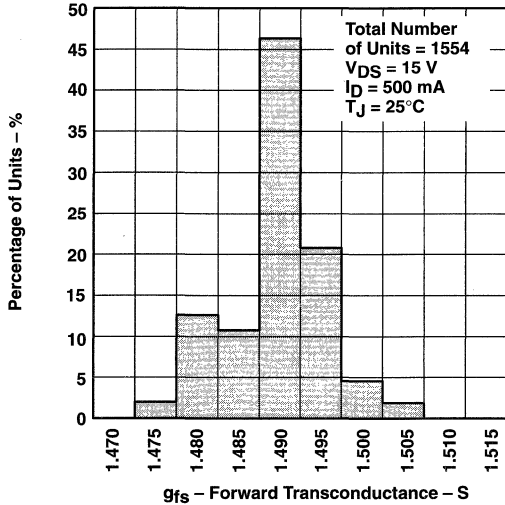
**Figure 7**

**DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



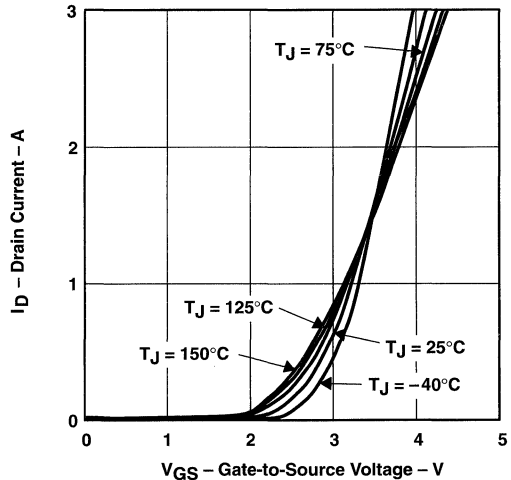
**Figure 8**

**DISTRIBUTION OF**  
**FORWARD TRANSCONDUCTANCE**



**Figure 9**

**DRAIN CURRENT**  
**vs**  
**GATE-TO-SOURCE VOLTAGE**

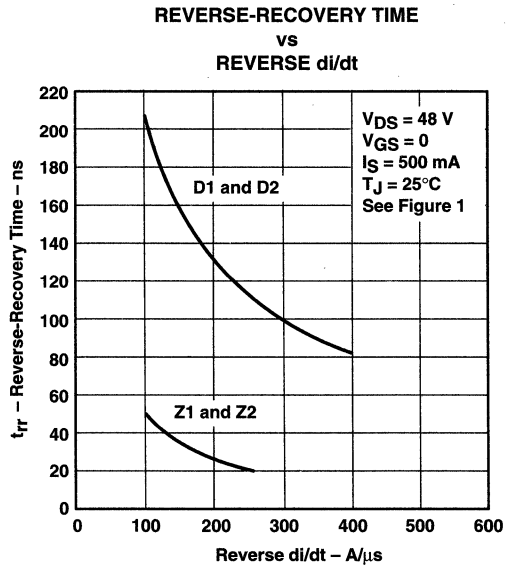
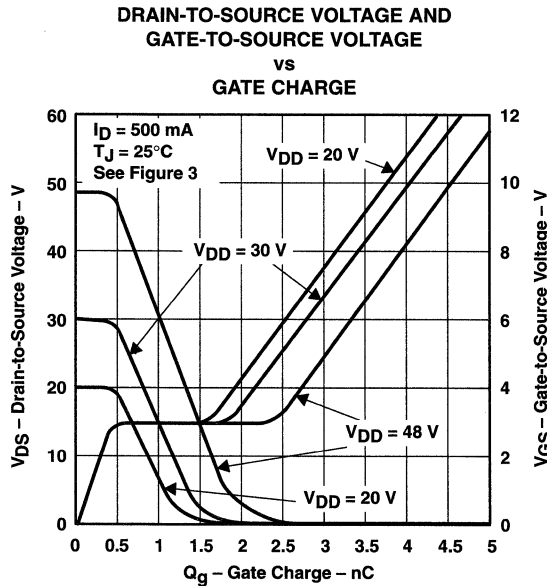
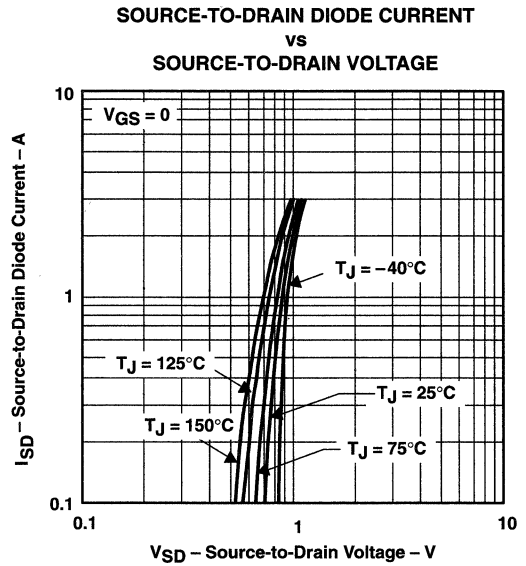
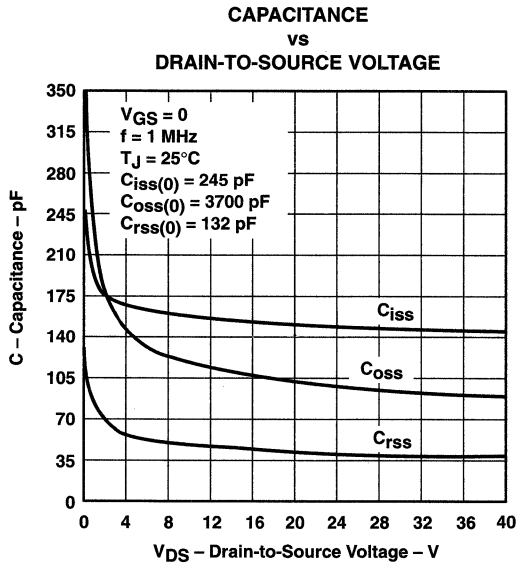


**Figure 10**

**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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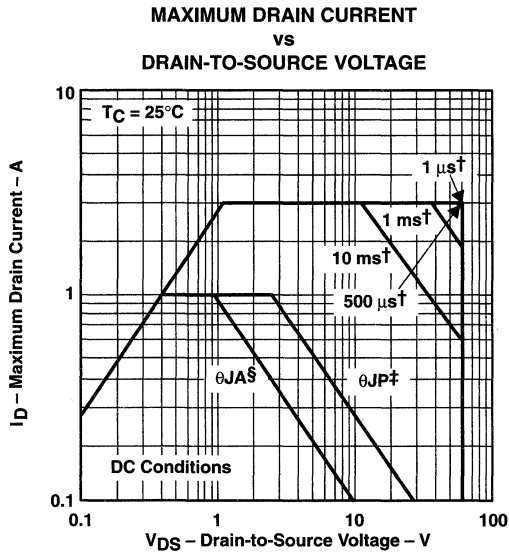
**TYPICAL CHARACTERISTICS**



**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

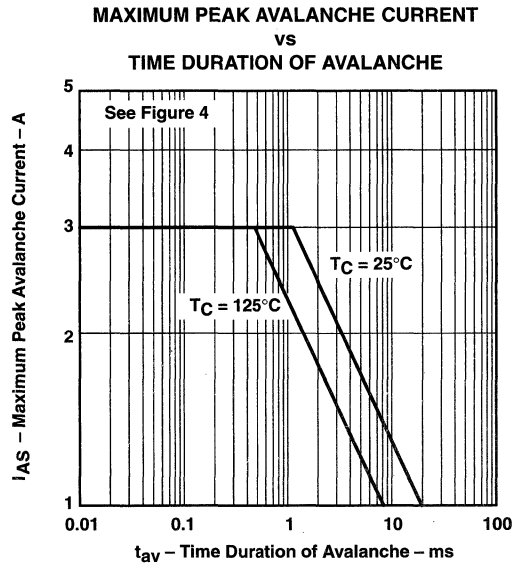
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**THERMAL INFORMATION**



† Less than 2% duty cycle  
‡ Device mounted in intimate contact with infinite heatsink.  
§ Device mounted on FR4 printed-circuit board with no heatsink.

**Figure 15**



**Figure 16**

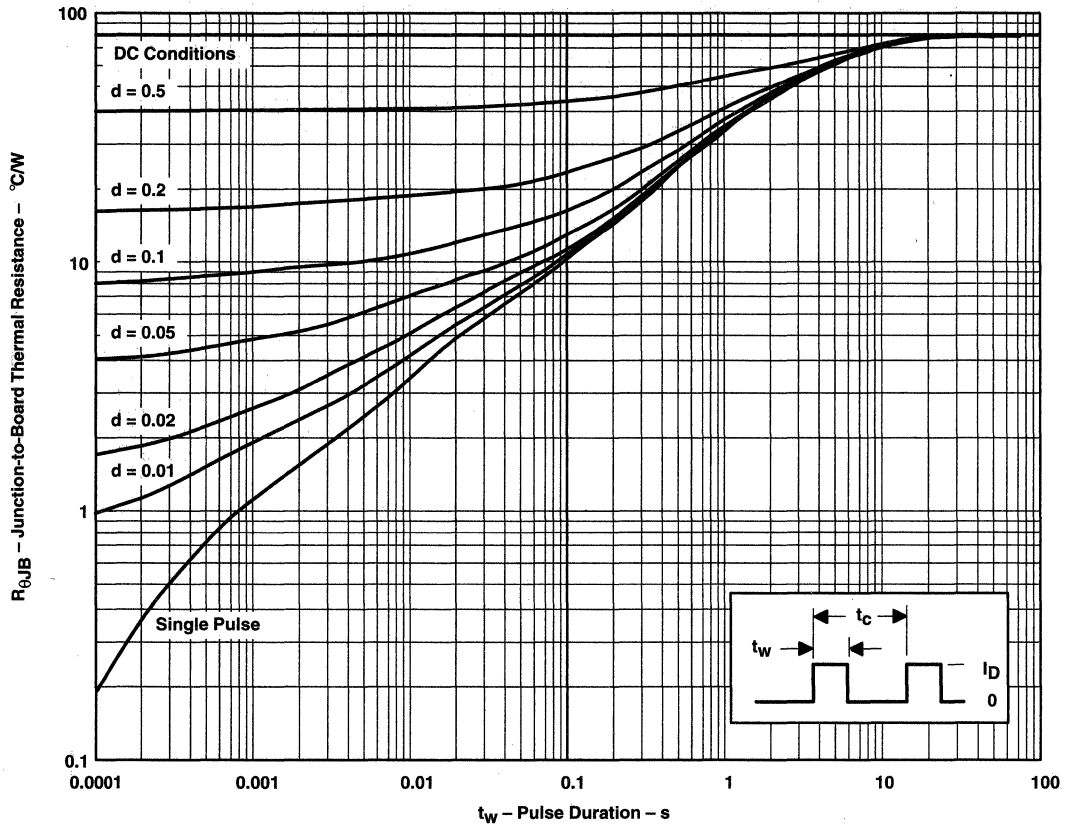


**TPIC5223L**  
**2-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**D PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**VS**  
**PULSE DURATION**



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

NOTE A:  $Z_{\theta B}(t) = r(t) R_{\theta JB}$

$t_w$  = pulse duration

$t_c$  = cycle time

$d$  = duty cycle =  $t_w/t_c$

**Figure 17**

# TPIC5302 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

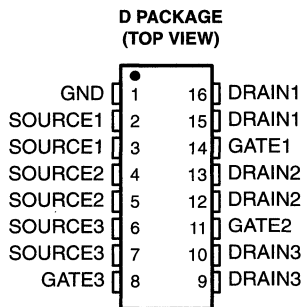
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- Low  $r_{DS(on)}$  . . . 0.3  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 7 A Per Channel
- Fast Commutation Speed

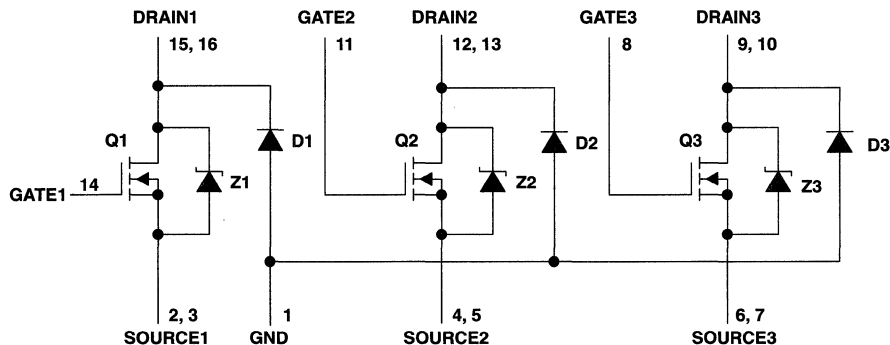
## description

The TPIC5302 is a monolithic power DMOS array that consists of three electrically isolated independent N-channel enhancement-mode DMOS transistors. The TPIC5302 is offered in a standard 16-pin small-outline surface-mount (D) package.

The TPIC5302 is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



## schematic



## absolute maximum ratings over operating case temperature range (unless otherwise noted)<sup>†</sup>

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage	100 V
Drain-to-GND voltage	100 V
Gate-to-source voltage, $V_{GS}$	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$	1.4 A
Continuous source-to-drain diode current	1.4 A
Pulsed drain current, each output, $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 6)	7 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^{\circ}\text{C}$ (see Figure 4)	10.5 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$	1087 mW
Operating virtual junction temperature range, $T_J$	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range, $T_{stg}$	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^{\circ}\text{C}$

<sup>†</sup> 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS  
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# TPIC5302

## 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, and D3)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.4 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.42	0.49	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.4 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3), See Notes 2 and 3			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.4 \text{ A}$			4.8		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_R = 48 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1.4 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$		0.3	0.35	$\Omega$
			$T_C = 125^\circ\text{C}$		0.41	0.5	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 2 and 3	$I_D = 0.7 \text{ A}$ ,	1.15	1.41		S
$C_{iss}$	Short-circuit input capacitance, common source				135	170	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ ,	$V_{GS} = 0$ ,		80	100	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source	$f = 1 \text{ MHz}$			30	40	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum and pulse duration  $\leq 5 \text{ ms}$ .

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ ,	$V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ , See Figure 1		35		ns
$Q_{RR}$	Total diode charge	$di/dt = 100 \text{ A}/\mu\text{s}$ ,			0.04		$\mu\text{C}$

### GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$ (see schematic, D1, D2, and D3)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_F = 0.5 \text{ A}$ ,	$V_{DS} = 48 \text{ V}$ , See Figure 1		130		ns
$Q_{RR}$	Total diode charge	$di/dt = 100 \text{ A}/\mu\text{s}$ ,			0.4		$\mu\text{C}$



# TPIC5302

## 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

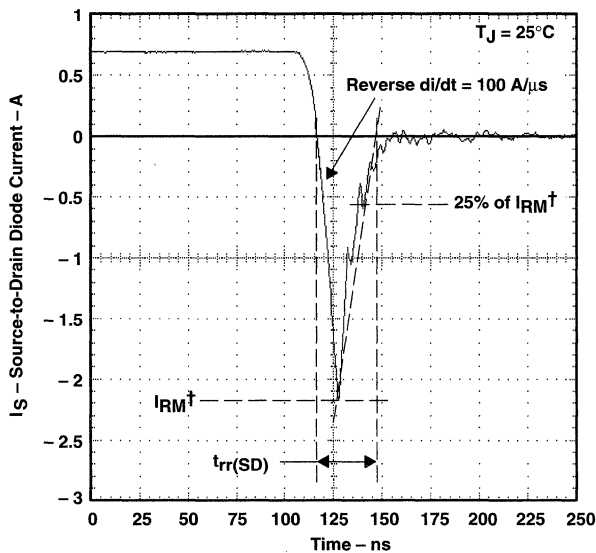
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{r1} = 10\text{ ns}$ , $t_{f1} = 10\text{ ns}$ , See Figure 2		23	46	ns
$t_{d(off)}$ Turn-off delay time			25	50	
$t_{r2}$ Rise time			5	10	
$t_{f2}$ Fall time			17	34	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.5\text{ A}$ , $V_{GS} = 10\text{ V}$ , See Figure 3		8	9.8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.5	0.63	
$Q_{gd}$ Gate-to-drain charge			1.5	1.85	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	All outputs with equal power, See Note 4		115		$^\circ\text{C/W}$
$R_{\theta JP}$ Junction-to-pin thermal resistance			32		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

### PARAMETER MEASUREMENT INFORMATION



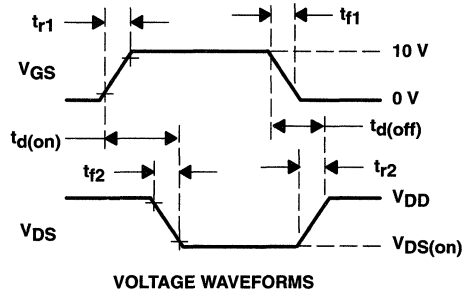
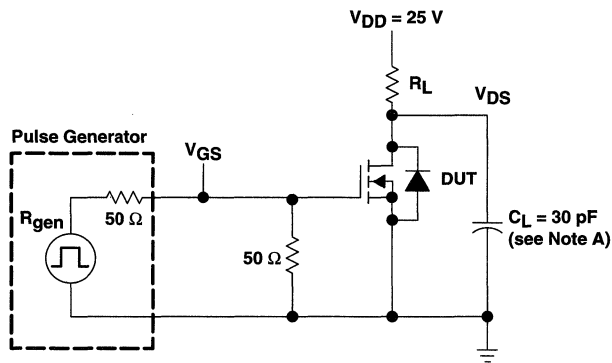
$^\dagger I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode

# TPIC5302 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

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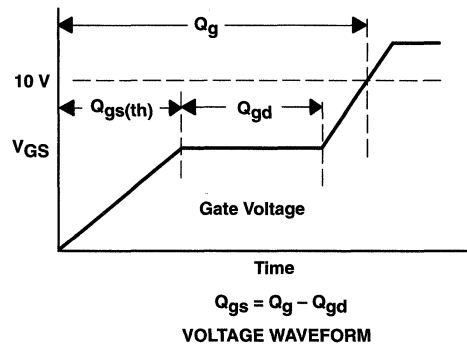
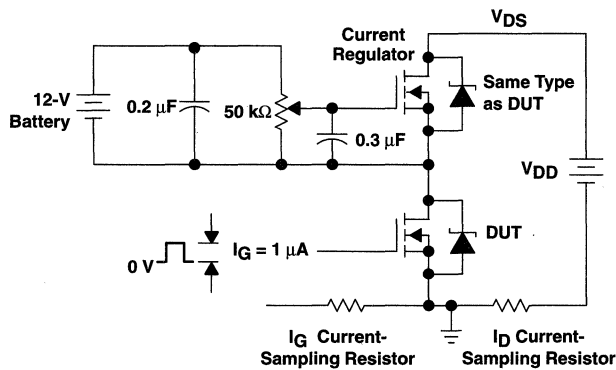
## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



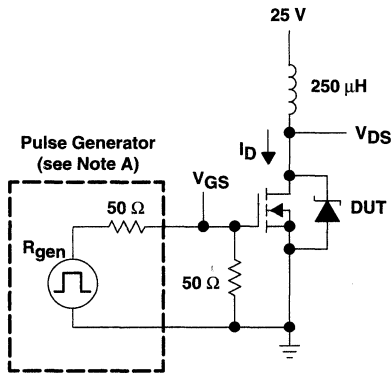
TEST CIRCUIT

Figure 3. Gate-Charge Test Circuit and Voltage Waveform

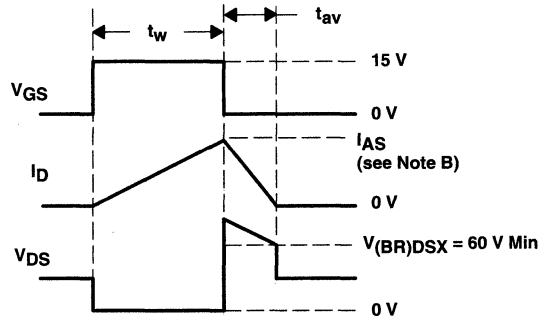
# TPIC5302 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



**TEST CIRCUIT**



**VOLTAGE AND CURRENT WAVEFORMS**

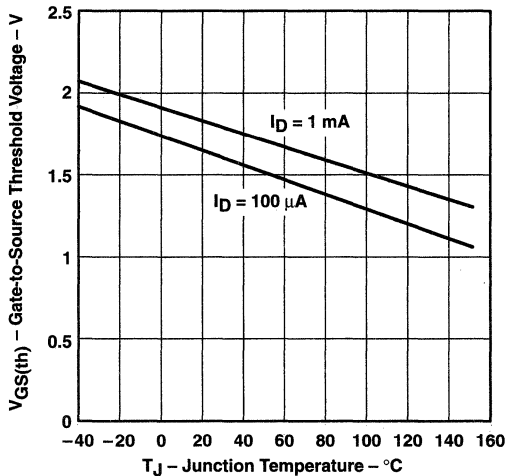
- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 7$  A, where  $t_{av}$  = avalanche time.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 10.5 \text{ mJ}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

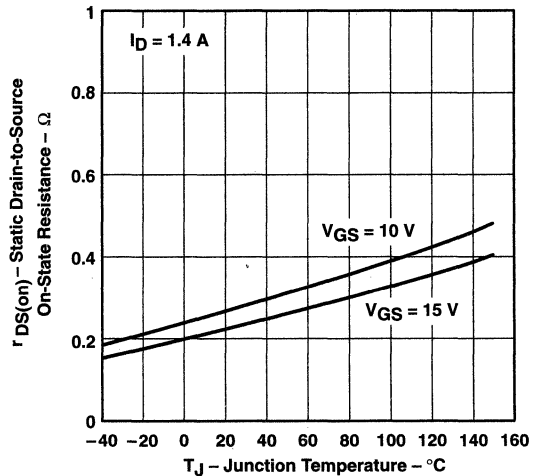
## TYPICAL CHARACTERISTICS

**GATE-TO-SOURCE THRESHOLD VOLTAGE  
vs  
JUNCTION TEMPERATURE**



**Figure 5**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
JUNCTION TEMPERATURE**



**Figure 6**

# TPIC5302 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

SLIS029B – APRIL 1994 – REVISED SEPTEMBER 1995

## TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

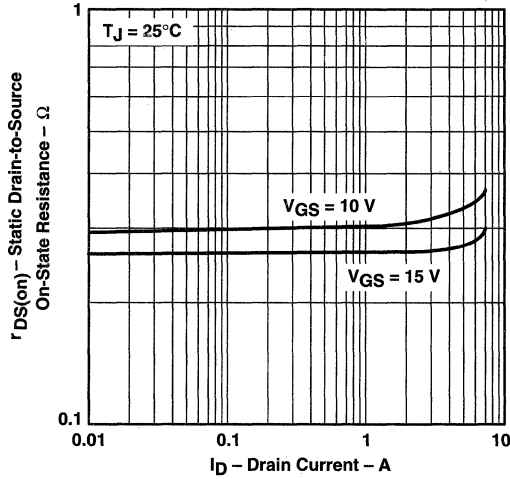


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

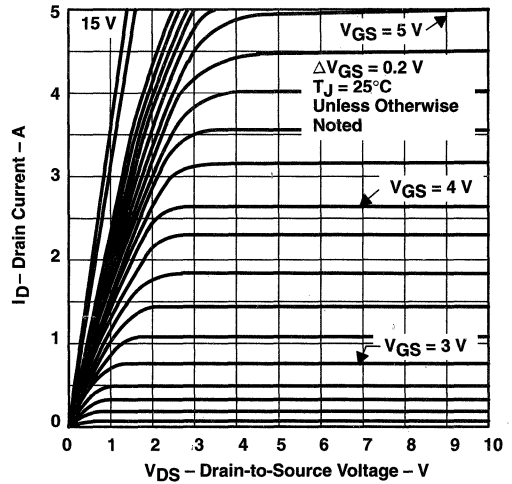


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

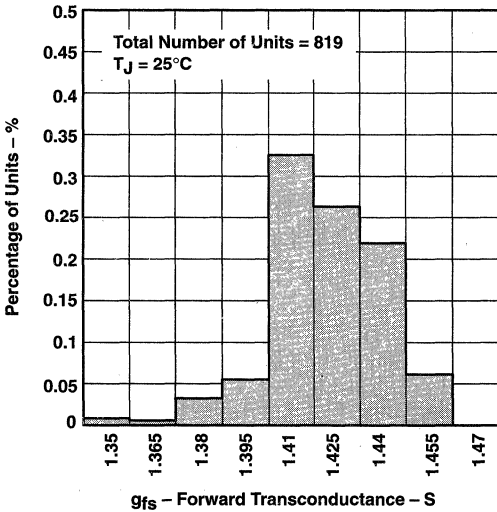


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

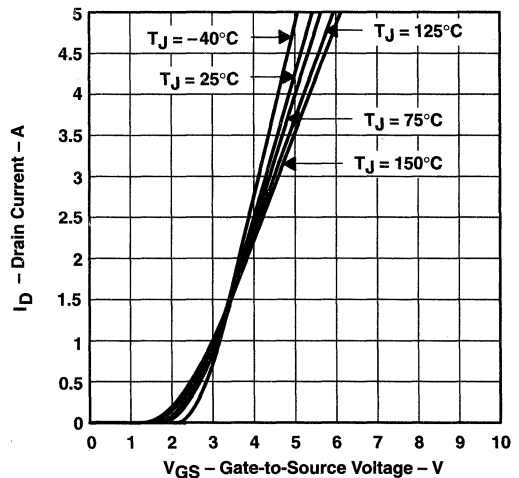


Figure 10

# TPIC5302

## 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

SLIS029B – APRIL 1994 – REVISED SEPTEMBER 1995

### TYPICAL CHARACTERISTICS

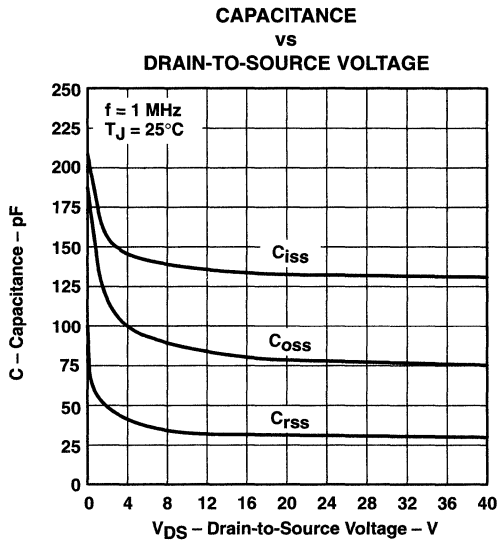


Figure 11

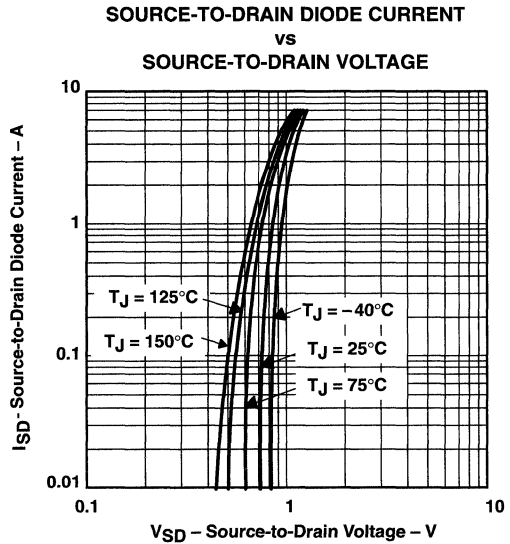


Figure 12

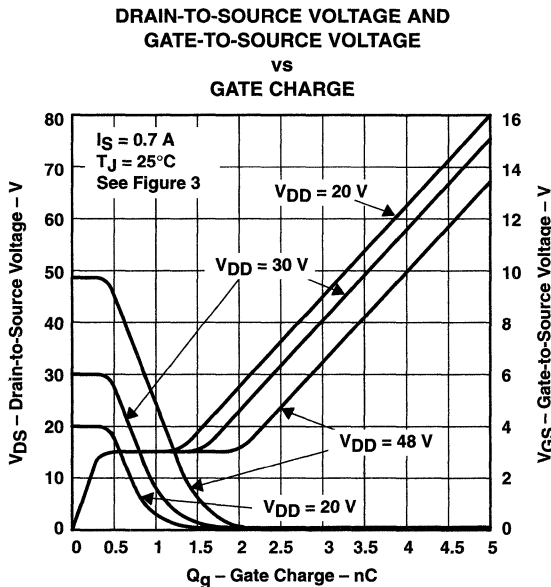


Figure 13

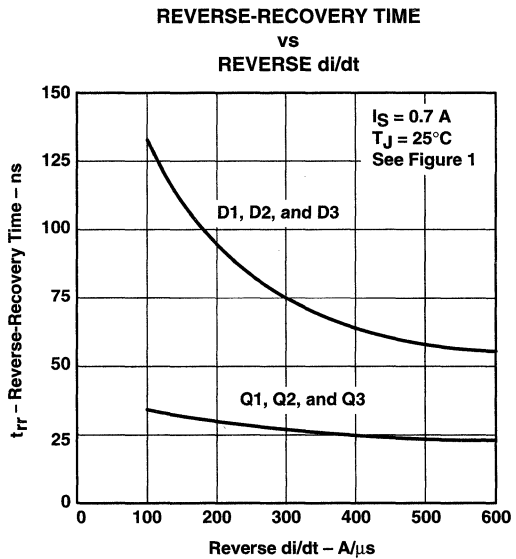


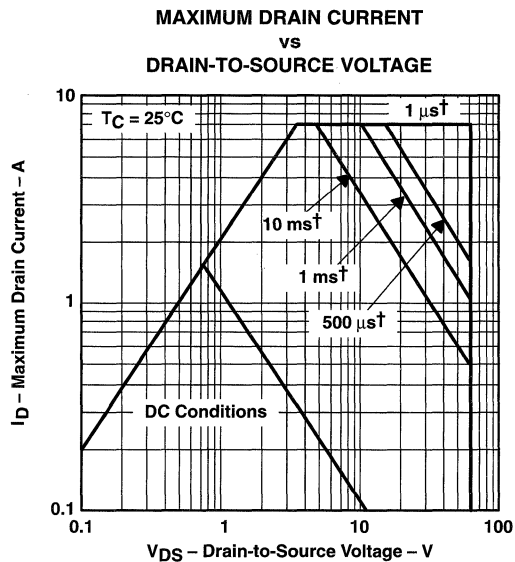
Figure 14



# TPIC5302 3-CHANNEL INDEPENDENT POWER DMOS ARRAY

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## THERMAL INFORMATION



† Less than 0.1 duty cycle

Figure 15

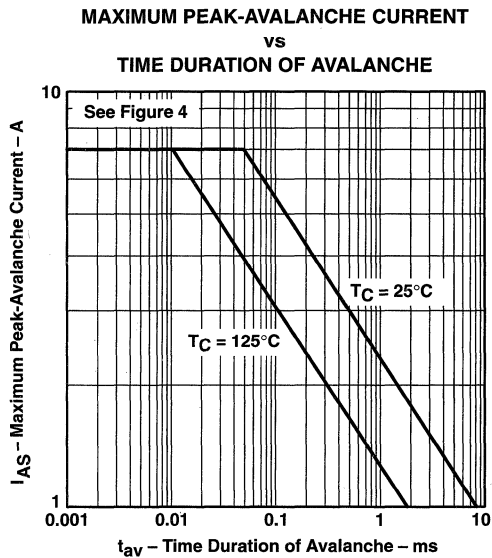


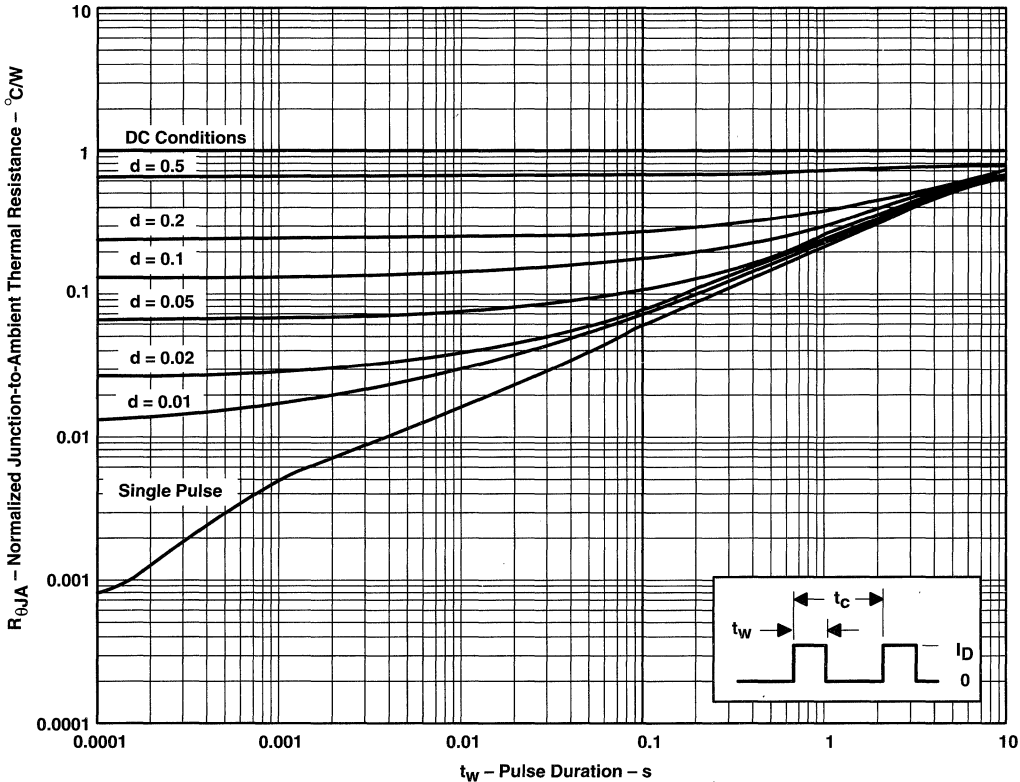
Figure 16

**TPIC5302**  
**3-CHANNEL INDEPENDENT POWER DMOS ARRAY**

SLIS029B – APRIL 1994 – REVISED SEPTEMBER 1995

**THERMAL INFORMATION**

**D PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heat sink

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**



# TPIC5303

## 3-CHANNEL INDEPENDENT GATE-PROTECTED POWER DMOS ARRAY

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- High Voltage Output . . . 60 V
- Extended ESD Capability . . . 4000 V
- Pulsed Current . . . 5 A Per Channel
- Fast Commutation Speed

### description

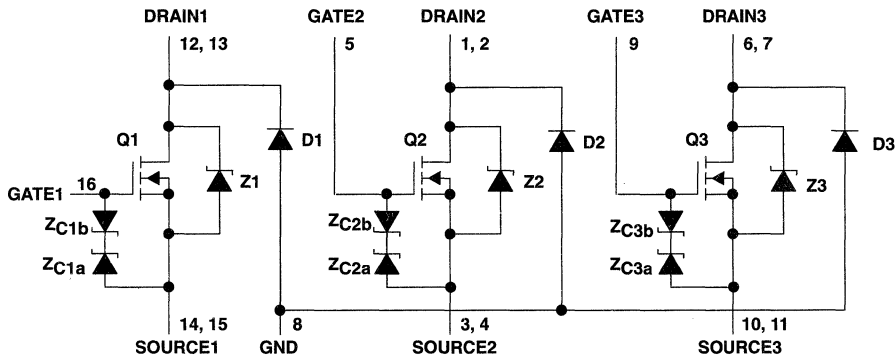
The TPIC5303 is a monolithic gate-protected power DMOS array that consists of three independent electrically isolated N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5303 is offered in a standard 16-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

D PACKAGE  
(TOP VIEW)

DRAIN2	1	16	GATE1
DRAIN2	2	15	SOURCE1
SOURCE2	3	14	SOURCE1
SOURCE2	4	13	DRAIN1
GATE2	5	12	DRAIN1
DRAIN3	6	11	SOURCE3
DRAIN3	7	10	SOURCE3
GND	8	9	GATE3

### schematic



NOTE A: For correct operation, no terminal pin may be taken below GND.

**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Drain-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1.4 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1.4 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	5 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15, and 16) .....	10.2 mJ
Continuous total power dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15) .....	1.08 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.8	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, D3)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.4 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.56	0.64	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.4 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3), See Notes 2 and 3 and Figure 12			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.4 \text{ A}$ (D1, D2, D3), See Notes 2 and 3			5		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ ,	$V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$		0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$		0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1.4 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$		0.4	0.46	$\Omega$
			$T_C = 125^\circ\text{C}$		0.62	0.66	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 0.7 \text{ A}$ ,	1	1.19		S
$C_{iss}$	Short-circuit input capacitance, common source				107	137	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ ,	$V_{GS} = 0$ , See Figure 11		71	89	
$C_{rss}$	Short-circuit reverse transfer capacitance, common source				22	28	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.7 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ ,	Z1, Z2, and Z3	92		ns
				D1, D2, and D3	244		
$Q_{RR}$	Total diode charge			Z1, Z2, and Z3	0.1		$\mu\text{C}$
				D1, D2, and D3	1.3		

**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

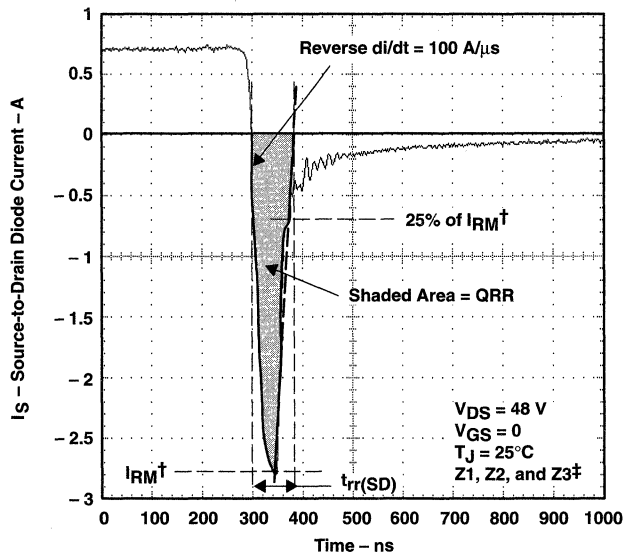
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 36\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2		25	40	ns
$t_{d(off)}$ Turn-off delay time			27	40	
$t_{r2}$ Rise time			15	25	
$t_{f2}$ Fall time			7	14	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.7\text{ A}$ , $V_{GS} = 10\text{ V}$ , See Figure 3		2.1	2.6	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.3	0.38	
$Q_{gd}$ Gate-to-drain charge			1.2	1.5	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		115		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		64		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		33		

- NOTES:
- Package mounted on an FR4 printed-circuit board with no heatsink.
  - Package mounted on a 24 inch<sup>2</sup>, 4-layer FR4 printed-circuit board.
  - Package mounted in intimate contact with infinite heatsink.
  - All outputs with equal power

**PARAMETER MEASUREMENT INFORMATION**



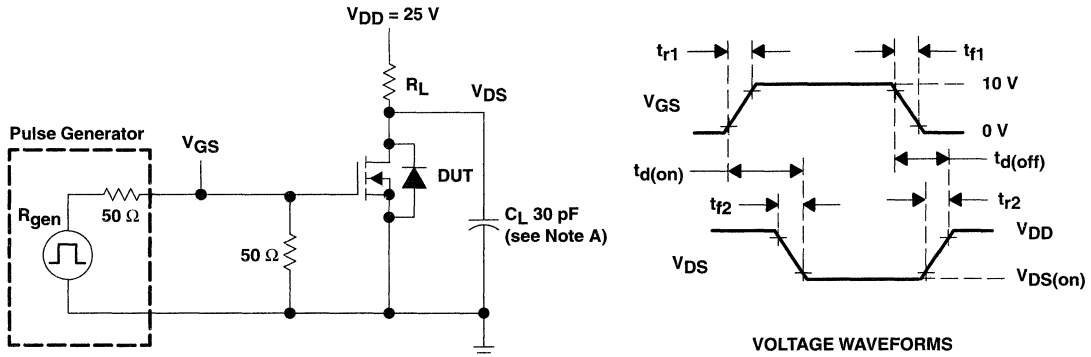
†  $I_{RM}$  = maximum recovery current

‡ The above waveform is representative of D1, D2, and D3 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**



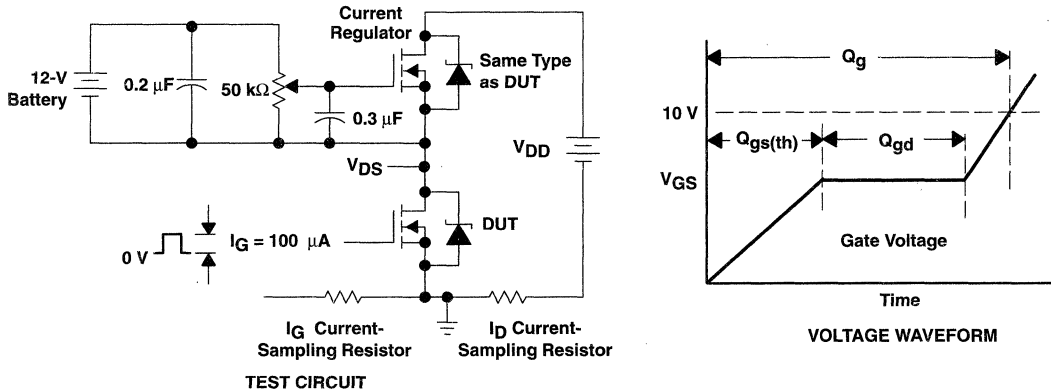
**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**

NOTE A:  $C_L$  includes probe and jig capacitance.

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**



**TEST CIRCUIT**

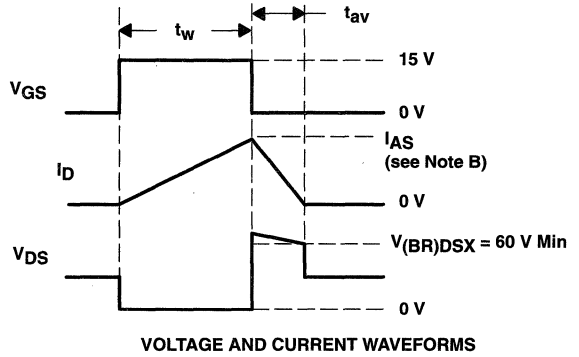
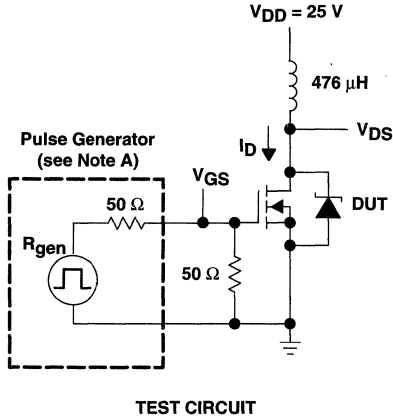
**Figure 3. Gate-Charge Test Circuit and Waveform**



**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**PARAMETER MEASUREMENT INFORMATION**

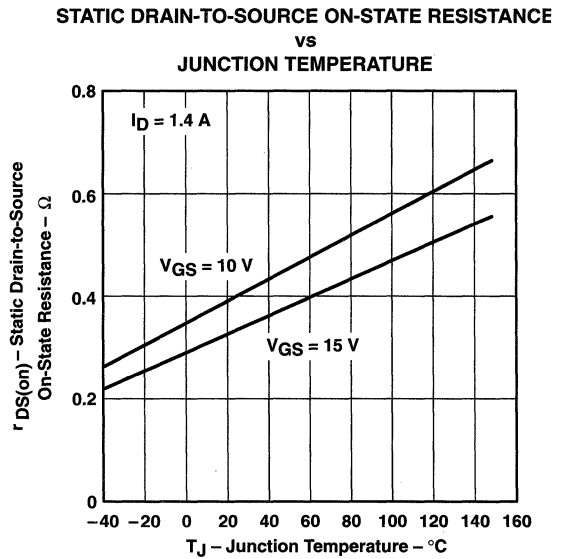
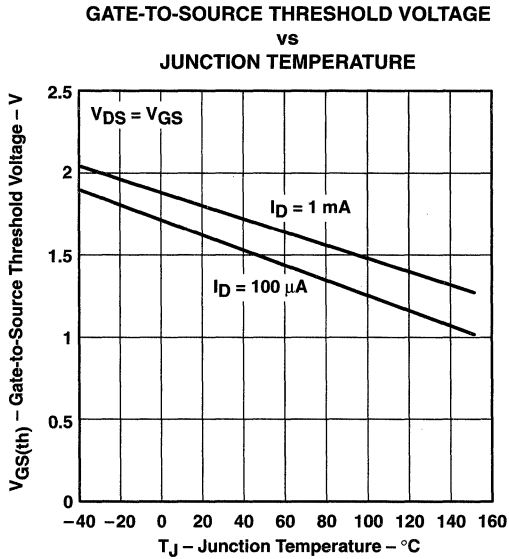


- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 5$  A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 10.2$  mJ, where  $t_{av}$  = avalanche time.

**Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**



**TYPICAL CHARACTERISTICS**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**DRAIN CURRENT**

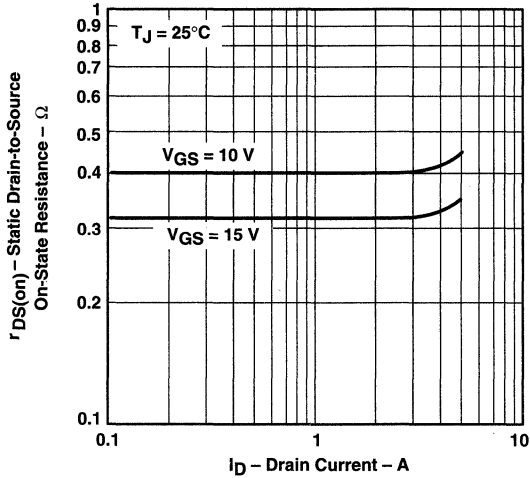


Figure 7

**DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**

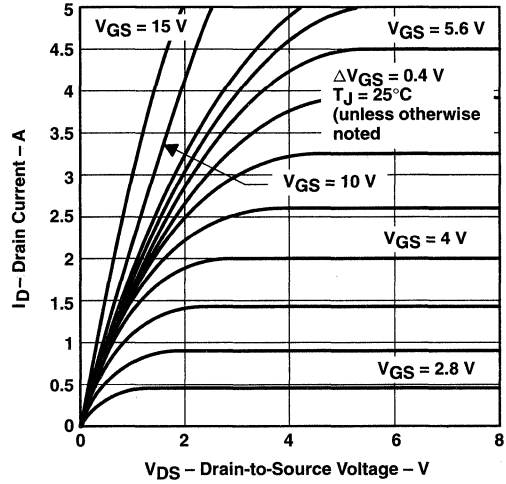


Figure 8

**DISTRIBUTION OF**  
**FORWARD TRANSCONDUCTANCE**

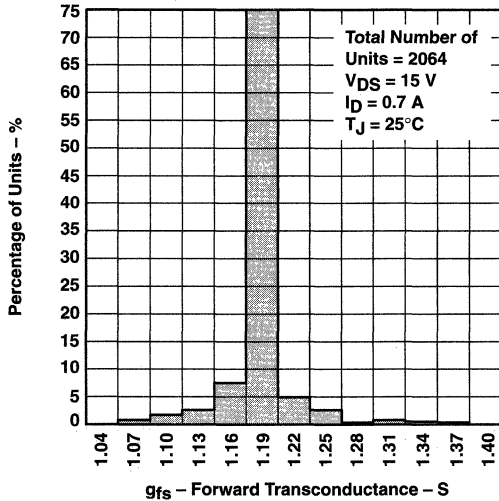


Figure 9

**DRAIN CURRENT**  
**vs**  
**GATE-TO-SOURCE VOLTAGE**

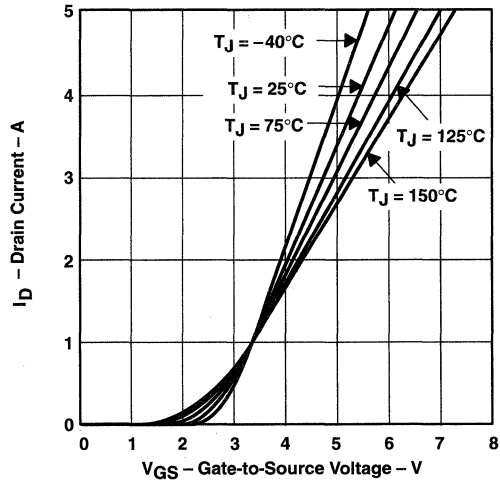
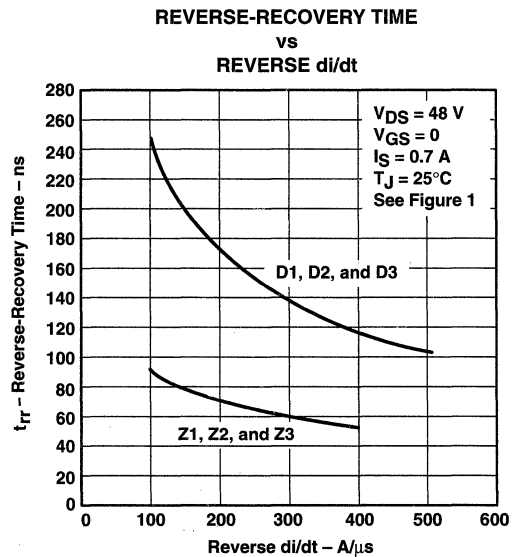
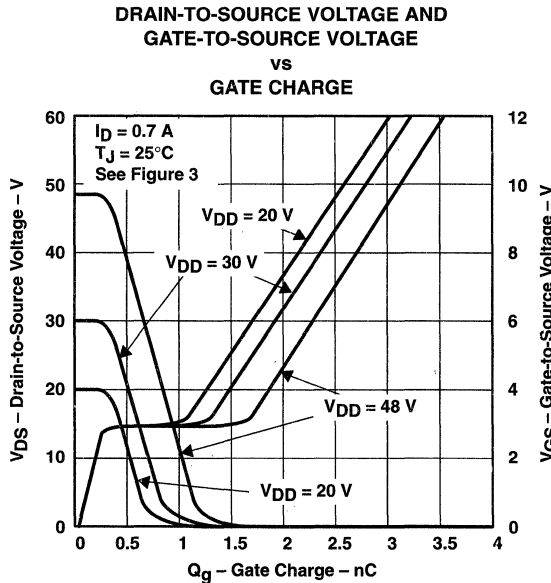
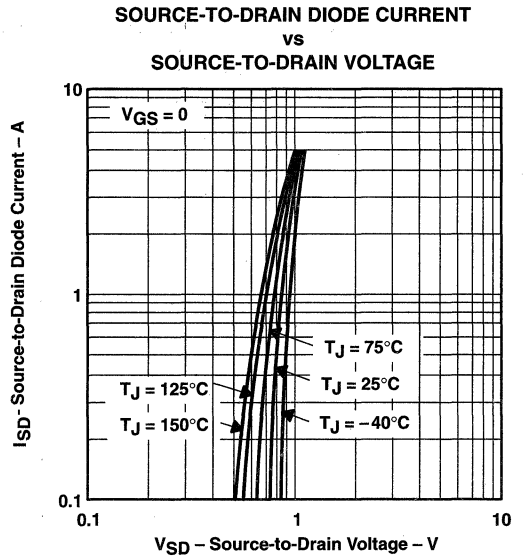
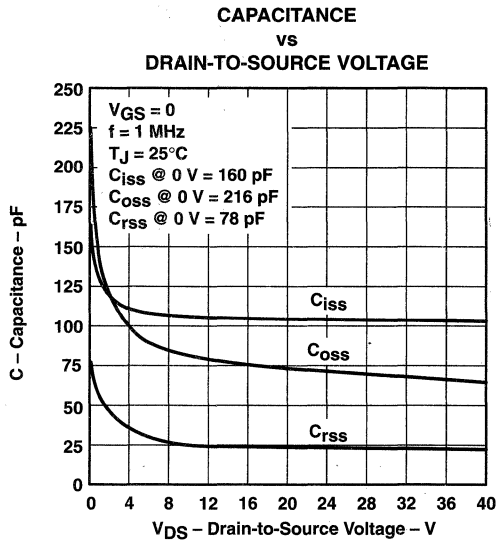


Figure 10

**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**TYPICAL CHARACTERISTICS**

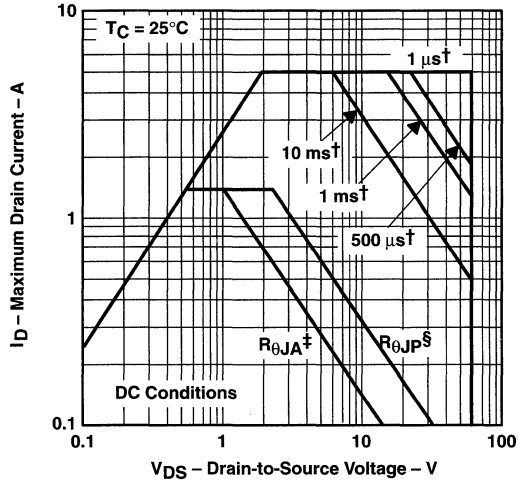


**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**THERMAL INFORMATION**

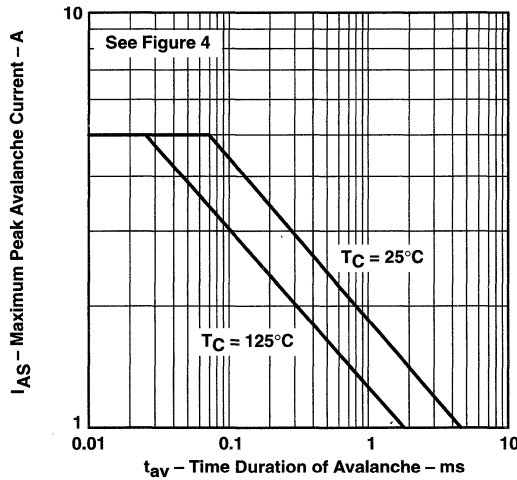
**MAXIMUM DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



† Less than 2% duty cycle  
‡ Device mounted on FR4 printed-circuit board with no heatsink.  
§ Device mounted in intimate contact with infinite heatsink.

**Figure 15**

**MAXIMUM PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



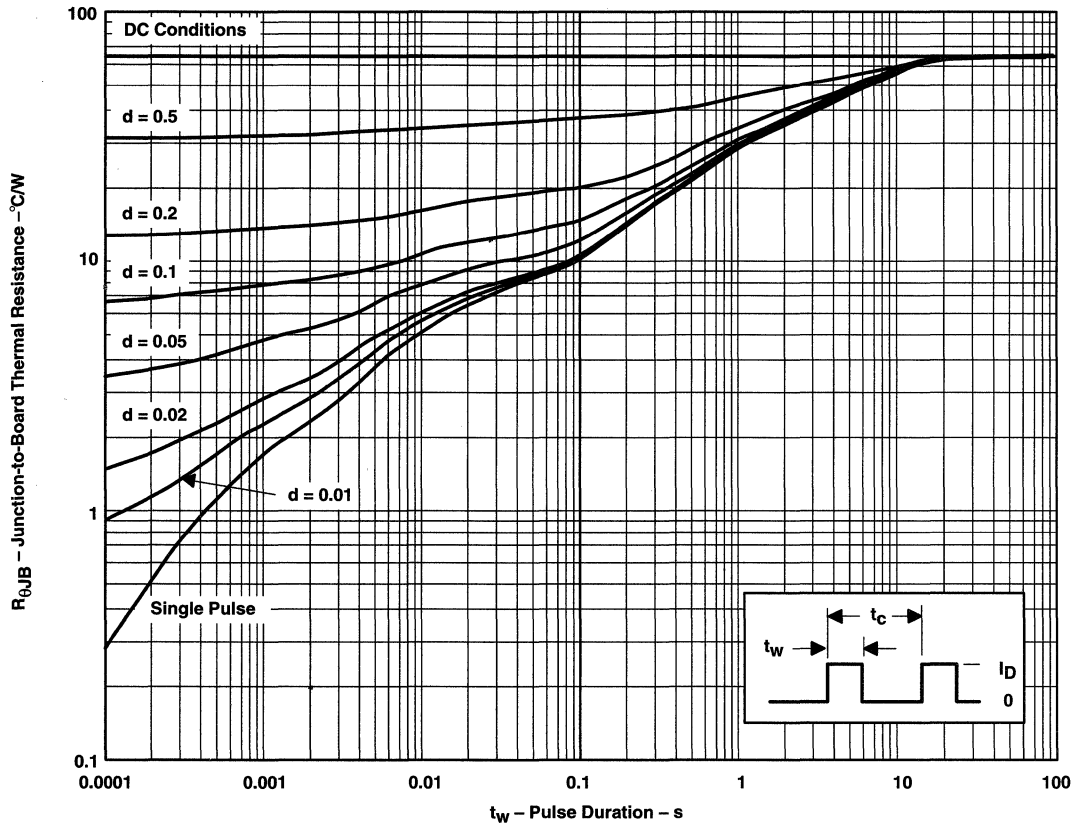
**Figure 16**

**TPIC5303**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

SLIS039A – SEPTEMBER 1994 – REVISED SEPTEMBER 1995

**THERMAL INFORMATION**

**D PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink

NOTE A:  $Z_{\theta JB}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17

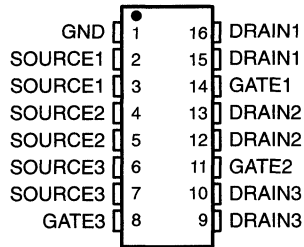
# TPIC5322L

## 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

SLIS034A – JUNE 1994 – REVISED NOVEMBER 1994

- Low  $r_{DS(on)}$  . . . 0.45  $\Omega$  Typ
- High-Voltage Outputs . . . 60 V
- Pulsed Current . . . 3 A Per Channel
- Fast Commutation Speed
- Direct Logic-Level Interface

**D PACKAGE  
(TOP VIEW)**

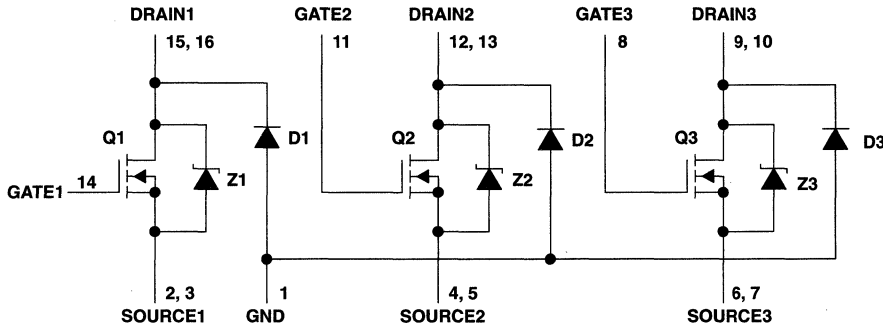


### description

The TPIC5322L is a monolithic logic-level power DMOS array that consists of three electrically isolated independent N-channel enhancement-mode DMOS transistors.

The TPIC5322L is offered in a standard 16-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



### absolute maximum ratings over operating case temperature range (unless otherwise noted)<sup>†</sup>

Drain-to-source voltage, $V_{DS}$ . . . . .	60 V
Source-to-GND voltage . . . . .	100 V
Drain-to-GND voltage . . . . .	100 V
Gate-to-source voltage, $V_{GS}$ . . . . .	$\pm 20$ V
Continuous drain current, each output, all outputs on, $T_C = 25^{\circ}\text{C}$ . . . . .	1 A
Continuous source-to-drain diode current, $T_C = 25^{\circ}\text{C}$ . . . . .	1 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^{\circ}\text{C}$ (see Note 1 and Figure 15) . . . . .	3 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^{\circ}\text{C}$ (see Figure 4) . . . . .	40.5 mJ
Continuous total power dissipation at (or below) $T_C = 25^{\circ}\text{C}$ . . . . .	1.09 W
Operating virtual junction temperature range, $T_J$ . . . . .	$-40^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Operating case temperature range, $T_C$ . . . . .	$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range . . . . .	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	$260^{\circ}\text{C}$

<sup>†</sup> 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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# TPIC5322L

## 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, and D3)	Drain-to-GND current = $250 \mu\text{A}$	100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3		0.45	0.525	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , See Notes 2 and 3 and Figure 12		0.85	1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$		3.7		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ , $V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.45	0.525	$\Omega$
			$T_C = 125^\circ\text{C}$	0.7	0.78	
$g_{fs}$	Forward transconductance	$V_{DS} = 10 \text{ V}$ , See Notes 2 and 3 and Figure 9	1	1.24		S
$C_{iss}$	Short-circuit input capacitance, common source			135	170	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$		80	100	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source	$V_{GS} = 0$ , See Figure 11		30	40	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain and GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$		35	ns
				Z1, Z2, Z3	110	
$Q_{RR}$	Total diode charge			0.035		$\mu\text{C}$
				Z1, Z2, Z3	0.35	



# TPIC5322L

## 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

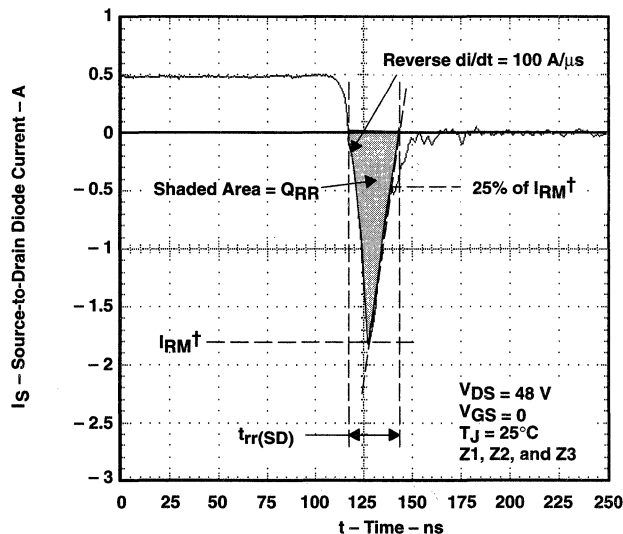
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		21	42	ns
$t_{d(off)}$ Turn-off delay time			20	40	
$t_r$ Rise time			5	10	
$t_f$ Fall time			13	26	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.5\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		3.1	3.8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.4	0.5	
$Q_{gd}$ Gate-to-drain charge			1.3	1.6	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance (see Note 4)	All outputs with equal power		115		$^\circ\text{C/W}$
$R_{\theta JP}$ Junction-to-pin thermal resistance			32		$^\circ\text{C/W}$

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

### PARAMETER MEASUREMENT INFORMATION



$\dagger I_{RM}$  = maximum recovery current

NOTE A. The above waveform is representative of D1, D2, and D3 in shape only.

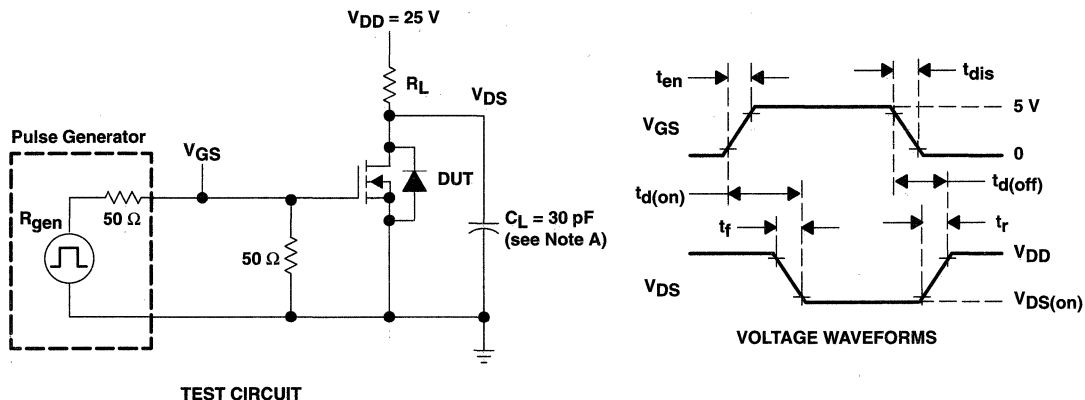
Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode



# TPIC5322L 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms

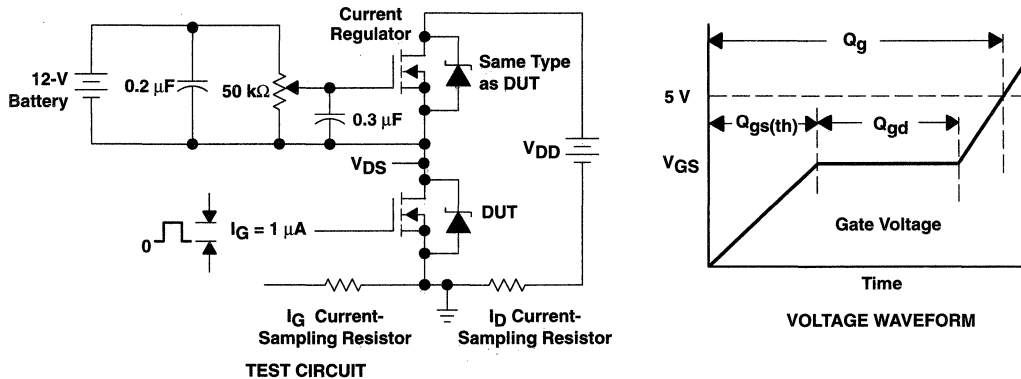


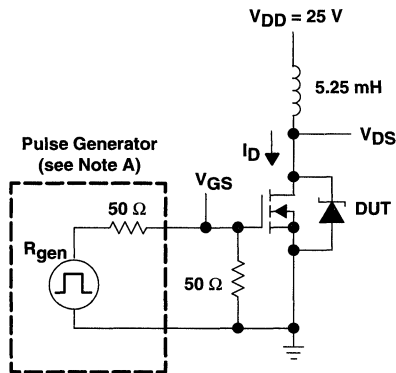
Figure 3. Gate-Charge Test Circuit and Voltage Waveform

# TPIC5322L

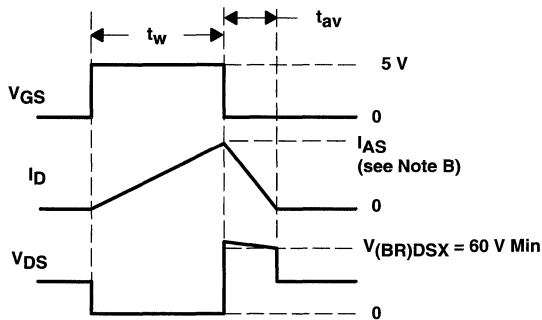
## 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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### PARAMETER MEASUREMENT INFORMATION



**TEST CIRCUIT**



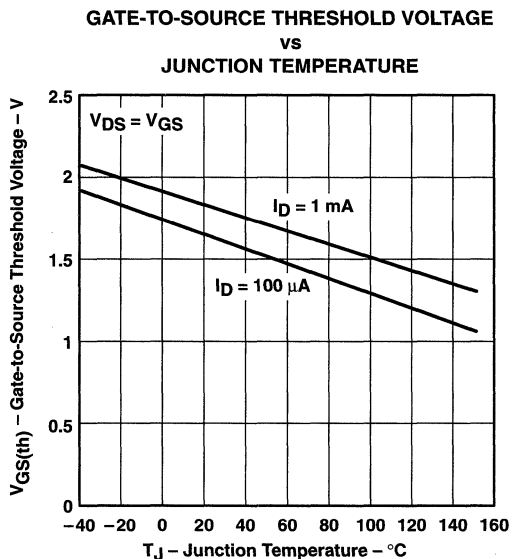
**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3 \text{ A}$ .

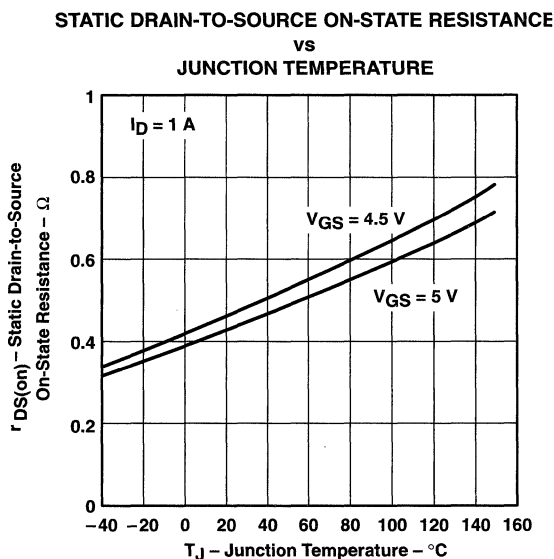
$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_w}{2} = 40.5 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

### TYPICAL CHARACTERISTICS



**Figure 5**



**Figure 6**

# TPIC5322L 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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## TYPICAL CHARACTERISTICS

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT**

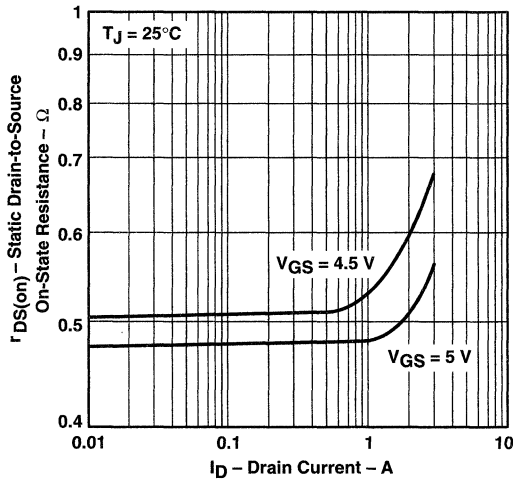


Figure 7

**DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE**

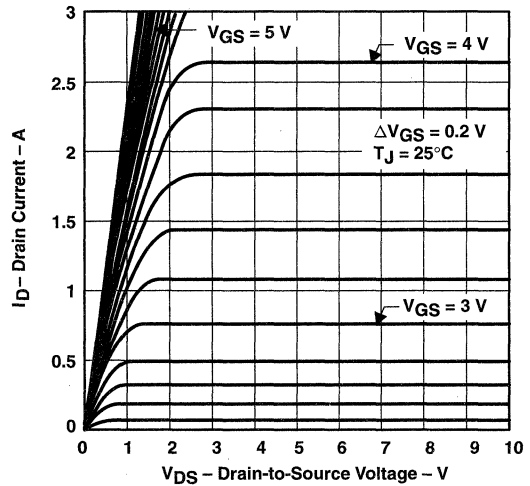


Figure 8

**DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE**

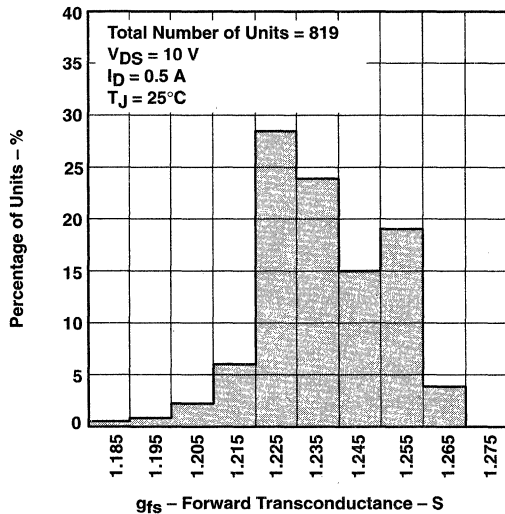


Figure 9

**DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE**

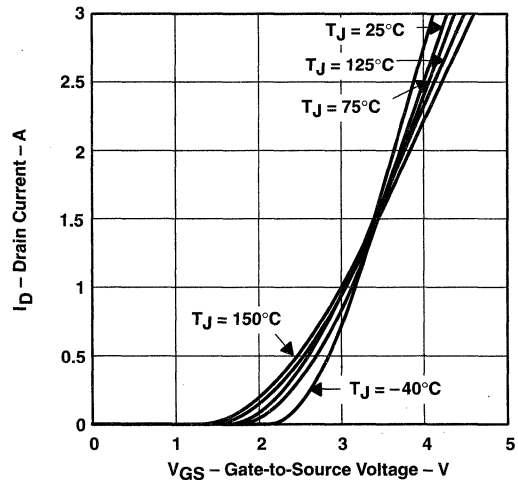


Figure 10

# TPIC5322L

## 3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY

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### TYPICAL CHARACTERISTICS

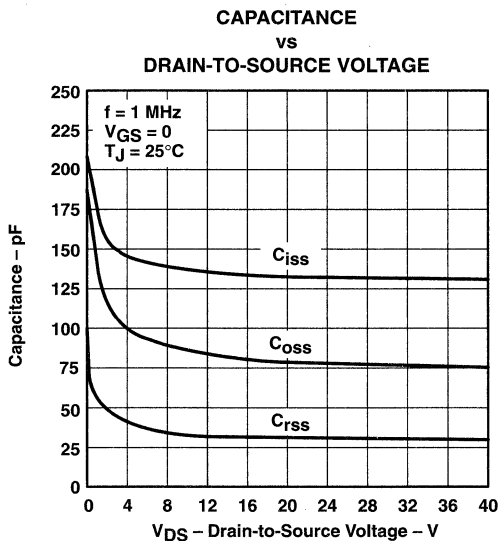


Figure 11

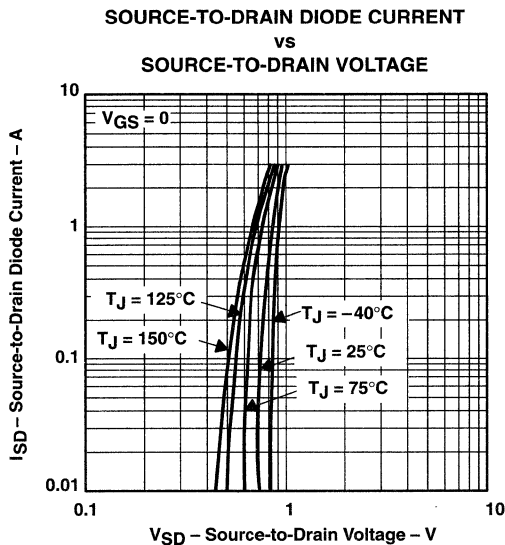


Figure 12

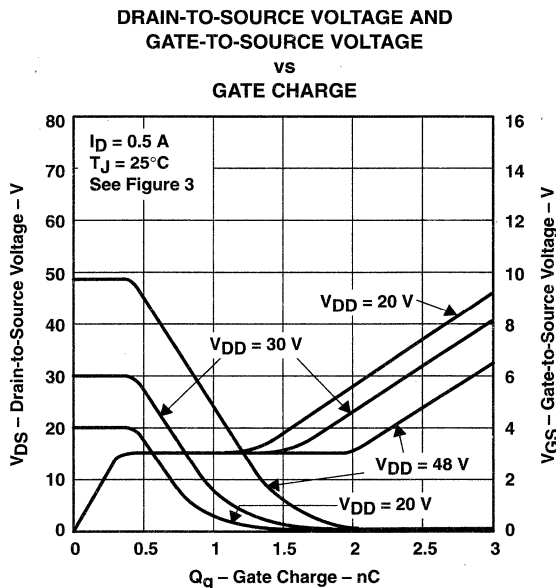


Figure 13

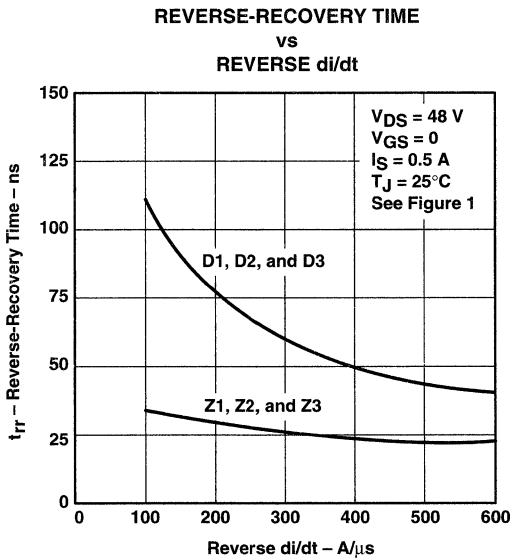
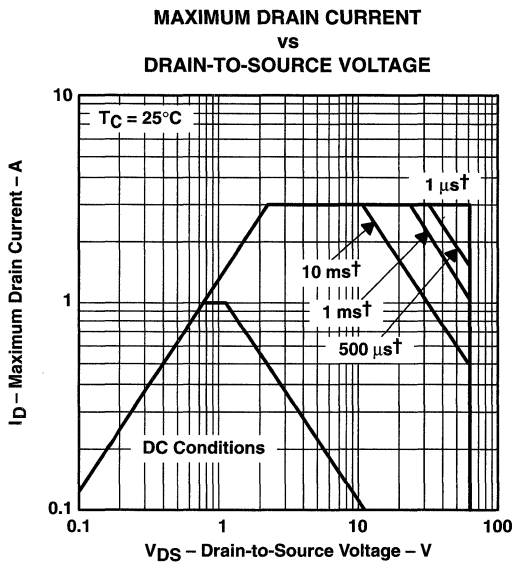


Figure 14

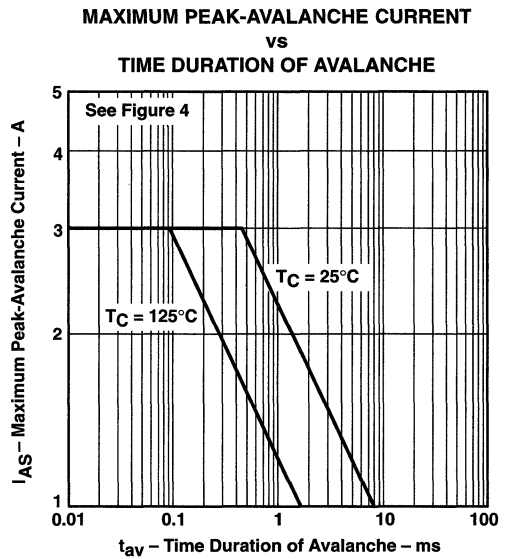
**TPIC5322L**  
**3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY**

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**THERMAL INFORMATION**



† Less than 2% duty cycle

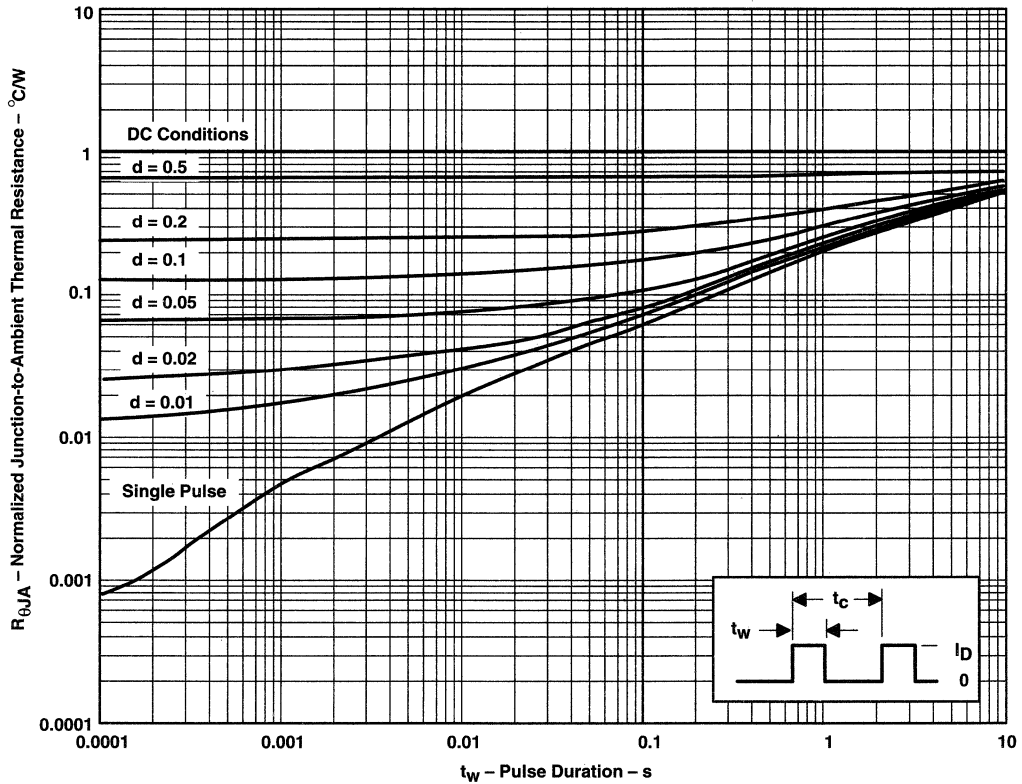


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**3-CHANNEL INDEPENDENT LOGIC-LEVEL POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**D PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**VS**  
**PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heat sink

- NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17



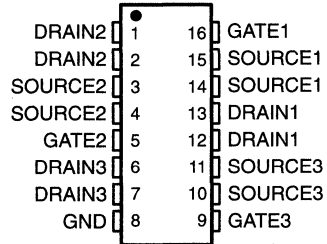
# TPIC5323L

## 3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

SLIS044A – NOVEMBER 1994 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 0.6  $\Omega$  Typ
- Voltage Output . . . 60 V
- Input Protection Circuitry . . . 18 V
- Pulsed Current . . . 3 A Per Channel
- Extended ESD Capability . . . 4000 V
- Direct Logic-Level Interface

**D PACKAGE  
(TOP VIEW)**

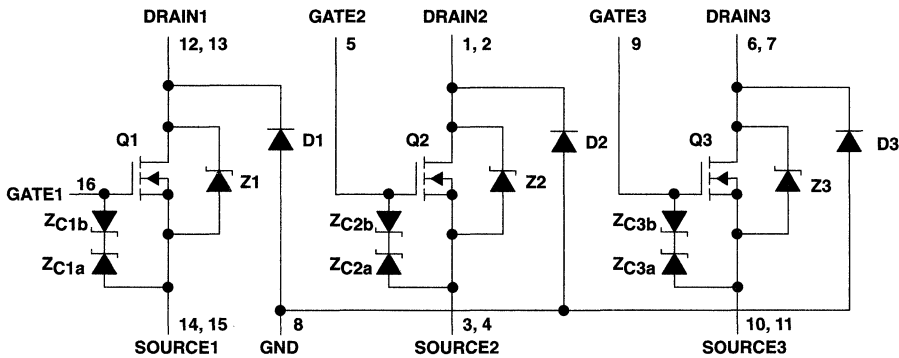


### description

The TPIC5323L is a monolithic gate-protected logic-level power DMOS array that consists of three electrically isolated independent N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5323L is offered in a standard 16-pin small-outline surface-mount (D) package and is characterized for operation over the case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### schematic



NOTE A: For correct operation, no terminal can be taken below GND.



# TPIC5323L

## 3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

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### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage	100 V
Drain-to-GND voltage	100 V
Gate-to-source voltage range, $V_{GS}$	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$	1 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$	1 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15)	3 A
Continuous gate-to-source zener diode current, $T_C = 25^\circ\text{C}$	$\pm 50$ mA
Pulsed gate-to-source zener diode current, $T_C = 25^\circ\text{C}$	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16)	22.5 mJ
Continuous total power dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15)	1.09 W
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$	1.5	1.8	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, D3)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 5 \text{ V}$ ,		0.6	0.7	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3), See Notes 2 and 3 and Figure 12			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$ (D1, D2, D3), See Notes 2 and 3			4		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ ,	$V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.6	0.65		$\Omega$
			$T_C = 125^\circ\text{C}$	0.85	0.9		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 500 \text{ mA}$ ,	0.89	1.06		S
$C_{iss}$	Short-circuit input capacitance, common source			107	137		pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ ,	$V_{GS} = 0$ , See Figure 11	71	89		
$C_{rss}$	Short-circuit reverse transfer capacitance, common source			22	28		

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 500 \text{ mA}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ ,	Z1, Z2, and Z3	75		ns
			$di/dt = 100 \text{ A}/\mu\text{s}$ ,	D1, D2, and D3	190		
$Q_{RR}$	Total diode charge			Z1, Z2, and Z3	0.08		$\mu\text{C}$
				D1, D2, and D3	0.85		



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**POWER DMOS ARRAY**

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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

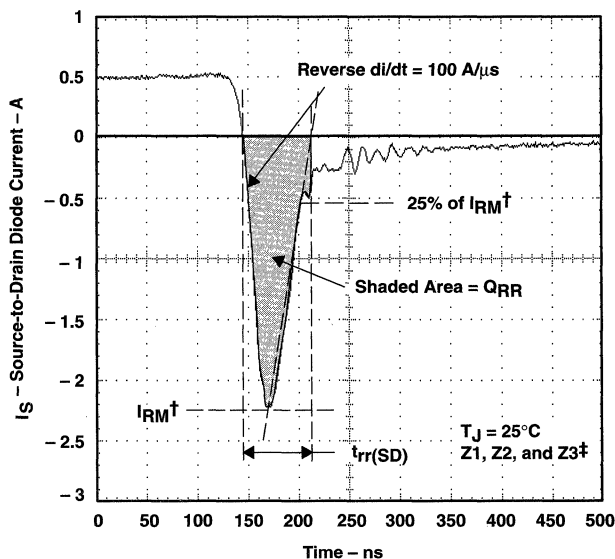
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{r1} = 10\text{ ns}$ , $t_{f1} = 10\text{ ns}$ , See Figure 2		34	50	ns
$t_{d(off)}$ Turn-off delay time			50	70	
$t_{r2}$ Rise time			20	30	
$t_{f2}$ Fall time			15	25	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 500\text{ mA}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		2	2.45	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.3	0.95	
$Q_{gd}$ Gate-to-drain charge			1.2	1.48	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		115		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		64		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		33		

- NOTES: 4. Package mounted on an FR4 printed-circuit board with no heatsink.  
 5. Package mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board.  
 6. Package mounted in intimate contact with infinite heatsink.  
 7. All outputs with equal power

**PARAMETER MEASUREMENT INFORMATION**



†  $I_{RM}$  = maximum recovery current

‡ The above waveform is representative of D1, D2, and D3 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**

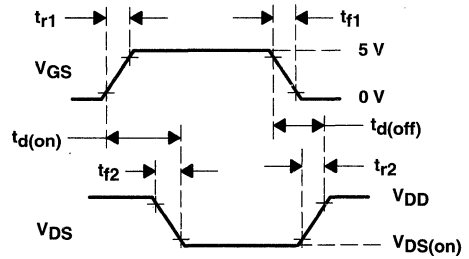
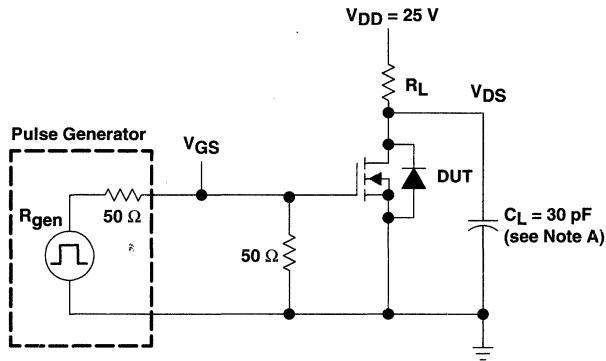


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**POWER DMOS ARRAY**

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**PARAMETER MEASUREMENT INFORMATION**

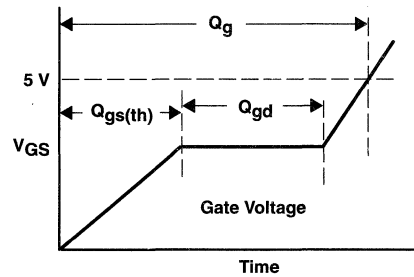
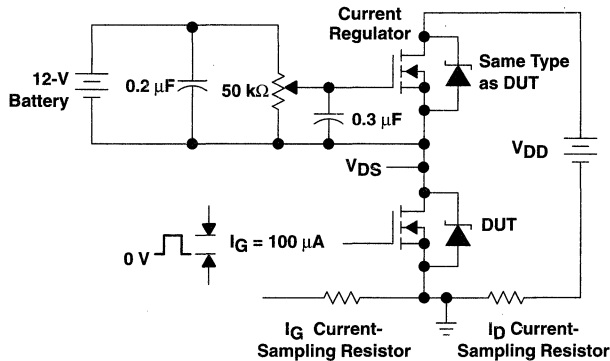


VOLTAGE WAVEFORMS

TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**



VOLTAGE WAVEFORM

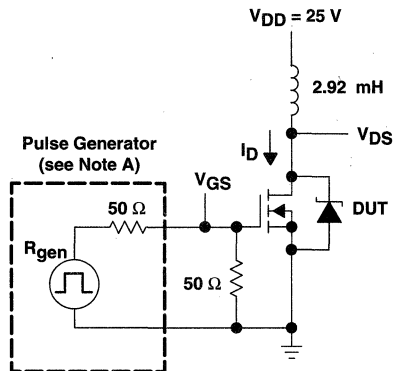
TEST CIRCUIT

**Figure 3. Gate-Charge Test Circuit and Waveform**

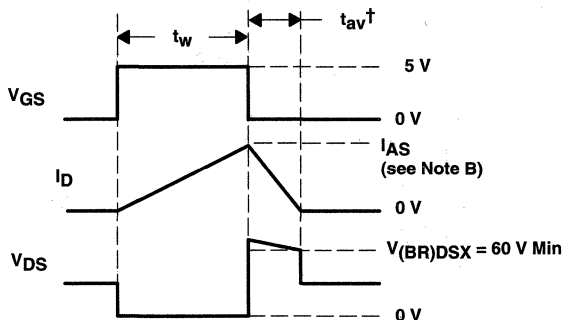
**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**



**VOLTAGE AND CURRENT WAVEFORMS**

† Non-JEDEC symbol for avalanche time

NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .

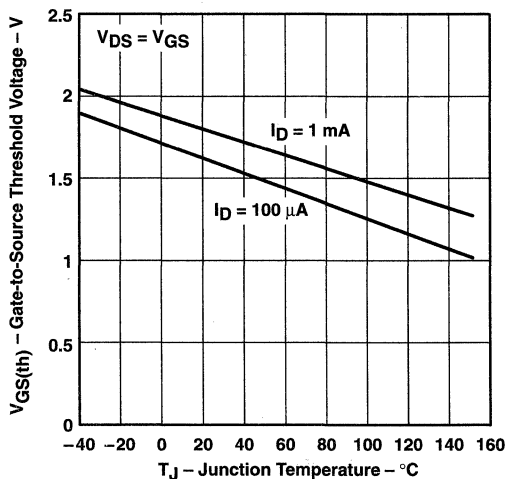
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 22.5 \text{ mJ, where } t_{av} = \text{avalanche time.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

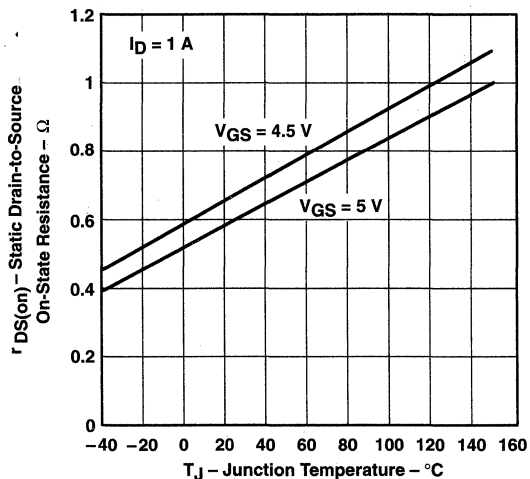
**TYPICAL CHARACTERISTICS**

**GATE-TO-SOURCE THRESHOLD VOLTAGE**  
**vs**  
**JUNCTION TEMPERATURE**



**Figure 5**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**JUNCTION TEMPERATURE**



**Figure 6**

**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**DRAIN CURRENT**

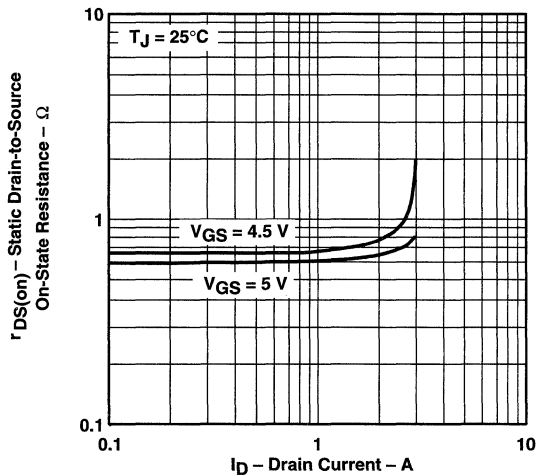


Figure 7

**DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**

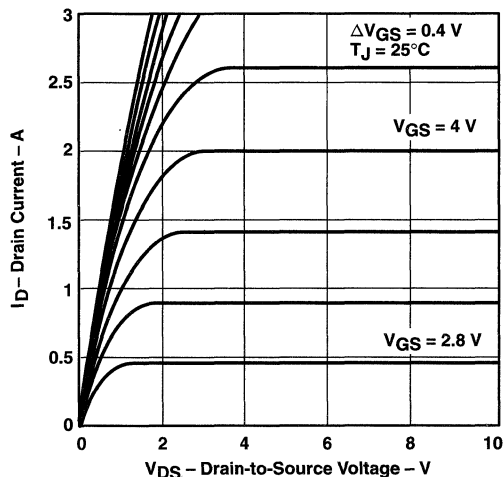


Figure 8

**DISTRIBUTION OF**  
**FORWARD TRANSCONDUCTANCE**

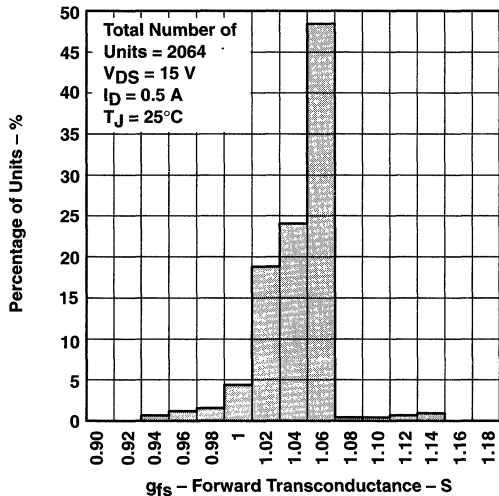


Figure 9

**DRAIN CURRENT**  
**vs**  
**GATE-TO-SOURCE VOLTAGE**

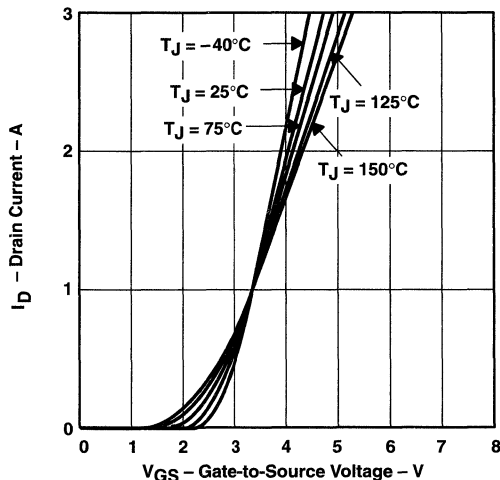
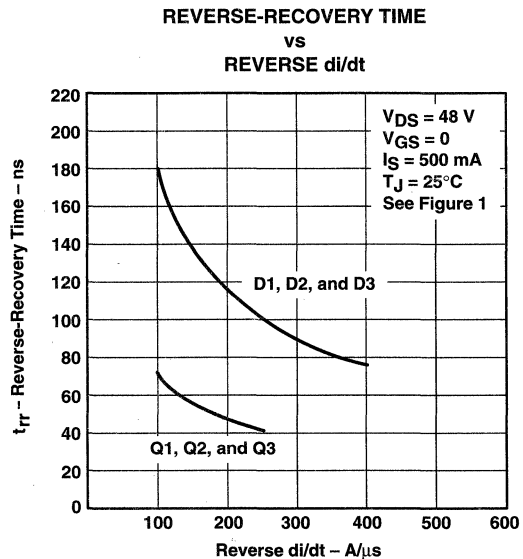
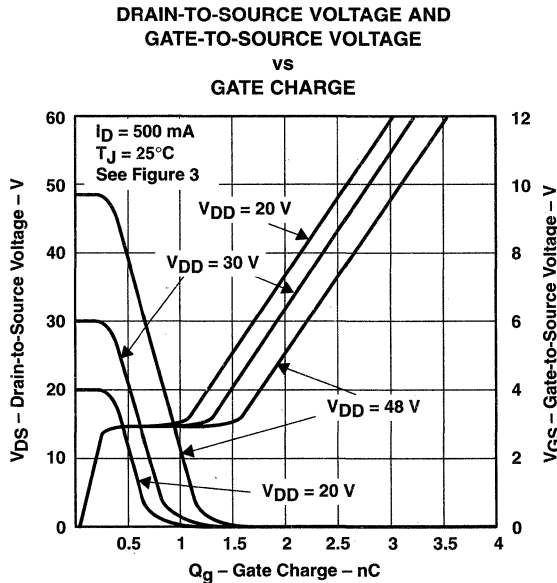
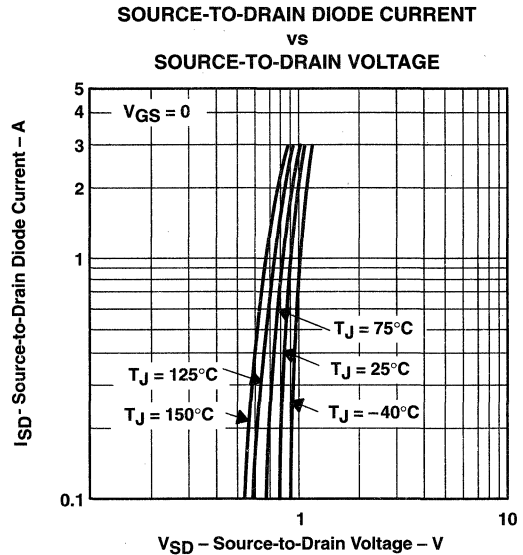
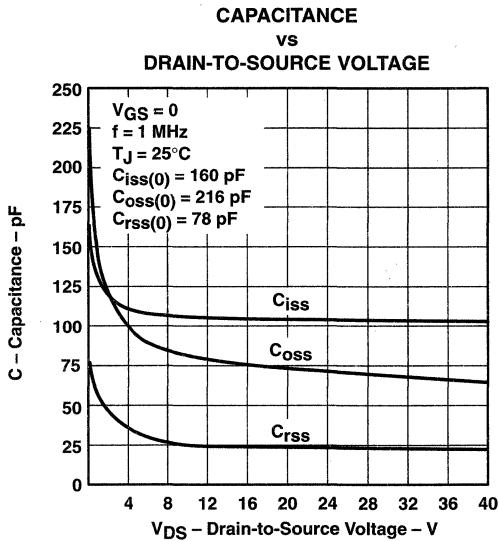


Figure 10

**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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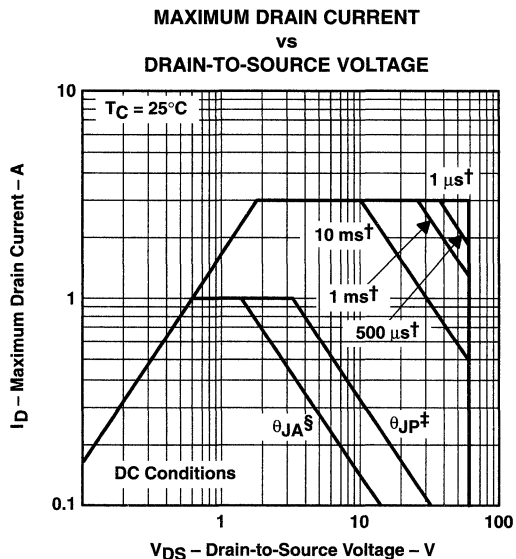
**TYPICAL CHARACTERISTICS**



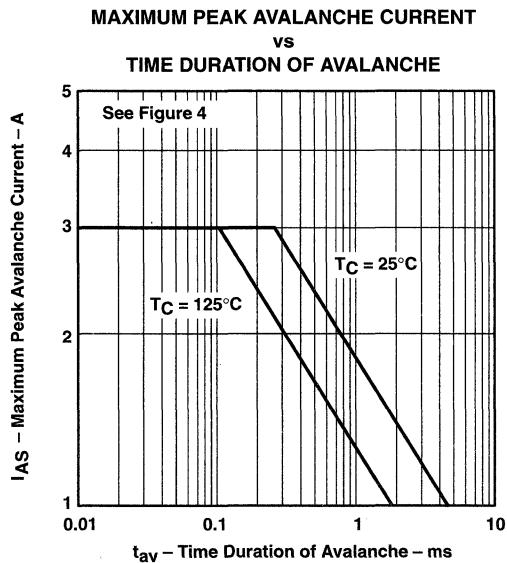
**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**



† Less than 2% duty cycle  
 ‡ Device mounted in intimate contact with infinite heatsink.  
 § Device mounted on FR4 printed-circuit board with no heatsink.



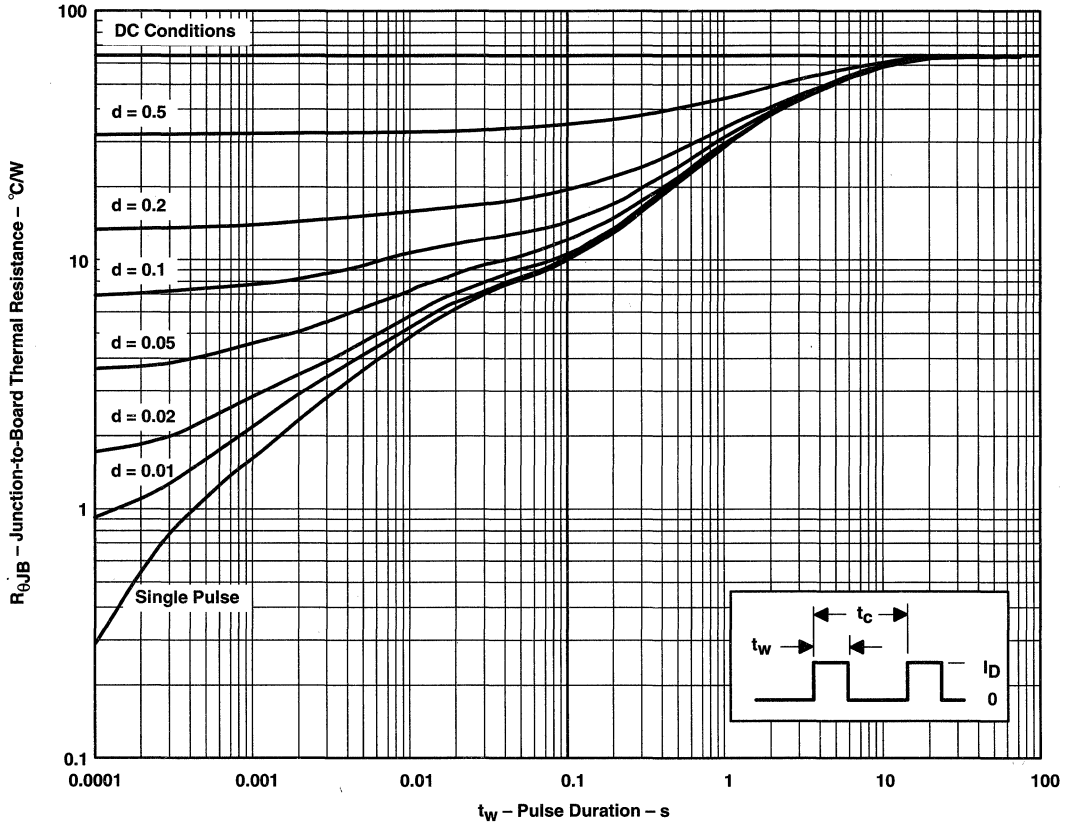


**TPIC5323L**  
**3-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**D PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

NOTE A:  $Z_{\theta B}(t) = r(t) R_{\theta JB}$

$t_w$  = pulse duration

$t_c$  = cycle time

$d$  = duty cycle =  $t_w/t_c$

**Figure 17**

# TPIC5401 H-BRIDGE GATE-PROTECTED POWER DMOS ARRAY

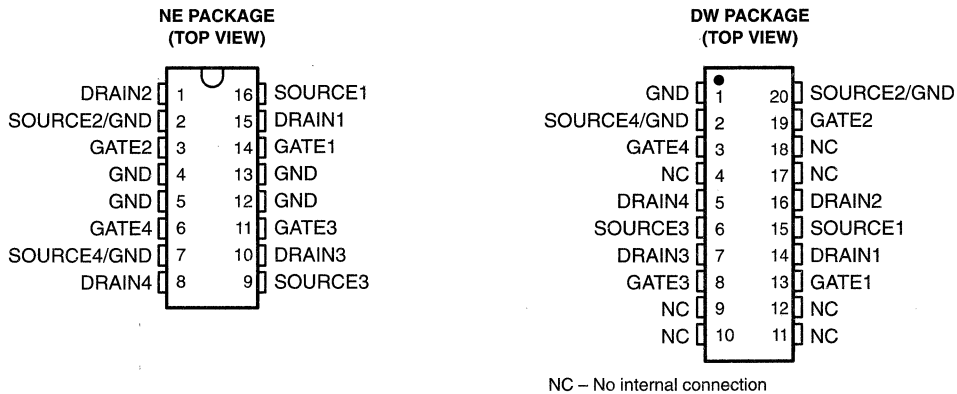
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- Low  $r_{DS(on)}$  . . . 0.3  $\Omega$  Typ
- High Voltage Output . . . 60 V
- Extended ESD Capability . . . 4000 V
- Pulsed Current . . . 10 A Per Channel
- Fast Commutation Speed

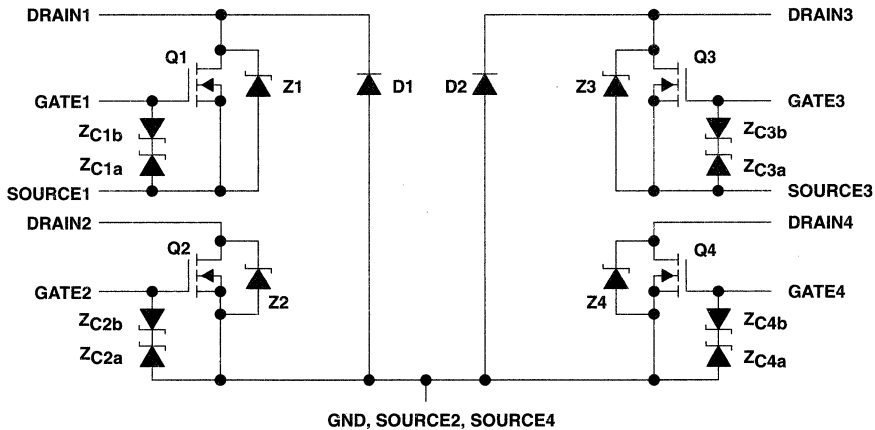
## description

The TPIC5401 is a monolithic gate-protected power DMOS array that consists of four electrically isolated N-channel enhancement-mode DMOS transistors, two of which are configured with a common source. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5401 is offered in a 16-pin thermally enhanced dual-in-line (NE) package and a 20-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



## schematic



NOTE: For correct operation, no terminal pin may be taken below GND.

**TPIC5401**  
**H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage (Q1, Q3) .....	100 V
Drain-to-GND voltage (Q1, Q3) .....	100 V
Drain-to-GND voltage (Q2, Q4) .....	60 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ : DW package .....	1.7 A
NE package .....	2 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	2 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	10 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15, and 16) .....	21 mJ
Continuous total dissipation .....	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$ .....	-40°C to 150°C
Operating case temperature range, $T_C$ .....	-40°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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/°C	279 mW
NE	2075 mW	16.6 mW/°C	415 mW



**TPIC5401**  
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**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.85	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 2 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.6	0.7	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 2 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3 and Figure 12			1	1.2	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 2 \text{ A}$ (D1, D2), See Notes 2 and 3			7.5		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ ,	$V_{DS} = 0$		20	200	nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 2 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.3	0.35	$\Omega$	
			$T_C = 125^\circ\text{C}$	0.47	0.5		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 1 \text{ A}$ , See Figure 9	1.6	1.9	S	
$C_{iss}$	Short-circuit input capacitance, common source			220	275	pF	
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ ,	$V_{GS} = 0$ ,	120	150		
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source	$f = 1 \text{ MHz}$ ,	See Figure 11	100	125		

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ ,	Z1 and Z3	120	ns	
				Z2 and Z4	280		
				D1 and D2	260		
$Q_{RR}$	Total diode charge			Z1 and Z3	0.12	$\mu\text{C}$	
				Z2 and Z4	0.9		
				D1 and D2	2.2		



**TPIC5401**  
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**POWER DMOS ARRAY**

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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

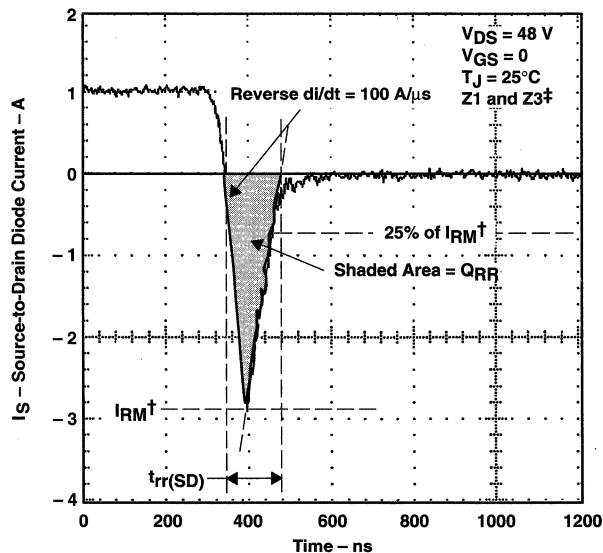
PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $t_{dis} = 10\text{ ns}$	$R_L = 25\ \Omega$ , See Figure 2	$t_{en} = 10\text{ ns}$	32	65	ns	
$t_{d(off)}$	Turn-off delay time				40	80		
$t_r$	Rise time				15	30		
$t_f$	Fall time				25	50		
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3	$I_D = 1\text{ A}$ ,	$V_{GS} = 10\text{ V}$ ,	6.6	8	nC	
$Q_{gs(th)}$	Threshold gate-to-source charge				0.8	1		
$Q_{gd}$	Gate-to-drain charge				2.6	3.2		
$L_d$	Internal drain inductance				5	nH		
$L_s$	Internal source inductance				5			
$R_g$	Internal gate resistance				0.25	$\Omega$		

**thermal resistances**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance (see Note 4)	DW	All outputs with equal power	90	$^\circ\text{C/W}$		
		NE		60			
$R_{\theta JB}$	Junction-to-board thermal resistance	DW		53			
$R_{\theta JP}$	Junction-to-pin thermal resistance	DW		30			
		NE		25			

NOTE 4: Package mounted on an FR4 printed-circuit board with no heatsink.

**PARAMETER MEASUREMENT INFORMATION**



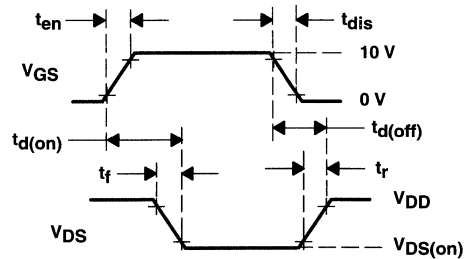
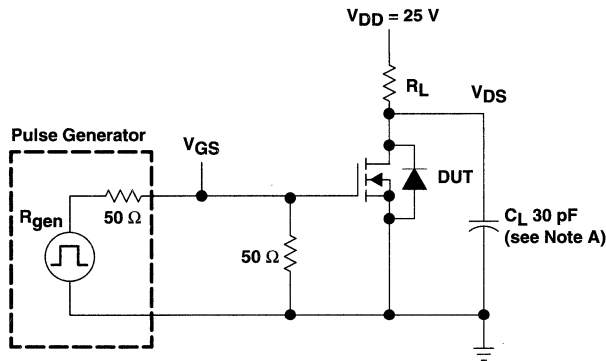
†  $I_{RM}$  = maximum recovery current

‡ The above waveform is representative of Z2, Z4, D1, and D2 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**



PARAMETER MEASUREMENT INFORMATION

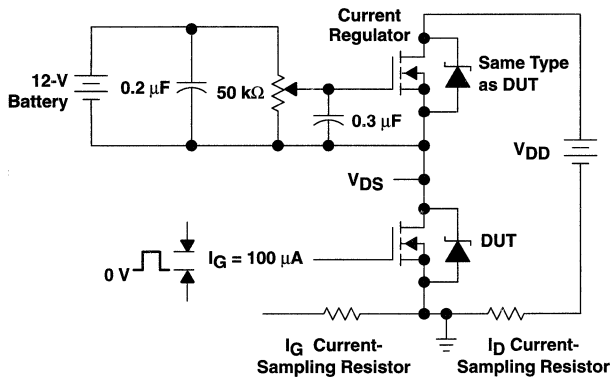


VOLTAGE WAVEFORMS

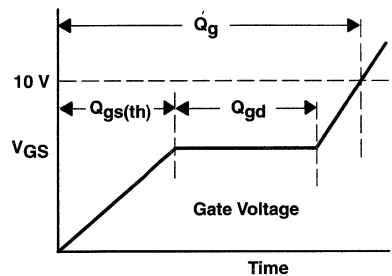
TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



TEST CIRCUIT



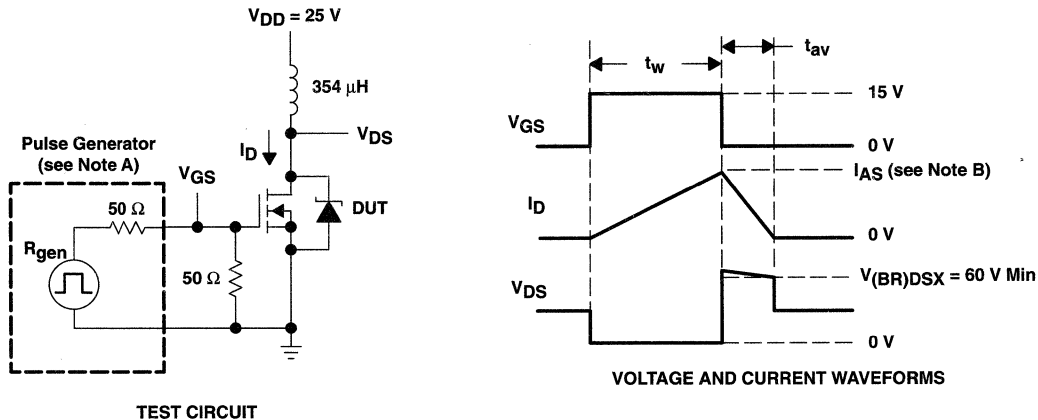
WAVEFORM

Figure 3. Gate-Charge Test Circuit and Waveform

**TPIC5401**  
**H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**PARAMETER MEASUREMENT INFORMATION**

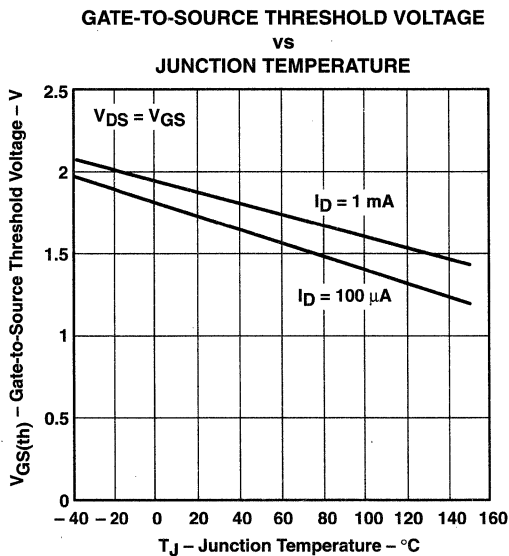


- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 10$  A.

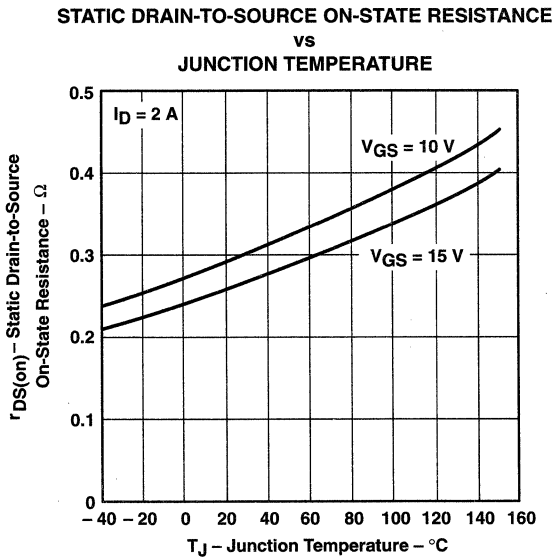
Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 21$  mJ.

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**



**Figure 5**



**Figure 6**

TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

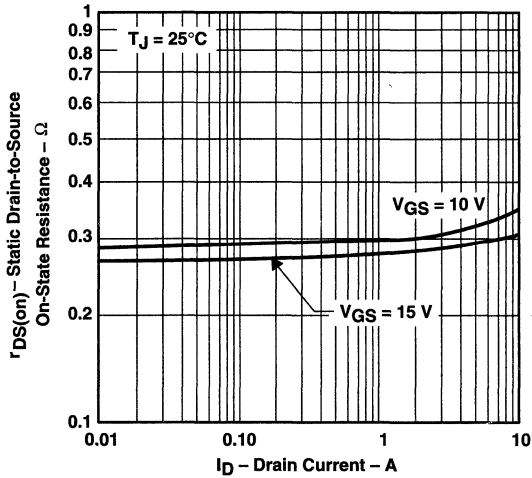


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

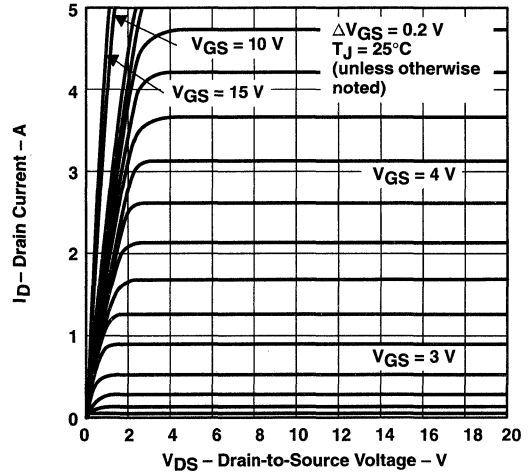


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

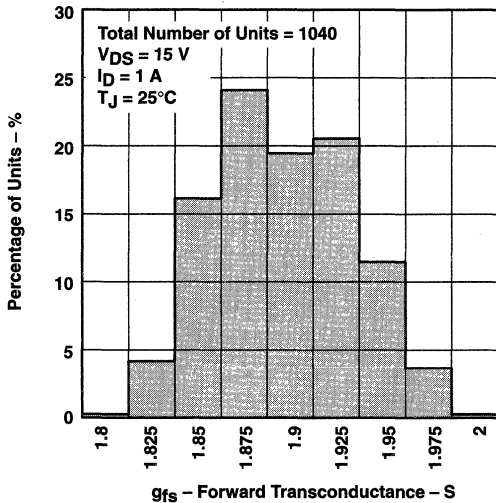


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

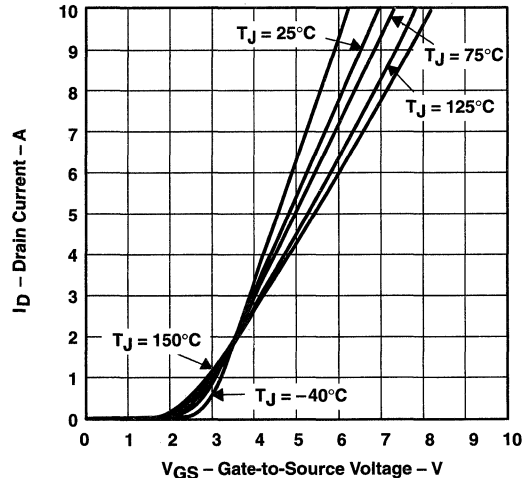


Figure 10



**TPIC5401**  
**H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

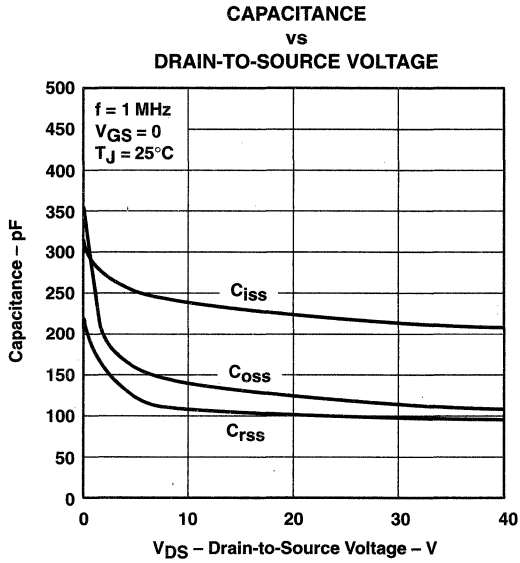


Figure 11

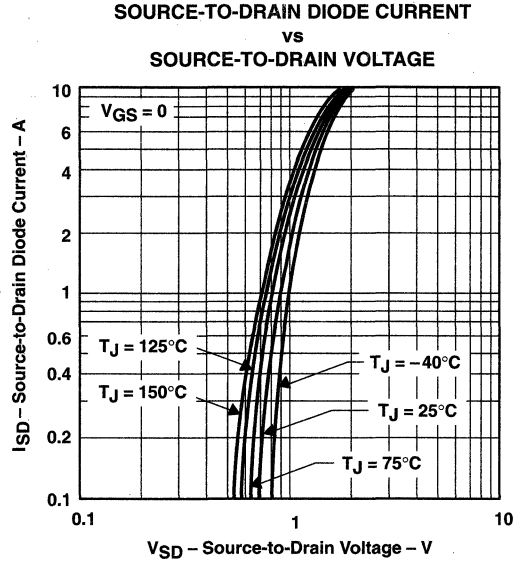


Figure 12

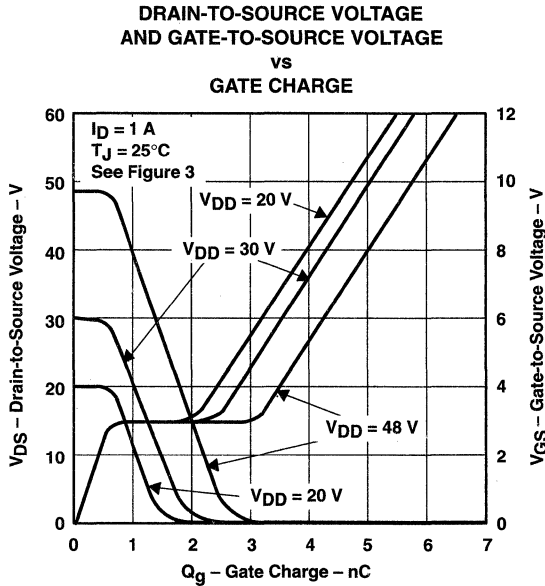


Figure 13

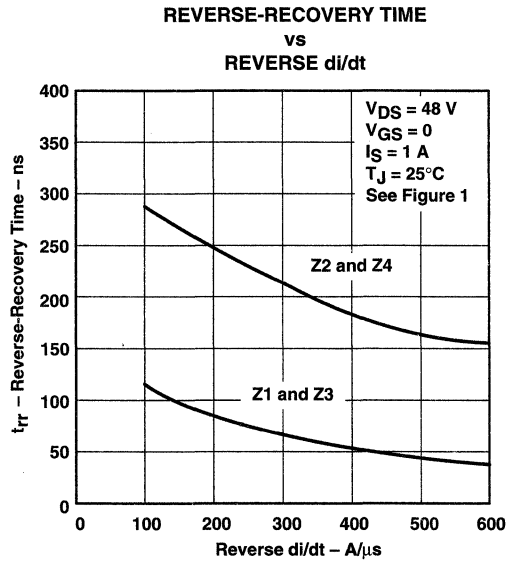
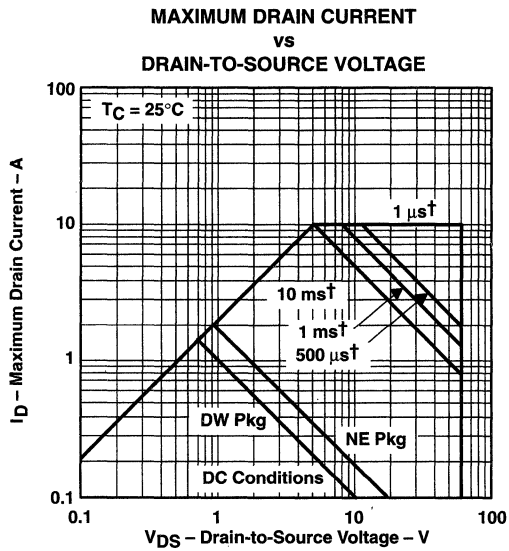


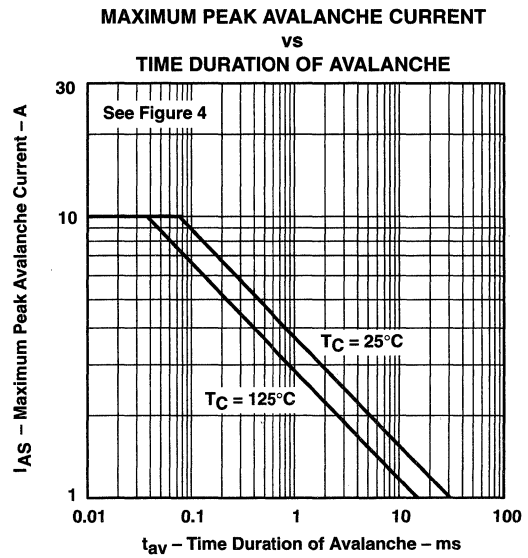
Figure 14



THERMAL INFORMATION



† Less than 2% duty cycle

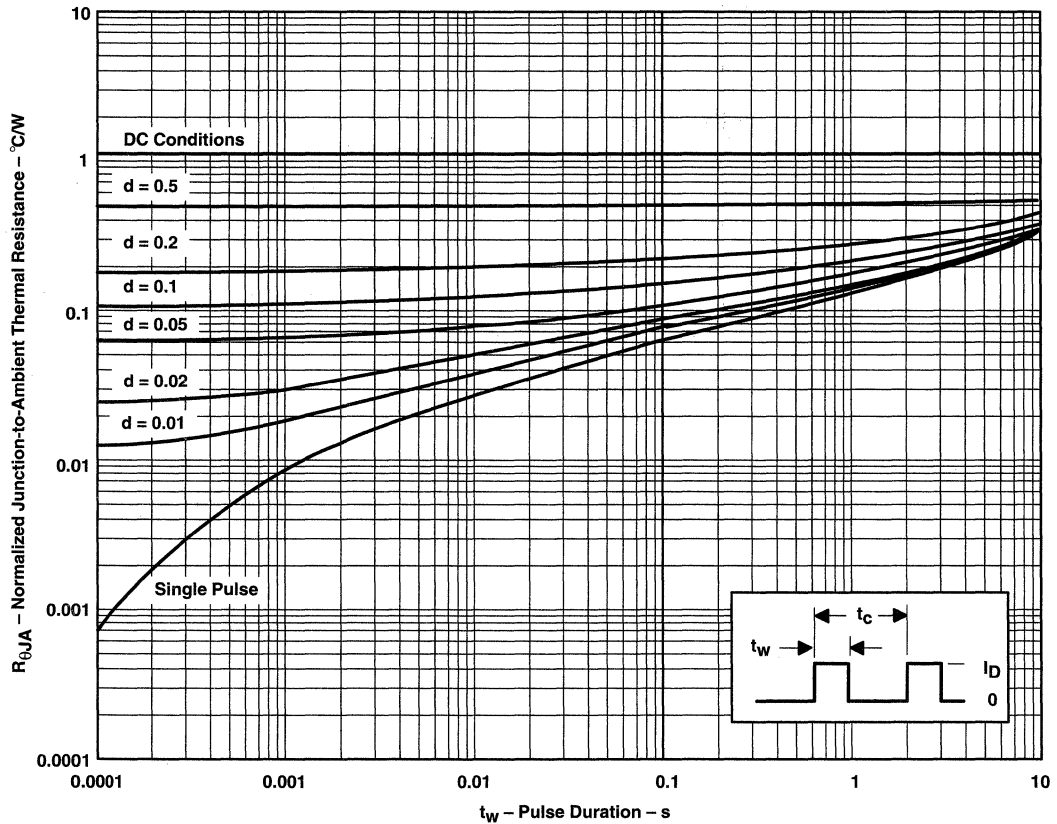


**TPIC5401**  
**H-BRIDGE GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**NE PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



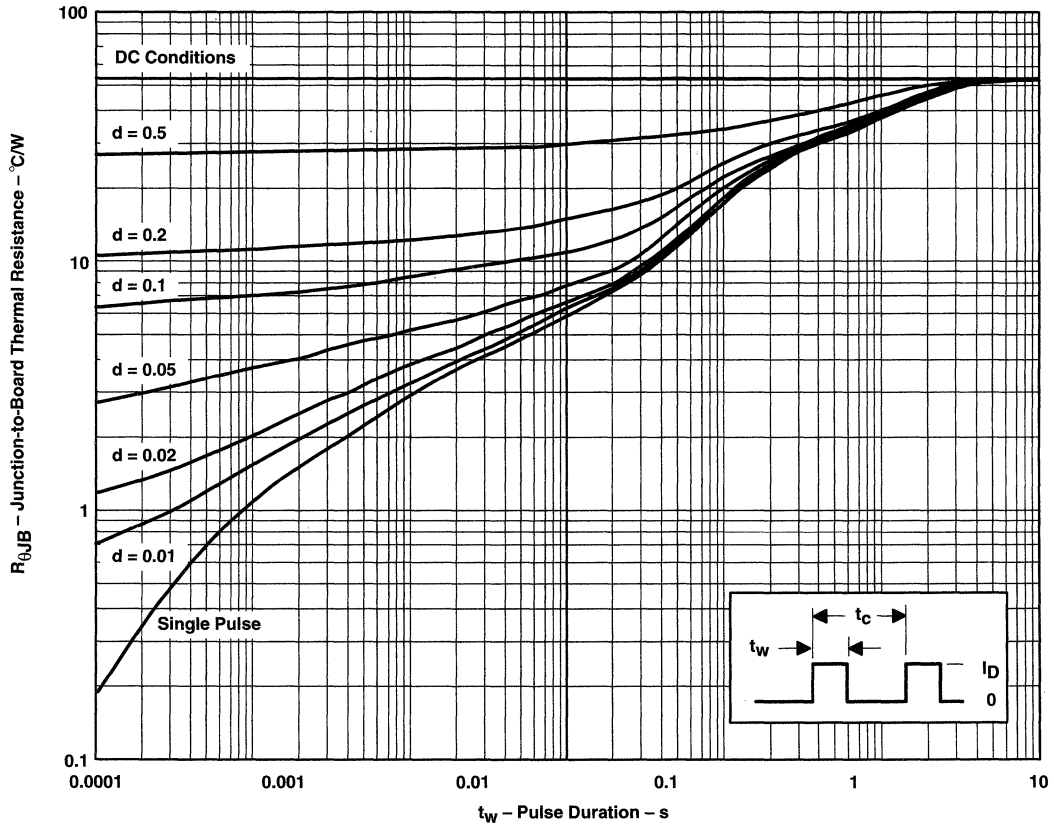
† Device mounted on FR4 printed-circuit board with no heatsink.

NOTE A.  $Z_{\theta JA}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**

THERMAL INFORMATION

DW PACKAGE†  
JUNCTION-TO-BOARD THERMAL RESISTANCE  
vs  
PULSE DURATION



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

NOTE B.  $Z_{\theta JB}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 18



# TPIC5403

## 4-CHANNEL INDEPENDENT GATE-PROTECTED POWER DMOS ARRAY

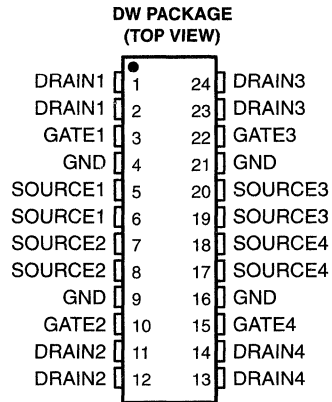
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- Low  $r_{DS(on)}$  . . . 0.23  $\Omega$  Typ
- High Voltage Output . . . 60 V
- Extended ESD Capability . . . 4000 V
- Pulsed Current . . . 11.25 A Per Channel
- Fast Commutation Speed

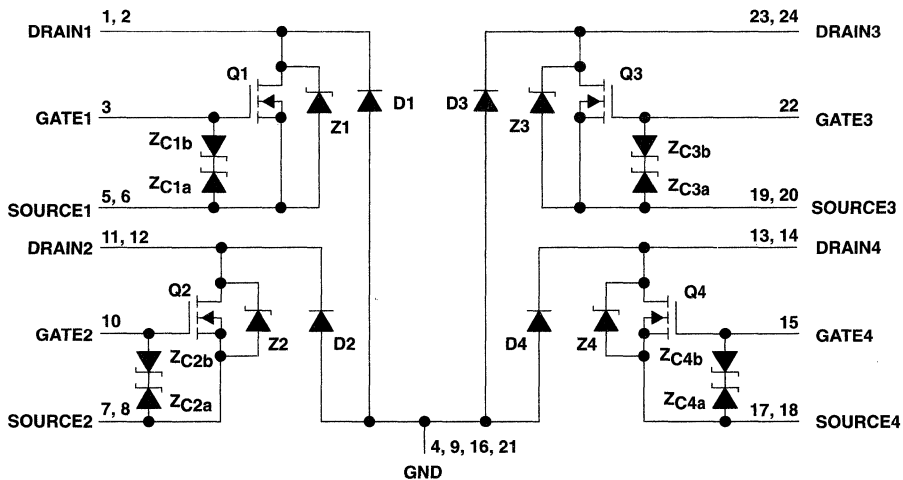
### description

The TPIC5403 is a monolithic gate-protected power DMOS array that consists of four independent electrically isolated N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5403 is offered in a 24-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



### schematic



NOTE A: For correct operation, no terminal may be taken below GND.

# TPIC5403

## 4-CHANNEL INDEPENDENT GATE-PROTECTED POWER DMOS ARRAY

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### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage	100 V
Drain-to-GND voltage	100 V
Gate-to-source voltage range, $V_{GS}$	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$	2.25 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$	2.25 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15)	11.25 A
Continuous gate-to-source zener diode current, $T_C = 25^\circ\text{C}$	$\pm 50$ mA
Pulsed gate-to-source zener diode current, $T_C = 25^\circ\text{C}$	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15, and 16)	17.2 mJ
Continuous total power dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15)	1.39 W
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.75	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$		18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$		9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, D3, and D4)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 2.25 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.5	0.62	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 2.25 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3 and Figure 12			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 2.25 \text{ A}$ (D1, D2, D3, D4), See Notes 2 and 3			2.5		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ ,	$V_{DS} = 0$	20	200		nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$	10	100		nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 2.25 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.23	0.27		$\Omega$
			$T_C = 125^\circ\text{C}$	0.35	0.4		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ ,	$I_D = 1.125 \text{ A}$ , See Notes 2 and 3 and Figure 9	1.6	2.1		S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ , $V_{GS} = 0$ , See Figure 11		200	250		pF
$C_{oss}$	Short-circuit output capacitance, common source			100	175		
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source			60	75		

- NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 1.125 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ ,	Z1, Z2, Z3, and Z4	80		ns
				D1, D2, D3, and D4	160		
$Q_{RR}$	Total diode charge			Z1, Z2, Z3, and Z4	0.12		$\mu\text{C}$
				D1, D2, D3, and D4	0.5		



**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 20\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2		32	55	ns
$t_{d(off)}$	Turn-off delay time			27	50	
$t_{r2}$	Rise time			14	30	
$t_{f2}$	Fall time			7	15	
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3 $I_D = 1.125\text{ A}$ , $V_{GS} = 10\text{ V}$ ,		6.6	8	nC
$Q_{gs(th)}$	Threshold gate-to-source charge			0.6	0.7	
$Q_{gd}$	Gate-to-drain charge			2.8	3.2	
$L_D$	Internal drain inductance			5		nH
$L_S$	Internal source inductance			5		
$R_g$	Internal gate resistance			0.25		$\Omega$

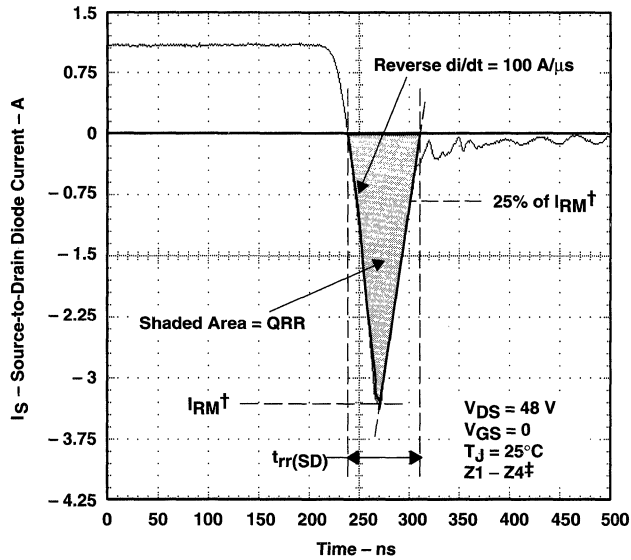
**thermal resistance**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	See Notes 4 and 7		90		$^\circ\text{C/W}$
$R_{\theta JB}$	Junction-to-board thermal resistance	See Notes 5 and 7		49		$^\circ\text{C/W}$
$R_{\theta JP}$	Junction-to-pin thermal resistance	See Notes 6 and 7		28		$^\circ\text{C/W}$

- NOTES:
4. Package mounted on an FR4 printed-circuit board with no heatsink
  5. Package mounted on a 24 inch<sup>2</sup>, 4-layer FR4 printed-circuit board
  6. Package mounted in intimate contact with infinite heatsink
  7. All outputs with equal power



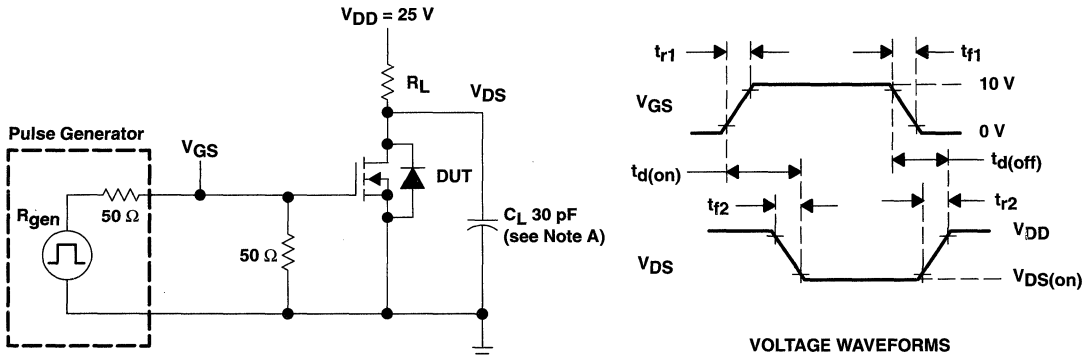
**PARAMETER MEASUREMENT INFORMATION**



$^\dagger I_{RM}$  = maximum recovery current

$\ddagger$  The above waveform is representative of D1, D2, D3, and D4 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**



**TEST CIRCUIT**

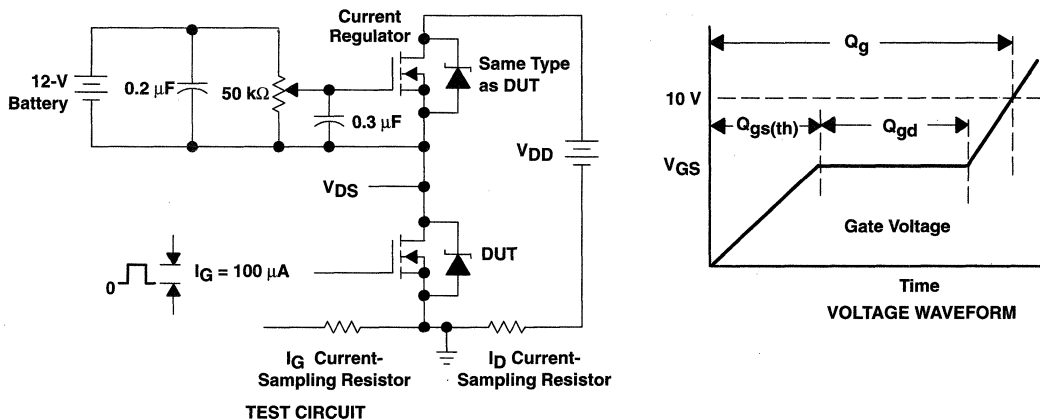
NOTE A:  $C_L$  includes probe and jig capacitance.

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**

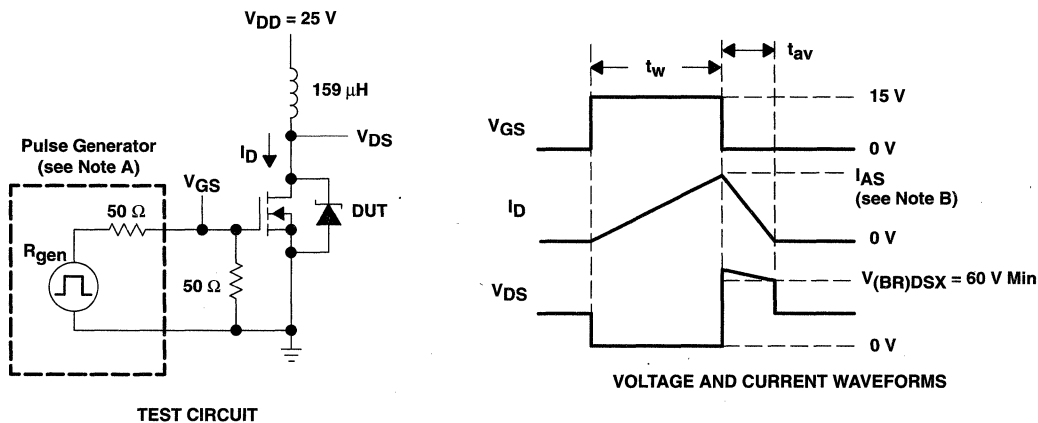
**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 11.25$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 17.2 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

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**TYPICAL CHARACTERISTICS**

**GATE-TO-SOURCE THRESHOLD VOLTAGE**  
**vs**  
**JUNCTION TEMPERATURE**

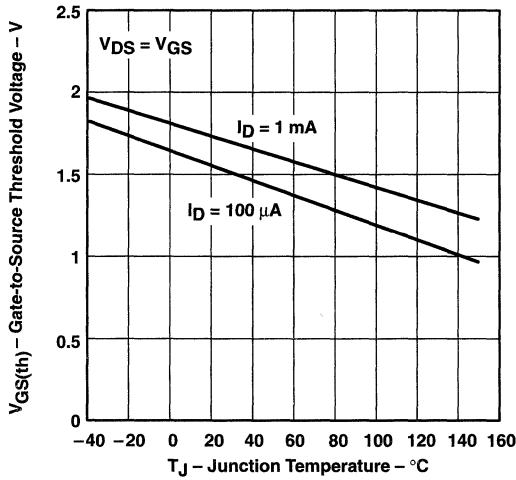


Figure 5

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**JUNCTION TEMPERATURE**

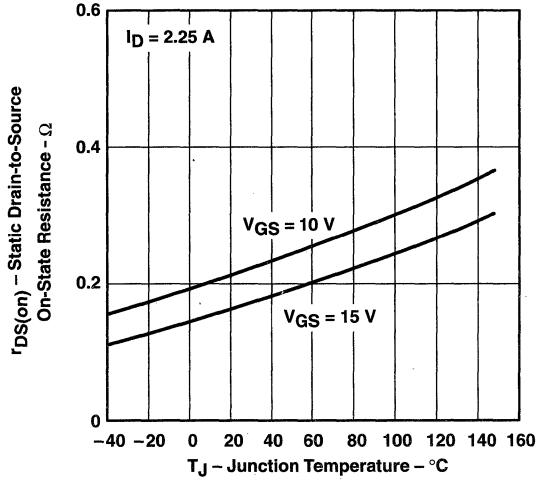


Figure 6

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
**vs**  
**DRAIN CURRENT**

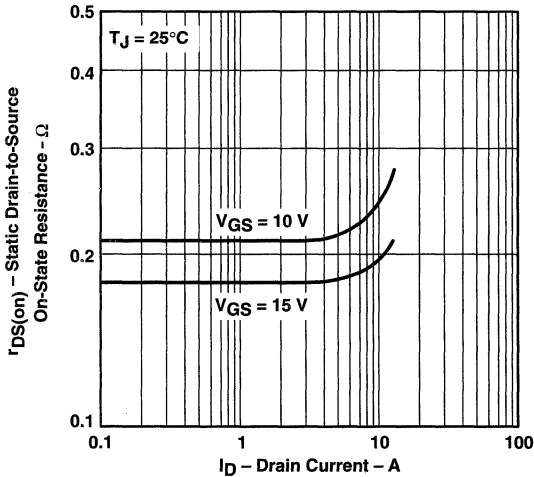


Figure 7

**DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**

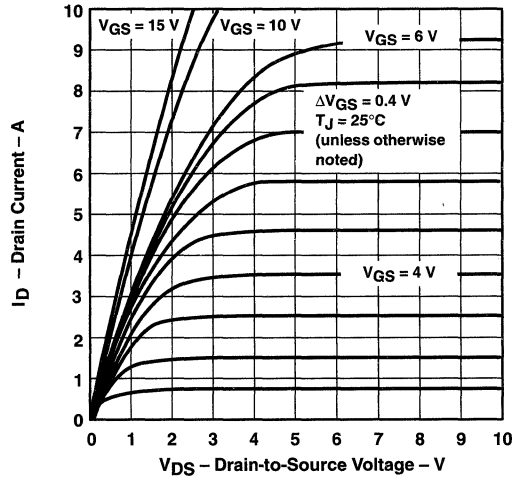


Figure 8

**PRODUCT PREVIEW**

**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

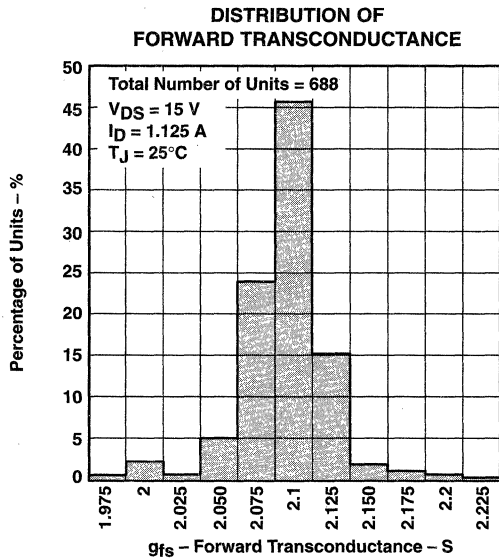


Figure 9

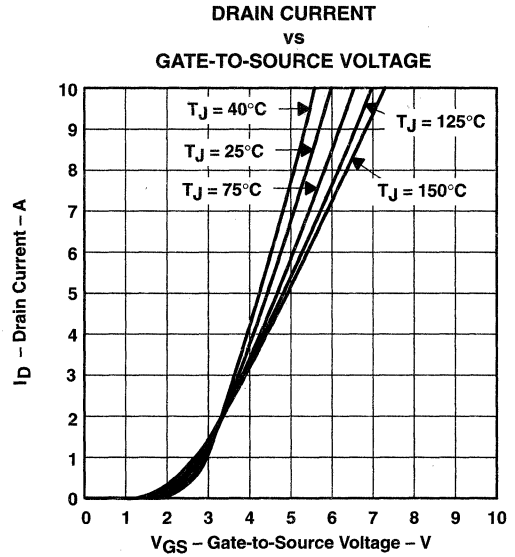


Figure 10

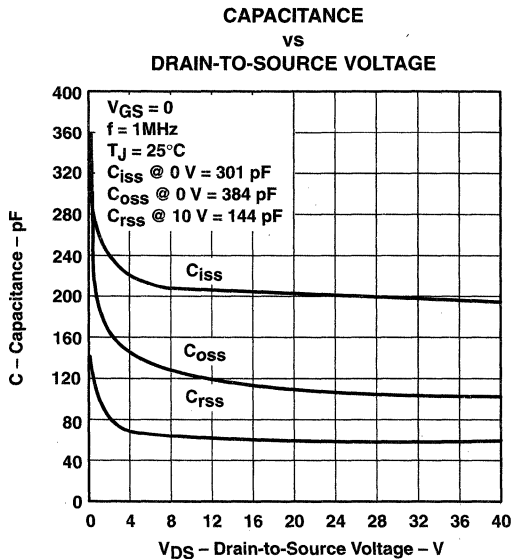


Figure 11

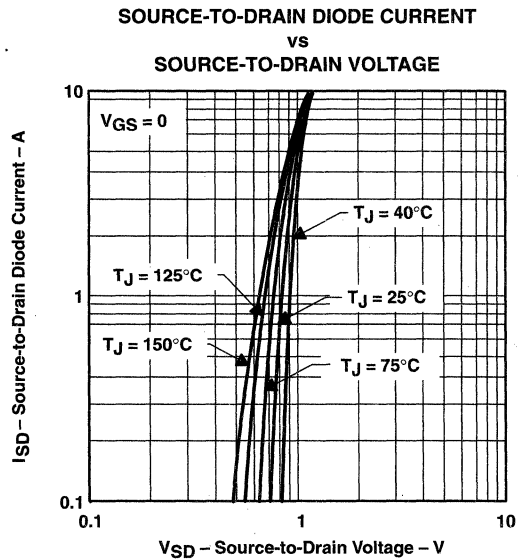


Figure 12

**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**TYPICAL CHARACTERISTICS**

**DRAIN-TO-SOURCE VOLTAGE AND**  
**GATE-TO-SOURCE VOLTAGE**  
**vs**  
**GATE CHARGE**

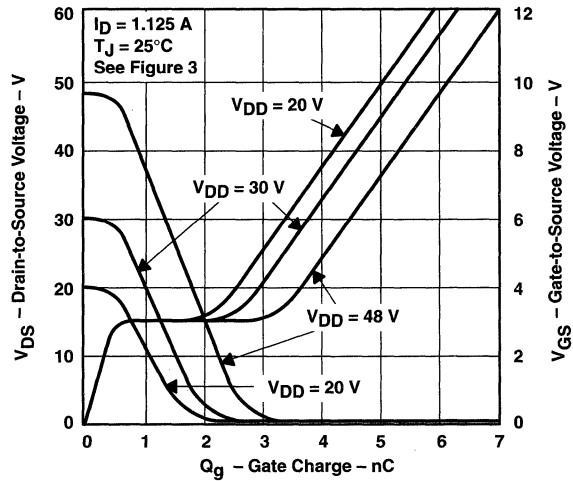


Figure 13

**REVERSE-RECOVERY TIME**  
**vs**  
**REVERSE  $di/dt$**

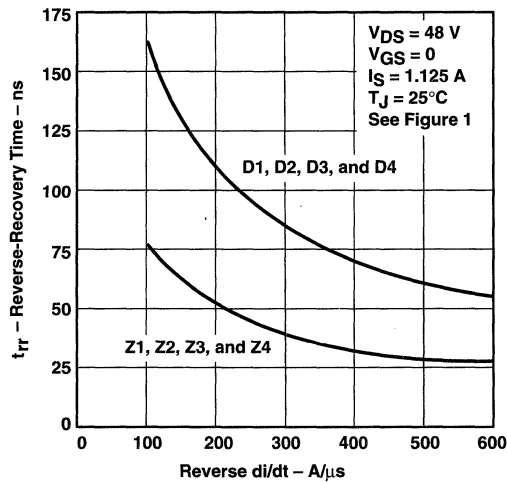


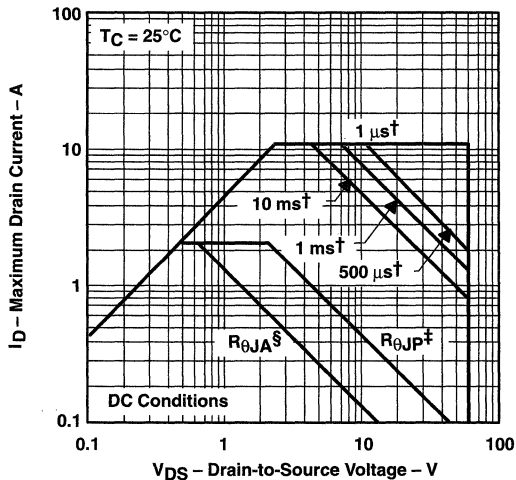
Figure 14

**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**MAXIMUM DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



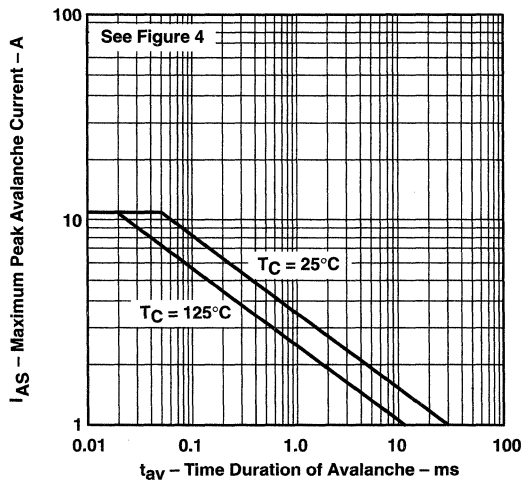
† Less than 2% duty cycle

‡ Device mounted in intimate contact with infinite heatsink.

§ Device mounted on FR4 printed circuit board with no heatsink.

**Figure 15**

**MAXIMUM PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



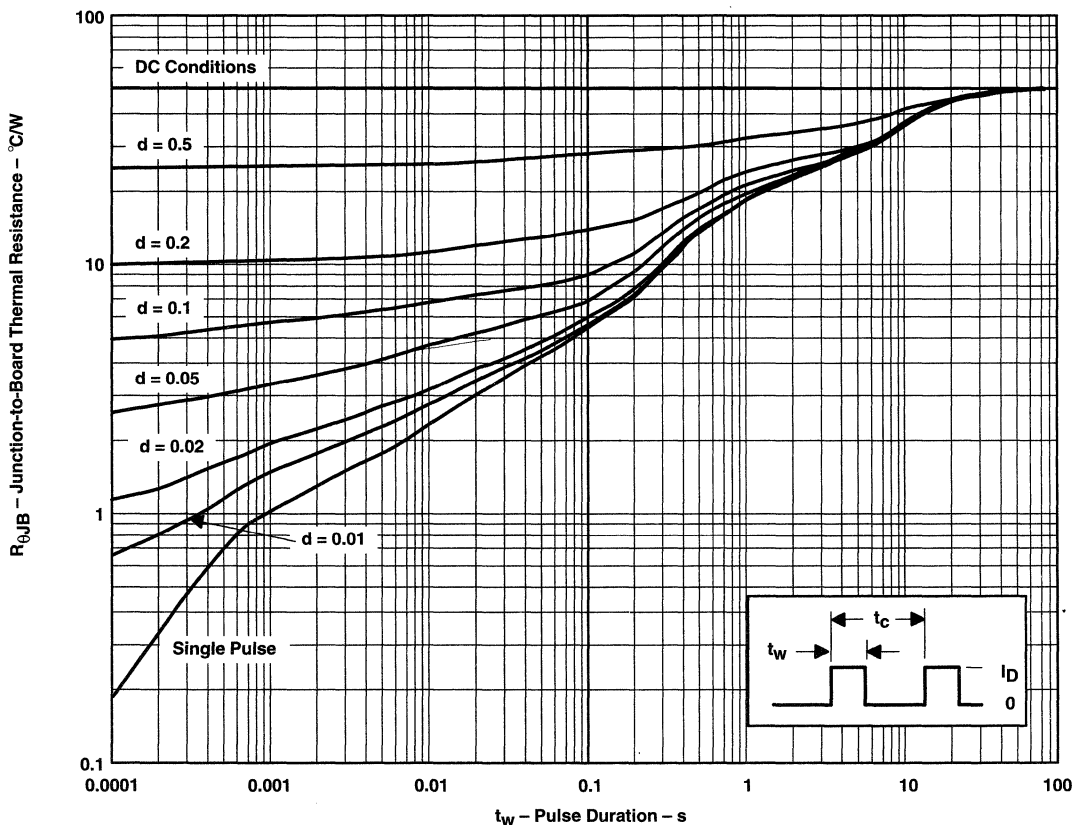
**Figure 16**

**TPIC5403**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**DW PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on 24in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

NOTE A:  $Z_{\theta JB}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**





# TPIC5404 H-BRIDGE POWER DMOS ARRAY

SLIS023B – MARCH 1994 – REVISED SEPTEMBER 1995

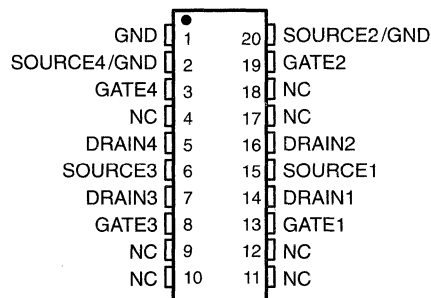
- Low  $r_{DS(on)}$  . . . 0.3  $\Omega$  Typ
- High-Voltage Output . . . 60 V
- Pulsed Current . . . 10 A Per Channel
- Fast Commutation Speed

## description

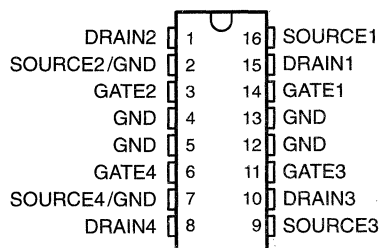
The TPIC5404 is a monolithic power DMOS array that consists of four electrically isolated N-channel enhancement-mode DMOS transistors, two of which are configured with a common source.

The TPIC5404 is offered in a 16-pin thermally enhanced dual-in-line (NE) package and a 20-pin wide-body surface-mount (DW) package. The TPIC5404 is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

DW PACKAGE  
(TOP VIEW)

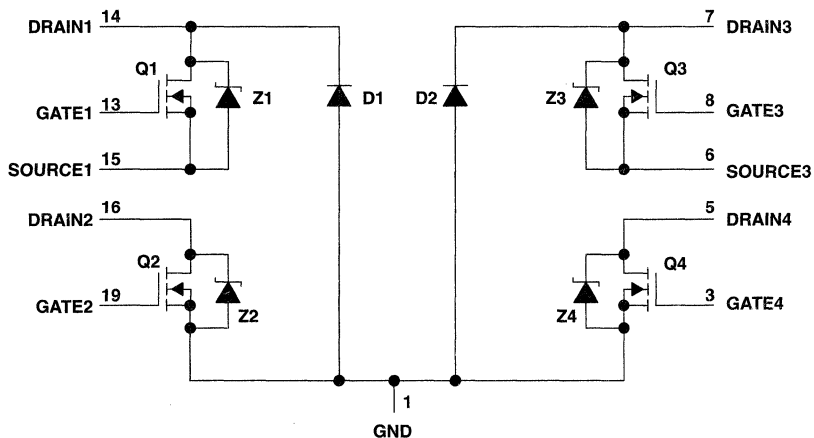


NE PACKAGE  
(TOP VIEW)



NC – No internal connection

## schematic



NOTE A: Pin numbers shown are for the DW package.

# TPIC5404

## H-BRIDGE POWER DMOS ARRAY

SLIS023B – MARCH 1994 – REVISED SEPTEMBER 1995

### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage (Q1, Q3)	100 V
Drain-to-GND voltage (Q1, Q3)	100 V
Drain-to-GND voltage (Q2, Q4)	60 V
Gate-to-source voltage, $V_{GS}$	$\pm 20$
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ : DW package	1.7 A
NE package	2 A
Continuous source-to-drain diode current (NE package)	2 A
Pulsed drain current, each output, $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15)	10 A
Single-pulse avalanche energy, $T_C = 25^\circ\text{C}$ (see Figures 4 and 16)	21 mJ
Continuous total power dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/ $^\circ\text{C}$	279 mW
NE	2075 mW	16.6 mW/ $^\circ\text{C}$	415 mW



# TPIC5404 H-BRIDGE POWER DMOS ARRAY

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## electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 2 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.6	0.7	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 2 \text{ A}$ (D1, D2), See Notes 2 and 3			7.5		V
$V_F(SD)$	Forward on-state voltage, source-to-drain	$I_S = 2 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3			1	1.2	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$	10	100	nA	
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$	10	100	nA	
$I_{lkg}$	Leakage current, drain-to-GND	$V_R = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 2 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.3	0.35	$\Omega$	
			$T_C = 125^\circ\text{C}$	0.41	0.5		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3	$I_D = 1 \text{ A}$ ,	1.6	1.9	S	
$C_{iss}$	Short-circuit input capacitance, common source			220	275	pF	
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$	$V_{GS} = 0$ ,	120	150		
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source			100	125		

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum, pulse duration  $\leq 5 \text{ ms}$ .

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

## source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ , $dI/dt = 100 \text{ A}/\mu\text{s}$ , See Figure 1	$V_{DS} = 48 \text{ V}$ , (Z1 and Z3),		120		ns
$Q_{RR}$	Total diode charge				0.12		$\mu\text{C}$
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ , $dI/dt = 100 \text{ A}/\mu\text{s}$ , See Figure 1	$V_{DS} = 48 \text{ V}$ , (Z2 and Z4),		280		ns
$Q_{RR}$	Total diode charge				0.9		$\mu\text{C}$

## GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$ (see schematic, D1 and D2)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_F = 1 \text{ A}$ , $dI/dt = 100 \text{ A}/\mu\text{s}$ ,	$V_{DS} = 48 \text{ V}$ ,		260		ns
$Q_{RR}$	Total diode charge		See Figure 1		2.2		$\mu\text{C}$



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## resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

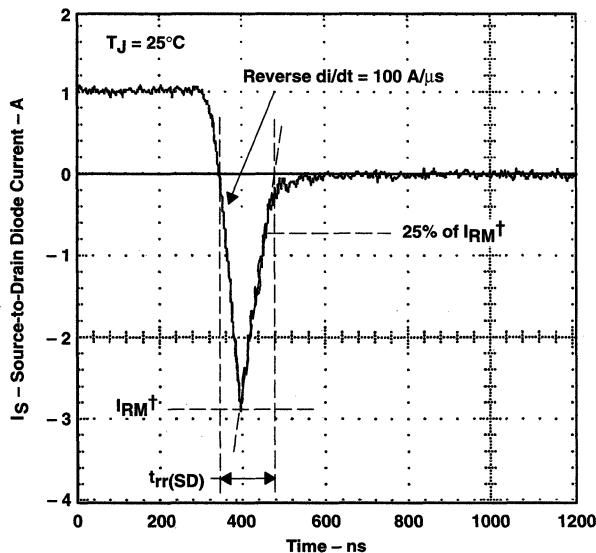
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $t_{f1} = 10\text{ ns}$ , $R_L = 25\ \Omega$ , See Figure 2		32	65	ns
$t_{d(off)}$	Turn-off delay time			40	80	
$t_{r2}$	Rise time			15	30	
$t_{f2}$	Fall time			25	50	
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3 $I_D = 1\text{ A}$ , $V_{GS} = 10\text{ V}$ ,		6.6	8	nC
$Q_{gs(th)}$	Threshold gate-to-source charge			0.8	1	
$Q_{gd}$	Gate-to-drain charge			2.6	3.2	
$L_D$	Internal drain inductance			5		nH
$L_S$	Internal source inductance			5		
$R_g$	Internal gate resistance			0.25		$\Omega$

## thermal resistance

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	DW package		90		$^\circ\text{C/W}$
		NE package	All outputs with equal power, See Note 4	60		
$R_{\theta JP}$	Junction-to-pin thermal resistance	DW package			30	$^\circ\text{C/W}$
		NE package			25	

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

## PARAMETER MEASUREMENT INFORMATION

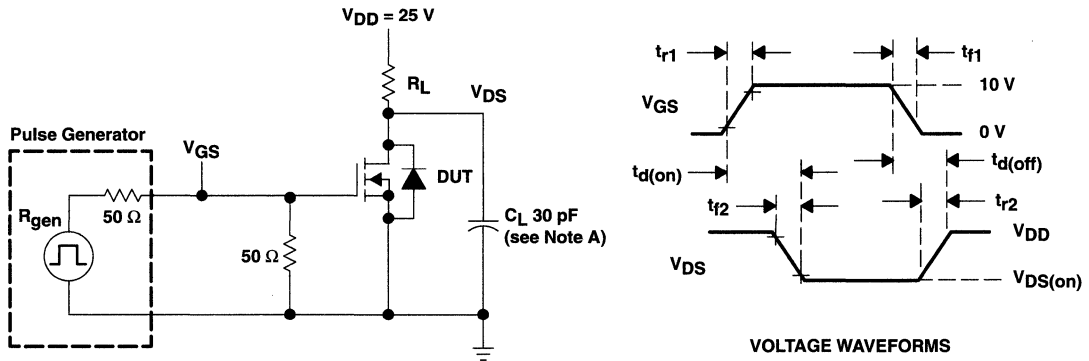


$^\dagger I_{RM}$  = maximum recovery current

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode



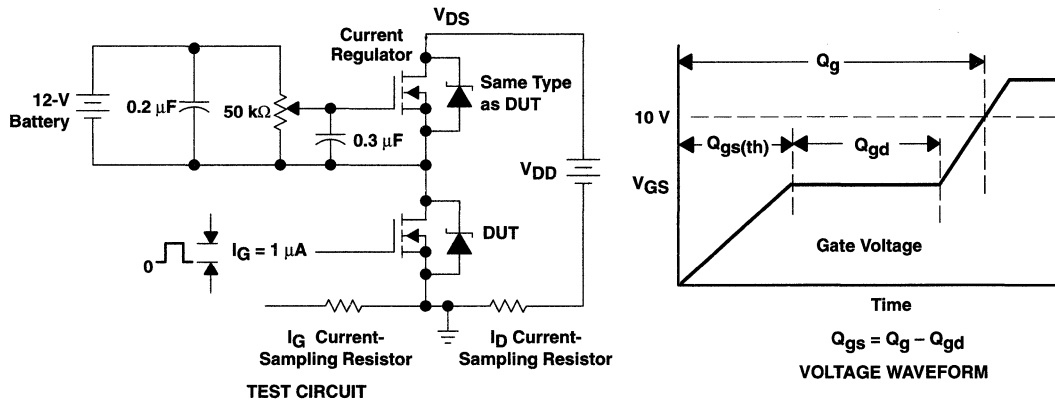
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



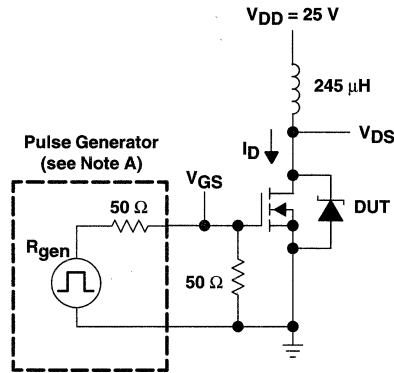
TEST CIRCUIT

Figure 3. Gate-Charge Test Circuit and Voltage Waveform

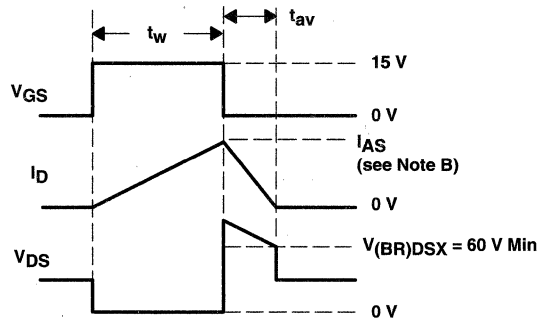
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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 10 \text{ A}$ , where  $t_{av}$  = avalanche time.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 21 \text{ mJ}$$

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

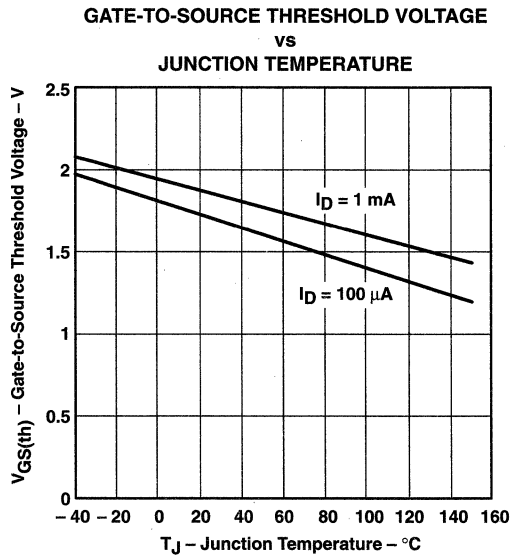


Figure 5

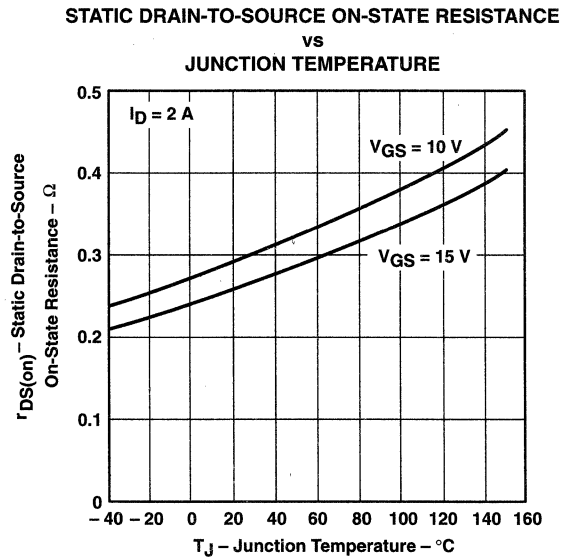


Figure 6



TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

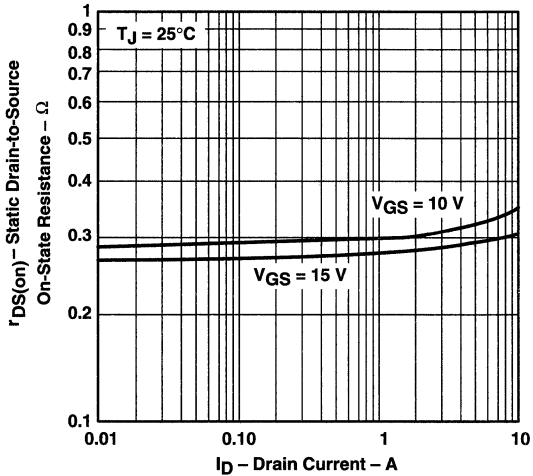


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

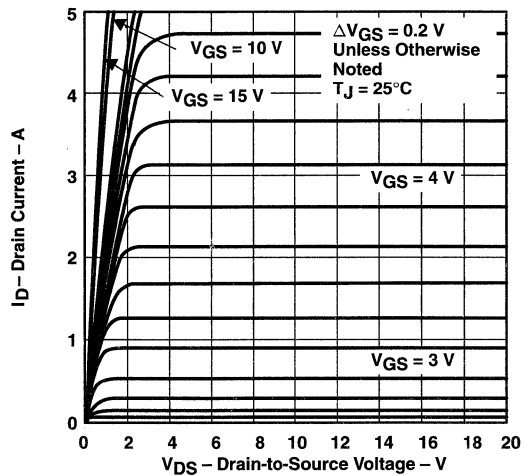


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

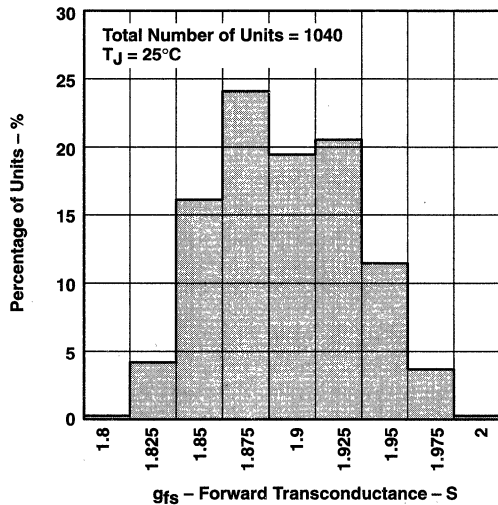


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

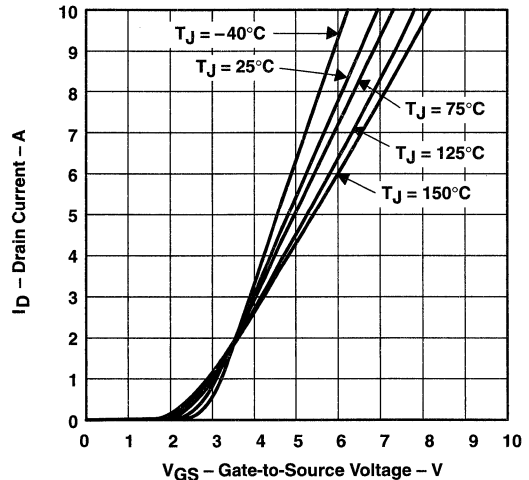


Figure 10



# TPIC5404 H-BRIDGE POWER DMOS ARRAY

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## TYPICAL CHARACTERISTICS

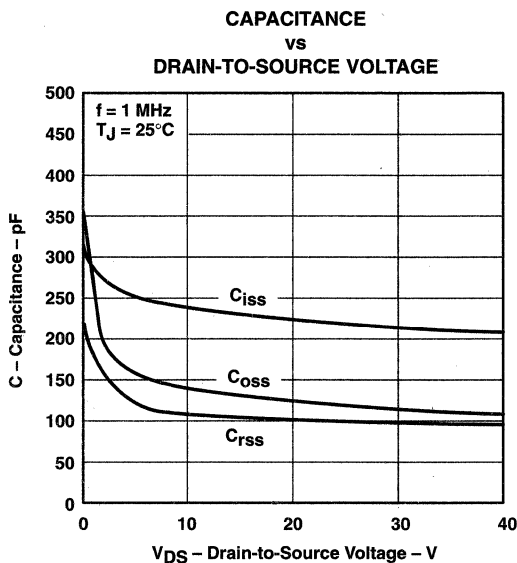


Figure 11

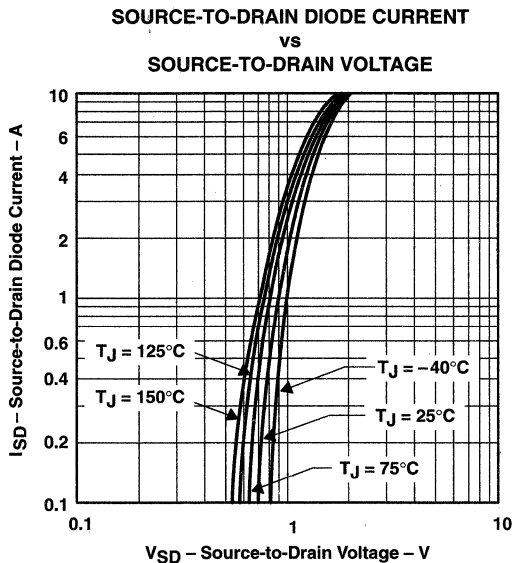


Figure 12

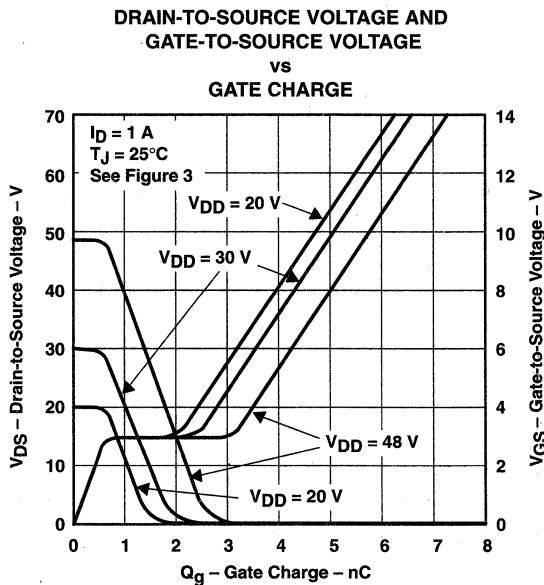


Figure 13

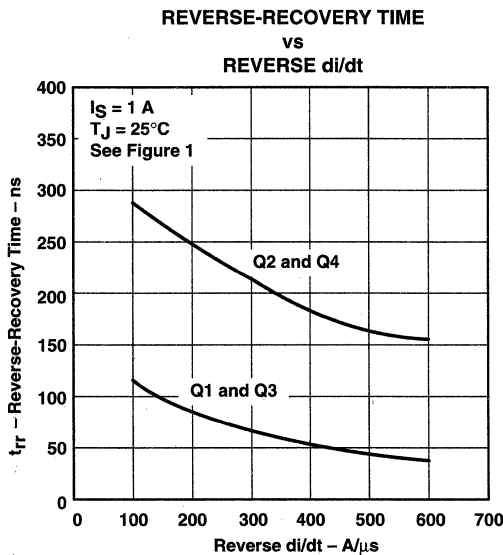
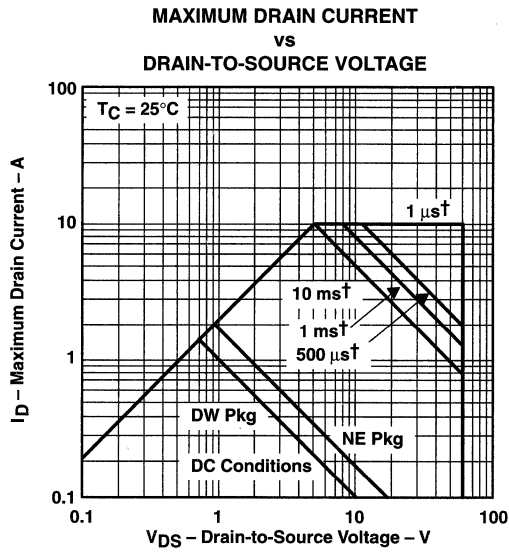


Figure 14

THERMAL INFORMATION



$^\dagger$  Less than 0.1 duty cycle

Figure 15

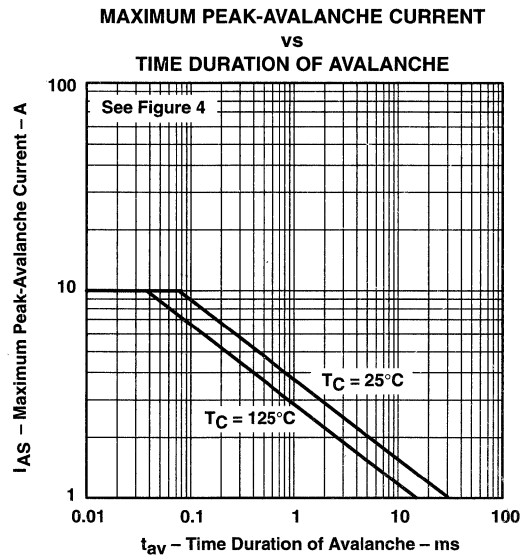


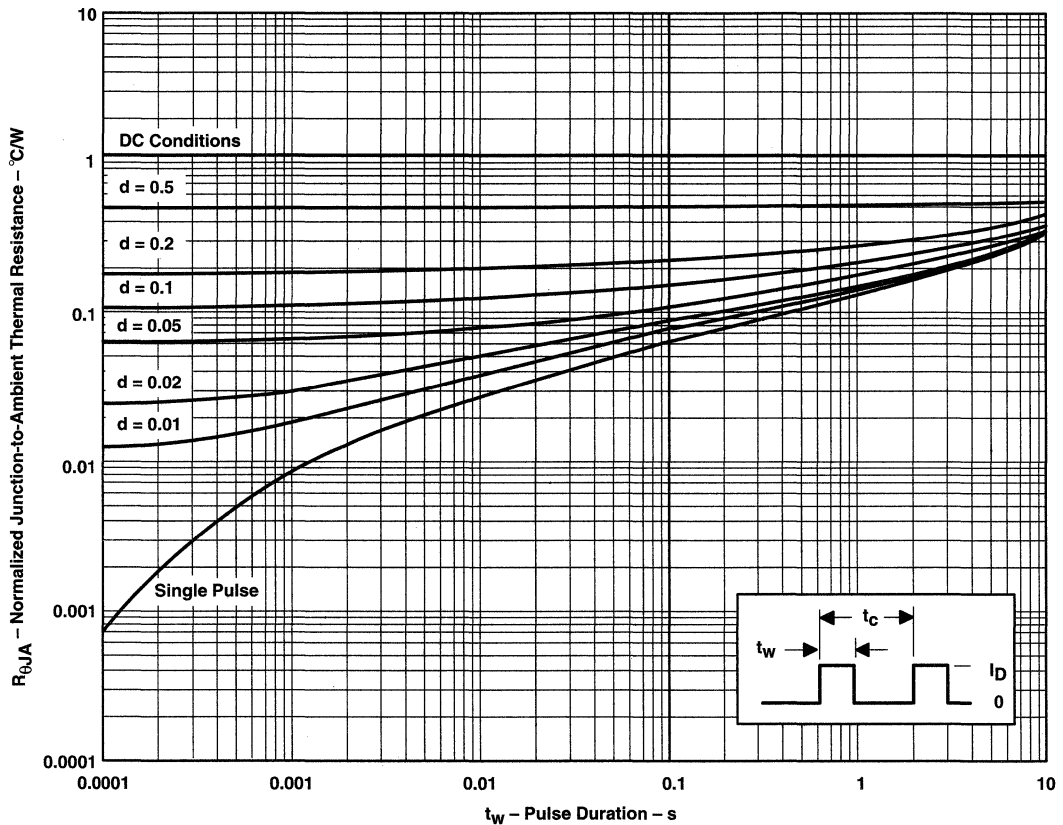
Figure 16

**TPIC5404**  
**H-BRIDGE POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**NE PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



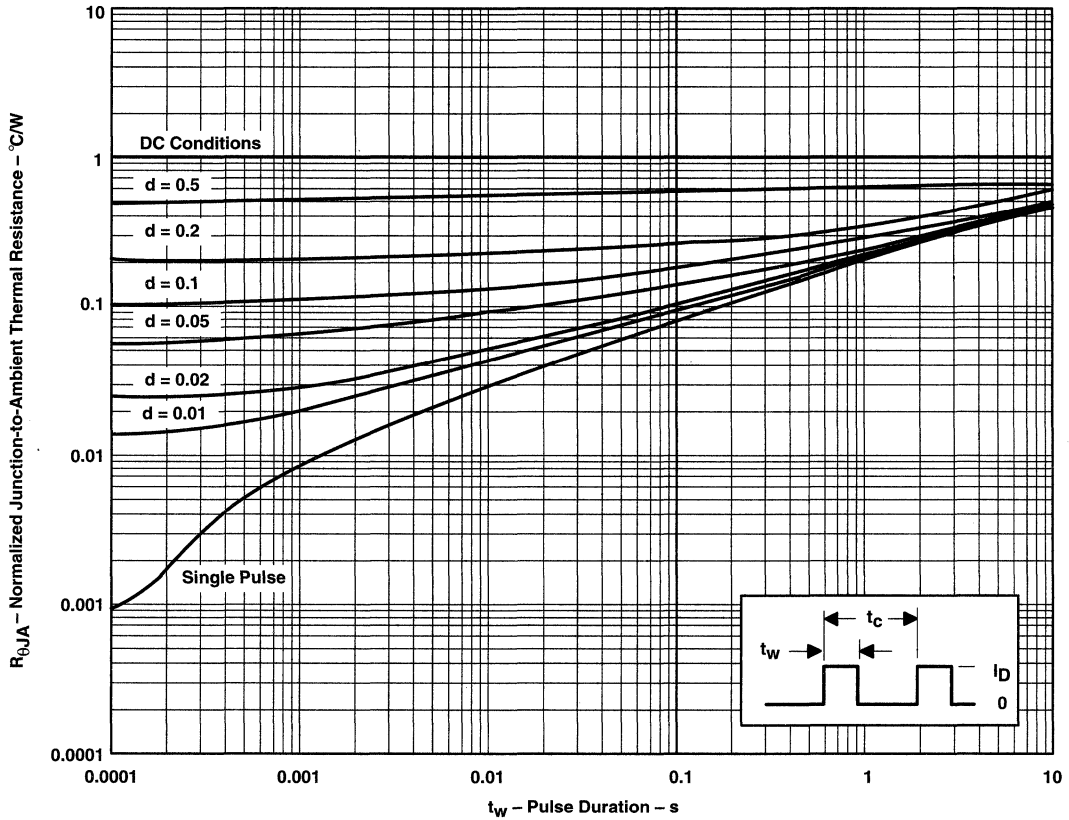
† Device mounted on FR4 printed-circuit board with no heat sink

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**

THERMAL INFORMATION

DW PACKAGE†  
NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE  
VS  
PULSE DURATION



† Device mounted on FR4 printed-circuit board with no heat sink

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 18



# TPIC5421L H-BRIDGE GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

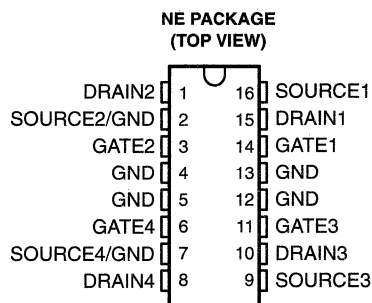
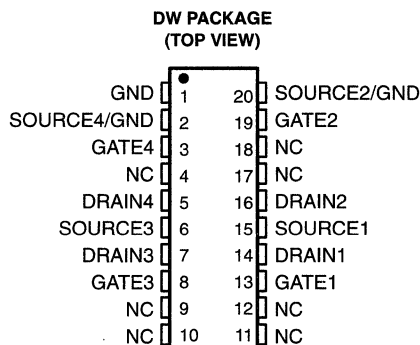
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- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- Voltage Output . . . 60 V
- Input Protection Circuitry . . . 18 V
- Pulsed Current . . . 3 A Per Channel
- Extended ESD Capability . . . 4000 V
- Direct Logic-Level Interface

## description

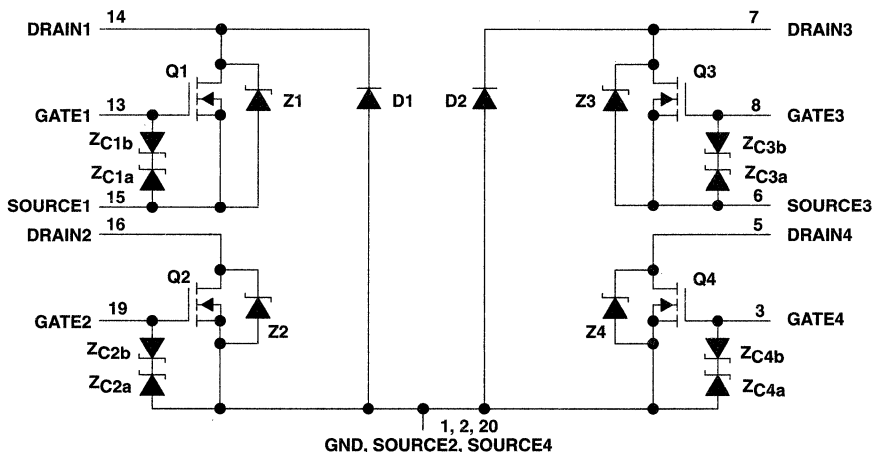
The TPIC5421L is a monolithic gate-protected logic-level power DMOS array that consists of four electrically isolated N-channel enhancement-mode DMOS transistors, two of which are configured with common source. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5421L is offered in a 20-pin wide-body surface-mount (DW) package and a 16-pin thermally-enhanced dual-in-line (NE) package and is characterized for operation over the case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



NC – No internal connection

## schematic



NOTE A: For correct operation, no terminal may be taken below GND.  
Pin numbers shown are for the DW package.

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**H-BRIDGE GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage (Q1, Q3) .....	100 V
Drain-to-GND voltage (Q1, Q3) .....	100 V
Drain-to-GND voltage (Q2, Q4) .....	60 V
Gate-to-source voltage, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ : NE package .....	1.5 A
..... DW package .....	1 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	3 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16) .....	180 mJ
Continuous total power dissipation .....	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1125 mW	9.0 mW/ $^\circ\text{C}$	225 mW
NE	2075 mW	16.6 mW/ $^\circ\text{C}$	415 mW



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**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ , $V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	1.5	1.85	2.2	V
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250 \mu\text{A}$	18			V
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250 \mu\text{A}$	9			V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = $250 \mu\text{A}$	100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3		0.4	0.475	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3 and Figure 12		0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$ (D1, D2), See Notes 2 and 3		4.6		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15 \text{ V}$ , $V_{DS} = 0$	20	200		nA
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ , $V_{DS} = 0$	10	100		nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.4	0.475	$\Omega$
			$T_C = 125^\circ\text{C}$	0.65	0.68	
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , $I_D = 0.5 \text{ A}$ , See Notes 2 and 3 and Figure 9	1.25	1.4		S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ , $V_{GS} = 0$ , See Figure 11		220	275	pF
$C_{oss}$	Short-circuit output capacitance, common source			120	150	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source			100	125	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	Z1 and Z3	55		ns
			Z2 and Z4	150		
			D1 and D2	200		
$Q_{RR}$	Total diode charge		Z1 and Z3	0.06		$\mu\text{C}$
			Z2 and Z4	0.3		
			D1 and D2	0.7		





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**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 25\ \Omega$ , $t_{r1} = 10\text{ ns}$ , See Figure 2		25	50	ns
$t_{d(off)}$	Turn-off delay time			20	40	
$t_{r2}$	Rise time			21	42	
$t_{f2}$	Fall time			9	18	
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.5\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		3.9	5	nC
$Q_{gs(th)}$	Threshold gate-to-source charge			0.55	0.8	
$Q_{gd}$	Gate-to-drain charge			2.5	3.6	
$L_D$	Internal drain inductance			5		nH
$L_S$	Internal source inductance			5		
$R_g$	Internal gate resistance			0.25		

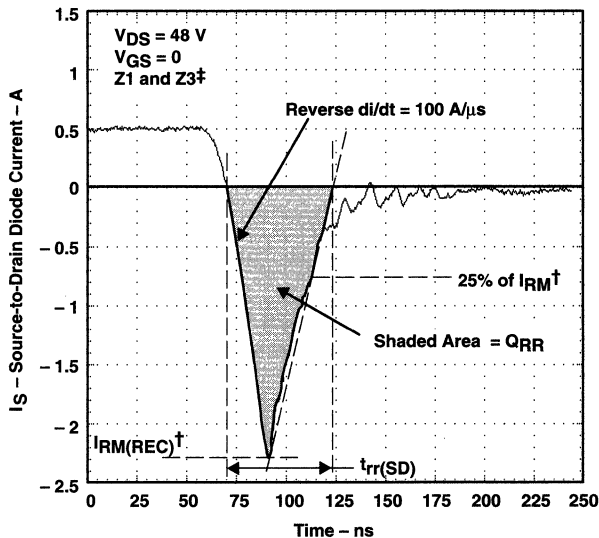
**thermal resistance**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	DW package		90		$^\circ\text{C/W}$
		NE package	See Notes 4 and 6	60		
$R_{\theta JB}$	Junction-to-board thermal resistance	DW package		See Notes 4 and 6	53	
$R_{\theta JP}$	Junction-to-pin thermal resistance	DW package	See Notes 5 and 6		30	
		NE package		25		

- NOTES:
4. Package mounted on an FR4 printed-circuit board with no heatsink.
  5. Package mounted in intimate contact with infinite heatsink.
  6. All outputs with equal power



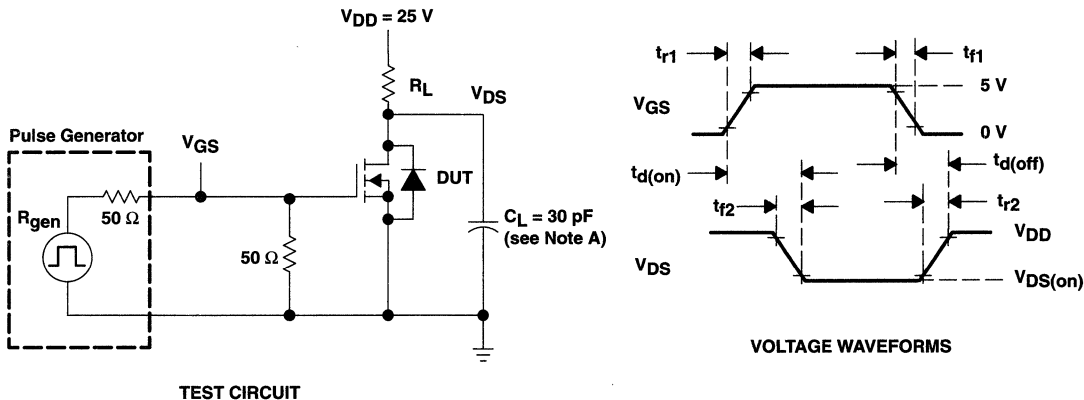
PARAMETER MEASUREMENT INFORMATION



†  $I_{RM(REC)}$  = maximum recovery current

‡ The above waveform is representative of Z2, Z4, D1, and D2 in shape only.

Figure 1. Reverse-Recovery-Current Waveforms of Source-to-Drain Diode



TEST CIRCUIT

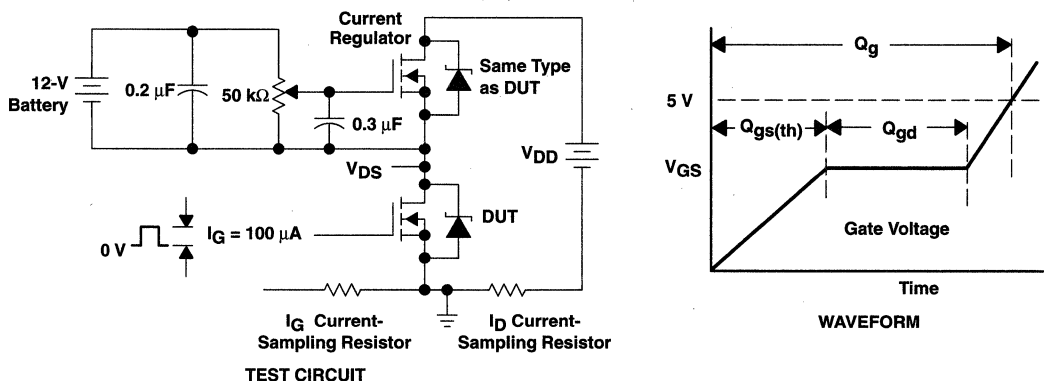
NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms

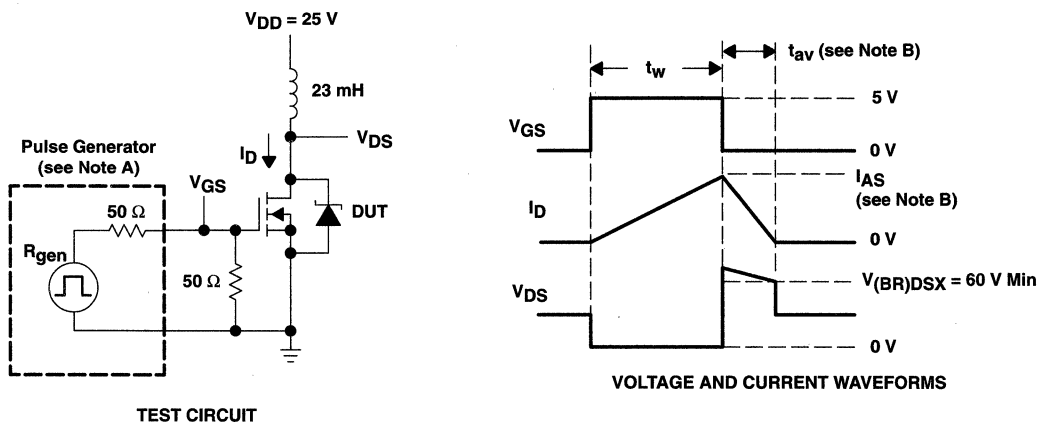
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**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Gate-Charge Test Circuit and Waveform**

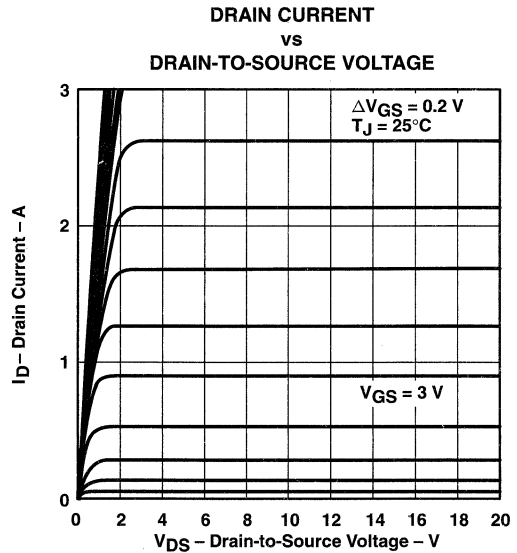
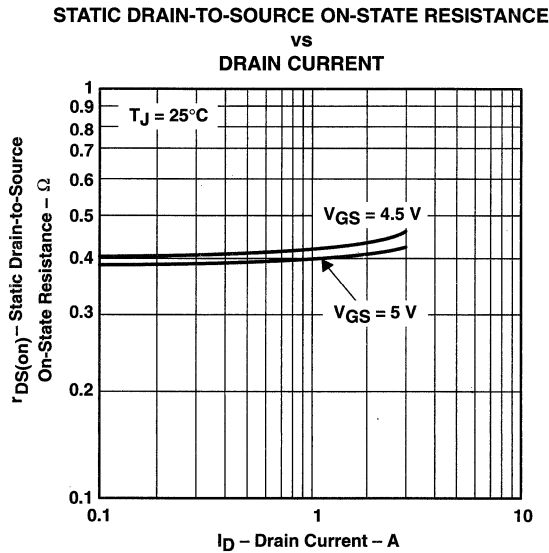
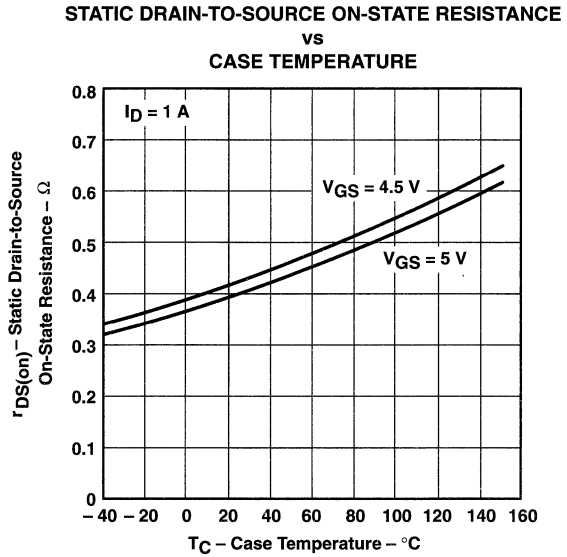
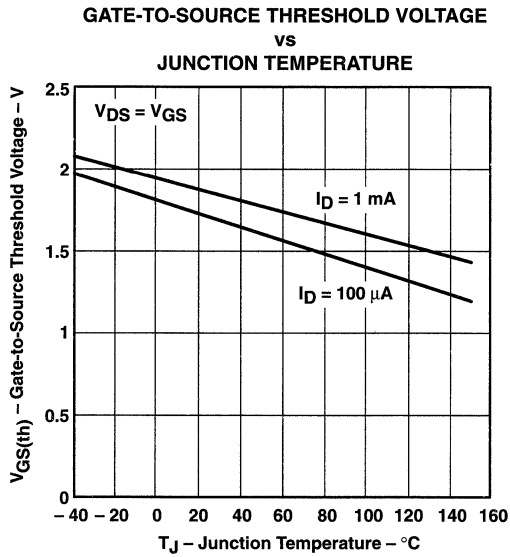


- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3$  A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 180$  mJ,  
 where  $t_{av}$  = avalanche time

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**



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## TYPICAL CHARACTERISTICS

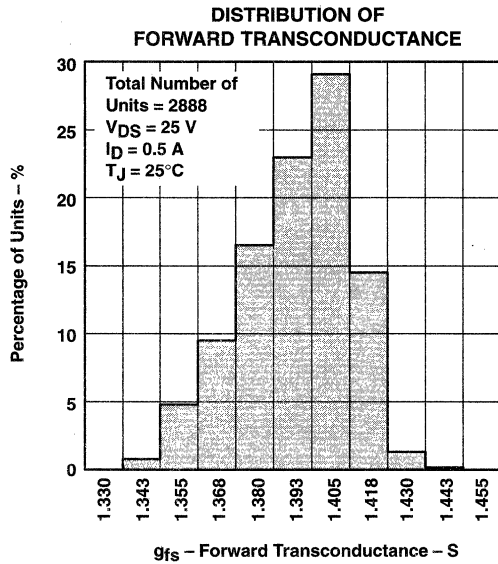


Figure 9

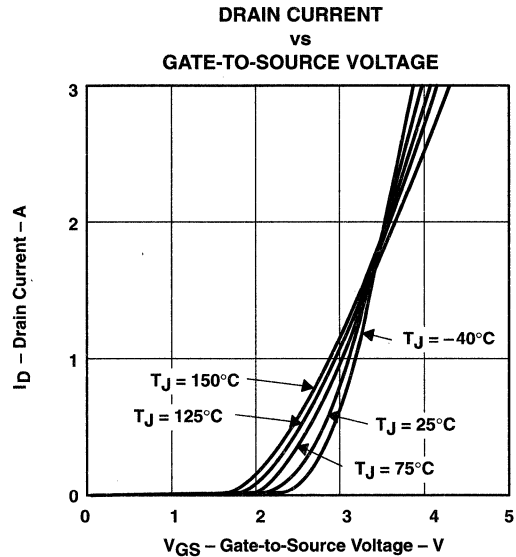


Figure 10

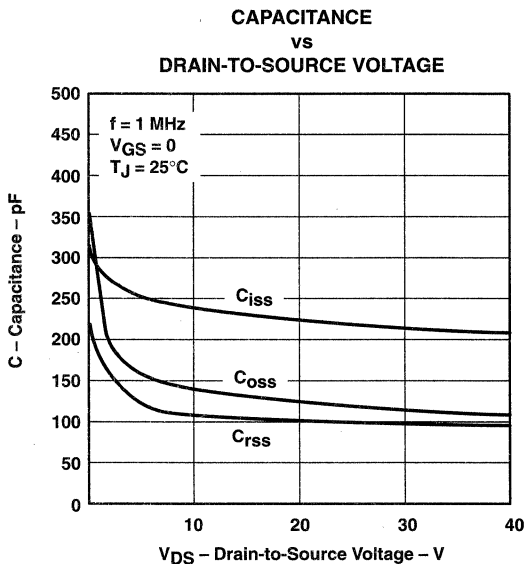


Figure 11

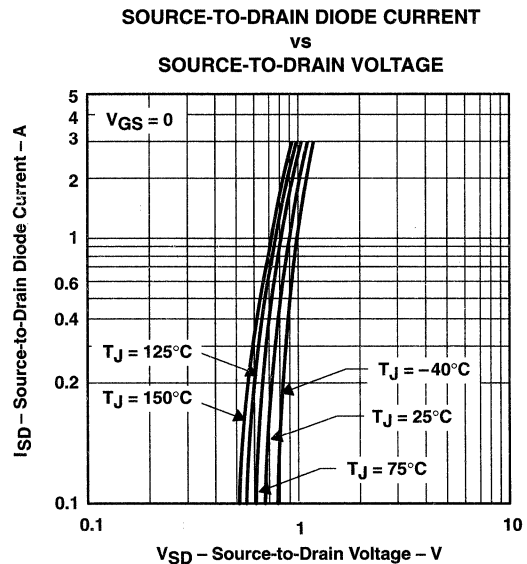


Figure 12

TYPICAL CHARACTERISTICS

DRAIN-TO-SOURCE VOLTAGE AND  
GATE-TO-SOURCE VOLTAGE  
vs  
GATE CHARGE

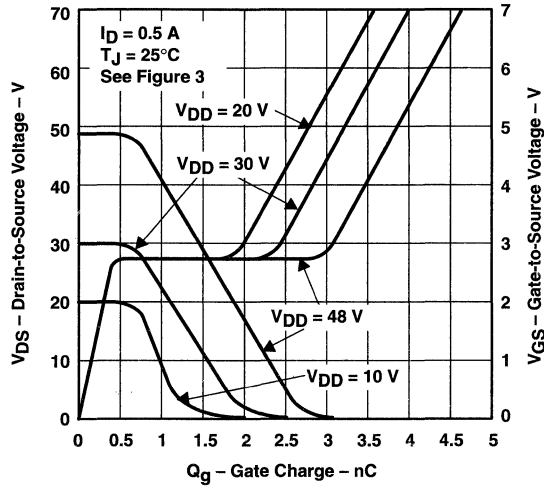


Figure 13

REVERSE-RECOVERY TIME  
vs  
REVERSE  $di/dt$

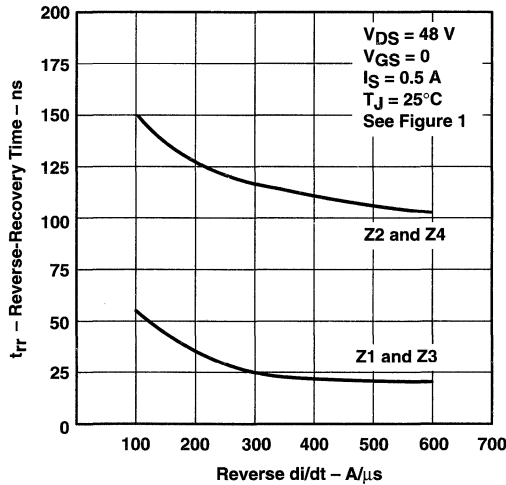


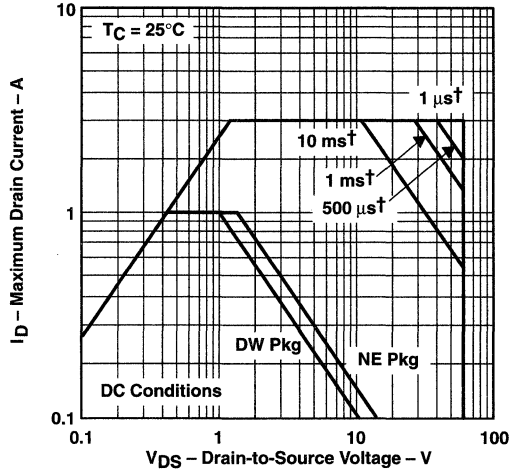
Figure 14

**TPIC5421L**  
**H-BRIDGE GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

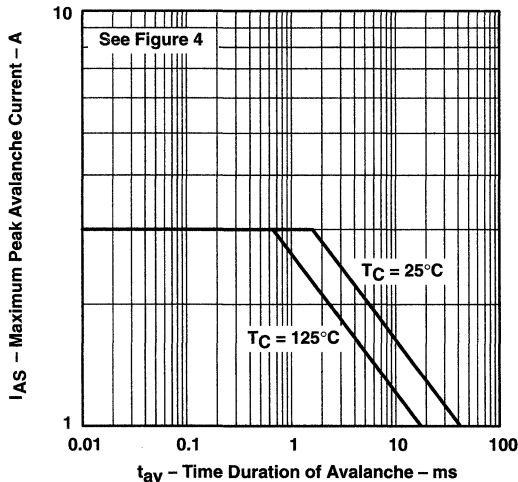
**MAXIMUM DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



† Less than 2% duty cycle

**Figure 15**

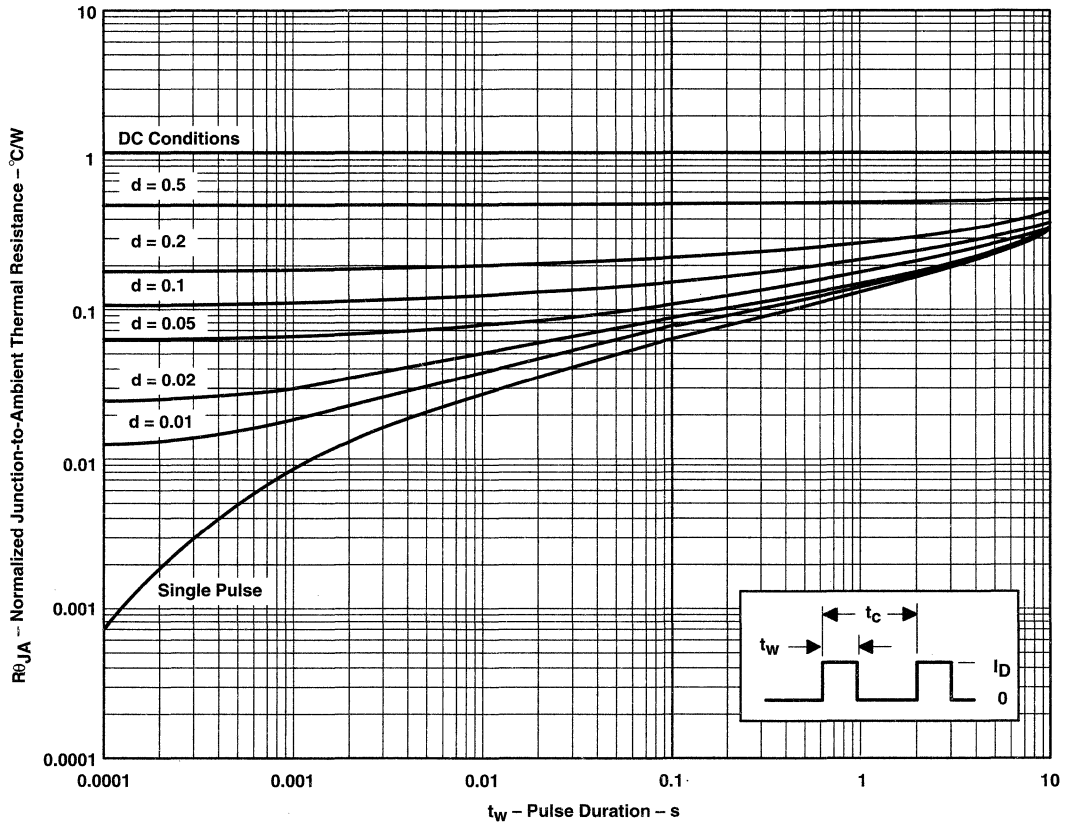
**MAXIMUM PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



**Figure 16**

THERMAL INFORMATION

NE PACKAGE†  
NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE  
VS  
PULSE DURATION



† Device mounted on FR4 printed-circuit board with no heatsink.

NOTES A:  $Z_{\theta JA}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17

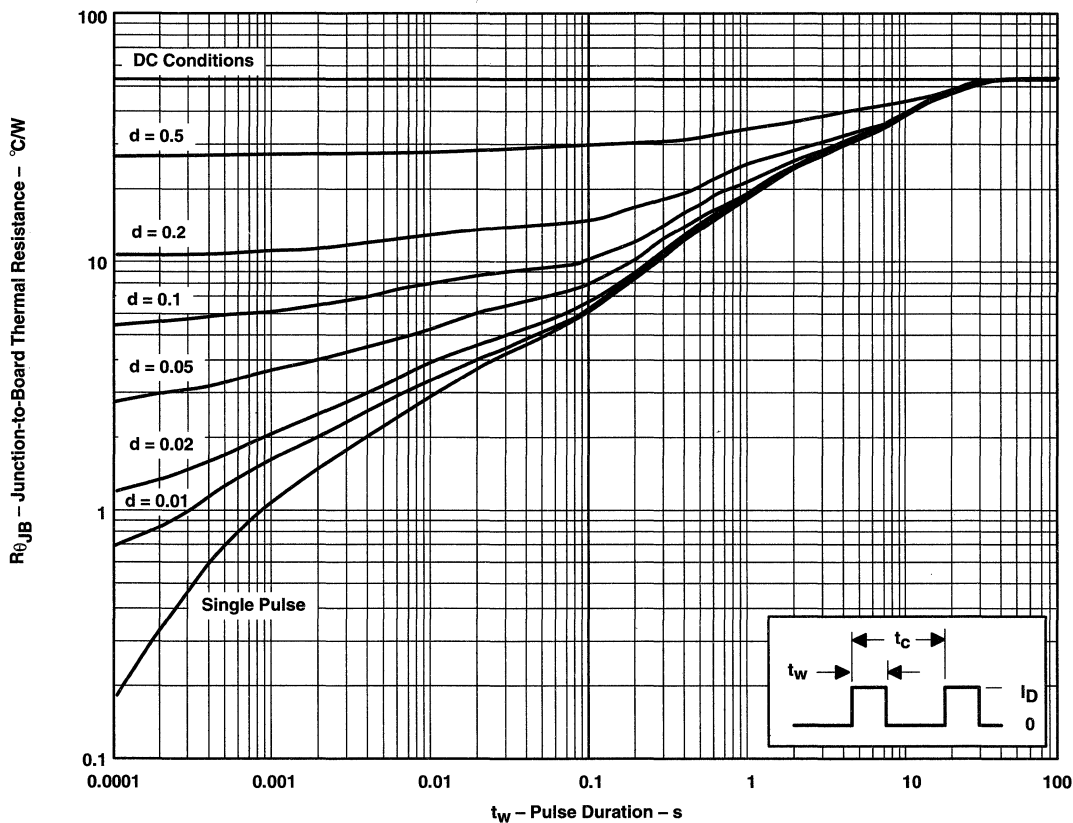


**TPIC5421L**  
**H-BRIDGE GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**DW PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**VS**  
**PULSE DURATION**



† Device mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

- NOTES A:  $Z_{\theta JB}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 18**

# TPIC5423L

## 4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL POWER DMOS ARRAY

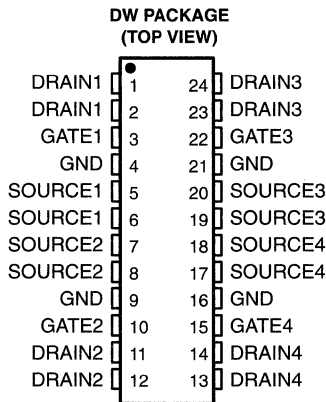
SLIS045 – NOVEMBER 1994

- Low  $r_{DS(on)}$  . . . 0.32  $\Omega$  Typ
- Voltage Output . . . 60 V
- Input Protection Circuitry . . . 18 V
- Pulsed Current . . . 4 A Per Channel
- Extended ESD Capability . . . 4000 V
- Direct Logic-Level Interface

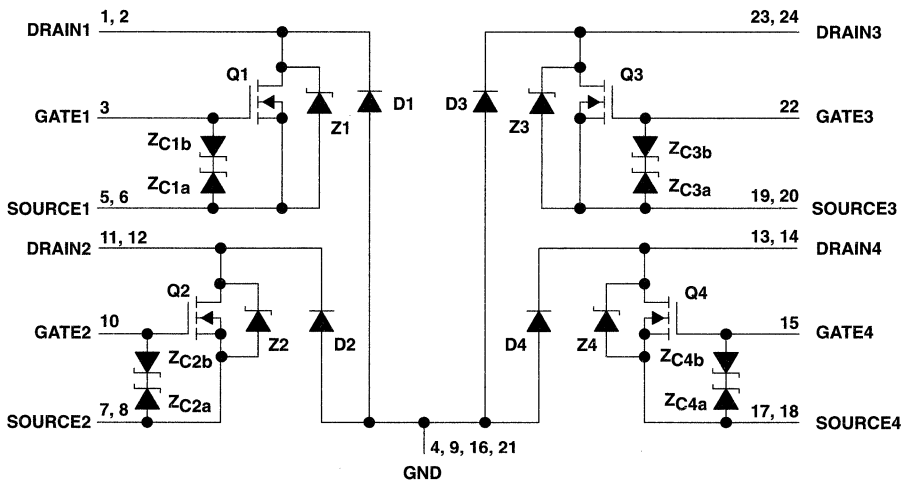
### description

The TPIC5423L is a monolithic gate-protected logic-level power DMOS array that consists of four electrically isolated independent N-channel enhancement-mode DMOS transistors. Each transistor features integrated high-current zener diodes ( $Z_{CXa}$  and  $Z_{CXb}$ ) to prevent gate damage in the event that an overstress condition occurs. These zener diodes also provide up to 4000 V of ESD protection when tested using the human-body model of a 100-pF capacitor in series with a 1.5-k $\Omega$  resistor.

The TPIC5423L is offered in a 24-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



### schematic



NOTE A: For correct operation, no terminal may be taken below GND.

**TPIC5423L**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

SLIS045 – NOVEMBER 1994

**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage .....	100 V
Drain-to-GND voltage .....	100 V
Gate-to-source voltage range, $V_{GS}$ .....	-9 V to 18 V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1.25 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1.25 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	4 A
Continuous gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 50$ mA
Pulsed gate-to-source zener-diode current, $T_C = 25^\circ\text{C}$ .....	$\pm 500$ mA
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16) .....	96 mJ
Continuous total dissipation, $T_C = 25^\circ\text{C}$ (see Figure 15) .....	1.39 W
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%



**TPIC5423L**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**

SLIS045 – NOVEMBER 1994

**electrical characteristics,  $T_C = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250\ \mu\text{A}$ , $V_{GS} = 0$	60		V	
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1\ \text{mA}$ , See Figure 5	$V_{DS} = V_{GS}$	1.5 1.75 2.2	V	
$V_{(BR)GS}$	Gate-to-source breakdown voltage	$I_{GS} = 250\ \mu\text{A}$	18		V	
$V_{(BR)SG}$	Source-to-gate breakdown voltage	$I_{SG} = 250\ \mu\text{A}$	9		V	
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage	Drain-to-GND current = $250\ \mu\text{A}$	100		V	
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.25\ \text{A}$ , See Notes 2 and 3	$V_{GS} = 5\ \text{V}$	0.4 0.47	V	
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1.25\ \text{A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3 and Figure 12		0.9 1.1	V	
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.25\ \text{A}$ (D1, D2, D3, D4), See Notes 2 and 3		2	V	
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48\ \text{V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$I_{GSSF}$	Forward-gate current, drain short circuited to source	$V_{GS} = 15\ \text{V}$ , $V_{DS} = 0$		20 200	nA	
$I_{GSSR}$	Reverse-gate current, drain short circuited to source	$V_{SG} = 5\ \text{V}$ , $V_{DS} = 0$		10 100	nA	
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48\ \text{V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5\ \text{V}$ , $I_D = 1.25\ \text{A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.32	0.375	$\Omega$
			$T_C = 125^\circ\text{C}$	0.44	0.55	
$g_{fs}$	Forward transconductance	$V_{DS} = 15\ \text{V}$ , See Notes 2 and 3 and Figure 9	$I_D = 0.625\ \text{A}$	1.25 1.63	S	
$C_{iss}$	Short-circuit input capacitance, common source			200 250	pF	
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25\ \text{V}$ , $f = 1\ \text{MHz}$	$V_{GS} = 0$ , See Figure 11	100 125		
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source			60 75		

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

**source-to-drain and GND-to-drain diode characteristics,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.625\ \text{A}$ , $V_{GS} = 0$ , $dI/dt = 100\ \text{A}/\mu\text{s}$ , See Figures 1 and 14	$Z1, Z2, Z3$ , and $Z4$	80	ns
			$D1, D2, D3$ , and $D4$	130	
$Q_{RR}$	Total diode charge	$I_S = 0.625\ \text{A}$ , $V_{GS} = 0$ , $dI/dt = 100\ \text{A}/\mu\text{s}$ , See Figures 1 and 14	$Z1, Z2, Z3$ , and $Z4$	0.8	$\mu\text{C}$
			$D1, D2, D3$ , and $D4$	0.66	

**TPIC5423L**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**  
 SLIS045 – NOVEMBER 1994

**resistive-load switching characteristics,  $T_C = 25^\circ\text{C}$**

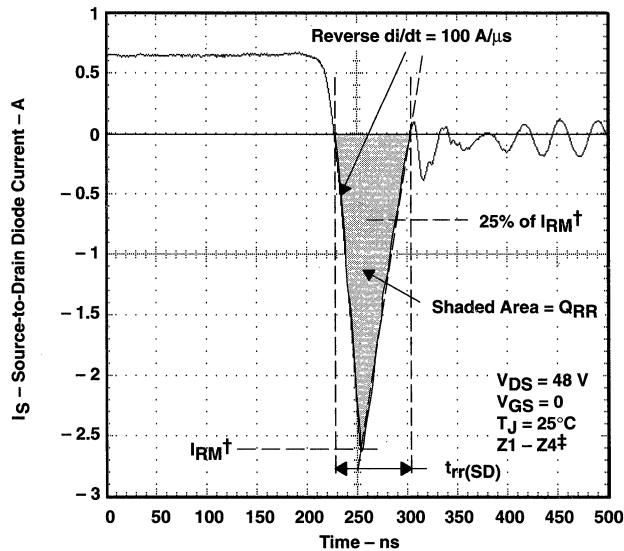
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 40\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		34	70	ns
$t_{d(off)}$ Turn-off delay time			20	40	
$t_r$ Rise time			28	55	
$t_f$ Fall time			15	30	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.625\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		6.6	8	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.5	0.6	
$Q_{gd}$ Gate-to-drain charge			2.6	3.2	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		$\Omega$

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See Notes 4 and 7		90		$^\circ\text{C/W}$
$R_{\theta JB}$ Junction-to-board thermal resistance	See Notes 5 and 7		49		
$R_{\theta JP}$ Junction-to-pin thermal resistance	See Notes 6 and 7		28		

- NOTES: 4. Package mounted on an FR4 printed-circuit board with no heatsink.  
 5. Package mounted on a 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board.  
 6. Package mounted in intimate contact with infinite heatsink.  
 7. All outputs with equal power.

**PARAMETER MEASUREMENT INFORMATION**



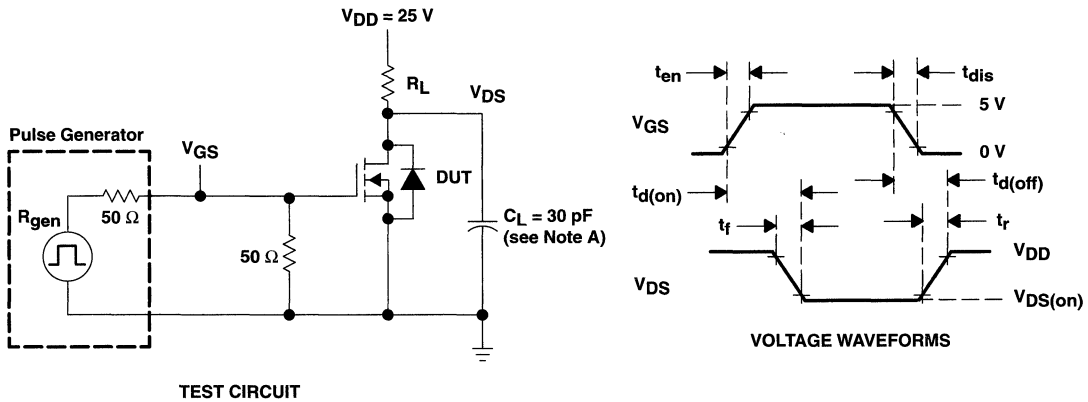
$^\dagger I_{RM}$  = maximum recovery current

$^\ddagger$  The above waveform is representative of D1, D2, D3, and D4 in shape only.

**Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode**

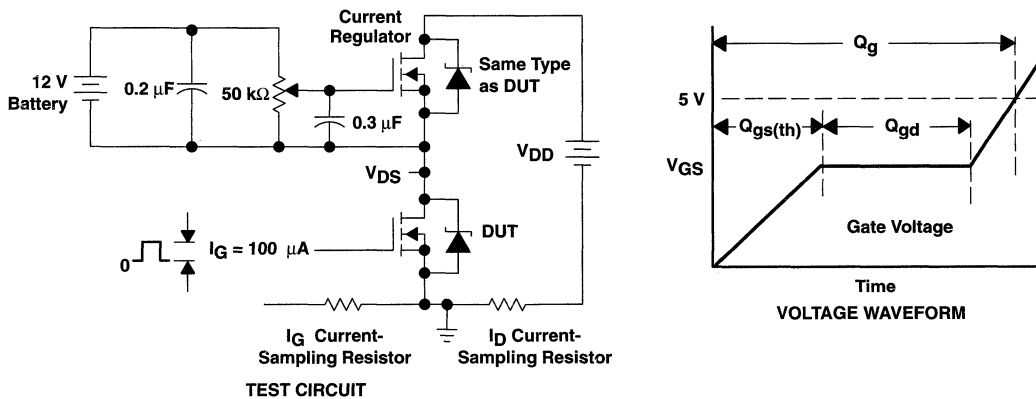


**TPIC5423L**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**  
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NOTE A:  $C_L$  includes probe and jig capacitance.

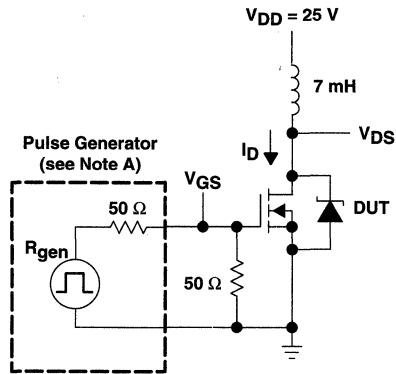
**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**



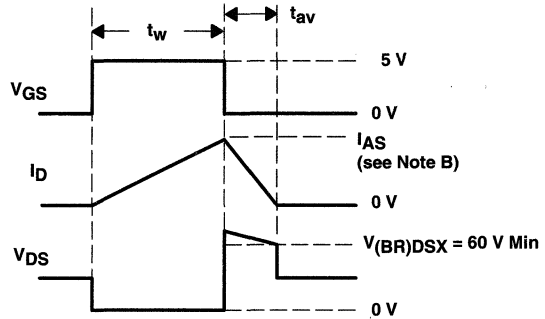
**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**

**TPIC5423L**  
**4-CHANNEL INDEPENDENT GATE-PROTECTED LOGIC-LEVEL**  
**POWER DMOS ARRAY**  
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**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**



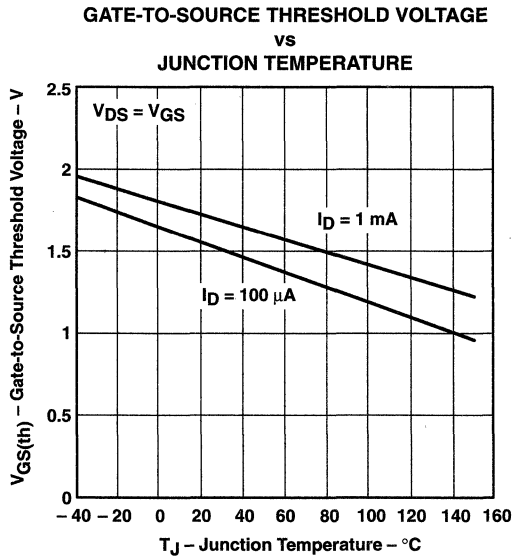
**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 4$  A.

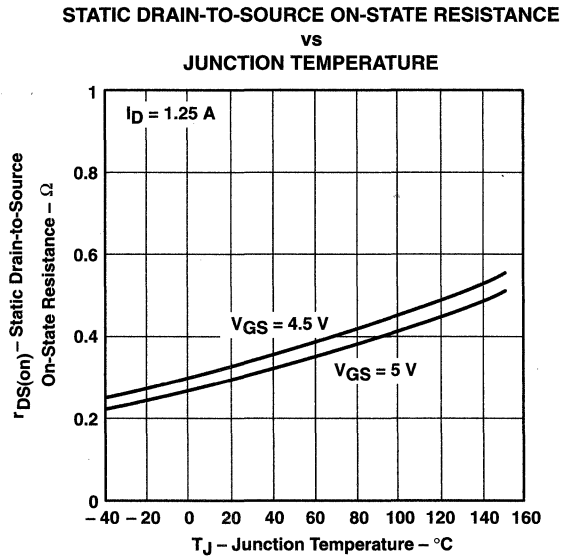
$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 96 \text{ mJ.}$$

**Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**TYPICAL CHARACTERISTICS**



**Figure 5**



**Figure 6**



**TYPICAL CHARACTERISTICS**

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE**  
 vs  
**DRAIN CURRENT**

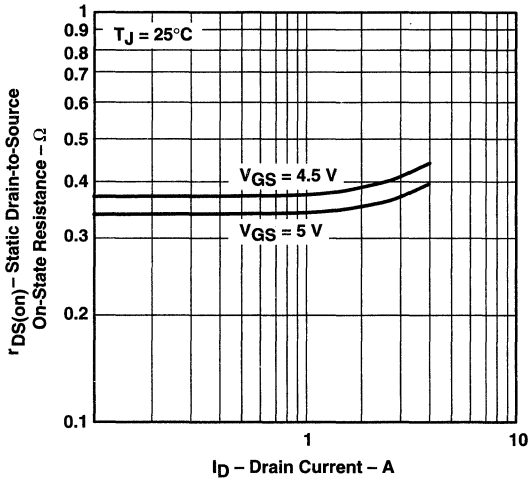


Figure 7

**DRAIN CURRENT**  
 vs  
**DRAIN-TO-SOURCE VOLTAGE**

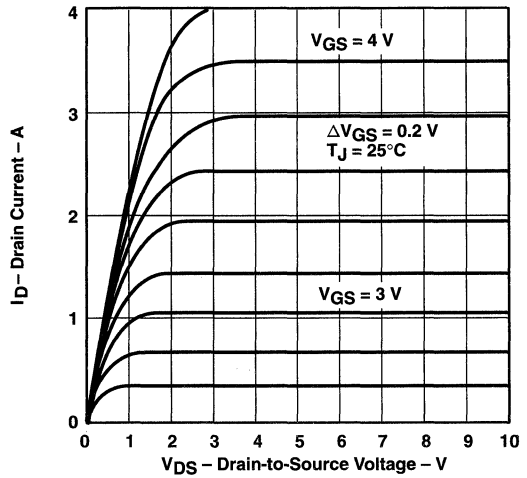


Figure 8

**DISTRIBUTION OF**  
**FORWARD TRANSCONDUCTANCE**

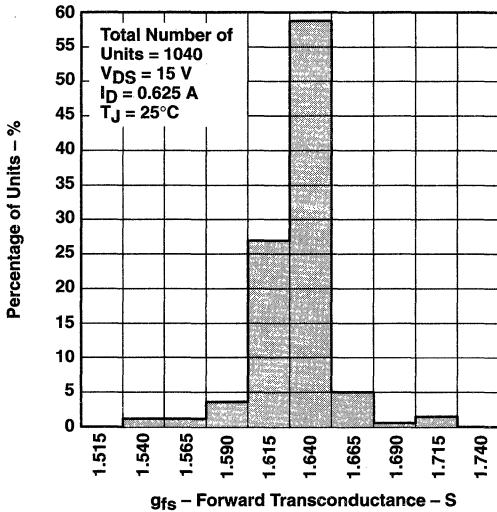


Figure 9

**DRAIN CURRENT**  
 vs  
**GATE-TO-SOURCE VOLTAGE**

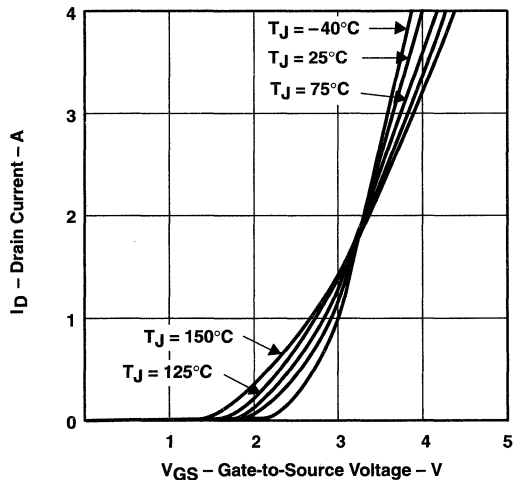
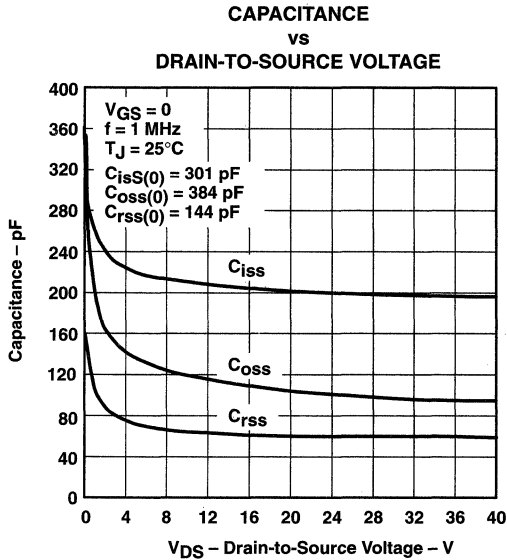


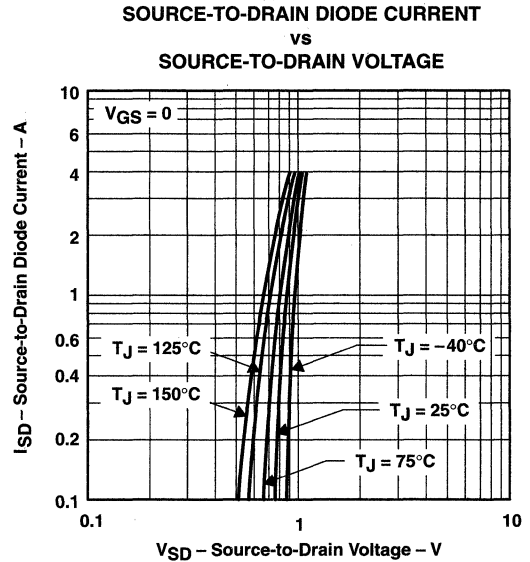
Figure 10



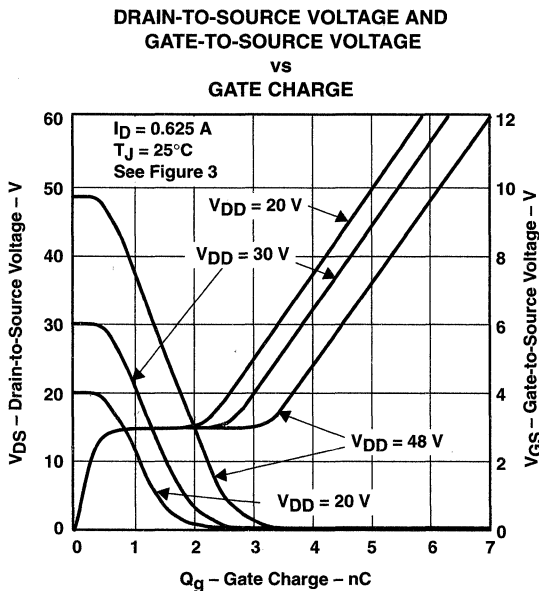
**TYPICAL CHARACTERISTICS**



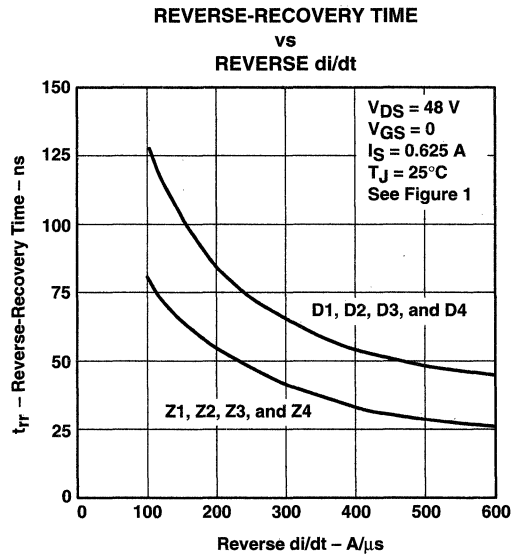
**Figure 11**



**Figure 12**



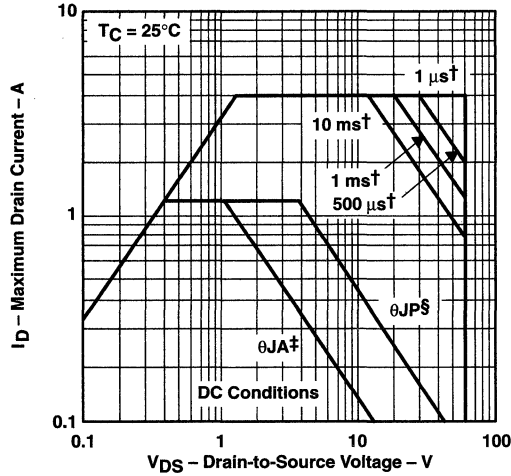
**Figure 13**



**Figure 14**

**THERMAL INFORMATION**

**MAXIMUM DRAIN CURRENT**  
**vs**  
**DRAIN-TO-SOURCE VOLTAGE**



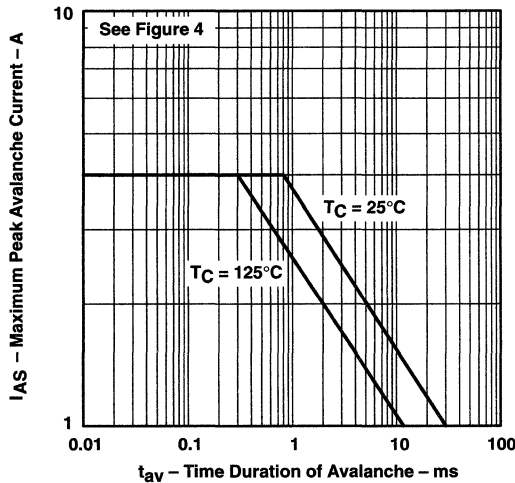
† Less than 2% duty cycle

‡ Device mounted on FR4 printed-circuit board with no heatsink.

§ Device mounted in intimate contact with infinite heatsink.

**Figure 15**

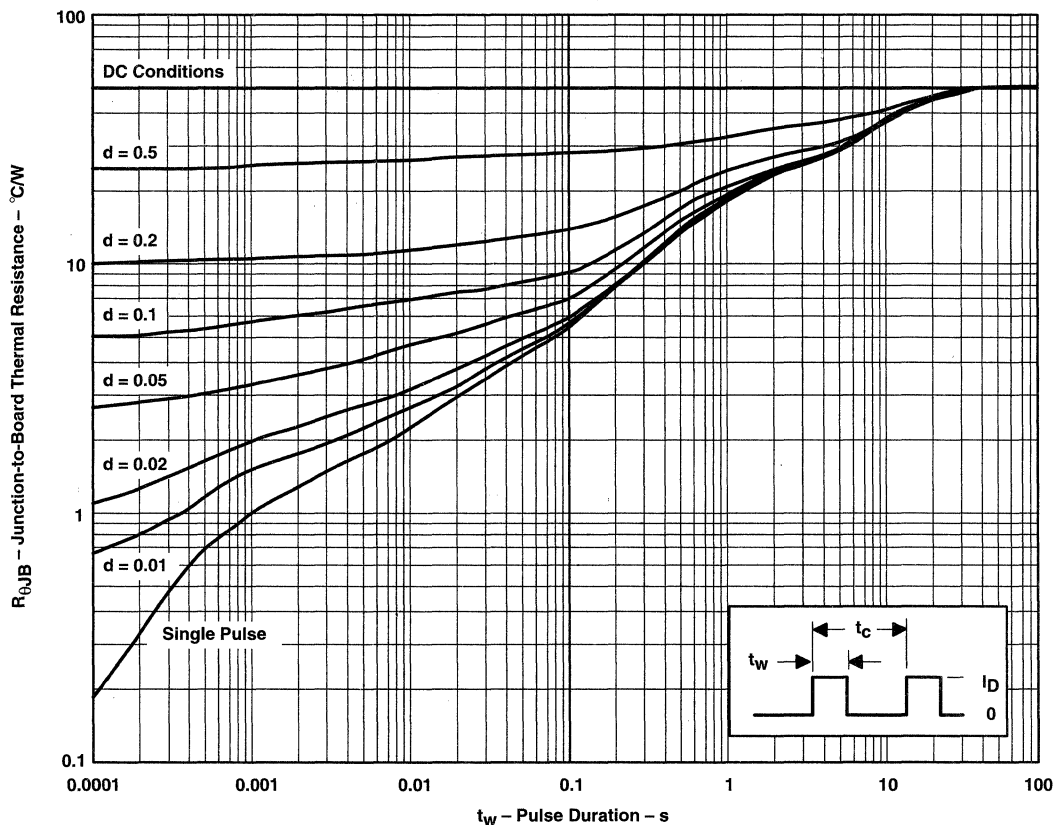
**MAXIMUM PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



**Figure 16**

**THERMAL INFORMATION**

**DW PACKAGE†**  
**JUNCTION-TO-BOARD THERMAL RESISTANCE**  
**VS**  
**PULSE DURATION**



† Device mounted on 24 in<sup>2</sup>, 4-layer FR4 printed-circuit board with no heatsink.

NOTE A:  $Z_{\theta B}(t) = r(t) R_{\theta JB}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**

# TPIC5424L H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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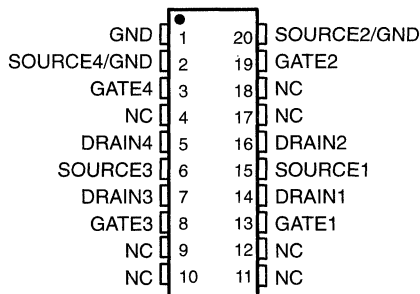
- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- High-Voltage Output . . . 60 V
- Pulsed Current . . . 3 A Per Channel
- Fast Commutation Speed
- Direct Logic-Level Interface

## description

The TPIC5424L is a monolithic logic-level power DMOS array that consists of four electrically isolated N-channel enhancement-mode DMOS transistors, two of which are configured with a common source.

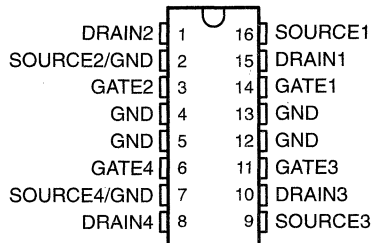
The TPIC5424L is offered in a 16-pin thermally enhanced dual-in-line (NE) package and a 20-pin wide-body surface-mount (DW) package. The TPIC5424L is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**DW PACKAGE  
(TOP VIEW)**

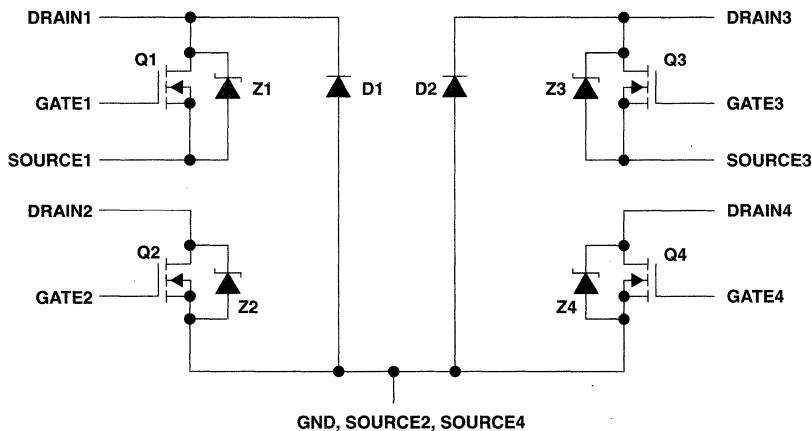


NC – No internal connection

**NE PACKAGE  
(TOP VIEW)**



## schematic



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



# TPIC5424L

## H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$	60 V
Source-to-GND voltage (Q1, Q3)	100 V
Drain-to-GND voltage (Q1, Q3)	100 V
Drain-to-GND voltage (Q2, Q4)	60 V
Gate-to-source voltage, $V_{GS}$	$\pm 20$ V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$	1 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$	1 A
Pulsed drain current, each output, $I_{max}$ , $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15)	3 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figure 4)	180 mJ
Continuous total dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%.

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/ $^\circ\text{C}$	279 mW
NE	2075 mW	16.6 mW/ $^\circ\text{C}$	415 mW

# TPIC5424L

## H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2)	Drain-to-GND current = 250 $\mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 5 \text{ V}$ ,		0.4	0.48	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4), See Notes 2 and 3 and Figure 12			1	1.2	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$ (D1, D2), See Notes 2 and 3			4.6		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 5 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$ (D1, D2)	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.4	0.48	$\Omega$	
			$T_C = 125^\circ\text{C}$	0.65	0.68		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ ,	$I_D = 0.5 \text{ A}$ , See Notes 2 and 3 and Figure 9	1.25	1.39		S
$C_{iss}$	Short-circuit input capacitance, common source				220	275	pF
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ ,	$V_{GS} = 0$ , See Figure 11		120	150	
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source				100	125	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain and GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ ,	Z1 and Z3	55		ns
				Z2 and Z4	150		
				D1 and D2	200		
$Q_{RR}$	Total diode charge			Z1 and Z3	0.06		$\mu\text{C}$
				Z2 and Z4	0.3		
				D1 and D2	0.7		



# TPIC5424L H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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## resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

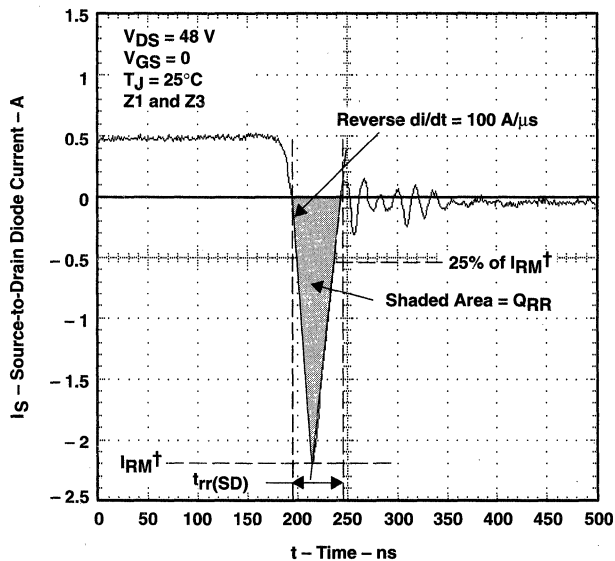
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 25\ \Omega$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		34	68	ns	
$t_{d(off)}$	Turn-off delay time			40	82		
$t_r$	Rise time			21	42		
$t_f$	Fall time			25	50		
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3	$I_D = 1\text{ A}$ ,	$V_{GS} = 10\text{ V}$ ,	3.9	5	nC
$Q_{gs(th)}$	Threshold gate-to-source charge				0.55	0.8	
$Q_{gd}$	Gate-to-drain charge				2.5	3.6	
$L_D$	Internal drain inductance			5	nH		
$L_S$	Internal source inductance			5			
$R_g$	Internal gate resistance			0.25			

## thermal resistance

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance (see Note 4)	DW package		90		$^\circ\text{C/W}$
		NE package		60		
$R_{\theta JP}$	Junction-to-pin thermal resistance	DW package		30		$^\circ\text{C/W}$
		NE package		25		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

## PARAMETER MEASUREMENT INFORMATION



$^\dagger I_{RM}$  = maximum recovery current

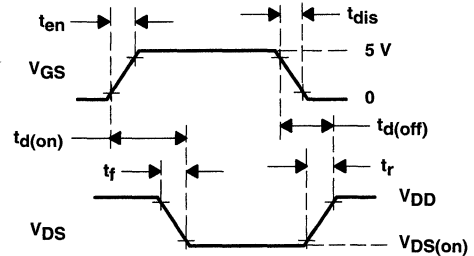
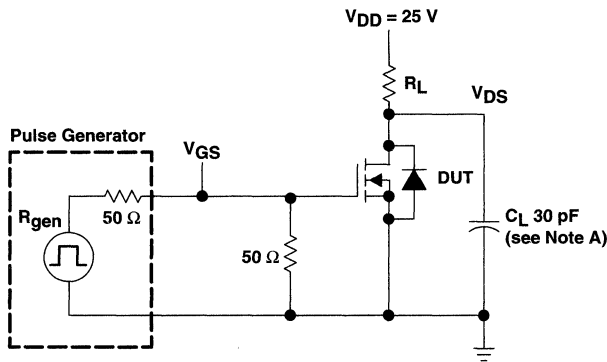
NOTE A. The above waveform is representative of Z2, Z4, D1, and D2 in shape only.

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode



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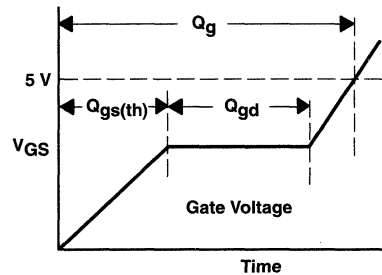
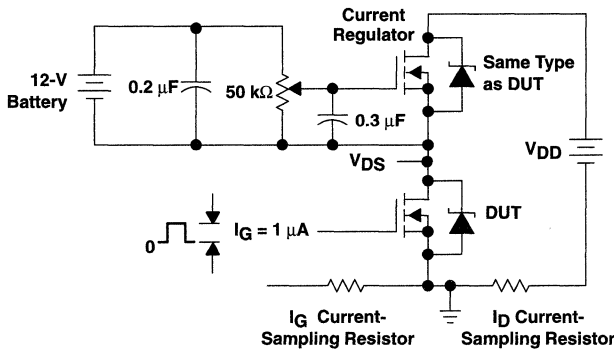
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



TEST CIRCUIT

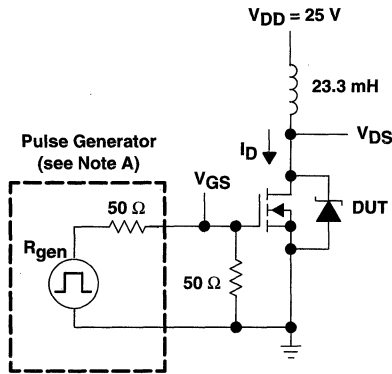
Figure 3. Gate-Charge Test Circuit and Waveform



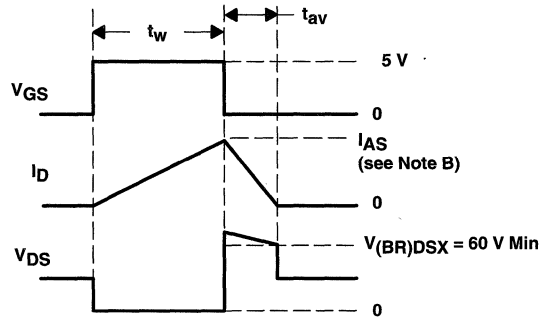
# TPIC5424L H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 180 \text{ mJ.}$$

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

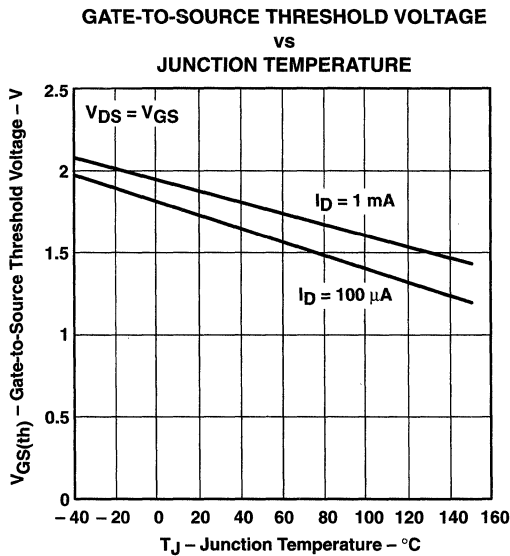


Figure 5

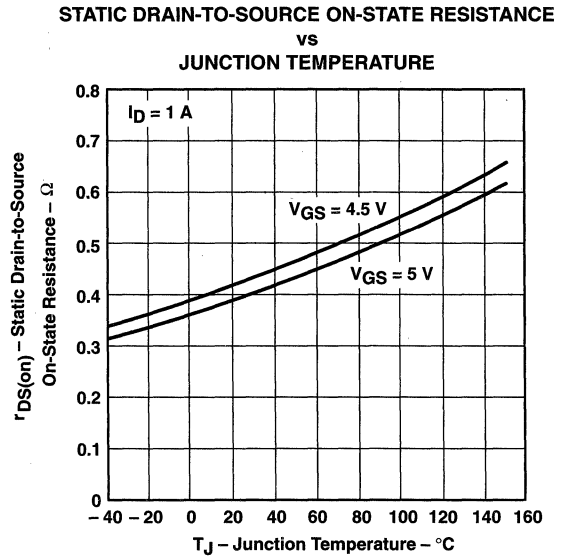


Figure 6

TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

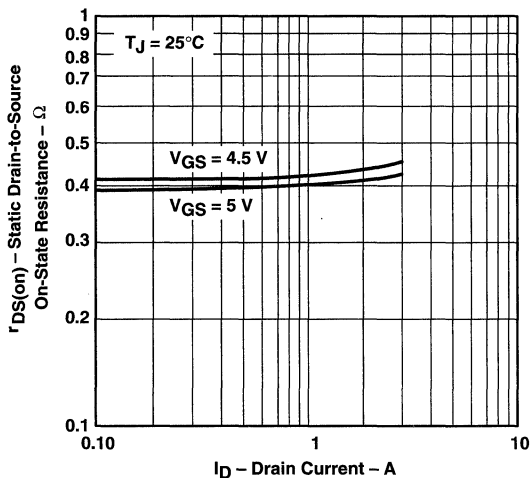


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

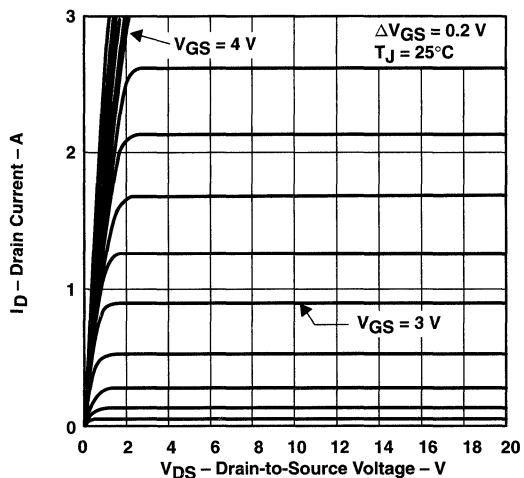


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

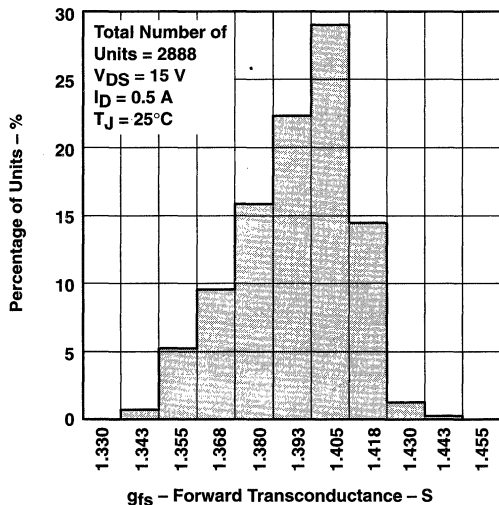


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

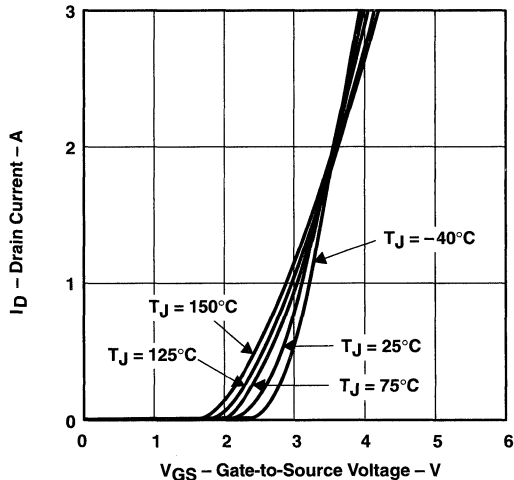


Figure 10

# TPIC5424L H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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## TYPICAL CHARACTERISTICS

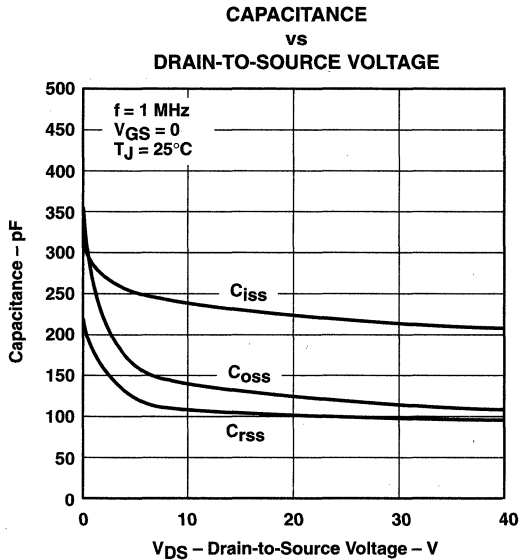


Figure 11

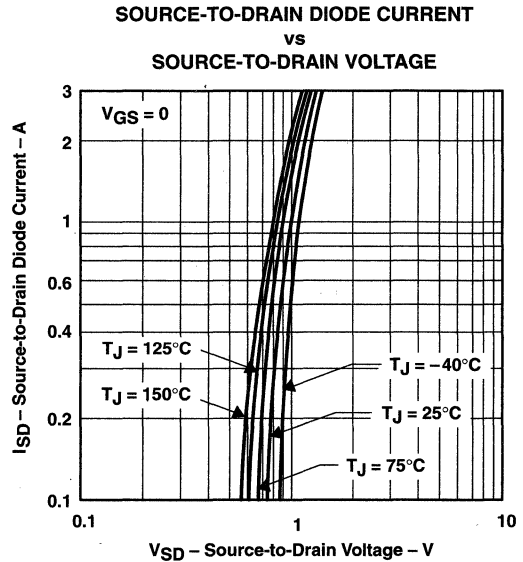


Figure 12

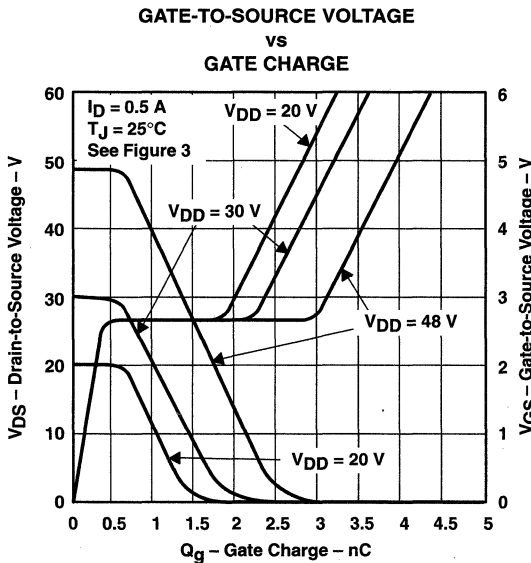


Figure 13

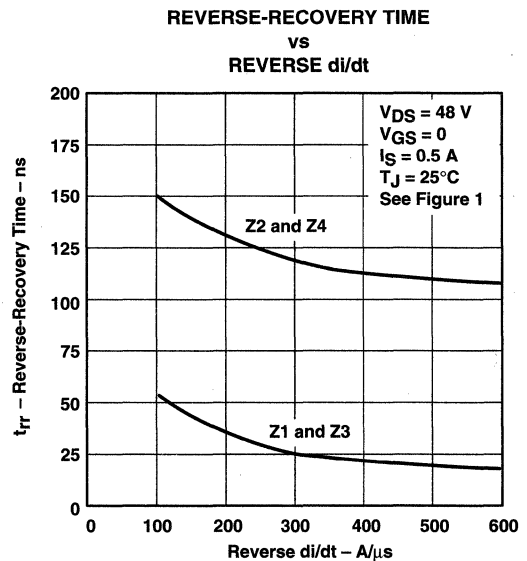
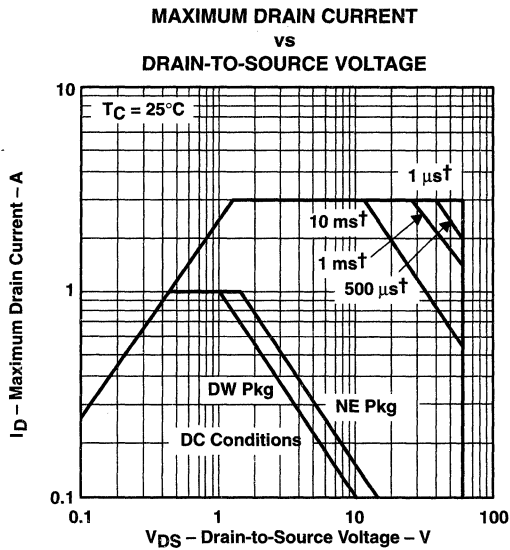


Figure 14

# TPIC5424L H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

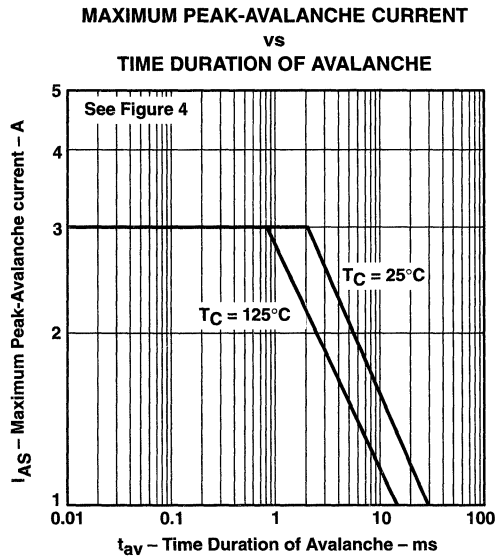
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## THERMAL INFORMATION



$^\dagger$  Less than 2% duty cycle

**Figure 15**



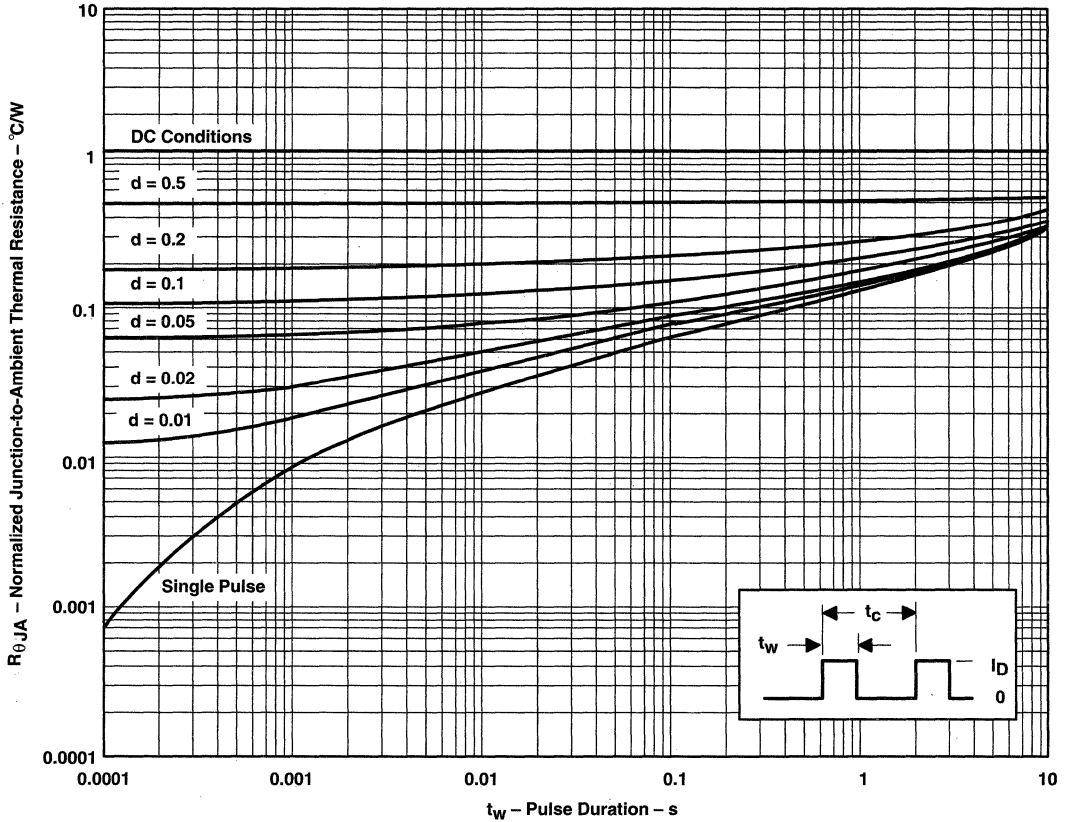
**Figure 16**

**TPIC5424L**  
**H-BRIDGE LOGIC-LEVEL POWER DMOS ARRAY**

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**THERMAL INFORMATION**

**NE PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



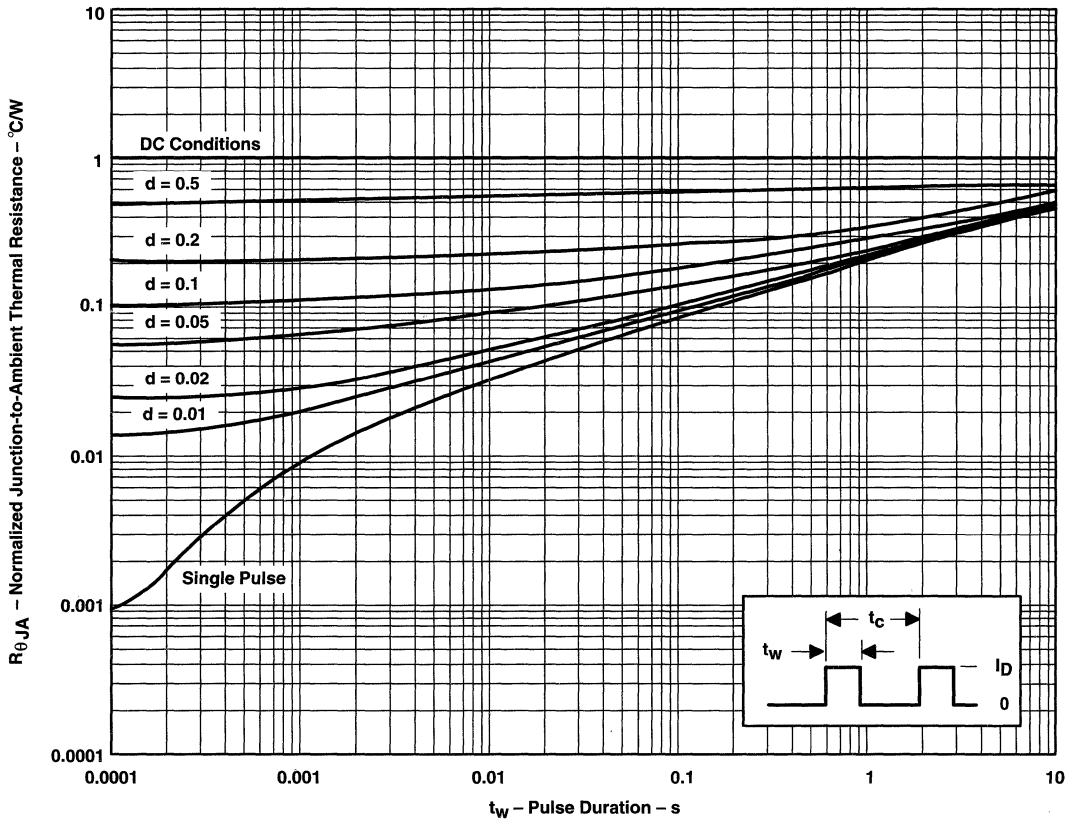
† Device mounted on FR4 printed-circuit board with no heat sink

- NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 17**

THERMAL INFORMATION

DW PACKAGE†  
NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE  
vs  
PULSE DURATION



† Device mounted on FR4 printed-circuit board with no heat sink

- NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 18



# TPIC5601 3-PHASE BRIDGE POWER DMOS ARRAY

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- Low  $r_{DS(on)}$  . . . 0.3  $\Omega$  Typ
- High-Voltage Output . . . 60 V
- Pulsed Current . . . 8 A Per Channel
- Fast Commutation Speed

## description

The TPIC5601 is a monolithic power DMOS array that consists of six electrically isolated N-channel enhancement-mode DMOS transistors, three of which are configured with a common source. The TPIC5601 is offered in a 20-pin wide-body surface-mount (DW) package.

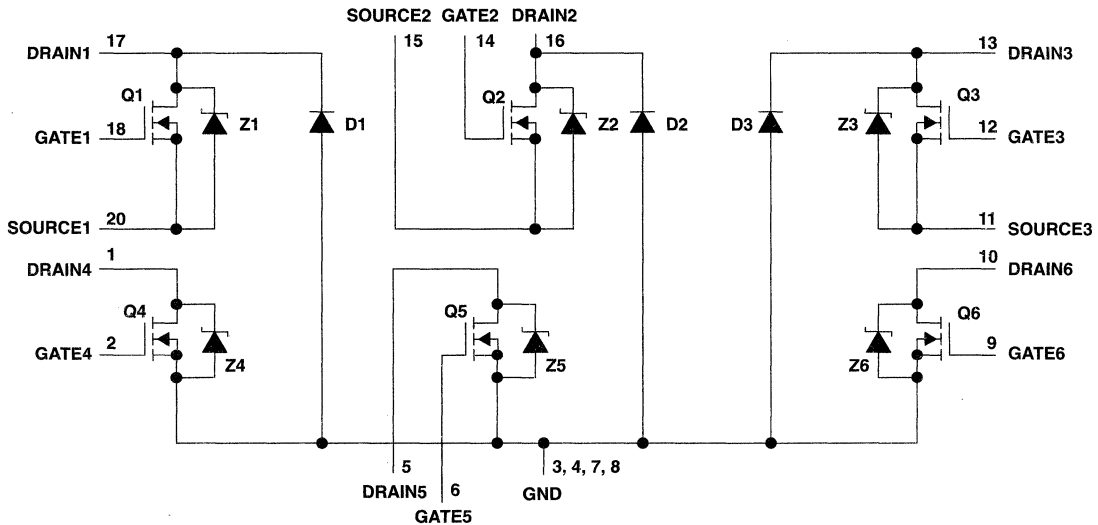
The TPIC5601 is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

DW PACKAGE  
(TOP VIEW)

DRAIN4	1	20	SOURCE1
GATE4	2	19	NC
GND	3	18	GATE1
GND	4	17	DRAIN1
DRAIN5	5	16	DRAIN2
GATE5	6	15	SOURCE2
GND	7	14	GATE2
GND	8	13	DRAIN3
GATE6	9	12	GATE3
DRAIN6	10	11	SOURCE3

NC – No internal connection

## schematic





# TPIC5601

## 3-PHASE BRIDGE POWER DMOS ARRAY

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### absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Drain-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Drain-to-GND voltage (Q4, Q5, and Q6) .....	60 V
Gate-to-source voltage range, $V_{GS}$ .....	$\pm 20$ V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1.7 A
Continuous source-to-drain diode current .....	1.7 A
Pulsed drain current, $I_D$ , each output, $T_C = 25^\circ\text{C}$ (see Note 1 and Figure 15) .....	8 A
Single-pulse avalanche energy, $E_A$ , $T_C = 25^\circ\text{C}$ (see Figures 4 and 16) .....	36 mJ
Continuous total power dissipation .....	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range, $T_{stg}$ .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms, duty cycle = 2%

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1125 mW	9.0 mW/ $^\circ\text{C}$	225 mW

# TPIC5601

## 3-PHASE BRIDGE POWER DMOS ARRAY

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### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ ,	$V_{DS} = V_{GS}$	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, and D3)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1.7 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 10 \text{ V}$ ,		0.51	0.6	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1.7 \text{ A}$ (D1, D2, D3), See Notes 2 and 3			7.5		V
$V_F(SD)$	Forward on-state voltage, source-to-drain	$I_S = 1.7 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4, Z5, Z6), See Notes 2 and 3			1	1.2	V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$	10	100	$\text{nA}$	
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$	10	100	$\text{nA}$	
$I_{lkg}$	Leakage current, drain-to-GND	$V_R = 48 \text{ V}$	$T_C = 25^\circ\text{C}$	0.05	1	$\mu\text{A}$	
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 10 \text{ V}$ , $I_D = 1.7 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.3	0.35	$\Omega$	
			$T_C = 125^\circ\text{C}$	0.41	0.5		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3	$I_D = 1 \text{ A}$ ,	1.2	1.75	S	
$C_{iss}$	Short-circuit input capacitance, common source			190	240	pF	
$C_{oss}$	Short-circuit output capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$	$V_{GS} = 0$ ,	100	125		
$C_{rss}$	Short-circuit reverse-transfer capacitance, common source			40	50		

- NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum, pulse duration  $\leq 5 \text{ ms}$ .  
3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , See Figure 1	(Z1, Z2, Z3),		65		ns
$Q_{RR}$	Total diode charge				0.12		$\mu\text{C}$
$t_{rr(SD)}$	Reverse-recovery time	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ , $V_{DS} = 48 \text{ V}$ , $di/dt = 100 \text{ A}/\mu\text{s}$ , See Figure 1	(Z4, Z5, Z6),		240		ns
$Q_{RR}$	Total diode charge				0.9		$\mu\text{C}$

### GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$ (see schematic, D1, D2, and D3)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_F = 1 \text{ A}$ ,	$V_{DS} = 48 \text{ V}$ ,		260		ns
$Q_{RR}$	Total diode charge	$di/dt = 100 \text{ A}/\mu\text{s}$ ,	See Figure 1	2.2			$\mu\text{C}$



# TPIC5601

## 3-PHASE BRIDGE POWER DMOS ARRAY

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### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 25\ \Omega$ , $t_{f1} = 10\text{ ns}$ , See Figure 2		32	65	ns	
$t_{d(off)}$	Turn-off delay time			40	80		
$t_{r2}$	Rise time			15	30		
$t_{f2}$	Fall time			25	50		
$Q_g$	Total gate charge	$V_{DS} = 48\text{ V}$ , See Figure 3		5	6	nC	
$Q_{GS}$	Threshold gate-to-source charge		$I_D = 1\text{ A}$ , $V_{GS} = 10\text{ V}$ ,		0.5		0.6
$Q_{GD}$	Gate-to-drain charge				1.9		2.3
$L_{(drain)}$	Internal drain inductance			5		nH	
$L_{(source)}$	Internal source inductance			5			
$R_g$	Internal gate resistance			0.25		$\Omega$	

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance		90		$^\circ\text{C/W}$
$R_{\theta JP}$	Junction-to-pin thermal resistance		27		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink.

### PARAMETER MEASUREMENT INFORMATION

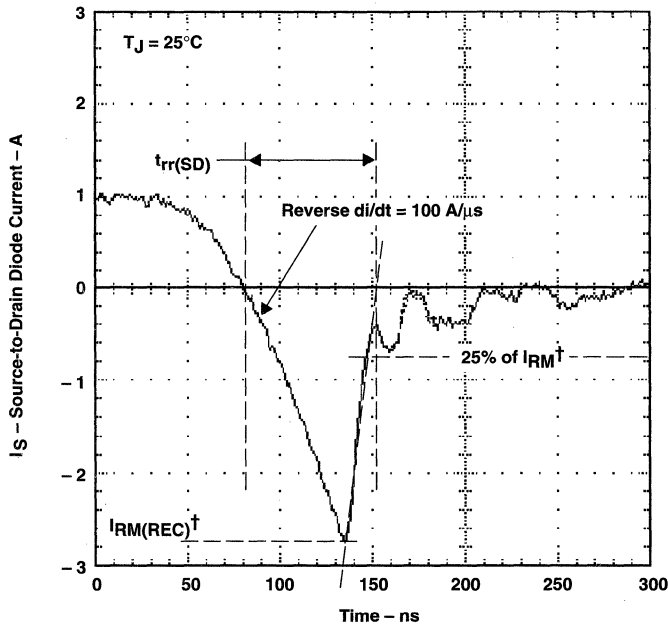
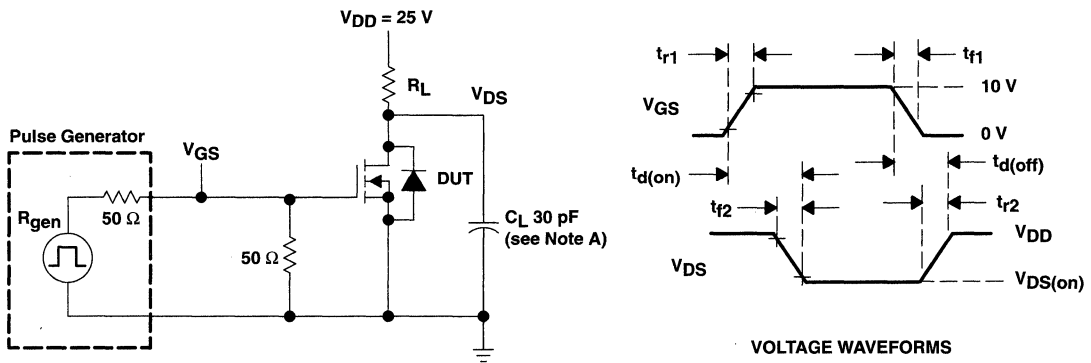


Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode



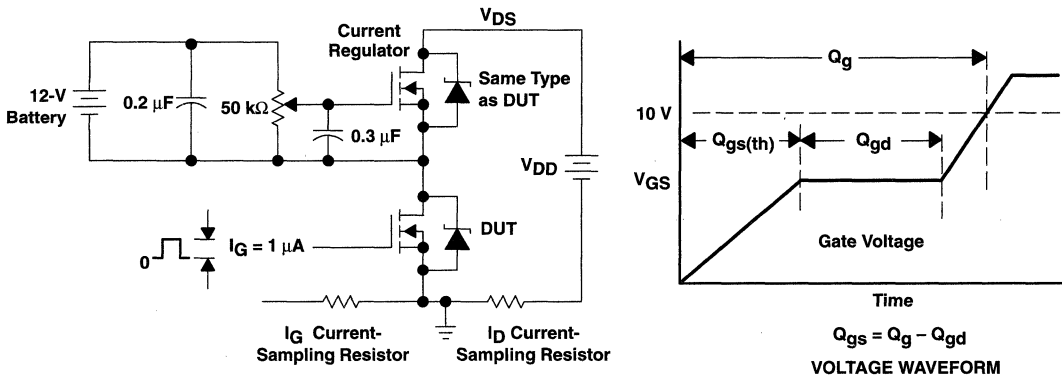
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms



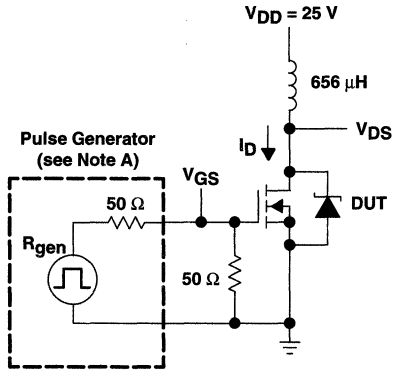
TEST CIRCUIT

Figure 3. Gate-Charge Test Circuit and Voltage Waveform

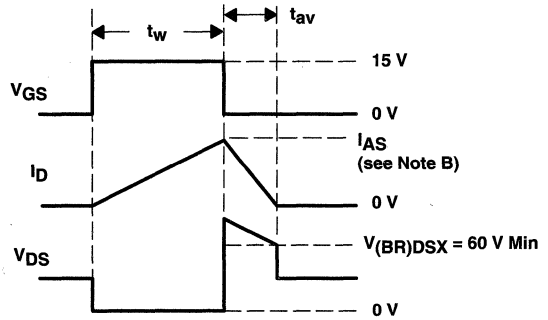
# TPIC5601 3-PHASE BRIDGE POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics: t<sub>r</sub> ≤ 10 ns, t<sub>f</sub> ≤ 10 ns, Z<sub>O</sub> = 50 Ω.  
B. Input pulse duration (t<sub>w</sub>) is increased until peak current I<sub>AS</sub> = 8 A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 36 \text{ mJ}$ , where  
t<sub>av</sub> = Avalanche time

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

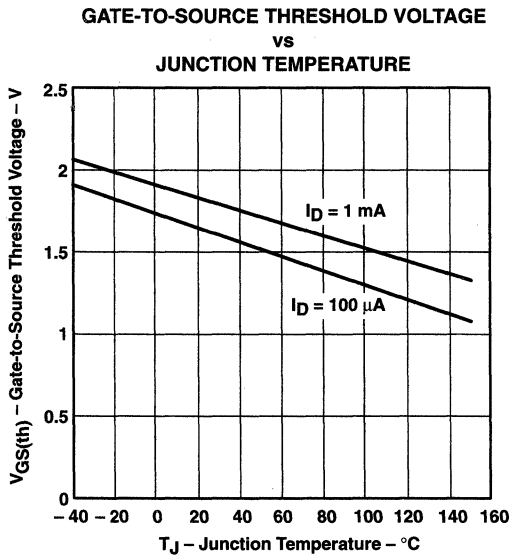


Figure 5

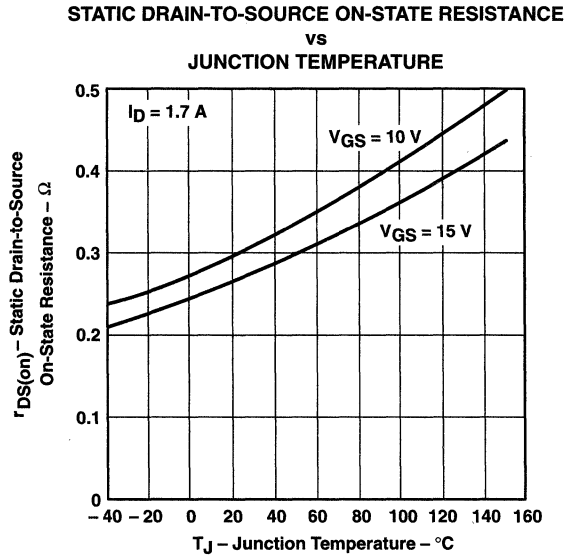


Figure 6

TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

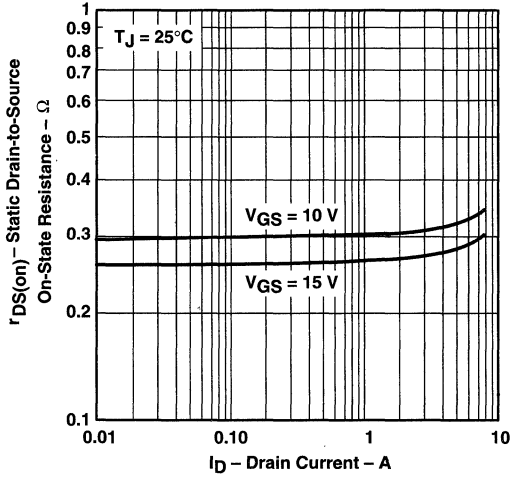


Figure 7

DRAIN CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE

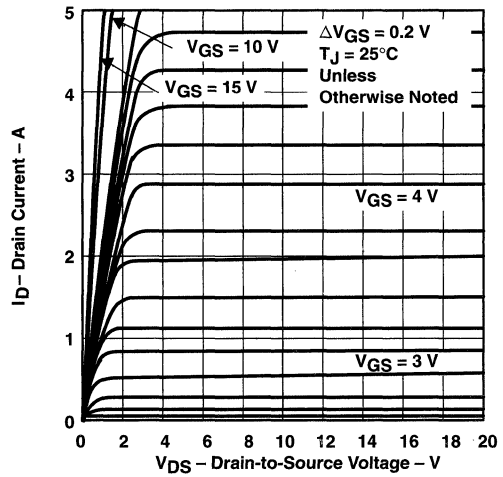


Figure 8

DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE

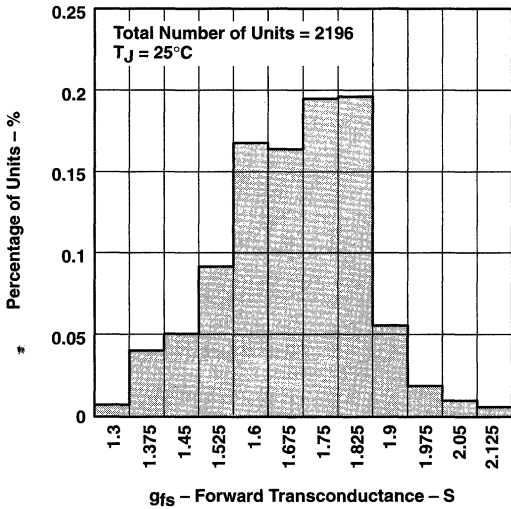


Figure 9

DRAIN CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE

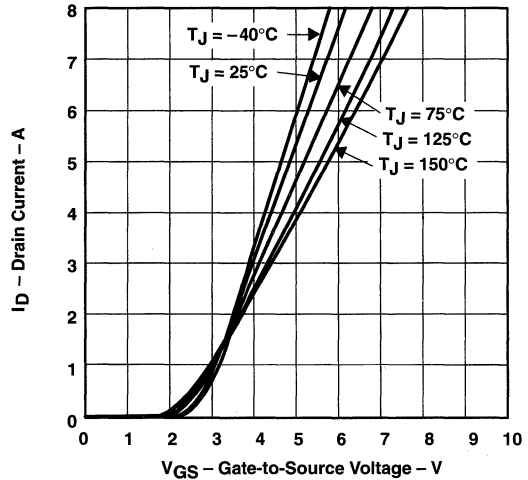


Figure 10

# TPIC5601

## 3-PHASE BRIDGE POWER DMOS ARRAY

SLIS022B – MARCH 1994 – REVISED OCTOBER 1995

### TYPICAL CHARACTERISTICS

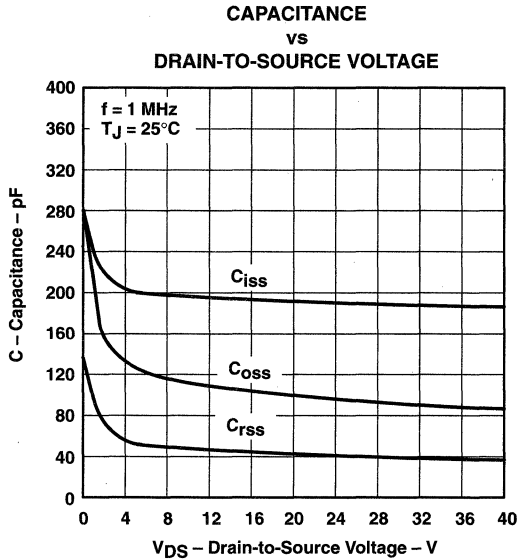


Figure 11

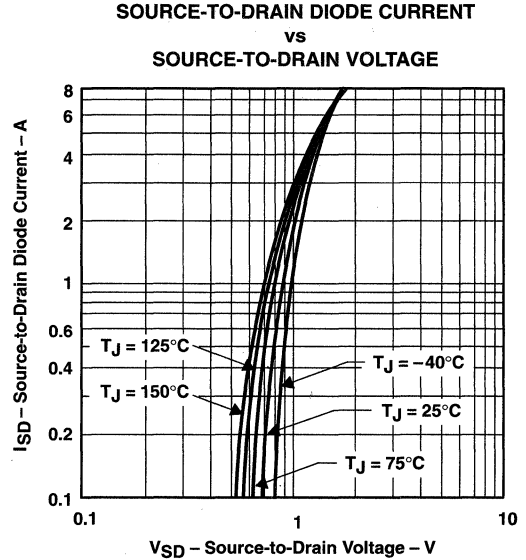


Figure 12

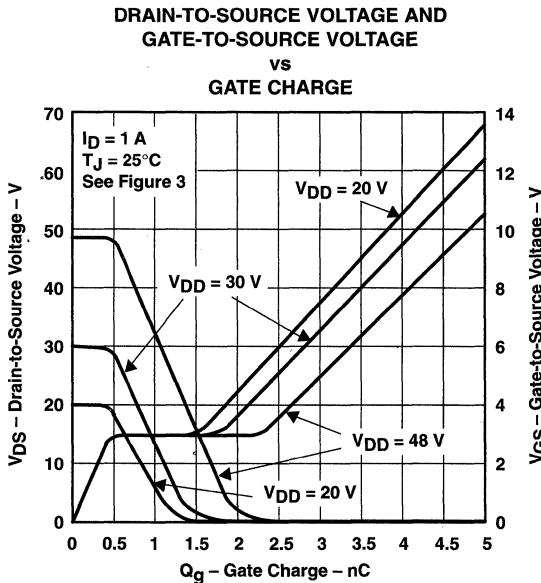


Figure 13

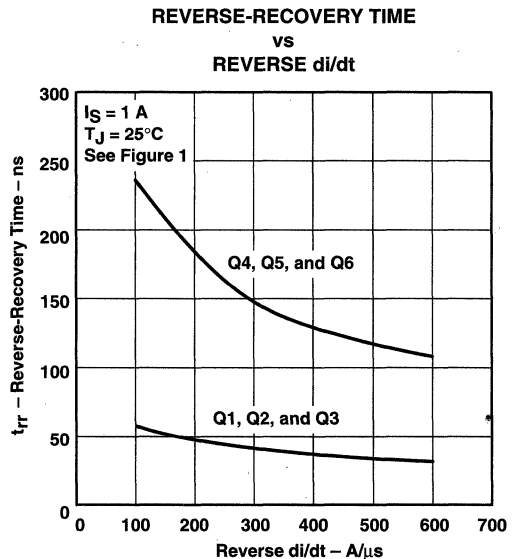
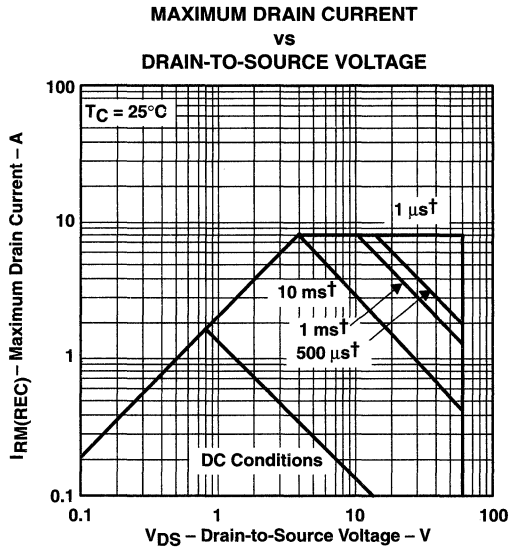


Figure 14

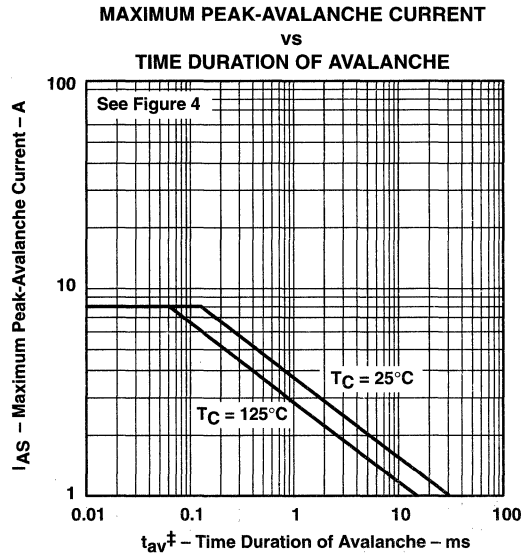


THERMAL INFORMATION



† Less than 0.1 duty cycle

Figure 15



‡ Non-JEDEC symbol for avalanche time.

Figure 16

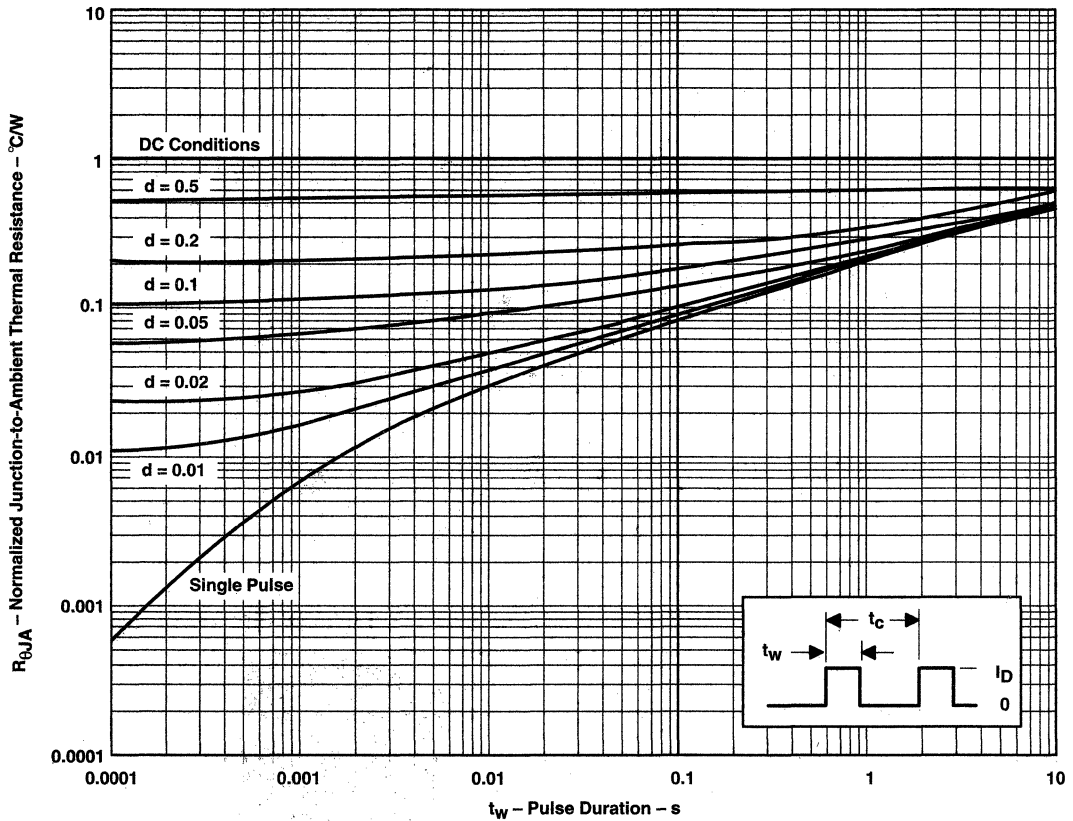


**TPIC5601**  
**3-PHASE BRIDGE POWER DMOS ARRAY**

SLIS022B – MARCH 1994 – REVISED OCTOBER 1995

**THERMAL INFORMATION**

**DW PACKAGE†**  
**NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE**  
**vs**  
**PULSE DURATION**



† Device mounted on FR4 printed-circuit board with no heatsink

NOTE A:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17



# TPIC5621L

## 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

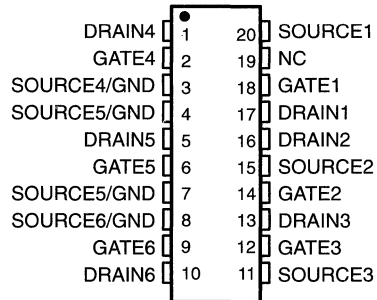
- Low  $r_{DS(on)}$  . . . 0.4  $\Omega$  Typ
- High-Voltage Output . . . 60 V
- Pulsed Current . . . 3 A Per Channel
- Fast Commutation Speed
- Direct Logic-Level Interface

### description

The TPIC5621L is a monolithic logic-level power DMOS array that consists of six electrically isolated N-channel enhancement-mode DMOS transistors, three of which are configured with a common source.

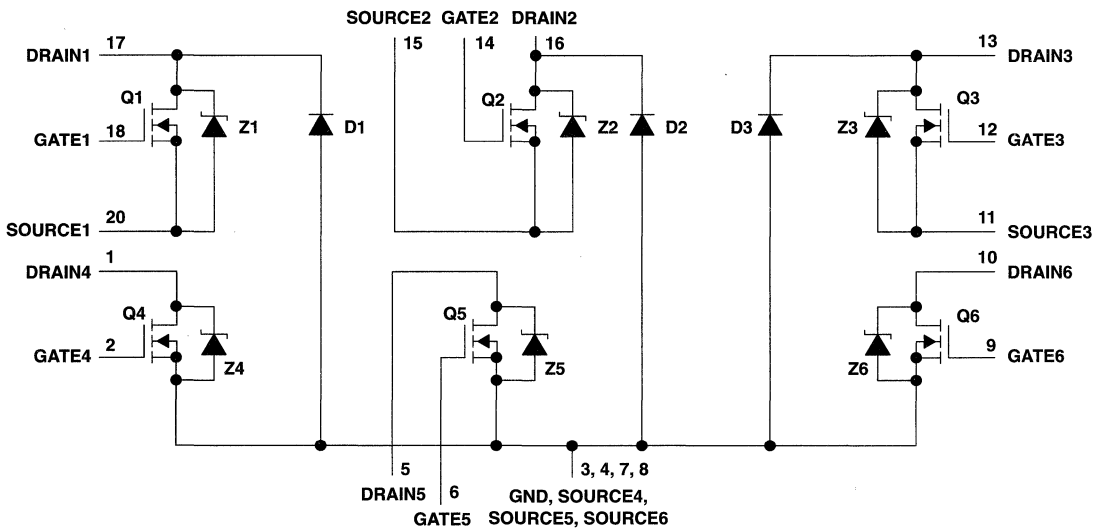
The TPIC5621L is offered in a 20-pin wide-body surface-mount (DW) package and is characterized for operation over the case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**DW PACKAGE  
(TOP VIEW)**



NC – No internal connection

### schematic



**TPIC5621L**  
**3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY**

SLIS033A— JUNE 1994 — REVISED NOVEMBER 1994

**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Drain-to-source voltage, $V_{DS}$ .....	60 V
Source-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Drain-to-GND voltage (Q1, Q2, and Q3) .....	100 V
Drain-to-GND voltage (Q4, Q5, and Q6) .....	60 V
Gate-to-source voltage range, $V_{GS}$ .....	$\pm 20$ V
Continuous drain current, each output, $T_C = 25^\circ\text{C}$ .....	1 A
Continuous source-to-drain diode current, $T_C = 25^\circ\text{C}$ .....	1 A
Pulsed drain current, $I_{max}$ , $T_C = 25^\circ\text{C}$ (each output, see Note 1 and Figure 15) .....	3 A
Single-pulse avalanche energy, $E_{AS}$ , $T_C = 25^\circ\text{C}$ (see Figures 4, 15 and 16) .....	162 mJ
Continuous total dissipation (see Figure 15) .....	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$ .....	$-40^\circ\text{C}$ to $150^\circ\text{C}$
Operating case temperature range, $T_C$ .....	$-40^\circ\text{C}$ to $125^\circ\text{C}$
Storage temperature range .....	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	$260^\circ\text{C}$

† 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.

NOTE 1: Pulse duration = 10 ms and duty cycle = 2%

**DISSIPATION RATING TABLE**

<b>PACKAGE</b>	<b><math>T_C \leq 25^\circ\text{C}</math> POWER RATING</b>	<b>DERATING FACTOR ABOVE <math>T_C = 25^\circ\text{C}</math></b>	<b><math>T_C = 125^\circ\text{C}</math> POWER RATING</b>
DW	1389 mW	11.1 mW/ $^\circ\text{C}$	279 mW

# TPIC5621L

## 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

### electrical characteristics, $T_C = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 250 \mu\text{A}$ ,	$V_{GS} = 0$	60			V
$V_{GS(th)}$	Gate-to-source threshold voltage	$I_D = 1 \text{ mA}$ , See Figure 5	$V_{DS} = V_{GS}$ ,	1.5	1.85	2.2	V
$V_{(BR)}$	Reverse drain-to-GND breakdown voltage (across D1, D2, and D3)	Drain-to-GND current = $250 \mu\text{A}$		100			V
$V_{DS(on)}$	Drain-to-source on-state voltage	$I_D = 1 \text{ A}$ , See Notes 2 and 3	$V_{GS} = 5 \text{ V}$ ,		0.4	0.48	V
$V_{F(SD)}$	Forward on-state voltage, source-to-drain	$I_S = 1 \text{ A}$ , $V_{GS} = 0$ (Z1, Z2, Z3, Z4, Z5, Z6), See Notes 2 and 3 and Figure 12			0.9	1.1	V
$V_F$	Forward on-state voltage, GND-to-drain	$I_D = 1 \text{ A}$ (D1, D2, D3), See Notes 2 and 3			4.6		V
$I_{DSS}$	Zero-gate-voltage drain current	$V_{DS} = 48 \text{ V}$ , $V_{GS} = 0$	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$I_{GSSF}$	Forward gate current, drain short circuited to source	$V_{GS} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{GSSR}$	Reverse gate current, drain short circuited to source	$V_{SG} = 16 \text{ V}$ ,	$V_{DS} = 0$		10	100	nA
$I_{lkg}$	Leakage current, drain-to-GND	$V_{DGND} = 48 \text{ V}$ (D1, D2, D3)	$T_C = 25^\circ\text{C}$	0.05	1		$\mu\text{A}$
			$T_C = 125^\circ\text{C}$	0.5	10		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$V_{GS} = 5 \text{ V}$ , $I_D = 1 \text{ A}$ , See Notes 2 and 3 and Figures 6 and 7	$T_C = 25^\circ\text{C}$	0.4	0.48		$\Omega$
			$T_C = 125^\circ\text{C}$	0.65	0.68		
$g_{fs}$	Forward transconductance	$V_{DS} = 15 \text{ V}$ , See Notes 2 and 3 and Figure 9	$I_D = 0.5 \text{ A}$ ,	1	1.29	1.45	S
$C_{iss}$	Short-circuit input capacitance, common source	$V_{DS} = 25 \text{ V}$ , $f = 1 \text{ MHz}$ ,	$V_{GS} = 0$ , See Figure 11		190	240	pF
$C_{oss}$	Short-circuit output capacitance, common source				100	125	
$C_{rss}$	Short-circuit reverse transfer capacitance, common source				40	50	

NOTES: 2. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

3. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

### source-to-drain and GND-to-drain diode characteristics, $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{rr}$	Reverse-recovery time	$I_S = 0.5 \text{ A}$ , $V_{GS} = 0$ , See Figures 1 and 14	$V_{DS} = 48 \text{ V}$ ,	Z1, Z2, Z3	65		ns
				Z4, Z5, Z6	150		
				D1, D2, D3	200		
$Q_{RR}$	Total diode charge		Z1, Z2, Z3	0.06		$\mu\text{C}$	
			Z4, Z5, Z6	0.3			
			D1, D2, D3	0.7			

# TPIC5621L

## 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

### resistive-load switching characteristics, $T_C = 25^\circ\text{C}$

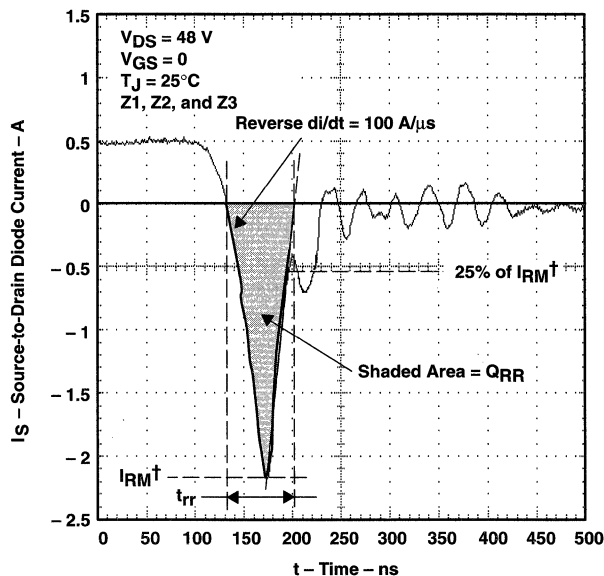
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(on)}$ Turn-on delay time	$V_{DD} = 25\text{ V}$ , $R_L = 50\ \Omega$ , $t_{en} = 10\text{ ns}$ , $t_{dis} = 10\text{ ns}$ , See Figure 2		34	68	ns
$t_{d(off)}$ Turn-off delay time			41	32	
$t_r$ Rise time			21	42	
$t_f$ Fall time			25	50	
$Q_g$ Total gate charge	$V_{DS} = 48\text{ V}$ , $I_D = 0.5\text{ A}$ , $V_{GS} = 5\text{ V}$ , See Figure 3		3.1	3.7	nC
$Q_{gs(th)}$ Threshold gate-to-source charge			0.5	0.6	
$Q_{gd}$ Gate-to-drain charge			1.9	2.3	
$L_D$ Internal drain inductance			5		nH
$L_S$ Internal source inductance			5		
$R_g$ Internal gate resistance			0.25		

### thermal resistance

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{\theta JA}$ Junction-to-ambient thermal resistance (see Note 4)	All outputs with equal power		90		$^\circ\text{C/W}$
$R_{\theta JP}$ Junction-to-pin thermal resistance			27		

NOTE 4: Package mounted on an FR4 printed-circuit board with no heat sink

### PARAMETER MEASUREMENT INFORMATION



†  $I_{RM}$  = maximum recovery current

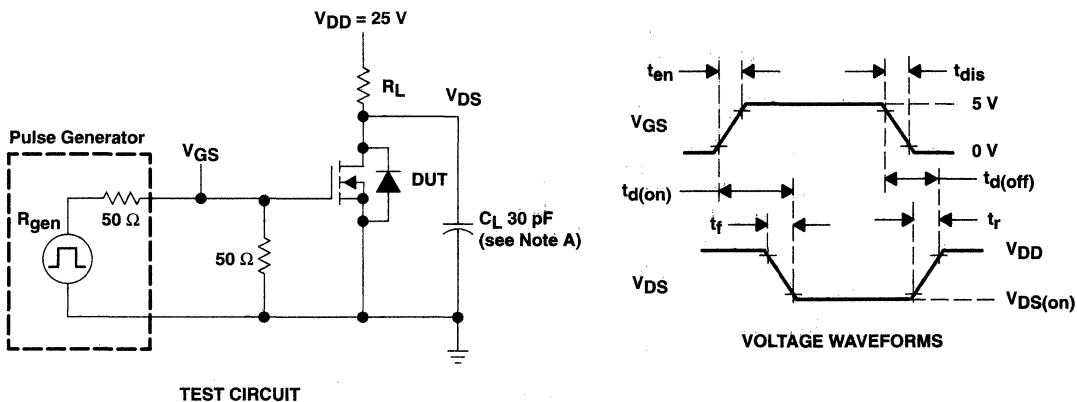
NOTE A. The above waveform is representative of Z4, Z5, Z6, D1, D2, and D3 in shape only.

Figure 1. Reverse-Recovery-Current Waveform of Source-to-Drain Diode

# TPIC5621L 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

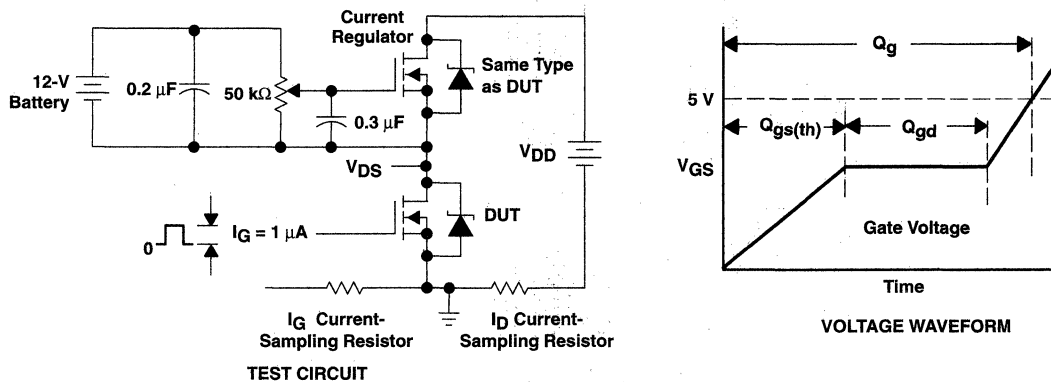
SLIS033A - JUNE 1994 - REVISED NOVEMBER 1994

## PARAMETER MEASUREMENT INFORMATION



NOTE A:  $C_L$  includes probe and jig capacitance.

**Figure 2. Resistive-Switching Test Circuit and Voltage Waveforms**

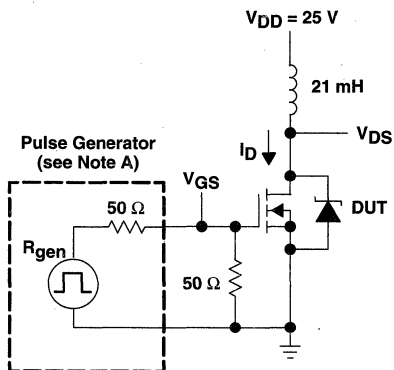


**Figure 3. Gate-Charge Test Circuit and Voltage Waveform**

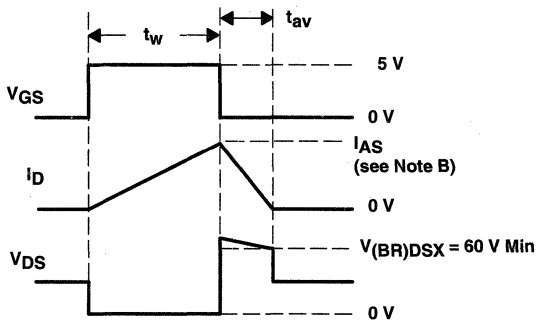
# TPIC5621L 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_0 = 50 \Omega$ .

B. Input pulse duration ( $t_w$ ) is increased until peak current  $I_{AS} = 3$  A.

$$\text{Energy test level is defined as } E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 162 \text{ mJ.}$$

Figure 4. Single-Pulse Avalanche-Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

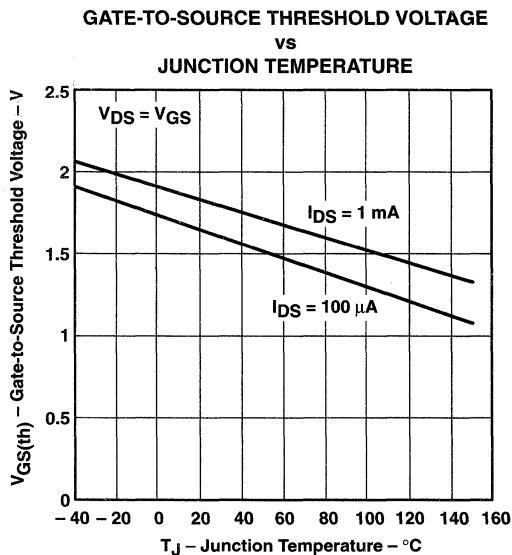


Figure 5

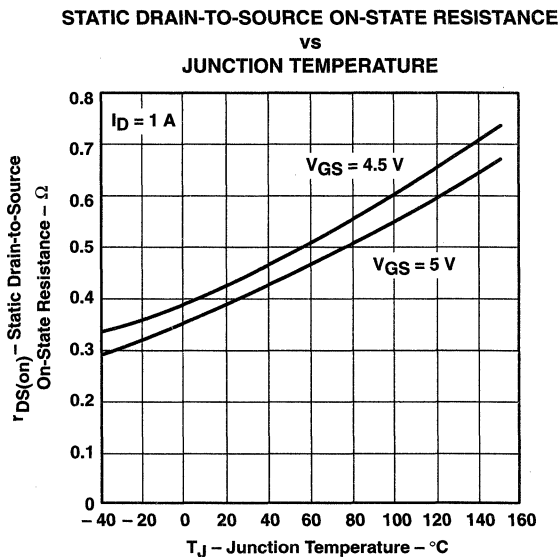


Figure 6

# TPIC5621L 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

## TYPICAL CHARACTERISTICS

**STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT**

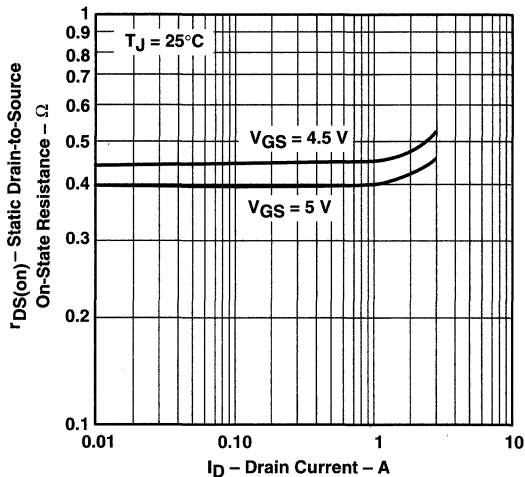


Figure 7

**DRAIN-TO-SOURCE CURRENT  
vs  
DRAIN-TO-SOURCE VOLTAGE**

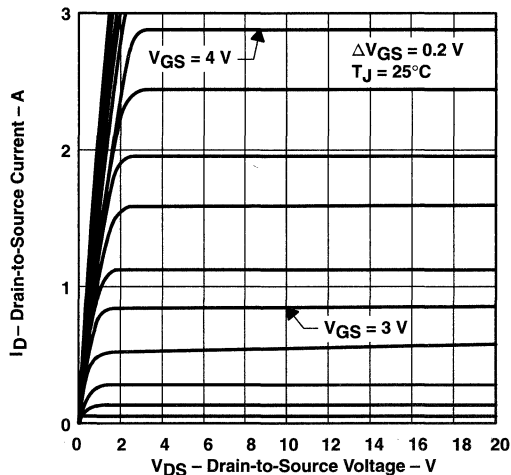


Figure 8

**DISTRIBUTION OF  
FORWARD TRANSCONDUCTANCE**

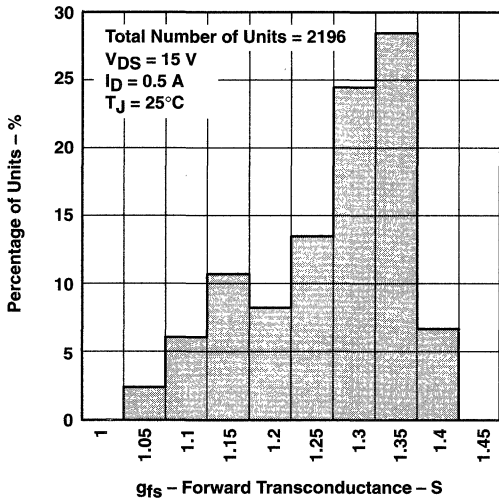


Figure 9

**DRAIN-TO-SOURCE CURRENT  
vs  
GATE-TO-SOURCE VOLTAGE**

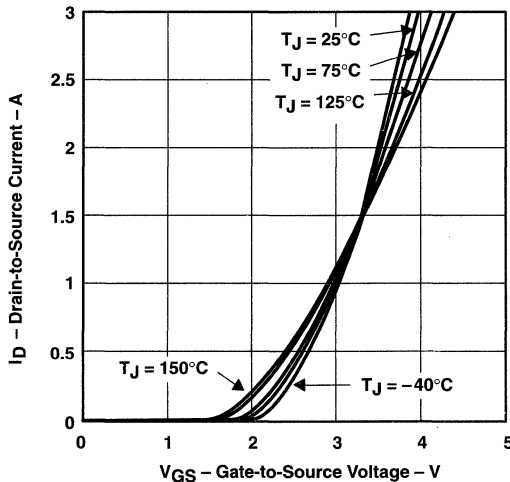


Figure 10



# TPIC5621L 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

## TYPICAL CHARACTERISTICS

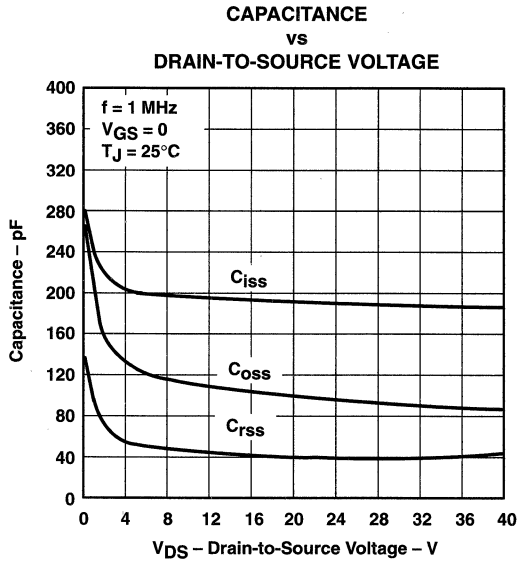


Figure 11

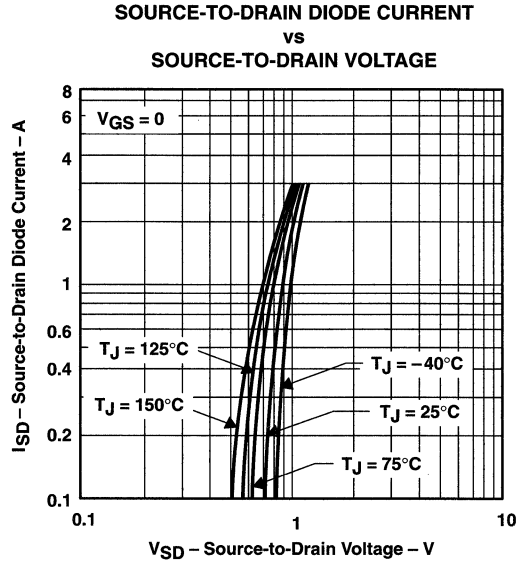


Figure 12

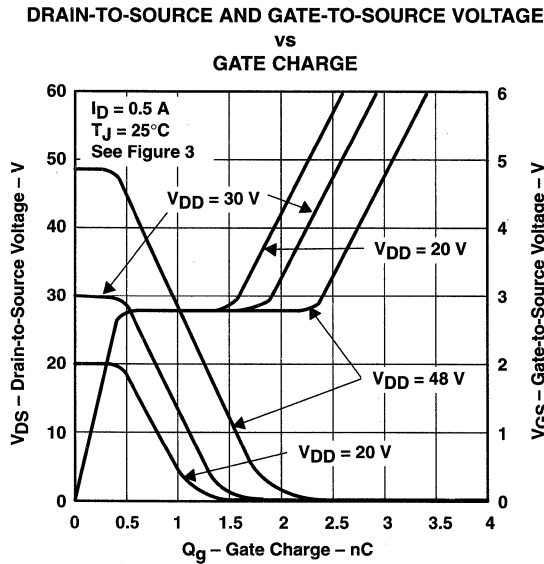


Figure 13

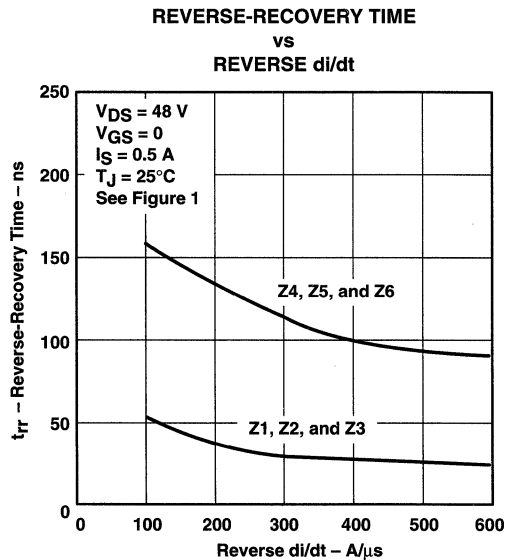
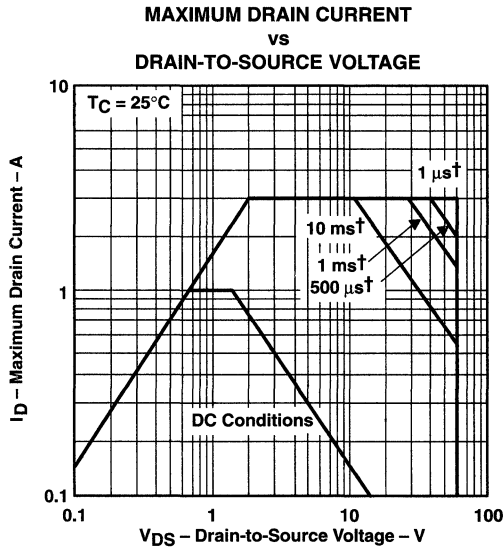


Figure 14

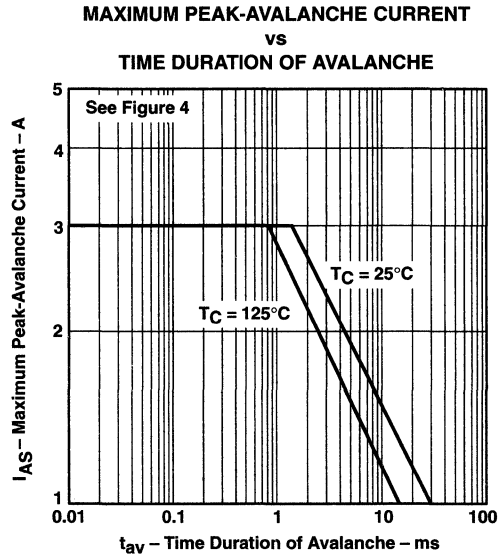
**TPIC5621L**  
**3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY**

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

**THERMAL INFORMATION**



**Figure 15**

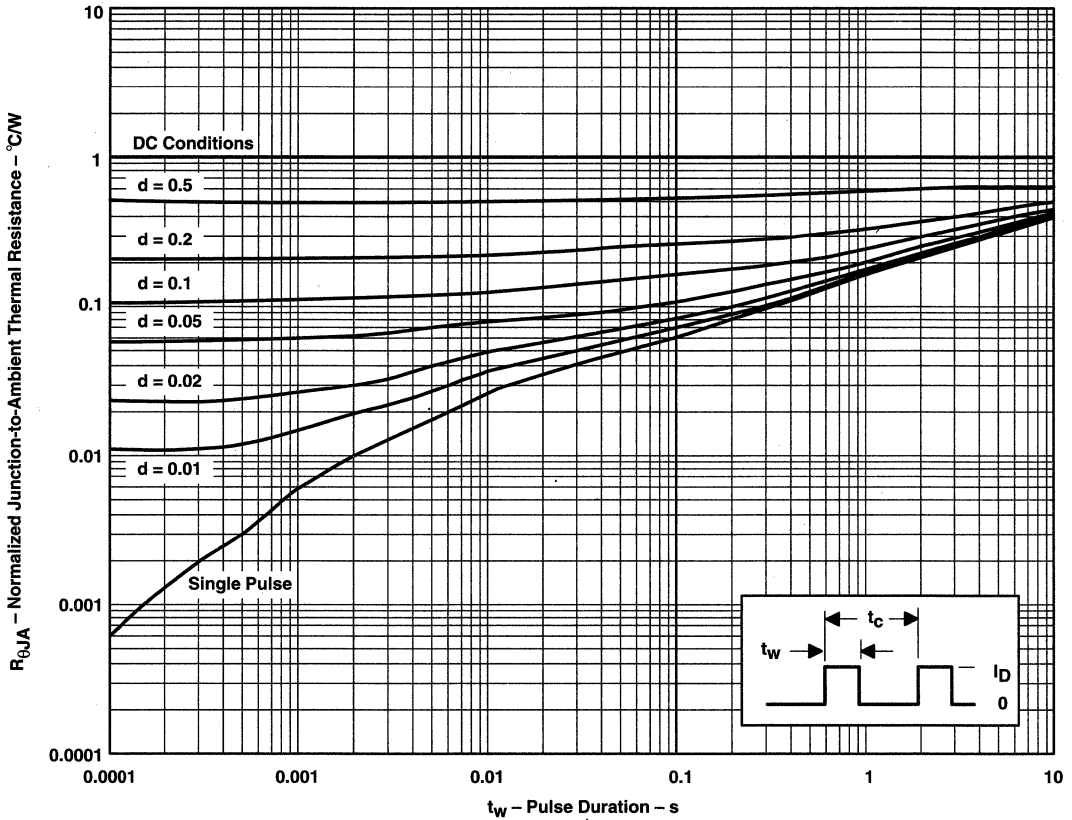


**Figure 16**

# TPIC5621L 3-PHASE BRIDGE LOGIC-LEVEL POWER DMOS ARRAY

SLIS033A – JUNE 1994 – REVISED NOVEMBER 1994

## THERMAL INFORMATION DW PACKAGE† NORMALIZED JUNCTION-TO-AMBIENT THERMAL RESISTANCE VS PULSE DURATION



† Device mounted on FR4 printed-circuit board with no heat sink

- NOTES:  $Z_{\theta A}(t) = r(t) R_{\theta JA}$   
 $t_w$  = pulse duration  
 $t_c$  = cycle time  
 $d$  = duty cycle =  $t_w/t_c$

Figure 17

# TPIC6259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS009A – APIRL 1992 – REVISED SEPTEMBER 1995

- Low  $r_{DS(on)}$  . . . 1.3  $\Omega$  Typical
- Avalanche Energy . . . 75 mJ
- Eight Power DMOS Transistor Outputs of 250-mA Continuous Current
- 1.5-A Pulsed Current Per Output
- Output Clamp Voltage at 45 V
- Four Distinct Function Modes
- Low Power Consumption

## description

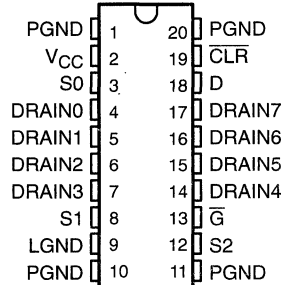
This power logic 8-bit addressable latch controls open-drain DMOS transistor outputs and is designed for general-purpose storage applications in digital systems. Specific uses include working registers, serial-holding registers, and decoders or demultiplexers. This is a multi-functional device capable of storing single-line data in eight addressable latches with 3-to-8 decoding or demultiplexing mode active-low DMOS outputs.

Four distinct modes of operation are selectable by controlling the clear ( $\overline{CLR}$ ) and enable ( $\overline{G}$ ) inputs as enumerated in the function table. In the addressable-latch mode, data at the data-in (D) terminal is written into the addressed latch. The addressed DMOS transistor output inverts the data input with all unaddressed DMOS-transistor outputs remaining in their previous states. In the memory mode, all DMOS-transistor outputs remain in their previous states and are unaffected by the data or address inputs. To eliminate the possibility of entering erroneous data in the latch, enable  $\overline{G}$  should be held high (inactive) while the address lines are changing. In the 3-to-8 decoding or demultiplexing mode, the addressed output is inverted with respect to the D input and all other outputs are high. In the clear mode, all outputs are high and unaffected by the address and data inputs.

Separate power and logic level ground pins are provided to facilitate maximum system flexibility. Pins 1, 10, 11, and 20 are internally connected, and each pin must be externally connected to the power system ground in order to minimize parasitic inductance. A single-point connection between pin 9, logic ground (LGND), and pins 1, 10, 11, and 20, power ground (PGND) must be externally made in a manner that reduces crosstalk between the logic and load circuits.

The TPIC6259 is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

DW OR N PACKAGE  
(TOP VIEW)



FUNCTION TABLE

INPUTS			OUTPUT OF ADDRESSED DRAIN	EACH OTHER DRAIN	FUNCTION
$\overline{CLR}$	$\overline{G}$	D			
H	L	H	L	$Q_{i0}$	Addressable Latch
H	L	L	H	$Q_{i0}$	
H	H	X	$Q_{i0}$	$Q_{i0}$	Memory
L	L	H	L	H	8-Line Demultiplexer
L	L	L	H	H	
L	H	X	H	H	Clear

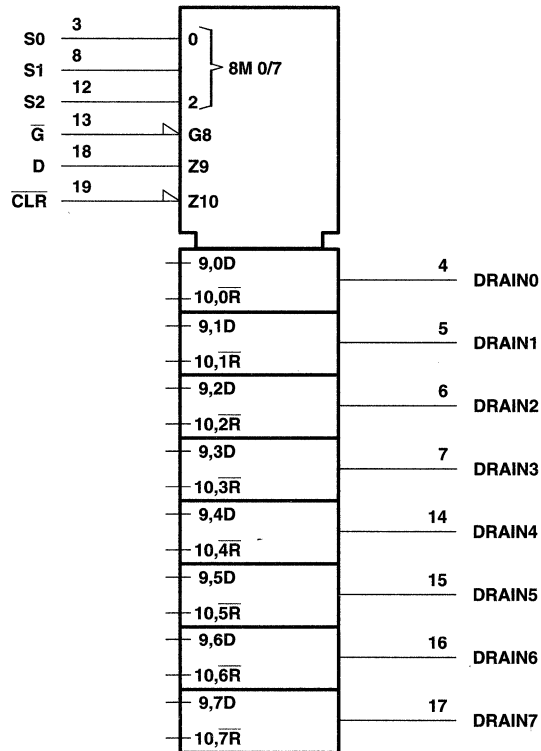
LATCH SELECTION TABLE

SELECT INPUTS			DRAIN ADDRESSED
S2	S1	S0	
L	L	L	0
L	L	H	1
L	H	L	2
L	H	H	3
H	L	L	4
H	L	H	5
H	H	L	6
H	H	H	7

# TPIC6259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS009A – APIRL 1992 – REVISED SEPTEMBER 1995

## logic symbol†

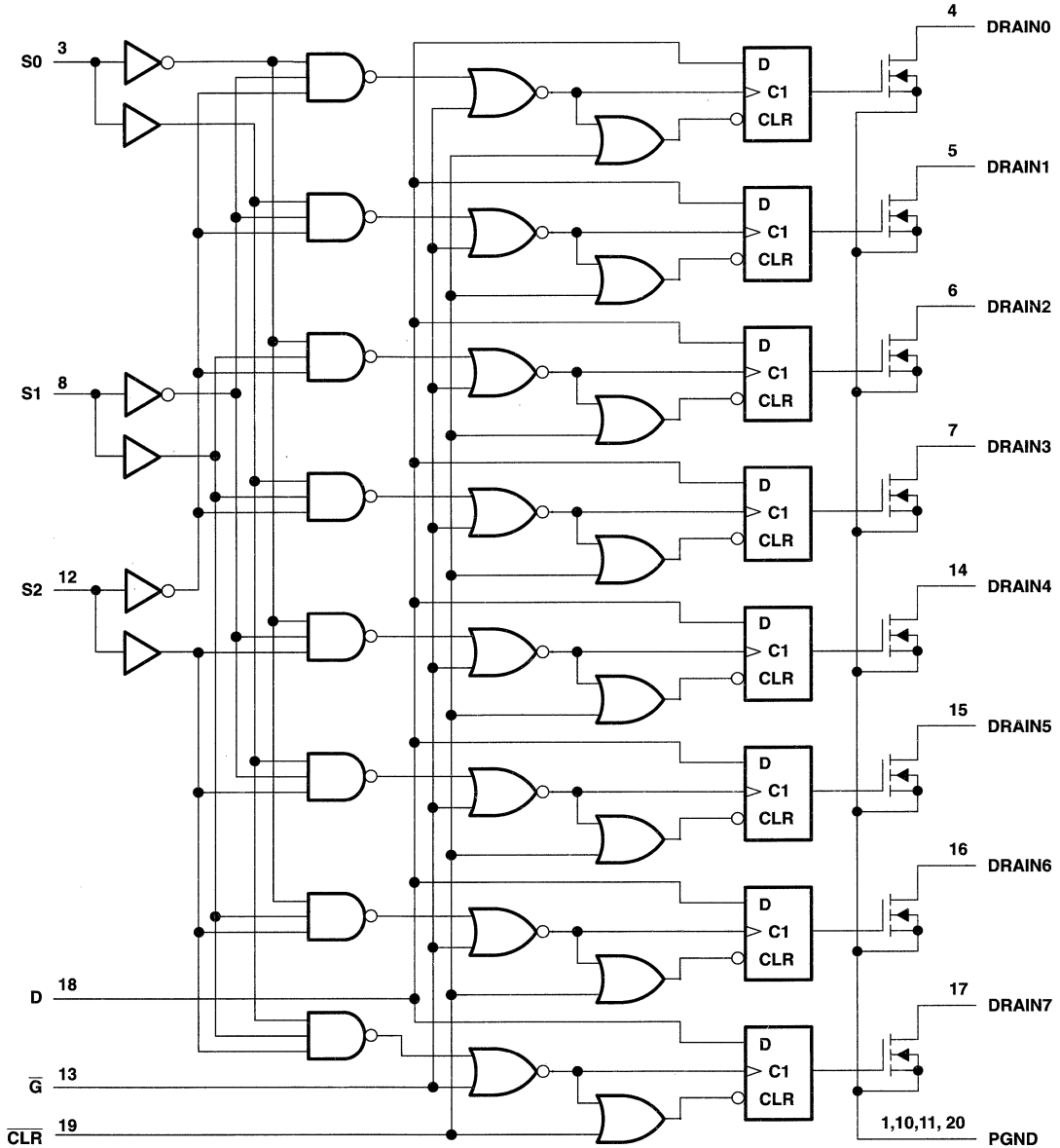


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

TPIC6259  
POWER LOGIC 8-BIT ADDRESSABLE LATCH

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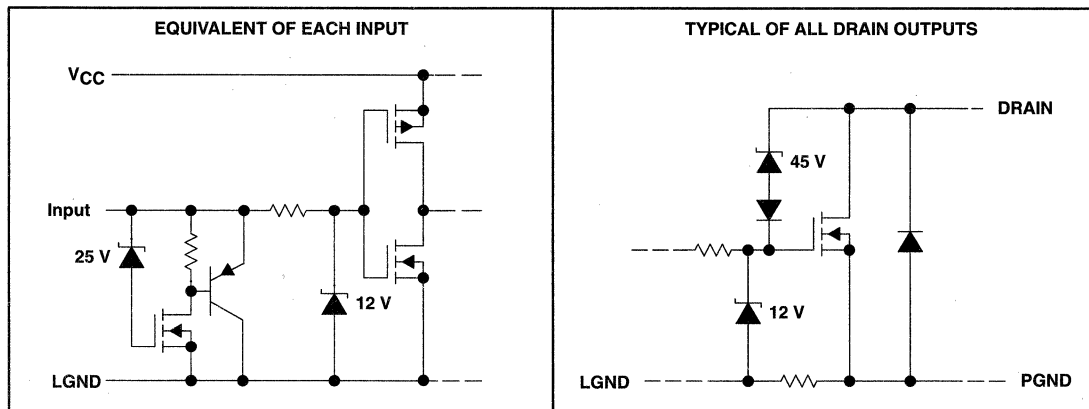
logic diagram (positive logic)



# TPIC6259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS009A—APIRL 1992—REVISED SEPTEMBER 1995

## schematic of inputs and outputs



## absolute maximum ratings over the recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	45 V
Continuous source-drain diode anode current	1 A
Pulsed source-drain diode anode current	2 A
Pulsed drain current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	750 mA
Continuous drain current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$	250 mA
Peak drain current single output, $I_{DM}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	2 A
Single-pulse avalanche energy, $E_{AS}$ (see Note 4)	75 mJ
Avalanche current, $I_{AS}$ (see Note 4)	1 A
Continuous total power dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to LGND and PGND.

2. Each power DMOS source is internally connected to PGND.

3. Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$

4. DRAIN supply voltage = 15 V, starting junction temperature,  $(T_{JS}) = 25^\circ\text{C}$ ,  $L = 100 \text{ mH}$ ,  $I_{AS} = 1 \text{ A}$  (see Figure 4).

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 125^\circ\text{C}$ POWER RATING
DW	1125 mW	9.0 mW/°C	225 mW
N	1150 mW	9.2 mW/°C	230 mW

**TPIC6259**  
**POWER LOGIC 8-BIT ADDRESSABLE LATCH**

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**recommended operating conditions over recommended operating temperature range (unless otherwise noted)**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$		0.15 $V_{CC}$	V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-1.8	1.5	A
Setup time, D high before $\overline{G}\uparrow$ , $t_{SU}$ (see Figure 2)	10		ns
Hold time, D high after $\overline{G}\uparrow$ , $t_H$ (see Figure 2)	5		ns
Pulse duration, $t_W$ (see Figure 2)	15		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$ Drain-source breakdown voltage	$I_D = 1\text{ mA}$	45			V
$V_{SD}$ Source-drain diode forward voltage	$I_F = 250\text{ mA}$ , See Note 3	0.85		1	V
$I_{IH}$ High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$ Logic supply current	$I_O = 0$ , All inputs low		15	100	$\mu\text{A}$
$I_N$ Nominal current	$V_{DS(on)} = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$ , See Notes 5, 6, and 7		250		mA
$I_{DSX}$ Off-state drain current	$V_{DS} = 40\text{ V}$		0.05	1	$\mu\text{A}$
	$V_{DS} = 40\text{ V}$ , $T_C = 125^\circ\text{C}$		0.15	5	
$r_{DS(on)}$ Static drain-source on-state resistance	$I_D = 250\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.3	2	$\Omega$
	$I_D = 250\text{ mA}$ , $T_C = 125^\circ\text{C}$ , $V_{CC} = 4.5\text{ V}$	See Notes 5 and 6 and Figures 8 and 9	2	3.2	
	$I_D = 500\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.3	2	

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$t_{PLH}$ Propagation delay time, low-to-high-level output from D	$C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ , See Figures 1, 2, and 10		625		ns	
$t_{PHL}$ Propagation delay time, high-to-low-level output from D			140		ns	
$t_r$ Rise time, drain output				650		ns
$t_f$ Fall time, drain output				400		ns
$t_a$ Reverse-recovery-current rise time		$I_F = 250\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3		100		ns
$t_{rr}$ Reverse-recovery time			300			

NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$ , duty cycle  $\leq 2\%$

5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .

**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JA}$ Thermal resistance junction-to-ambient	DW package		111	$^\circ\text{C}/\text{W}$
	N package	All 8 outputs with equal power	108	



# TPIC6259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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## PARAMETER MEASUREMENT INFORMATION

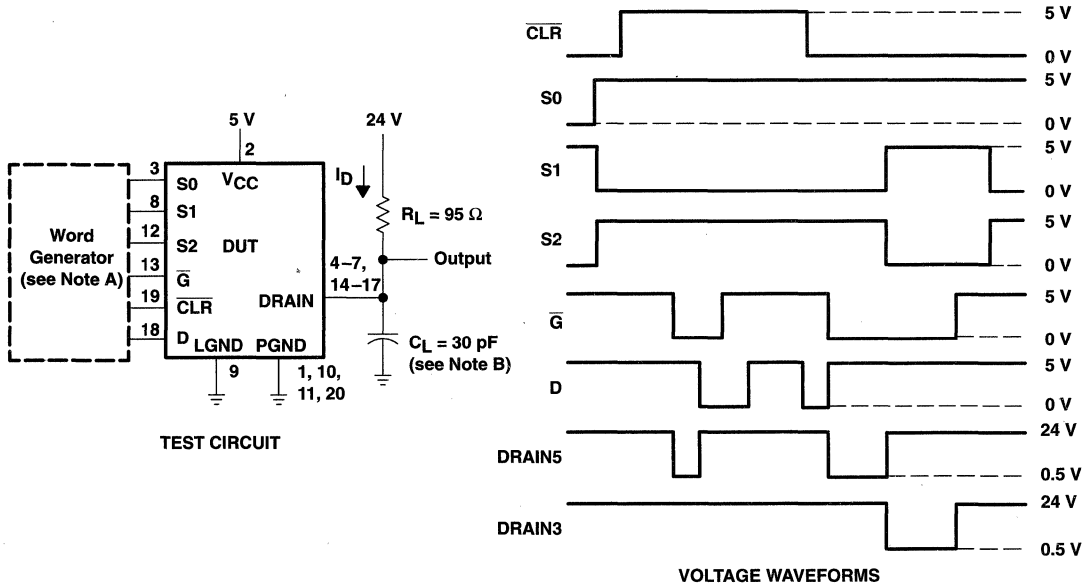


Figure 1. Typical Operation Mode

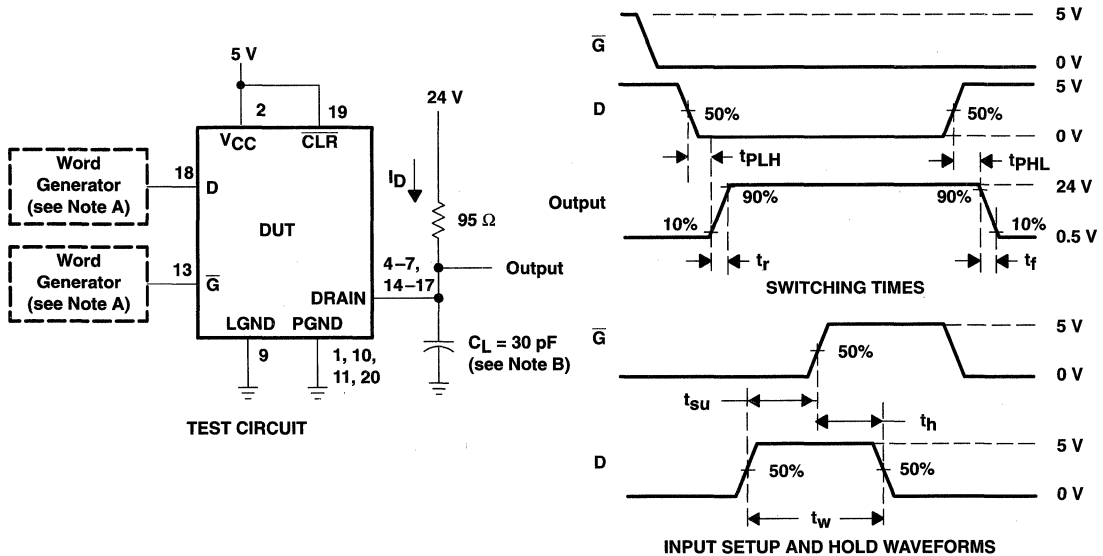
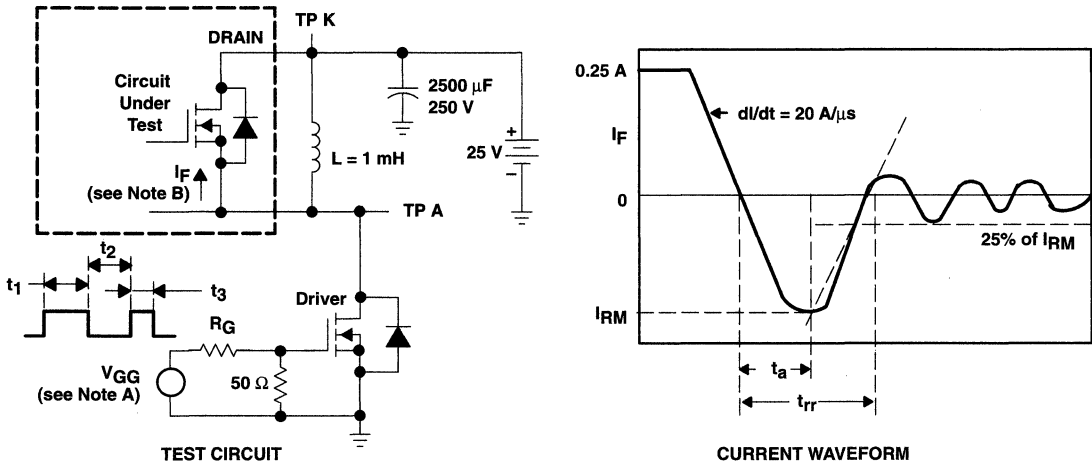


Figure 2. Test Circuit, Switching Times, and Voltage Waveforms

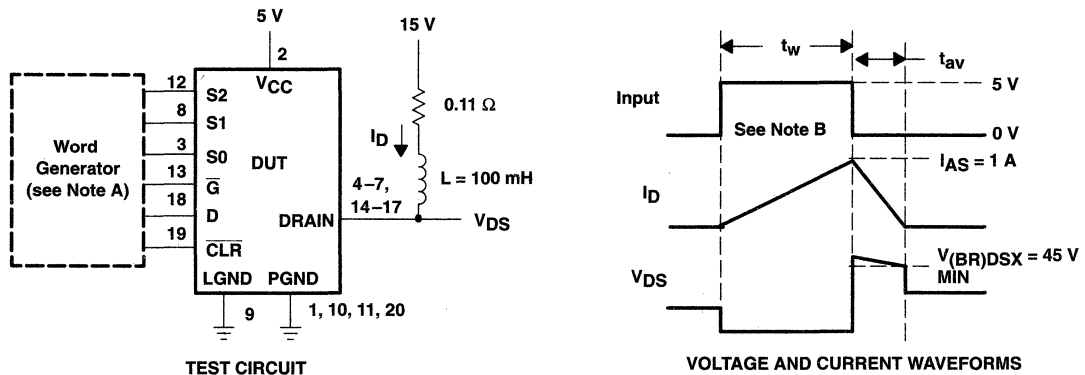
- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.25 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .  
B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-Drain Diode



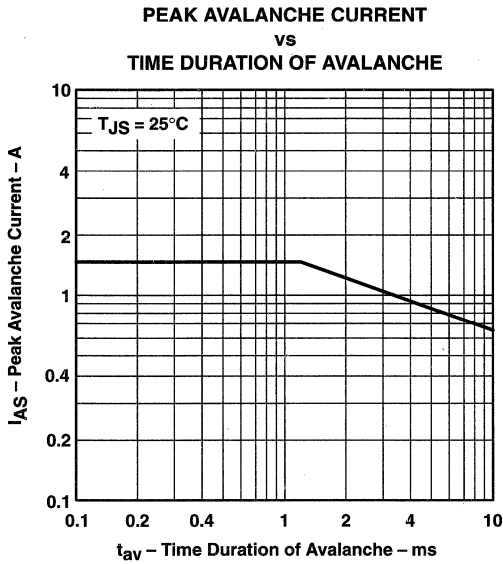
- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_0 = 50 \Omega$ .  
B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 1 \text{ A}$ .  
Energy test level is defined as  $E_{AS} = I_{AS} \times V_{(BR)DSX} \times t_{av}/2 = 75 \text{ mJ}$ .

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

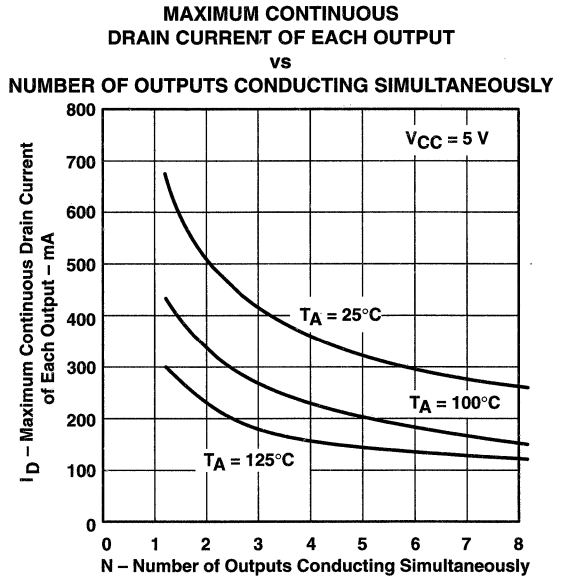
**TPIC6259**  
**POWER LOGIC 8-BIT ADDRESSABLE LATCH**

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**TYPICAL CHARACTERISTICS**

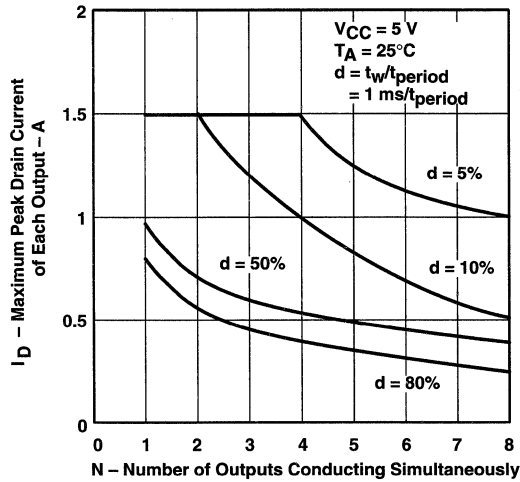


**Figure 5**



**Figure 6**

**MAXIMUM PEAK DRAIN CURRENT**  
**OF EACH OUTPUT**  
**vs**  
**NUMBER OF OUTPUTS CONDUCTING SIMULTANEOUSLY**



**Figure 7**

TYPICAL CHARACTERISTICS

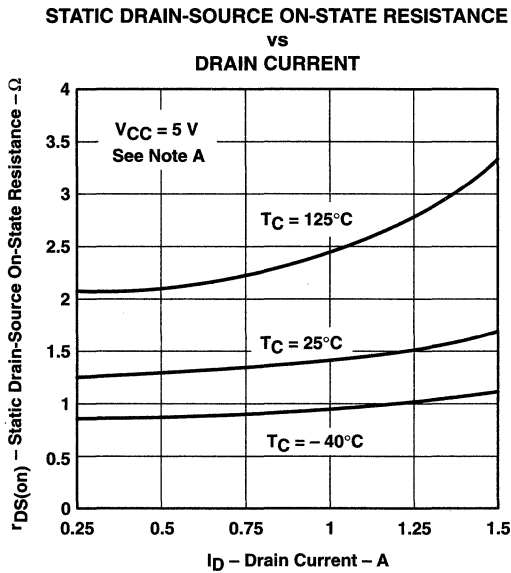


Figure 8

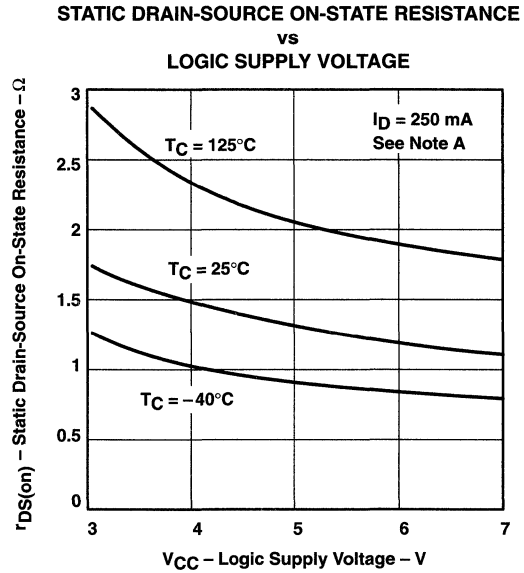


Figure 9

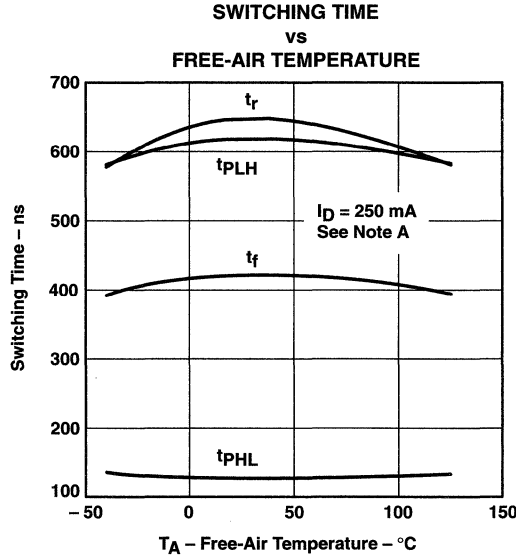


Figure 10

NOTE A: Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.



# TPIC6273 POWER LOGIC OCTAL D-TYPE LATCH

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- Low  $r_{DS(on)}$  . . . 1.3  $\Omega$  Typ
- Avalanche Energy . . . 75 mJ
- Eight Power DMOS Transistor Outputs of 250-mA Continuous Current
- 1.5-A Pulsed Current Per Output
- Output Clamp Voltage up to 45 V
- Low Power Consumption

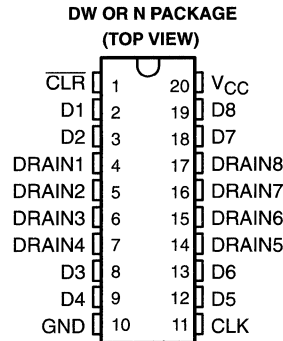
## description

The TPIC6273 is a monolithic high-voltage high-current power logic octal D-type latch with DMOS transistor outputs designed for use in systems that require relatively high load power. The device contains a built-in voltage clamp on the outputs for inductive transient protection. Power driver applications include relays, solenoids, and other medium-current or high-voltage loads.

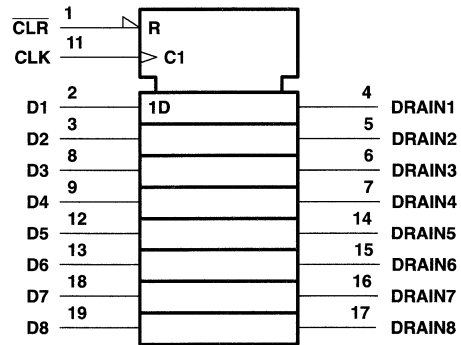
The TPIC6273 contains eight positive-edge-triggered D-type flip-flops with a direct clear input. Each flip-flop features an open-drain power DMOS transistor output.

When clear ( $\overline{CLR}$ ) is high, information at the D inputs meeting the setup time requirements is transferred to the DRAIN outputs on the positive-going edge of the clock pulse. Clock triggering occurs at a particular voltage level and is not directly related to the transition time of the positive-going pulse. When the clock input (CLK) is at either the high or low level, the D input signal has no effect at the output. An asynchronous  $\overline{CLR}$  is provided to turn all eight DMOS-transistor outputs off.

The TPIC6273 is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



## logic symbol



† This symbol is in accordance with ANSI/IEEE Standard 91-1984 and IEC Publication 617-12.

**FUNCTION TABLE  
(each channel)**

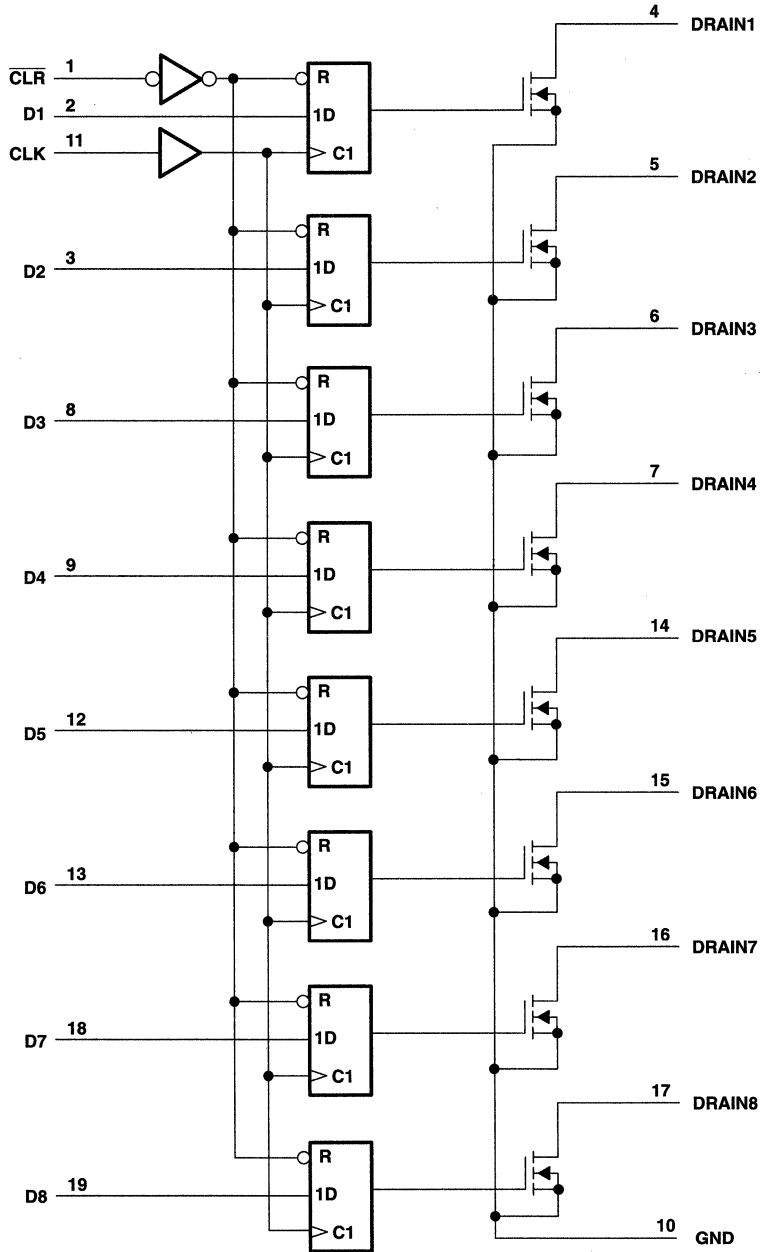
INPUTS			OUTPUT
CLR	CLK	D	DRAIN
L	X	X	H
H	↑	H	L
H	↑	L	H
H	L	X	Latched

H = high level, L = low level, X = irrelevant

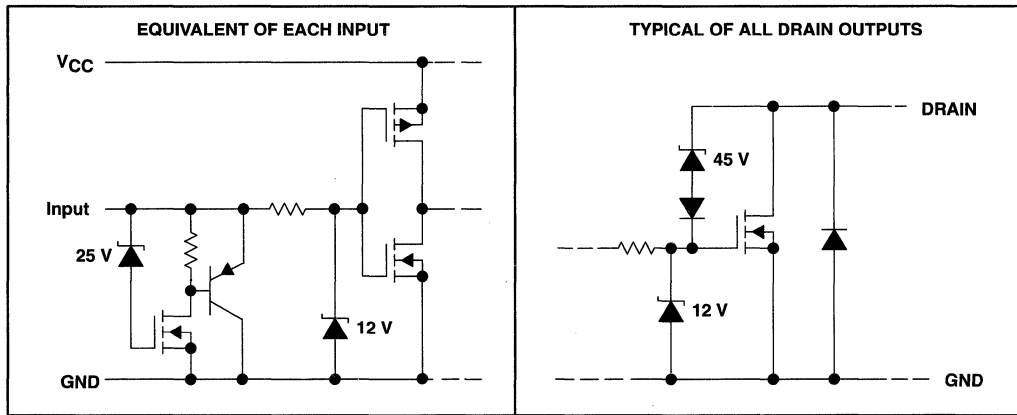
# TPIC6273 POWER LOGIC OCTAL D-TYPE LATCH

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## logic diagram (positive logic)



**schematic of inputs and outputs**



**absolute maximum ratings over recommended operating case temperature range (unless otherwise noted)†**

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	45 V
Continuous source-drain diode anode current	1 A
Pulsed source-drain diode anode current	2 A
Pulsed drain current, each output, all outputs on, $I_{DN}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	750 mA
Continuous drain current, each output, all outputs on, $I_{DN}$ , $T_A = 25^\circ\text{C}$	250 mA
Peak drain current single output, $I_{DM}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	2 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	75 mJ
Avalanche current, $I_{AS}$ (see Note 4)	1 A
Continuous total power dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to GND.  
 2. Each power DMOS source is internally connected to GND.  
 3. Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$   
 4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C, L = 100 mH,  $I_{AS} = 1 \text{ A}$  (see Figure 4).

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 125^\circ\text{C}$ POWER RATING
DW	1125 mW	9.0 mW/°C	225 mW
N	1150 mW	9.2 mW/°C	230 mW



# TPIC6273

## POWER LOGIC OCTAL D-TYPE LATCH

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recommended operating conditions over recommended operating temperature range (unless otherwise noted)

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$		0.15 $V_{CC}$	V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-1.8	1.5	A
Setup time, D high before $\text{CLK}\uparrow$ , $t_{SU}$ (see Figure 2)	10		ns
Hold time, D high after $\text{CLK}\uparrow$ , $t_H$ (see Figure 2)	15		ns
Pulse duration, $t_W$ (see Figure 2)	25		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-source breakdown voltage	$I_D = 1\text{ mA}$	45			V
$V_{SD}$	Source-drain diode forward voltage	$I_F = 250\text{ mA}$ , See Note 3		0.85	1	V
$I_{IH}$	High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$	Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$	Logic supply current	$I_O = 0$ , All inputs low		15	100	$\mu\text{A}$
$I_N$	Nominal current	$V_{DS(on)} = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$		250		mA
$I_{DSX}$	Off-state drain current	$V_{DS} = 40\text{ V}$		0.05	1	$\mu\text{A}$
		$V_{DS} = 40\text{ V}$ , $T_C = 125^\circ\text{C}$		0.15	5	
$r_{DS(on)}$	Static drain-source on-state resistance	$I_D = 250\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.3	2	$\Omega$
		$I_D = 250\text{ mA}$ , $T_C = 125^\circ\text{C}$ , $V_{CC} = 4.5\text{ V}$	See Notes 5 and 6 and Figures 8 and 9	2	3.2	
		$I_D = 500\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.3	2	

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from CLK	$C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ , See Figures 1, 2, and 10		625		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from CLK			150		ns
$t_r$	Rise time, drain output			675		ns
$t_f$	Fall time, drain output			400		ns
$t_a$	Reverse-recovery-current rise time		$I_F = 250\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3		100	
$t_{rr}$	Reverse-recovery time		300			

- NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$ , duty cycle  $\leq 2\%$   
 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.  
 7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .

thermal resistance

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JA}$	Thermal resistance, junction-to-ambient	All 8 outputs with equal power		111	$^\circ\text{C}/\text{W}$
			DW package		
				108	



PARAMETER MEASUREMENT INFORMATION

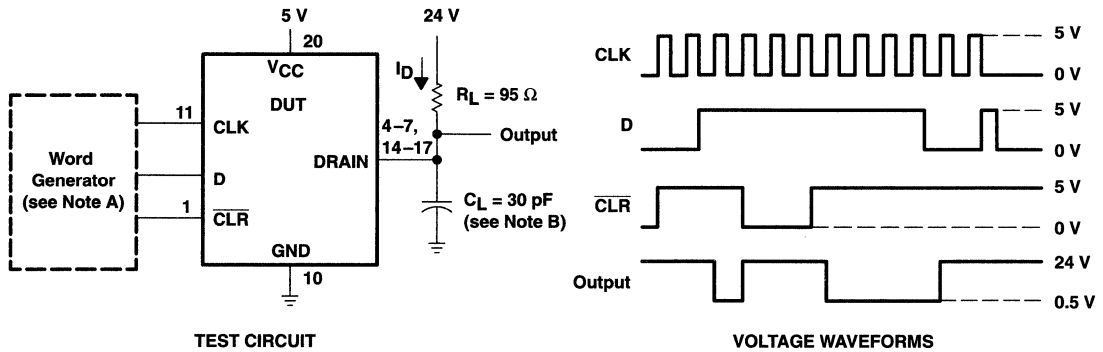


Figure 1. Resistive Load Normal Operation

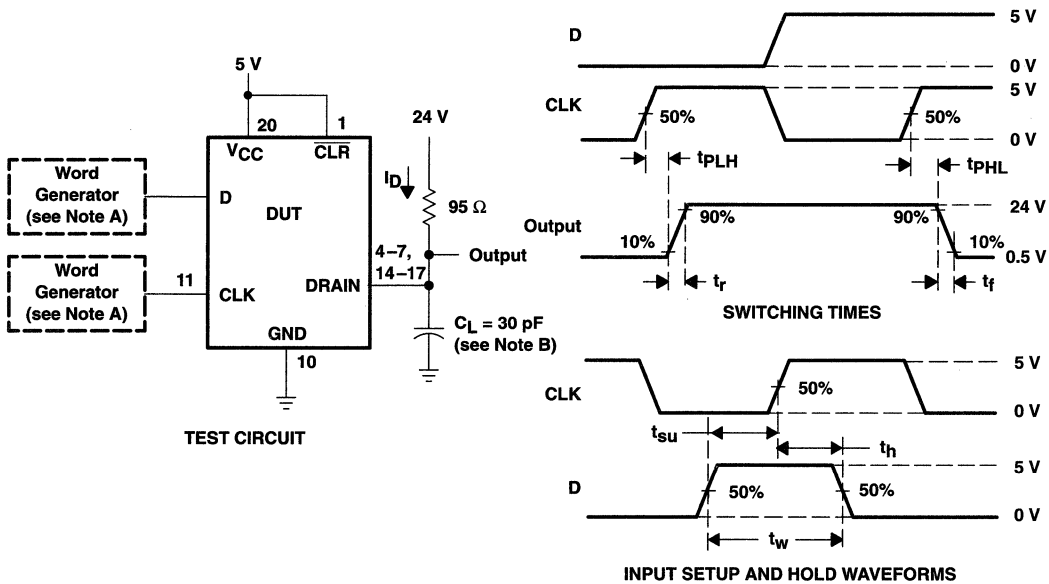


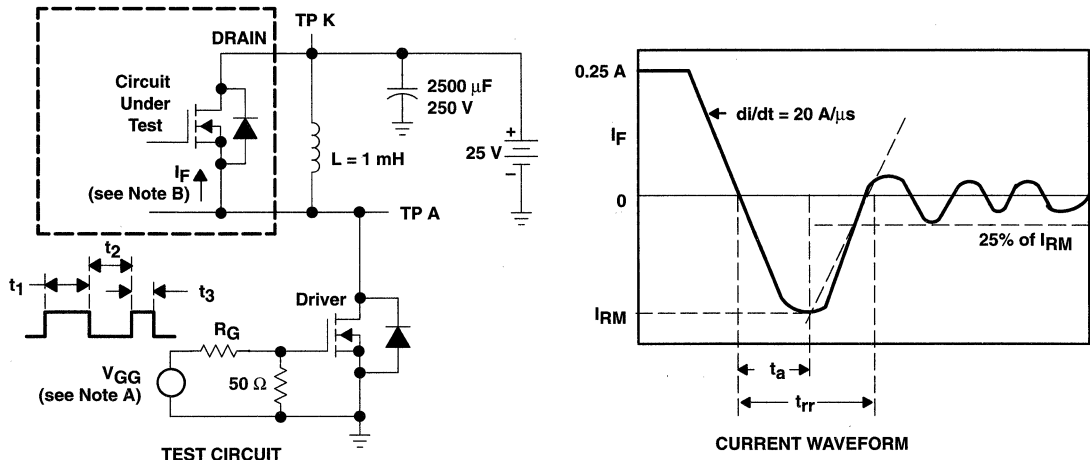
Figure 2. Test Circuit, Switching Times, and Voltage Waveforms

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 KHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

# TPIC6273 POWER LOGIC OCTAL D-TYPE LATCH

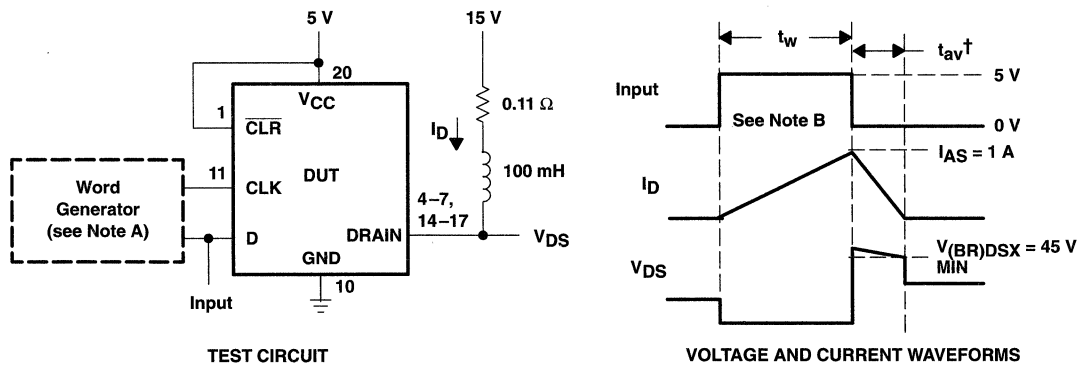
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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.25 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .  
B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-Drain Diode



† Non-JEDEC symbol for avalanche time.

- NOTES: A. The word generator A has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_0 = 50 \Omega$ .  
B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 1 \text{ A}$ .  
Energy test is defined as  $E_{AS} = I_{AS} \times V(BR)DSX \times t_{av}/2 = 75 \text{ mJ}$ , where  $t_{av}$  = avalanche time.

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

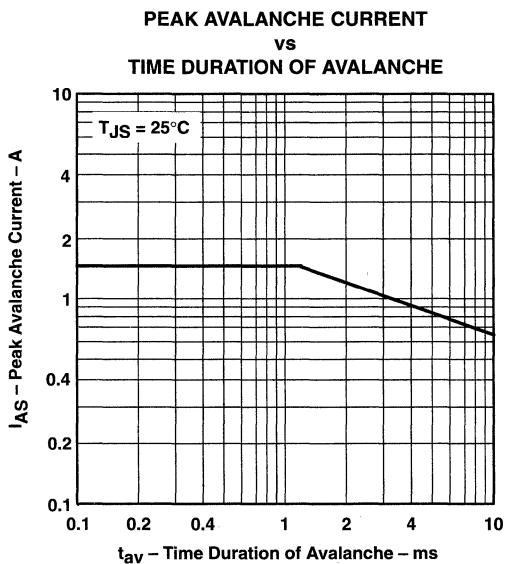


Figure 5

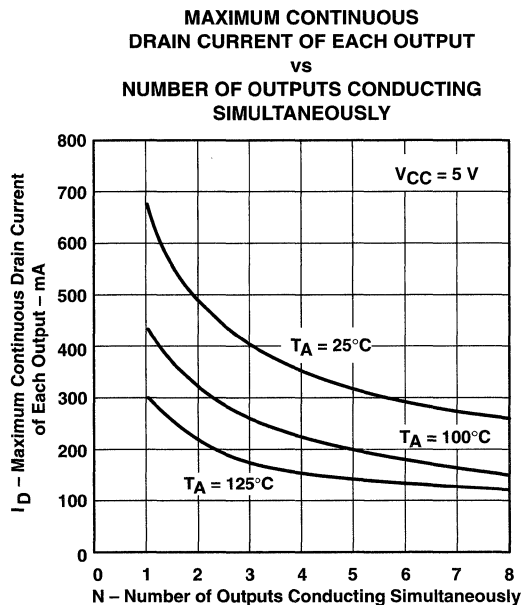


Figure 6

MAXIMUM PEAK DRAIN CURRENT  
OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

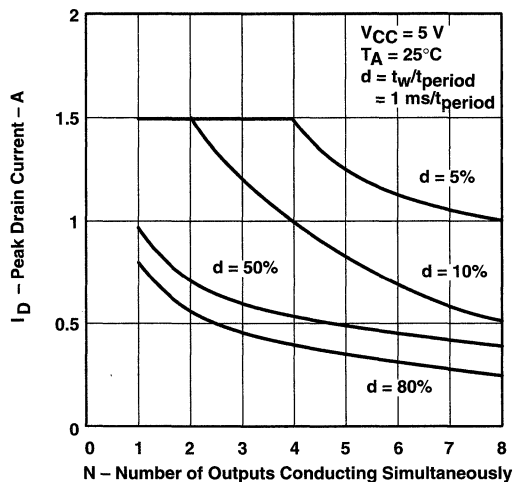
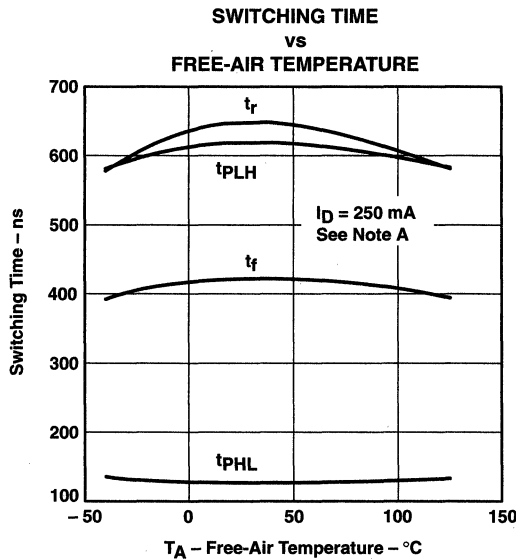
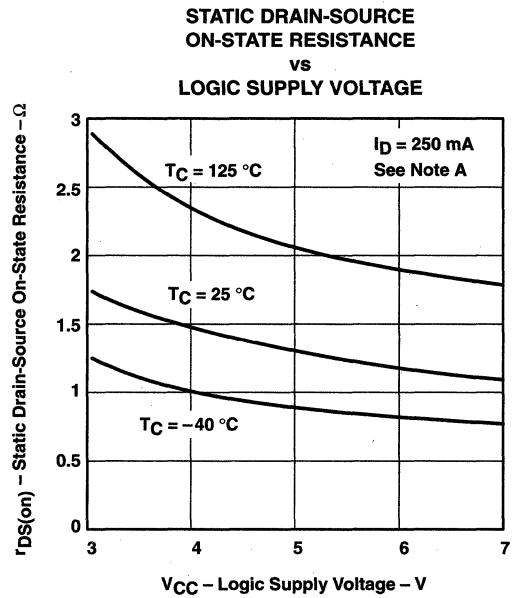
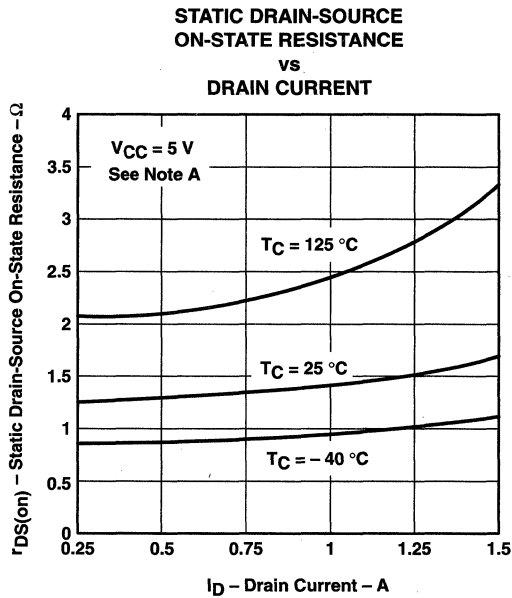


Figure 7

# TPIC6273 POWER LOGIC OCTAL D-TYPE LATCH

SLIS011A – APRIL 1992 – REVISED OCTOBER 1995

## TYPICAL CHARACTERISTICS



NOTE A: Technique should limit  $T_J - T_C$  to 10°C maximum.

# TPIC6595 POWER LOGIC 8-BIT SHIFT REGISTER

SLIS010A – APRIL 1992 – REVISED OCTOBER 1995

- Low  $r_{DS(on)}$  . . . 1.3  $\Omega$  Typical
- Avalanche Energy . . . 75 mJ
- Eight Power DMOS Transistor Outputs of 250-mA Continuous Current
- 1.5-A Pulsed Current Per Output
- Output Clamp Voltage at 45 V
- Devices Are Cascadable
- Low Power Consumption

## description

The TPIC6595 is a monolithic, high-voltage, high-current power 8-bit shift register designed for use in systems that require relatively high load power. The device contains a built-in voltage clamp on the outputs for inductive transient protection. Power driver applications include relays, solenoids, and other medium-current or high-voltage loads.

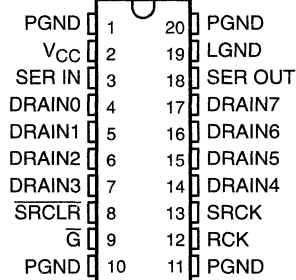
This device contains an 8-bit serial-in, parallel-out shift register that feeds an 8-bit D-type storage register. Data transfers through both the shift and storage registers on the rising edge of the shift-register clock (SRCK) and the register clock (RCK) respectively. The storage register transfers data to the output buffer when shift-register clear (SRCLR) is high. When SRCLR is low, the input shift register is cleared. When output enable ( $\bar{G}$ ) is held high, all data in the output buffers is held low and all drain outputs are off. When  $\bar{G}$  is held low, data from the storage register is transparent to the output buffers. The serial output (SER OUT) allows for cascading of the data from the shift register to additional devices.

Outputs are low-side, open-drain DMOS transistors with output ratings of 45 V and 250-mA continuous sink current capability. When data in the output buffers is low, the DMOS-transistor outputs are off. When data is high, the DMOS-transistor outputs have sink current capability.

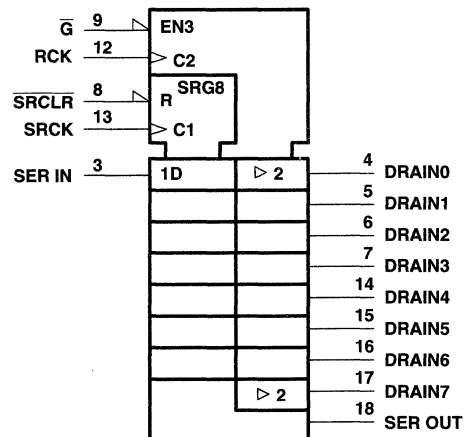
Separate power and logic level ground pins are provided to facilitate maximum system flexibility. Pins 1, 10, 11, and 20 are internally connected, and each pin must be externally connected to the power system ground in order to minimize parasitic inductance. A single-point connection between pin 19, logic ground (LGND) and pins 1, 10, 11, and 20, power ground (PGND) must be externally made in a manner that reduces crosstalk between the logic and load circuits.

The TPIC6595 is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

DW OR N PACKAGE  
(TOP VIEW)



## logic symbol†

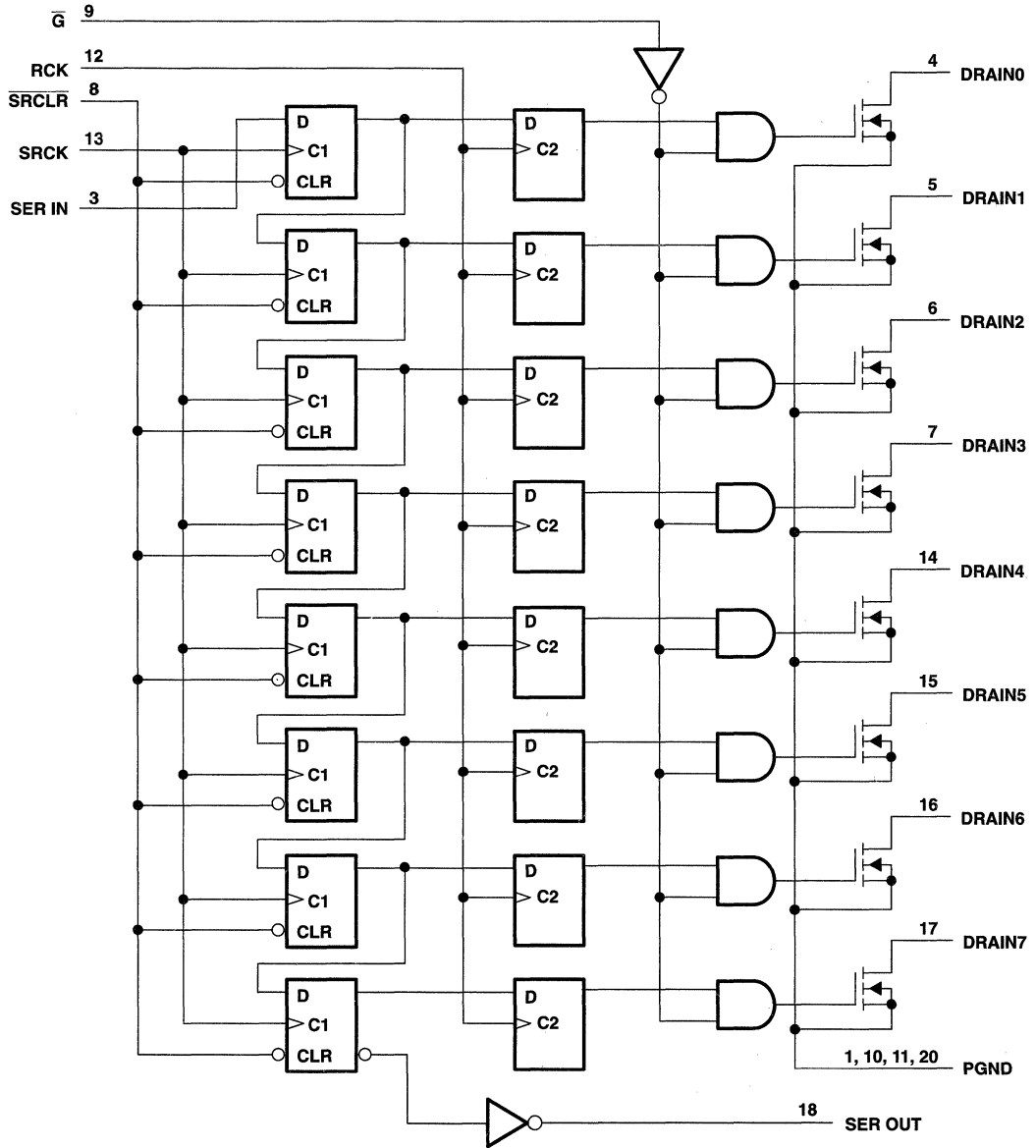


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

# TPIC6595 POWER LOGIC 8-BIT SHIFT REGISTER

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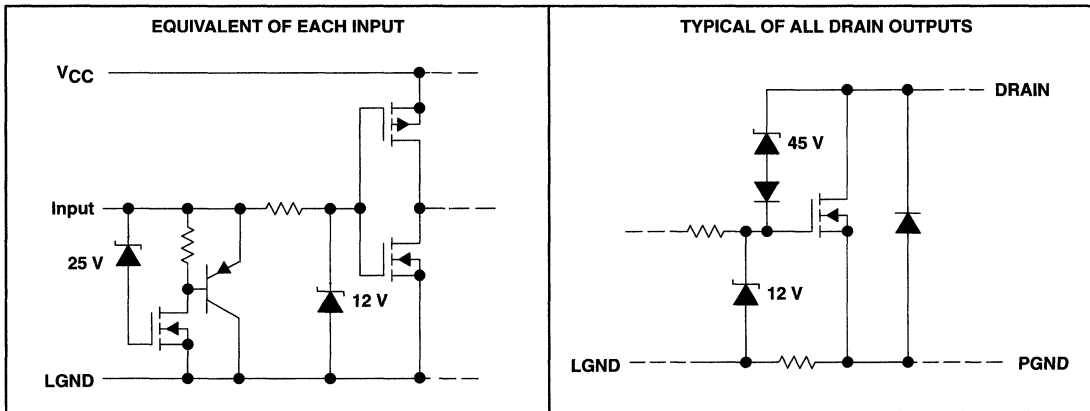
## logic diagram (positive logic)



# TPIC6595 POWER LOGIC 8-BIT SHIFT REGISTER

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## schematic of inputs and outputs



## absolute maximum ratings over recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	45 V
Continuous source-drain diode anode current	1 A
Pulsed source-drain diode anode current	2 A
Pulsed drain current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	750 mA
Continuous drain current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$	250 mA
Peak drain current single output, $I_{DM}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	2 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	75 mJ
Avalanche current, $I_{AS}$ (see Note 4)	1 A
Continuous total power dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°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 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:
- All voltage values are with respect to LGND and PGND.
  - Each power DMOS source is internally connected to PGND.
  - Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$
  - DRAIN supply voltage = 15 V, starting junction temperature,  $(T_{JS}) = 25^\circ\text{C}$ ,  $L = 100 \text{ mH}$ ,  $I_{AS} = 1 \text{ A}$  (see Figure 4).

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 125^\circ\text{C}$ POWER RATING
DW	1125 mW	9.0 mW/°C	225 mW
N	1150 mW	9.2 mW/°C	230 mW



# TPIC6595

## POWER LOGIC 8-BIT SHIFT REGISTER

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**recommended operating conditions over recommended operating temperature range (unless otherwise noted)**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$	0.15 $V_{CC}$		V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-1.8	1.5	A
Setup time, SER IN high before SRCK $\uparrow$ , $t_{SU}$ (see Figure 2)	10		ns
Hold time, SER IN high after SRCK $\uparrow$ , $t_H$ (see Figure 2)	10		ns
Pulse duration, $t_W$ (see Figure 2)	20		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$ Drain-source breakdown voltage	$I_D = 1\text{ mA}$	45			V
$V_{SD}$ Source-drain diode forward voltage	$I_F = 250\text{ mA}$ , See Note 3	0.85		1	V
$V_{OH}$ High-level output voltage, SER OUT	$I_{OH} = -20\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	4.4	4.49		V
	$I_{OH} = -4\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	4.1	4.3		
$V_{OL}$ Low-level output voltage, SER OUT	$I_{OH} = 20\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	0.002		0.1	V
	$I_{OH} = 4\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	0.2		0.4	
$h_{ys}$ Input hysteresis	$V_{DS} = 15\text{ V}$	1.3			V
$I_{IH}$ High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$				1
$I_{IL}$ Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$				-1
$I_{CCL}$ Logic supply current	$I_O = 0$ , All inputs low	15		100	$\mu\text{A}$
$I_{CC}(\text{FRQ})$ Logic supply current frequency	$f_{SRCK} = 5\text{ MHz}$ , $I_O = 0$ , $C_L = 30\text{ pF}$ , See Figure 1, Figure 2, and Figure 6	0.6		5	mA
$I_N$ Nominal current	$V_{DS}(\text{on}) = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$	See Notes 5, 6, and 7		250	mA
$I_{DSX}$ Off-state drain current	$V_{DS} = 40\text{ V}$	0.05		1	$\mu\text{A}$
	$V_{DS} = 40\text{ V}$ , $T_C = 125^\circ\text{C}$	0.15		5	
$r_{DS}(\text{on})$ Static drain-source on-state resistance	$I_D = 250\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	1.3		2	$\Omega$
	$I_D = 250\text{ mA}$ , $T_C = 125^\circ\text{C}$ , $V_{CC} = 4.5\text{ V}$	2		3.2	
	$I_D = 500\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	1.3		2	

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output from $\bar{G}$	$C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ , See Figure 1 and Figure 2	650			ns
$t_{PHL}$ Propagation delay time, high-to-low-level output from $\bar{G}$		150			ns
$t_r$ Rise time, drain output		750			ns
$t_f$ Fall time, drain output		425			ns
$t_a$ Reverse-recovery-current rise time	$I_F = 250\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3	100			ns
$t_{TR}$ Reverse-recovery time		300			

- NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$ , duty cycle  $\leq 2\%$   
 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.  
 7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .



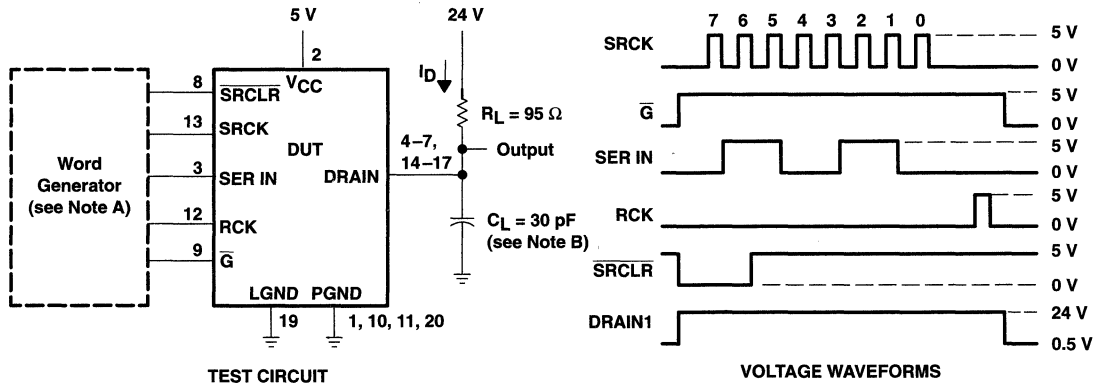
**TPIC6595**  
**POWER LOGIC 8-BIT SHIFT REGISTER**

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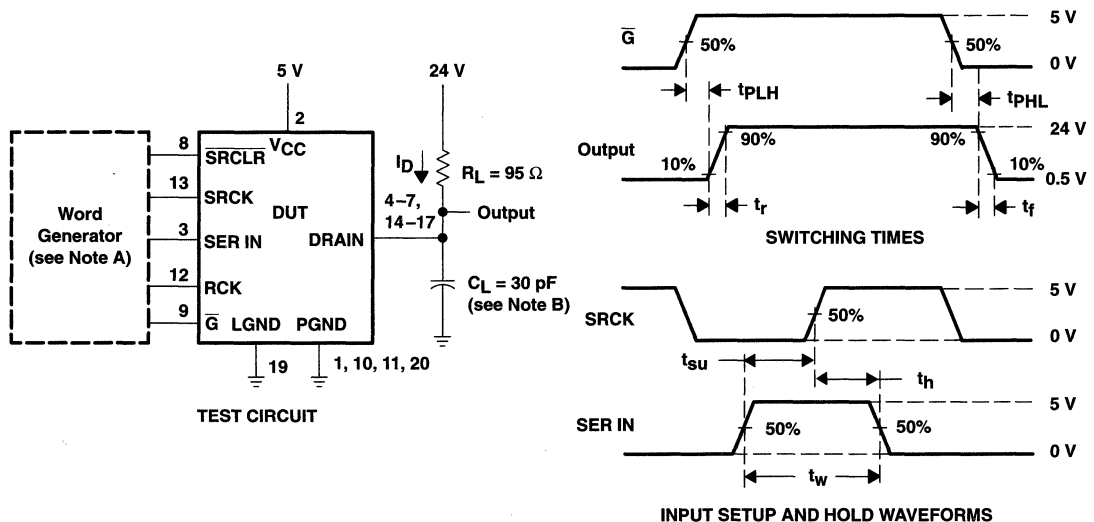
**thermal resistance**

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
R <sub>θJA</sub>	Thermal resistance, junction-to-ambient	DW package		111	°C/W
		N package	All 8 outputs with equal power	108	

**PARAMETER MEASUREMENT INFORMATION**



**Figure 1. Resistive Load Operation**



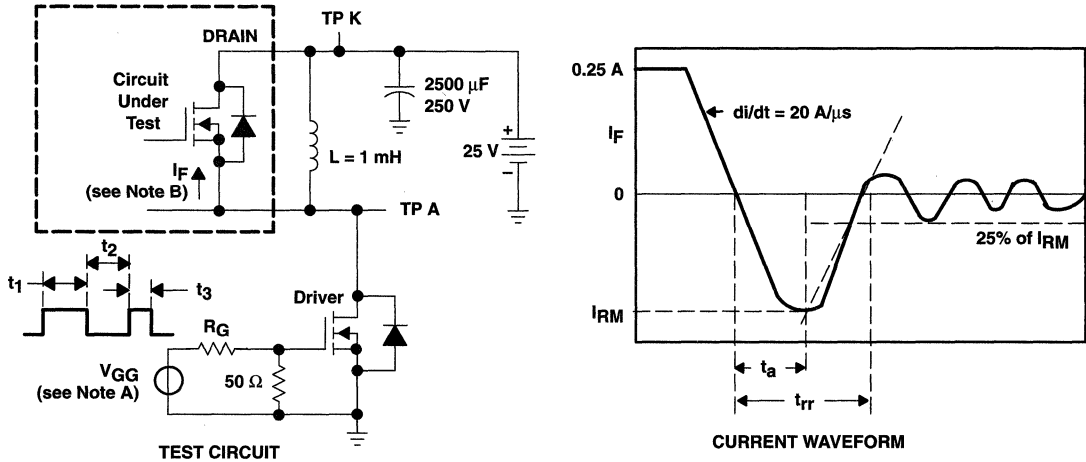
**Figure 2. Test Circuit, Switching Times, and Voltage Waveforms**

NOTES: A. Outputs DRAIN 1, 2, 5, and 6 low (PGND), all other DRAIN outputs are at 24 V. The word generator has the following characteristics:  $t_r \leq 10\ \text{ns}$ ,  $t_f \leq 10\ \text{ns}$ ,  $t_w = 300\ \text{ns}$ , pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50\ \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

# TPIC6595 POWER LOGIC 8-BIT SHIFT REGISTER

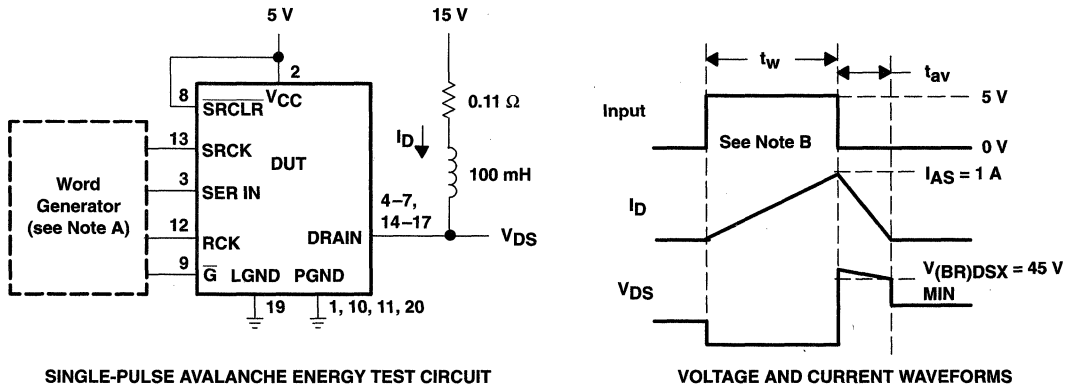
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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.25 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-Drain Diode



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 1 \text{ A}$ .  
 Energy test level is defined as  $E_{AS} = I_{AS} \times V_{(BR)DSX} \times t_{av}/2 = 75 \text{ mJ}$ , where  $t_{av}$  = avalanche time.

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

PEAK AVALANCHE CURRENT  
vs  
TIME DURATION OF AVALANCHE

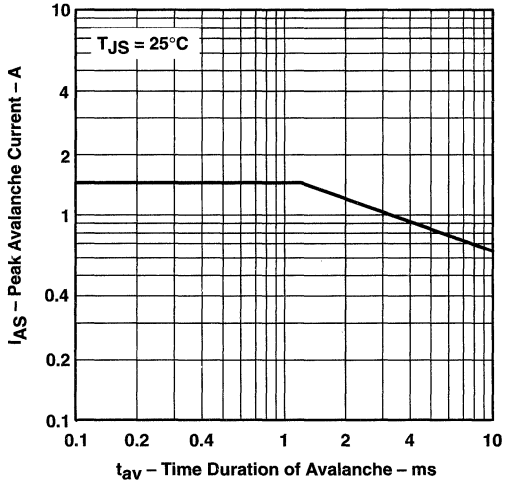


Figure 5

SUPPLY CURRENT  
vs  
FREQUENCY

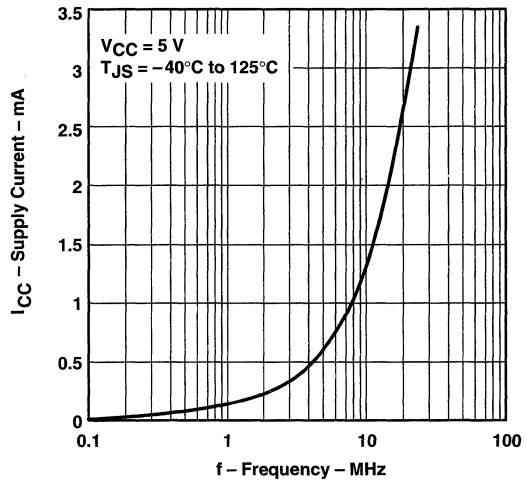


Figure 6

MAXIMUM CONTINUOUS  
DRAIN CURRENT OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

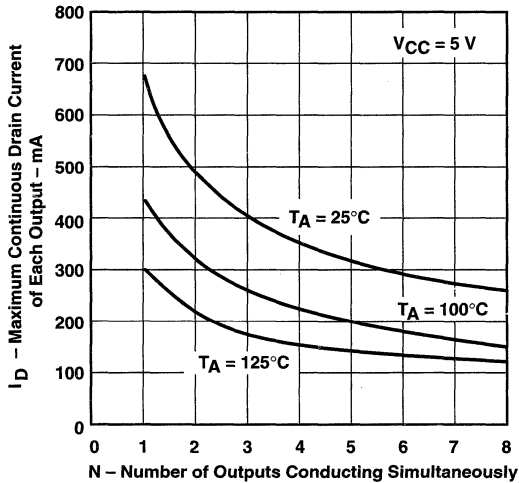


Figure 7

MAXIMUM PEAK DRAIN CURRENT  
OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

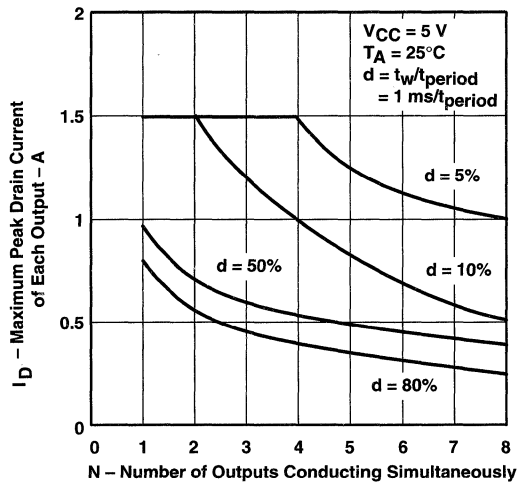
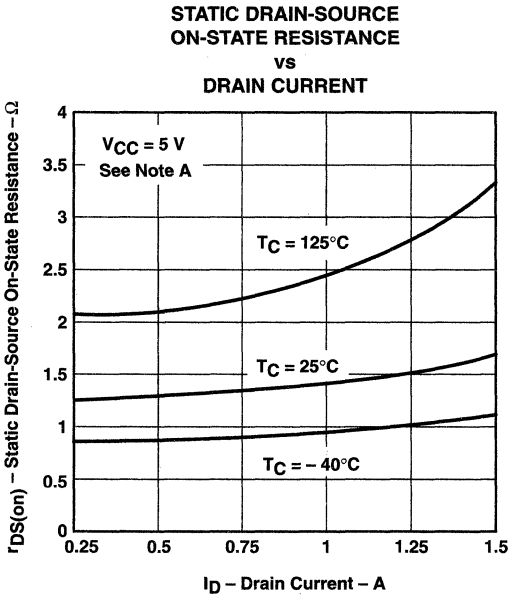


Figure 8

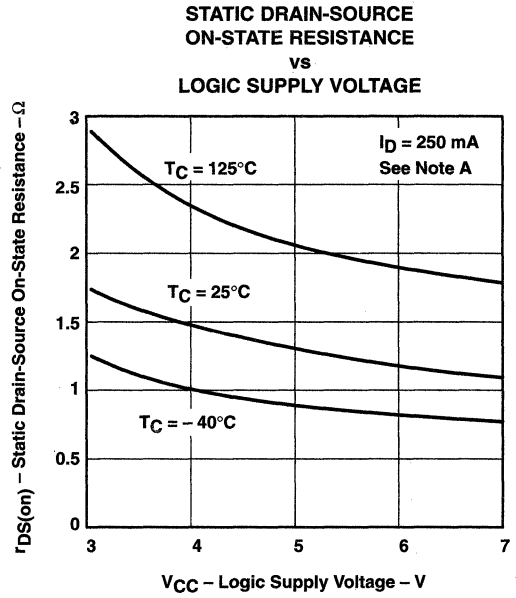
**TPIC6595**  
**POWER LOGIC 8-BIT SHIFT REGISTER**

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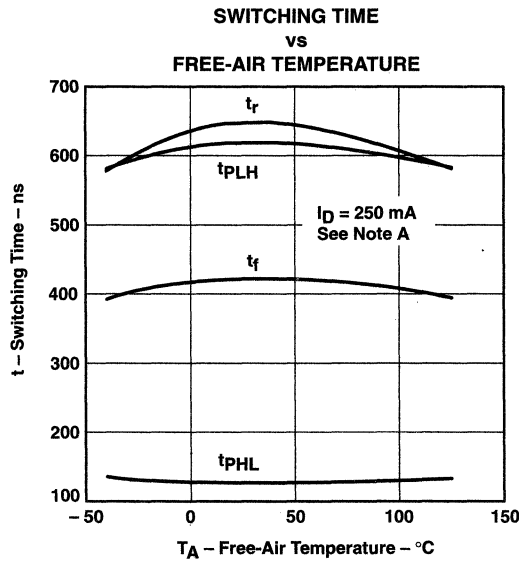
**TYPICAL CHARACTERISTICS**



**Figure 9**



**Figure 10**



**Figure 11**

NOTE A: Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.



# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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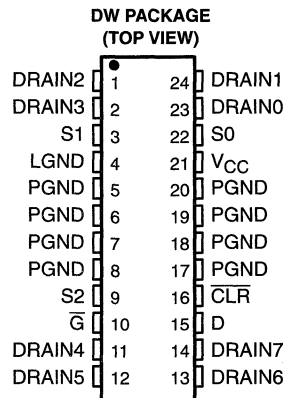
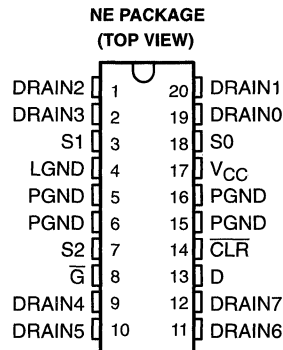
- Low  $r_{DS(on)}$  . . . 1  $\Omega$  Typ
- Output Short-Circuit Protection
- Avalanche Energy . . . 75 mJ
- Eight 350-mA DMOS Outputs
- 50-V Switching Capability
- Four Distinct Function Modes
- Low Power Consumption

## description

This power logic 8-bit addressable latch controls open-drain DMOS-transistor outputs and is designed for general-purpose storage applications in digital systems. Specific uses include working registers, serial-holding registers, and decoders or demultiplexers. This is a multi-functional device capable of operating as eight addressable latches or an 8-line demultiplexer with active-low DMOS outputs. Each open-drain DMOS transistor features an independent chopping current-limiting circuit to prevent damage in the case of a short circuit.

Four distinct modes of operation are selectable by controlling the clear (CLR) and enable ( $\bar{G}$ ) inputs as enumerated in the function table. In the addressable-latch mode, data at the data-in (D) terminal is written into the addressed latch. The addressed DMOS-transistor output inverts the data input with all unaddressed DMOS-transistor outputs remaining in their previous states. In the memory mode, all DMOS-transistor outputs remain in their previous states and are unaffected by the data or address inputs. To eliminate the possibility of entering erroneous data in the latch, enable  $\bar{G}$  should be held high (inactive) while the address lines are changing. In the 8-line demultiplexing mode, the addressed output is inverted with respect to the D input and all other outputs are high. In the clear mode, all outputs are high and unaffected by the address and data inputs.

Separate power ground (PGND) and logic ground (LGND) terminals are provided to facilitate maximum system flexibility. All PGND terminals are internally connected, and each PGND terminal must be externally connected to the power system ground in order to minimize parasitic impedance. A single-point connection between LGND and PGND must be made externally in a manner that reduces crosstalk between the logic and load circuits.



**FUNCTION TABLE**

INPUTS			OUTPUT OF ADDRESSED DRAIN	EACH OTHER DRAIN	FUNCTION
CLR	$\bar{G}$	D			
H	L	H	L	$Q_{i0}$	Addressable Latch
H	L	L	H	$Q_{i0}$	
H	H	X	$Q_{i0}$	$Q_{i0}$	Memory
L	L	H	L	H	8-Line Demultiplexer
L	L	L	H	H	
L	H	X	H	H	Clear

**LATCH SELECTION TABLE**

SELECT INPUTS			DRAIN ADDRESSED
S2	S1	S0	
L	L	L	0
L	L	H	1
L	H	L	2
L	H	H	3
H	L	L	4
H	L	H	5
H	H	L	6
H	H	H	7

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



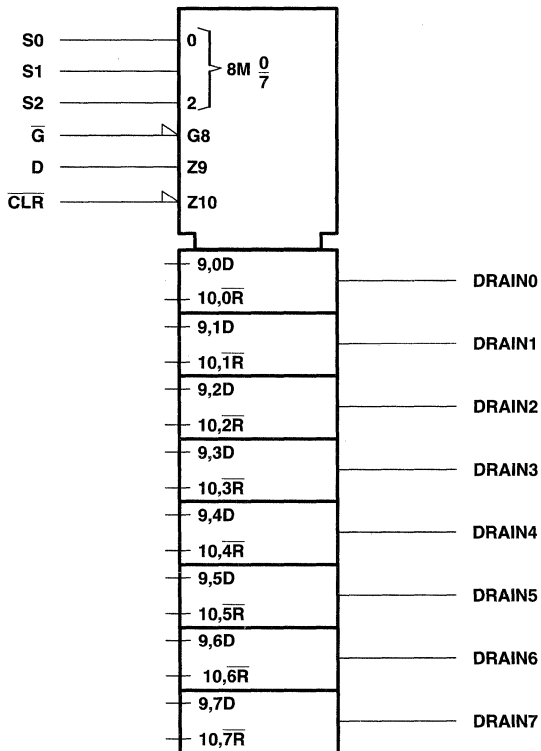
# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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## description (continued)

The TPIC6A259 is offered in a thermally-enhanced dual-in-line (NE) package and a wide-body, surface-mount (DW) package. The TPIC6A259 is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

## logic symbol†

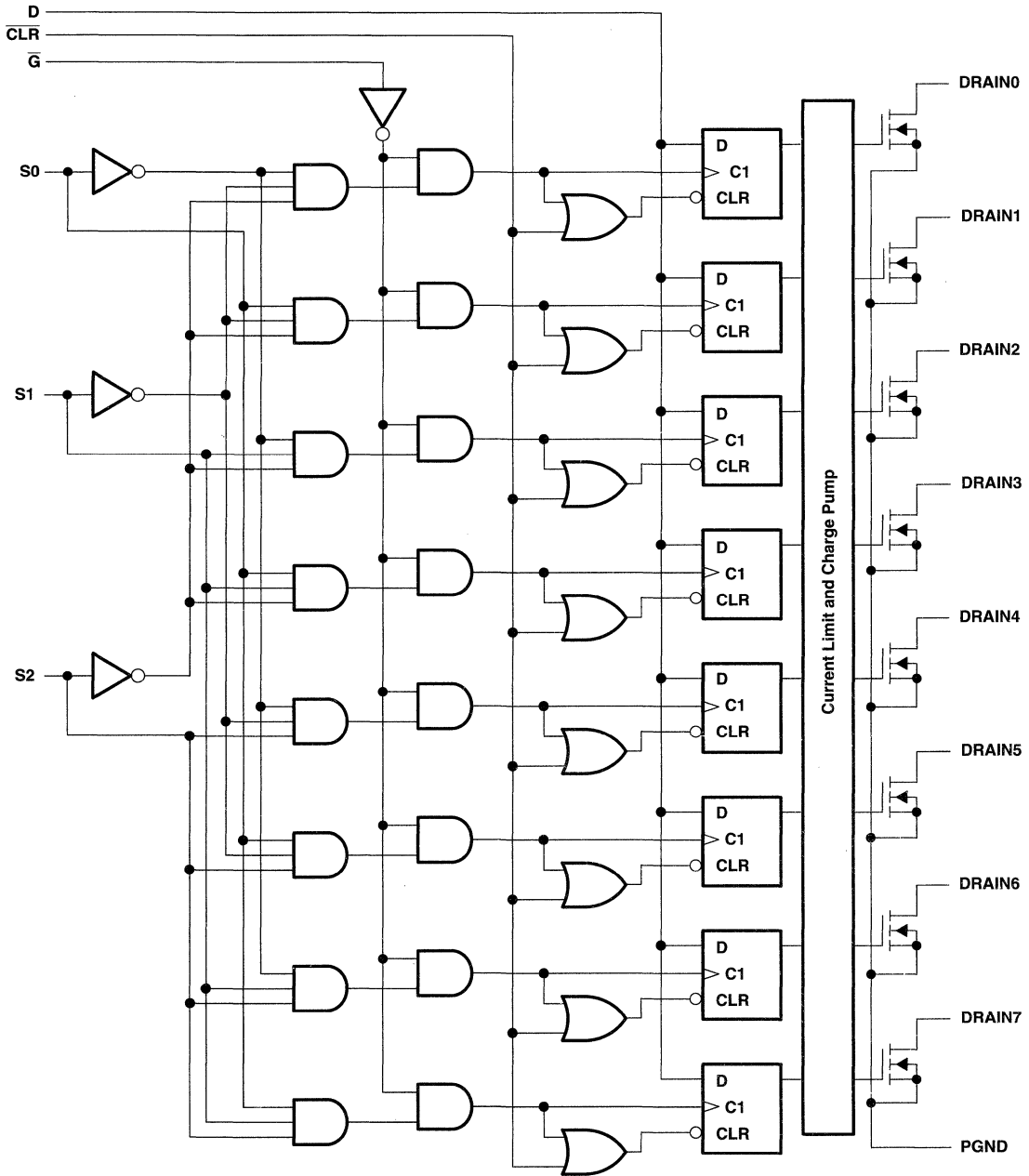


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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logic diagram (positive logic)

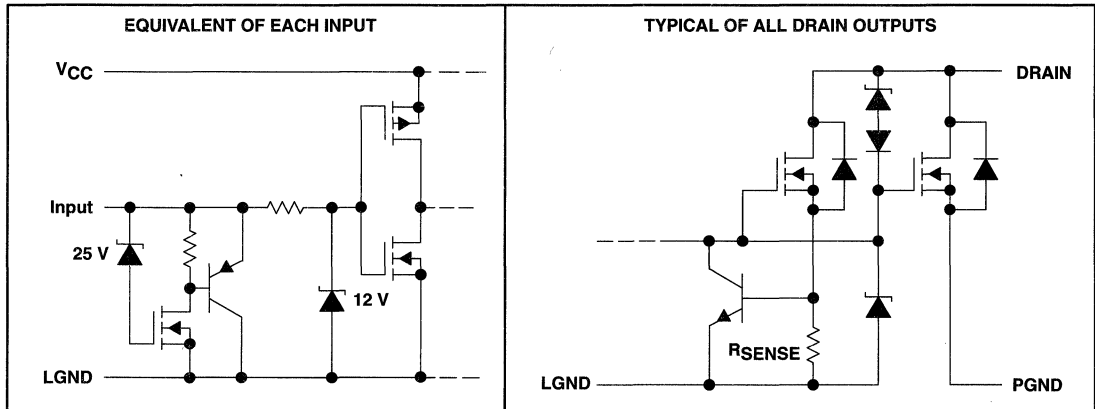




# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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## schematic of inputs and outputs



## absolute maximum ratings over the recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	50 V
Continuous source-to-drain diode anode current	1 A
Pulsed source-to-drain diode anode current (see Note 3)	2 A
Pulsed drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$ (see Note 3)	1.1 A
Continuous drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$	350 mA
Peak drain current single output, $T_C = 25^\circ\text{C}$ (see Note 3)	1.1 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 6)	75 mJ
Avalanche current, $I_{AS}$ (see Note 4)	600 mA
Continuous total dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°C to 150°C
Operating case temperature range, $T_C$	-40°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 are with respect to LGND and PGND.  
 2. Each power DMOS source is internally connected to PGND.  
 3. Pulse duration  $\leq 100 \mu\text{s}$ , and duty cycle  $\leq 2\%$ .  
 4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C, L = 210 mH, and  $I_{AS}$  = 600 mA (see Figure 6).

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1750 mW	14 mW/°C	350 mW
NE	2500 mW	20 mW/°C	500 mW

# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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## recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	$0.85 V_{CC}$	$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	$0.15 V_{CC}$	V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-1.8	0.6	A
Setup time, D high before $\overline{G}\uparrow$ , $t_{SU}$ (see Figure 2)	10		ns
Hold time, D high before $\overline{G}\uparrow$ , $t_H$ (see Figure 2)	5		ns
Pulse duration, $t_W$ (see Figure 2)	15		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$ Drain-to-source breakdown voltage	$I_D = 1\text{ mA}$	50			V
$V_{SD}$ Source-to-drain diode forward voltage	$I_F = 350\text{ mA}$ , See Note 3		0.8	1.1	V
$I_{IH}$ High-level input current	$V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$ Logic supply current	$I_O = 0$ , $V_I = V_{CC}$ or 0		0.5	5	mA
$I_{OK}$ Output current at which chopping starts	$T_C = 25^\circ\text{C}$ , See Note 5 and Figures 3 and 4	0.6	0.8	1.1	A
$I_{(nom)}$ Nominal current	$V_{DS(on)} = 0.5\text{ V}$ , $I_{(nom)} = I_D$ , $T_C = 85^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ , See Notes 5, 6, and 7		350		mA
$I_D$ Off-state drain current	$V_{DS} = 40\text{ V}$ , $T_C = 25^\circ\text{C}$		0.1	1	$\mu\text{A}$
	$V_{DS} = 40\text{ V}$ , $T_C = 125^\circ\text{C}$		0.2	5	
$r_{DS(on)}$ Static drain-to-source on-state resistance	$I_D = 350\text{ mA}$ , $T_C = 25^\circ\text{C}$	See Notes 5 and 6 and Figures 9 and 10	1	1.5	$\Omega$
	$I_D = 350\text{ mA}$ , $T_C = 125^\circ\text{C}$		1.7	2.5	

## switching characteristics, $V_{CC} = 5\text{ V}$ , $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PHL}$ Propagation delay time, high- to low-level output from D	$C_L = 30\text{ pF}$ , $I_D = 350\text{ mA}$ , See Figures 1, 2, and 11		30		ns
$t_{PLH}$ Propagation delay time, low- to high-level output from D			125		ns
$t_r$ Rise time, drain output			60		ns
$t_f$ Fall time, drain output			30		ns
$t_a$ Reverse-recovery-current rise time		$I_F = 350\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 5		100	
$t_{rr}$ Reverse-recovery time			300		ns

- NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$  and duty cycle  $\leq 2\%$ .  
 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.  
 7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .

## thermal resistance

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JC}$ Thermal resistance, junction-to-case	DW		10	$^\circ\text{C}/\text{W}$
	NE	All eight outputs with equal power	10	
$R_{\theta JA}$ Thermal resistance, junction-to-ambient	DW		50	$^\circ\text{C}/\text{W}$
	NE	All eight outputs with equal power	50	



# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

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## PARAMETER MEASUREMENT INFORMATION

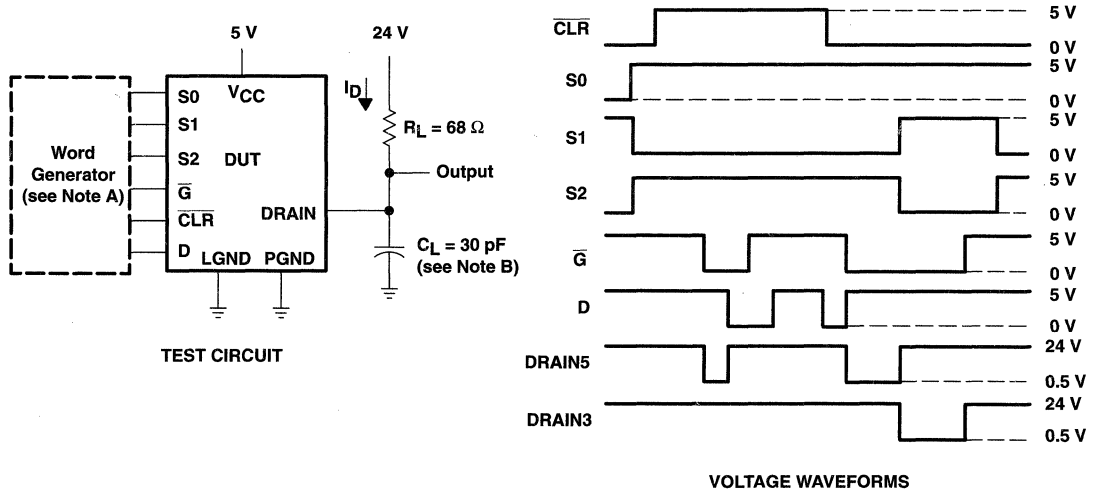


Figure 1. Typical Operation Mode

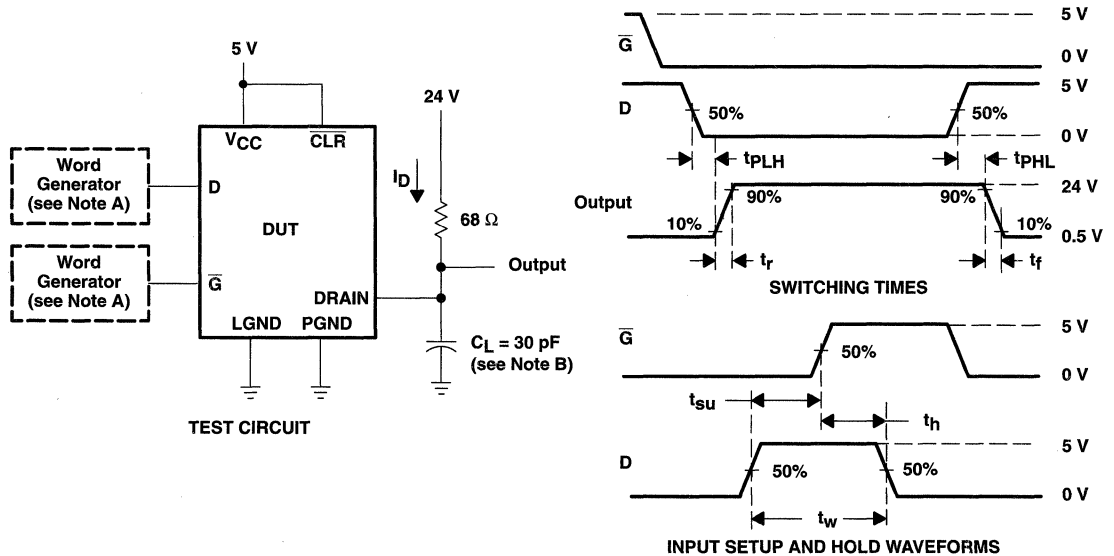
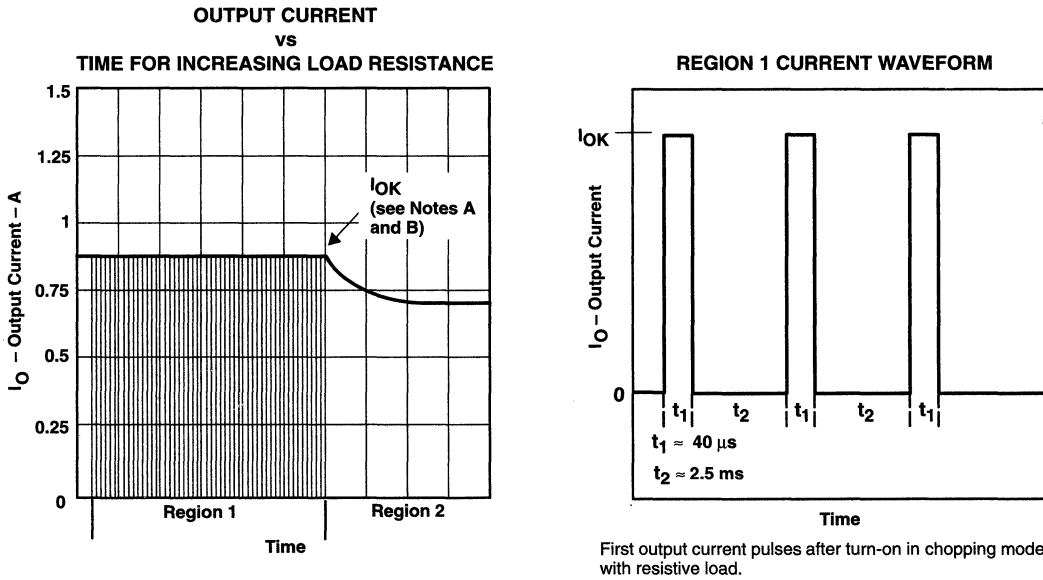


Figure 2. Test Circuit, Switching Times, and Voltage Waveforms

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. Figure 3 illustrates the output current characteristics of the device energizing a load having initially low, increasing resistance, e.g., an incandescent lamp. In region 1, chopping occurs and the peak current is limited to  $I_{OK}$ . In region 2, output current is continuous. The same characteristics occur in reverse order when the device energizes a load having an initially high, decreasing resistance.
- B. Region 1 duty cycle is approximately 2%.

Figure 3. Chopping-Mode Characteristics

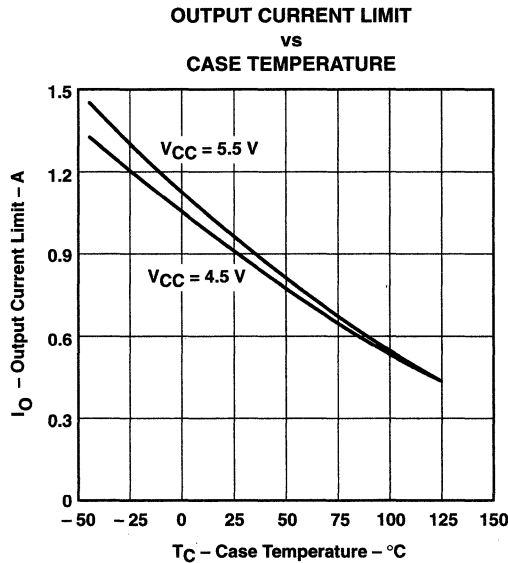
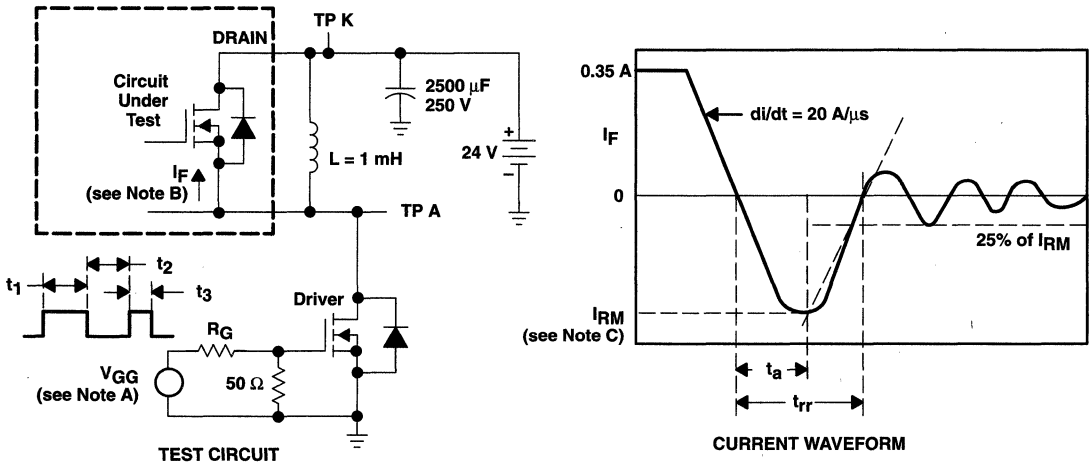


Figure 4

# TPIC6A259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

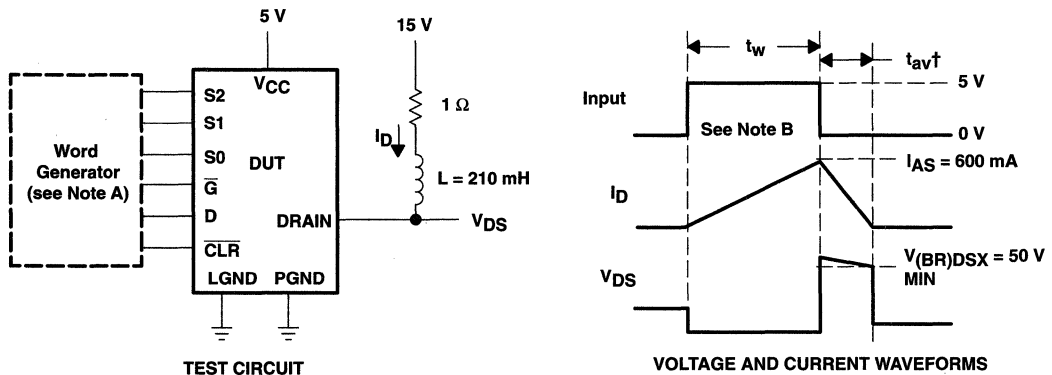
SLIS004B – APRIL 1993 – REVISED SEPTEMBER 1995

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.35 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.  
 C.  $I_{RM}$  = maximum recovery current

Figure 5. Reverse-Recovery-Current Test Circuit and Waveforms of Source-Drain Diode



† Non-JEDEC symbol for avalanche time.

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 600 \text{ mA}$ .  
 Energy test level is defined as  $E_{AS} = (I_{AS} \times V_{(BR)DSX} \times t_{avt})/2 = 75 \text{ mJ}$ .

Figure 6. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

MAXIMUM CONTINUOUS  
DRAIN CURRENT OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

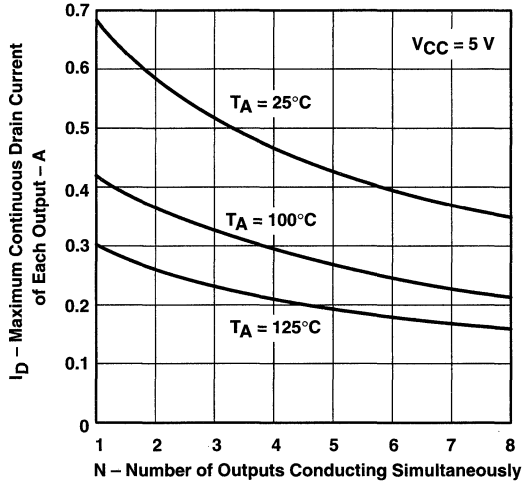


Figure 7

MAXIMUM PEAK DRAIN CURRENT  
OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

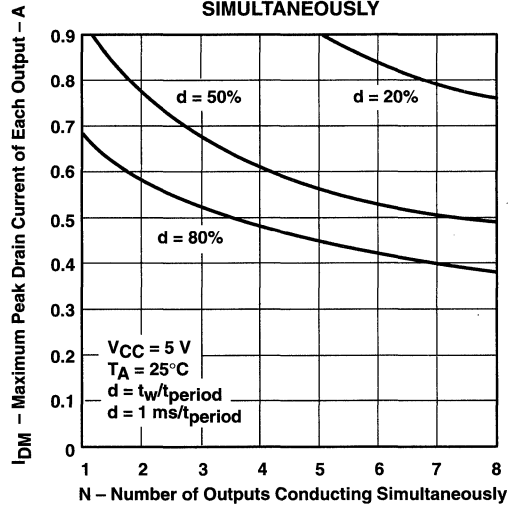


Figure 8

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
DRAIN CURRENT

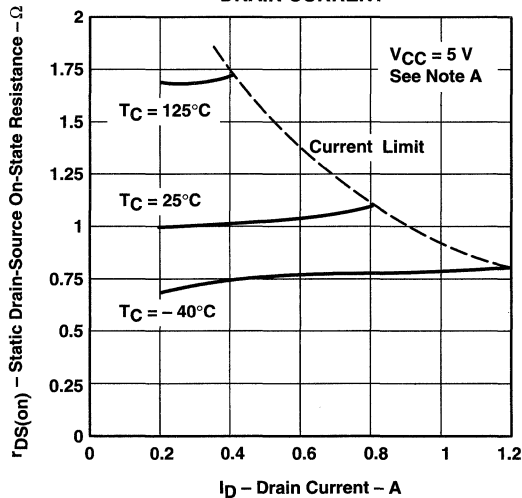


Figure 9

STATIC DRAIN-SOURCE  
ON-STATE RESISTANCE  
vs  
LOGIC SUPPLY VOLTAGE

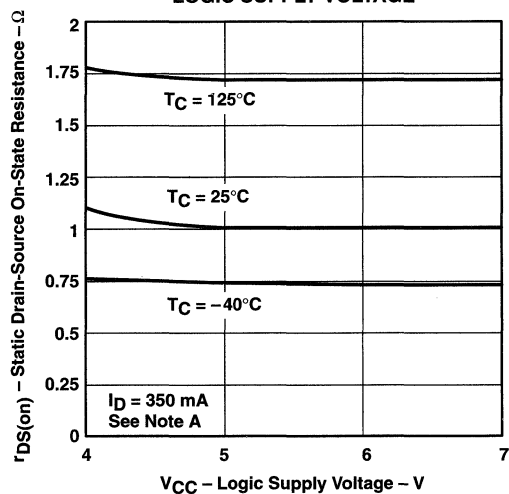


Figure 10

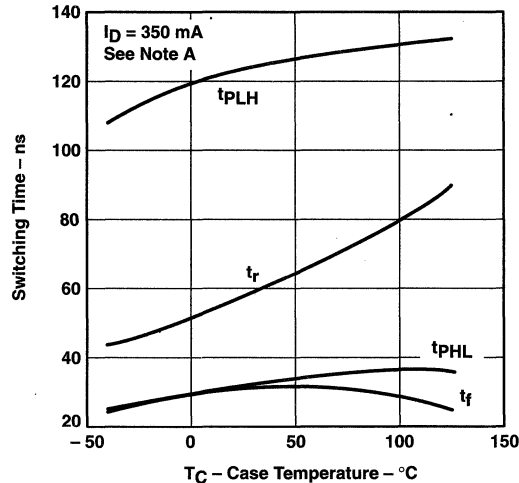
NOTE A: Technique should limit  $T_J - T_C$  to 10°C maximum.

**TPIC6A259**  
**POWER LOGIC 8-BIT ADDRESSABLE LATCH**

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**TYPICAL CHARACTERISTICS**

**SWITCHING TIME**  
**vs**  
**CASE TEMPERATURE**

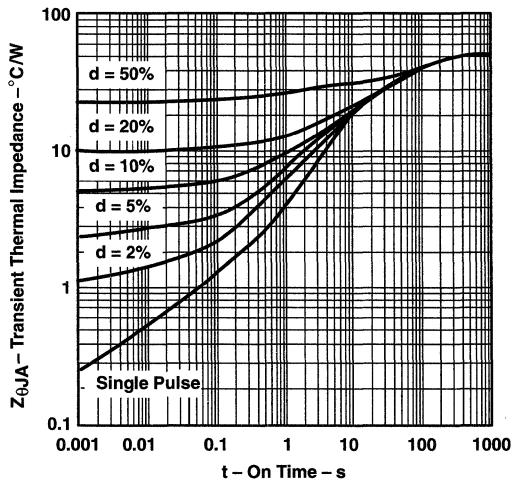


NOTE A: Technique should limit  $T_J - T_C$  to 10°C maximum.

**Figure 11**

**THERMAL INFORMATION**

**NE PACKAGE**  
**TRANSIENT THERMAL IMPEDANCE**  
**vs**  
**ON TIME**



The single-pulse curve represents measured data. The curves for various pulse durations are based on the following equation:

$$Z_{\theta JA} = \left| \frac{t_w}{t_c} \right| R_{\theta JA} + \left| 1 - \frac{t_w}{t_c} \right| Z_{\theta}(t_w + t_c) + Z_{\theta}(t_w) - Z_{\theta}(t_c)$$

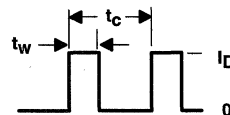
Where:

$Z_{\theta}(t_w)$  = the single-pulse thermal impedance for  $t = t_w$  seconds

$Z_{\theta}(t_c)$  = the single-pulse thermal impedance for  $t = t_c$  seconds

$Z_{\theta}(t_w + t_c)$  = the single-pulse thermal impedance for  $t = t_w + t_c$  seconds

$$d = t_w/t_c$$



**Figure 12**

# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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- Low  $r_{DS(on)}$  . . . 1  $\Omega$  Typ
- Output Short-Circuit Protection
- Avalanche Energy . . . 75 mJ
- Eight 350-mA DMOS Outputs
- 50-V Switching Capability
- Devices Are Cascadable
- Low Power Consumption

## description

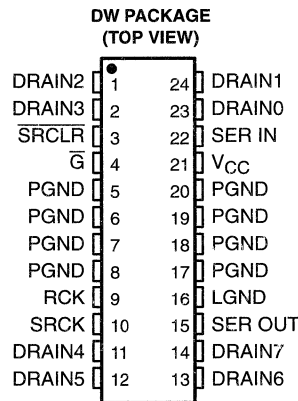
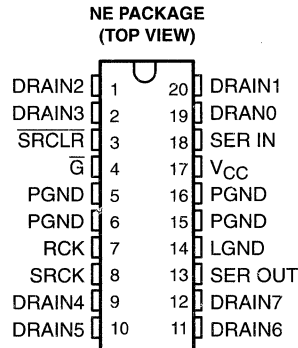
The TPIC6A595 is a monolithic, high-voltage, high-current power logic 8-bit shift register designed for use in systems that require relatively high load power. The device contains a built-in voltage clamp on the outputs for inductive transient protection. Power driver applications include relays, solenoids, and other medium-current or high-voltage loads. Each open-drain DMOS transistor features an independent chopping current-limiting circuit to prevent damage in the case of a short circuit.

This device contains an 8-bit serial-in, parallel-out shift register that feeds an 8-bit, D-type storage register. Data transfers through both the shift and storage registers on the rising edge of the shift-register clock (SRCK) and the register clock (RCK), respectively. The storage register transfers data to the output buffer when shift-register clear (SRCLR) is high. When SRCLR is low, the input shift register is cleared. When output enable ( $\bar{G}$ ) is held high, all data in the output buffers is held low and all drain outputs are off. When  $\bar{G}$  is held low, data from the storage register is transparent to the output buffers. The serial output (SER OUT) allows for cascading of the data from the shift register to additional devices.

Outputs are low-side, open-drain DMOS transistors with output ratings of 50 V and a 350-mA continuous sink current capability. When data in the output buffers is low, the DMOS-transistor outputs are off. When data is high, the DMOS-transistor outputs have sink current capability.

Separate power ground (PGND) and logic ground (LGND) terminals are provided to facilitate maximum system flexibility. All PGND terminals are internally connected, and each PGND terminal must be externally connected to the power system ground in order to minimize parasitic impedance. A single-point connection between LGND and PGND must be made externally in a manner that reduces crosstalk between the logic and load circuits.

The TPIC6A595 is offered in a thermally-enhanced dual-in-line (NE) package and a wide-body surface-mount (DW) package. The TPIC6A595 is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

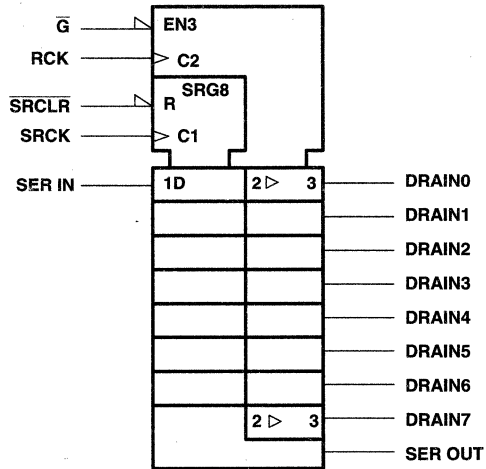




# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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logic symbol†

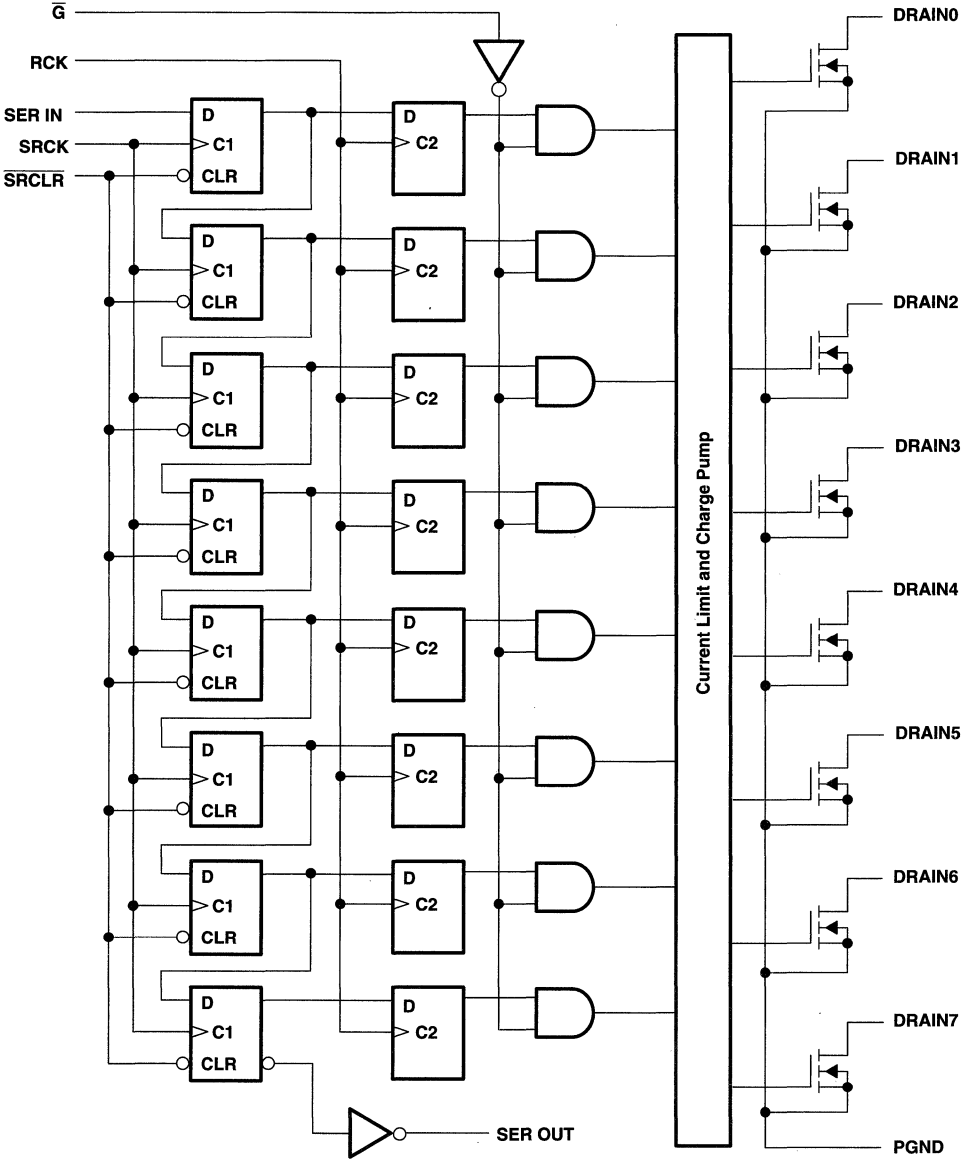


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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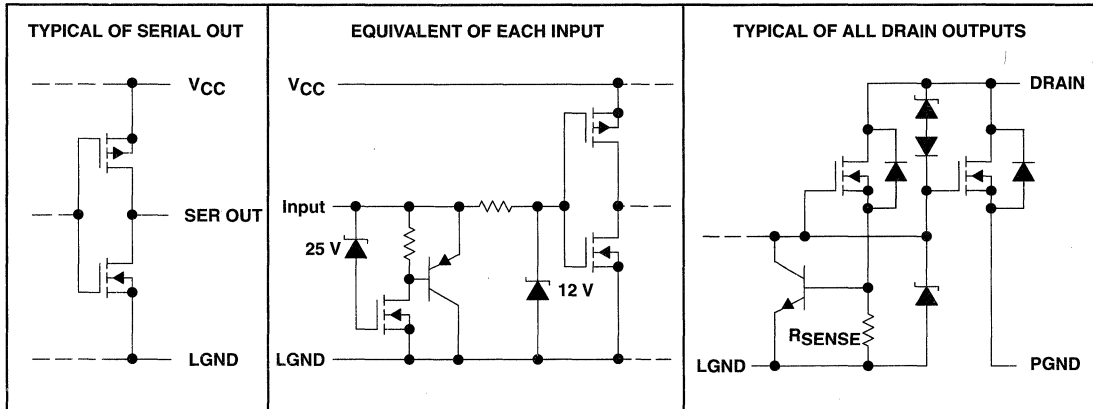
logic diagram (positive logic)



# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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## schematic of inputs and outputs



## absolute maximum ratings over recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	50 V
Continuous source-drain diode anode current	1 A
Pulsed source-drain diode anode current (see Note 3)	2 A
Pulsed drain current, each output, all outputs on, $I_{DN}$ , $T_A = 25^\circ\text{C}$ (see Note 3)	1.1 A
Continuous drain current, each output, all outputs on, $I_{DN}$ , $T_A = 25^\circ\text{C}$	350 mA
Peak drain current, single output, $T_A = 25^\circ\text{C}$ (see Note 3)	1.1 A
Single-pulse avalanche energy, $E_{AS}$ (see Figure 6)	75 mJ
Avalanche current, $I_{AS}$ (see Note 4)	600 mA
Continuous total dissipation	See Dissipation Rating Table
Operating case temperature range, $T_C$	-40°C to 125°C
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to LGND and PGND.
  2. Each power DMOS source is internally connected to PGND.
  3. Pulse duration  $\leq 100 \mu\text{s}$  and duty cycle  $\leq 2\%$ .
  4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C,  $L = 210 \text{ mH}$ ,  $I_{AS} = 600 \text{ mA}$  (see Figure 6).

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1750 mW	14 mW/°C	350 mW
NE	2500 mW	20 mW/°C	500 mW

# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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## recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	$0.85 V_{CC}$	$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	$0.15 V_{CC}$	V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-1.8	0.6	A
Setup time, SER IN high before SRCK $\uparrow$ , $t_{SU}$ (see Figure 2)	10		ns
Hold time, SER IN high after SRCK $\uparrow$ , $t_H$ (see Figure 2)	10		ns
Pulse duration, $t_W$ (see Figure 2)	20		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-to-source breakdown voltage $I_D = 1\text{ mA}$	50			V
$V_{SD}$	Source-to-drain diode forward voltage $I_F = 350\text{ mA}$ , See Note 3		0.8	1.1	V
$V_{OH}$	High-level output voltage, SER OUT $I_{OH} = -20\text{ }\mu\text{A}$ $I_{OH} = -4\text{ mA}$	$V_{CC}-0.1$ $V_{CC}-0.5$	$V_{CC}$		V
$V_{OL}$	Low-level output voltage, SER OUT $I_{OL} = 20\text{ }\mu\text{A}$ $I_{OL} = 4\text{ mA}$		0 0.2	0.1 0.5	V
$I_{IH}$	High-level input current $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$	Low-level input current $V_I = 0$			-1	$\mu\text{A}$
$I_{O(chop)}$	Output current at which chopping starts $T_C = 25^\circ\text{C}$ , See Note 5 and Figures 3 and 4	0.6	0.8	1.1	A
$I_{CC}$	Logic supply current $I_O = 0$ , $V_I = V_{CC}$ or 0		0.5	5	mA
$I_{CC(FRQ)}$	Logic supply current at frequency $f_{SRCK} = 5\text{ MHz}$ , $I_O = 0$ , $C_L = 30\text{ pF}$ , $V_I = V_{CC}$ or 0, $V_{CC} = 5\text{ V}$ , See Figure 7		1.3		mA
$I_{(nom)}$	Nominal current $V_{DS(on)} = 0.5\text{ V}$ , $V_{CC} = 5\text{ V}$ , $I_{(nom)} = I_D$ , $T_C = 85^\circ\text{C}$ , See Notes 5, 6, and 7		350		mA
$I_D$	Drain current, off-state $V_{DS} = 40\text{ V}$ , $T_C = 25^\circ\text{C}$ $V_{DS} = 40\text{ V}$ , $T_C = 125^\circ\text{C}$		0.1 0.2	1 5	$\mu\text{A}$
$r_{DS(on)}$	Static drain-source on-state resistance $I_D = 350\text{ mA}$ , $T_C = 25^\circ\text{C}$ $I_D = 350\text{ mA}$ , $T_C = 125^\circ\text{C}$ $I_D = 350\text{ mA}$ , $T_C = 40^\circ\text{C}$			1 1.7 1.5 2.5	$\Omega$

- NOTES: 3. Pulse duration  $\leq 100\text{ }\mu\text{s}$  and duty cycle  $\leq 2\%$   
5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.  
7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .

# TPIC6A595

## POWER LOGIC 8-BIT SHIFT REGISTER

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### switching characteristics, $V_{CC} = 5\text{ V}$ , $T_C = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PHL}$	Propagation delay time, high-to-low-level output from $\bar{Q}$	$C_L = 30\text{ pF}$ , $I_D = 350\text{ mA}$ , See Figures 1, 2, and 12		30		ns
$t_{PLH}$	Propagation delay time, low-to-high-level output from $\bar{Q}$			125		ns
$t_r$	Rise time, drain output			60		ns
$t_f$	Fall time, drain output			30		ns
$t_a$	Reverse-recovery-current rise time	$I_F = 350\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 5		100		ns
$t_{rr}$	Reverse-recovery time			300		ns

NOTES: 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

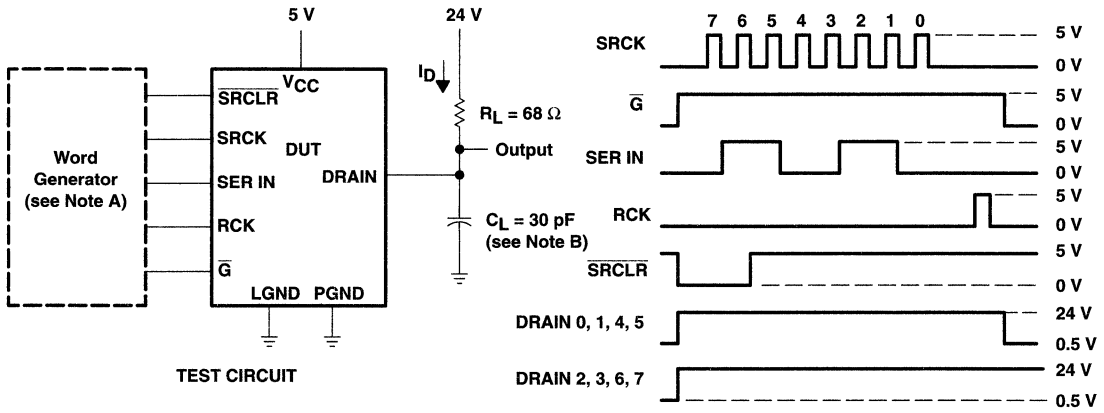
### thermal resistance

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JC}$	Thermal resistance, junction-to-case	All eight outputs with equal power	DW	10	$^\circ\text{C}/\text{W}$
			NE	10	
$R_{\theta JA}$	Thermal resistance, junction-to-ambient	All eight outputs with equal power	DW	50	$^\circ\text{C}/\text{W}$
			NE	50	

# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

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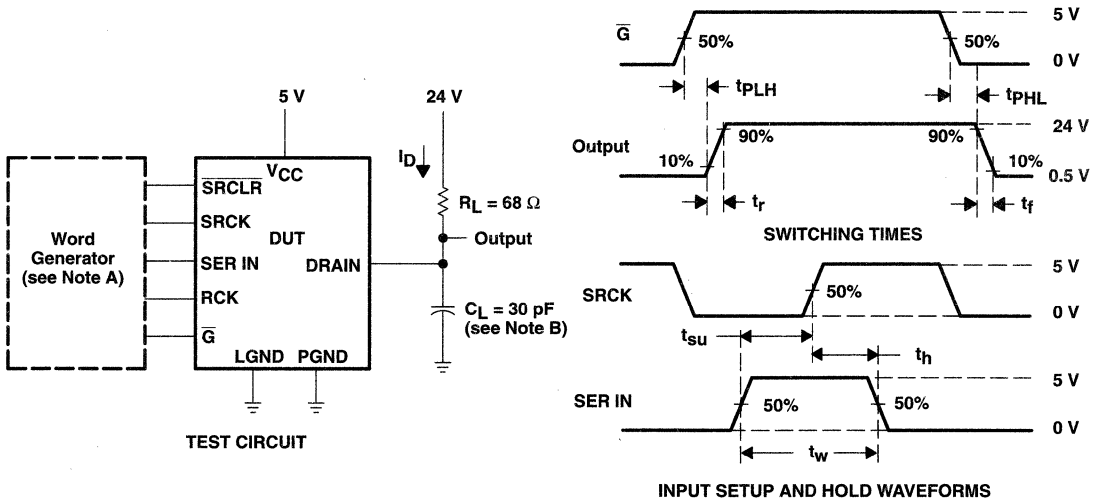
## PARAMETER MEASUREMENT INFORMATION



### VOLTAGE WAVEFORMS

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

**Figure 1. Resistive Load Operation**



### INPUT SETUP AND HOLD WAVEFORMS

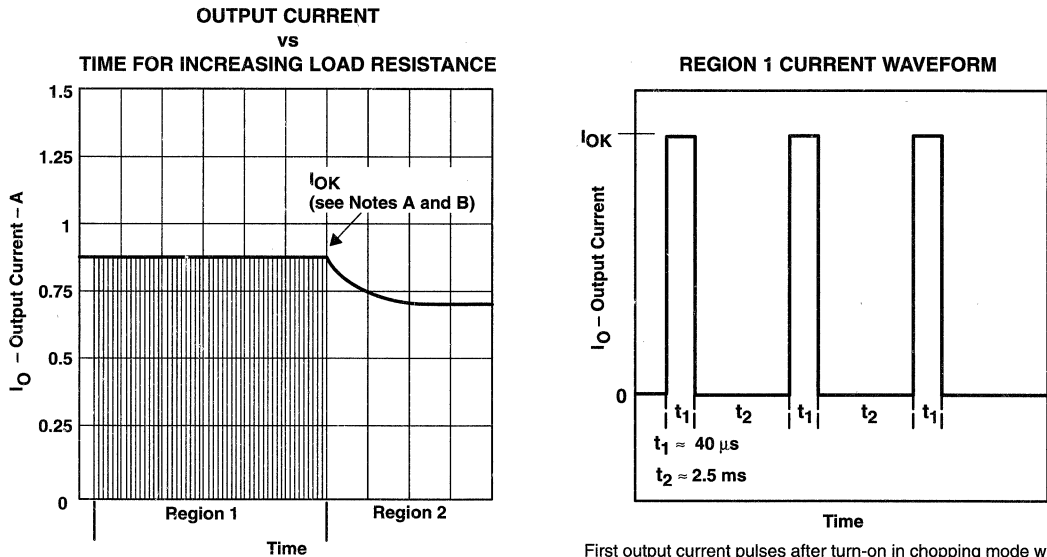
- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

**Figure 2. Test Circuit, Switching Times, and Voltage Waveforms**

**TPIC6A595**  
**POWER LOGIC 8-BIT SHIFT REGISTER**

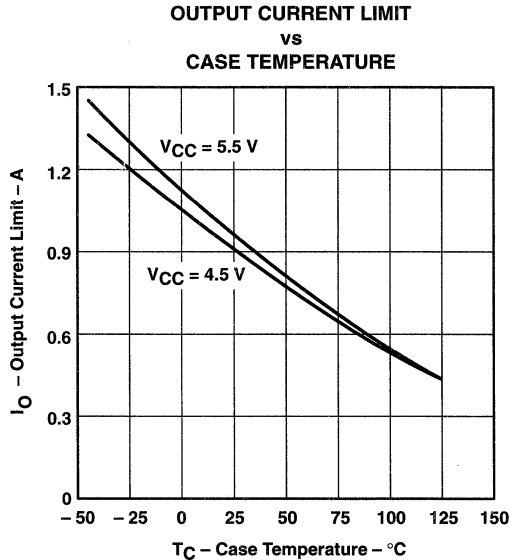
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**PARAMETER MEASUREMENT INFORMATION**



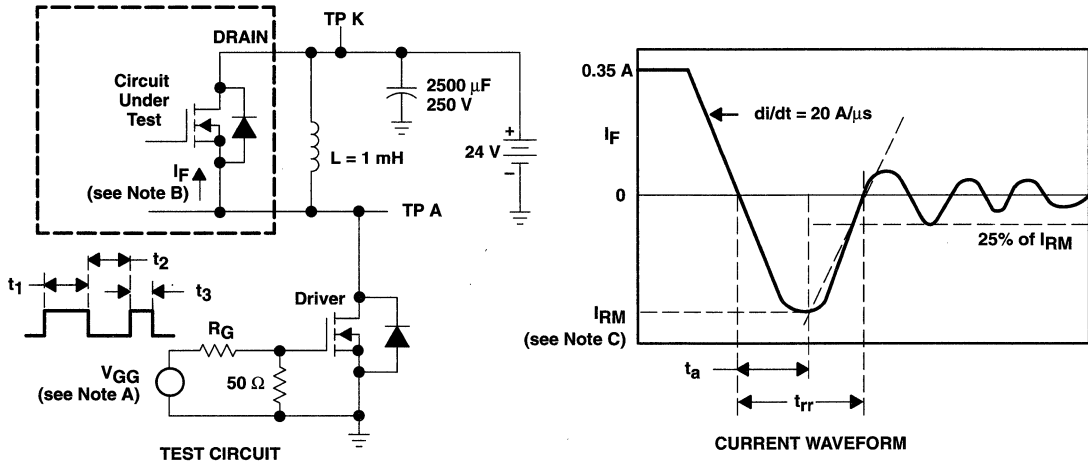
- NOTES: A. Figure 3 illustrates the output current characteristics of the device energizing a load having initially low, increasing resistance, e.g., an incandescent lamp. In region 1, chopping occurs and the peak current is limited to  $I_{OK}$ . In region 2, output current is continuous. The same characteristics occur in reverse order when the device energizes a load having an initially high, decreasing resistance.
- B. Region 1 duty cycle is approximately 2%.

**Figure 3. Chopping-Mode Characteristics**



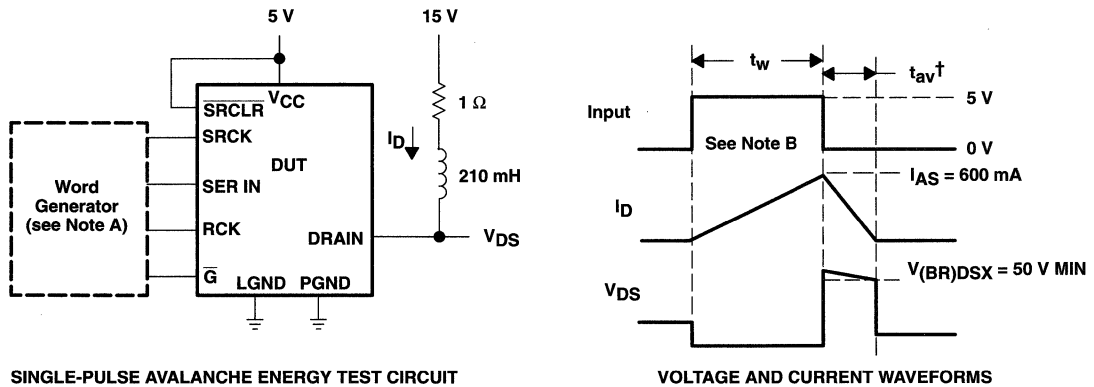
**Figure 4**

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.35 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.  
 C.  $I_{RM}$  = maximum recovery current

Figure 5. Reverse-Recovery-Current Test Circuit and Waveforms of Source-Drain Diode



- † Non JEDEC symbol for avalanche time.  
 NOTES: A. The word generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 600 \text{ mA}$ .  
 Energy test level is defined as  $E_{AS} = (I_{AS} \times V_{(BR)DSX} \times t_{av})/2 = 75 \text{ mJ}$ .

Figure 6. Single-Pulse Avalanche Energy Test Circuit and Waveforms



# TPIC6A595 POWER LOGIC 8-BIT SHIFT REGISTER

SLIS005A – APRIL 1993 – REVISED JANUARY 1995

## TYPICAL CHARACTERISTICS

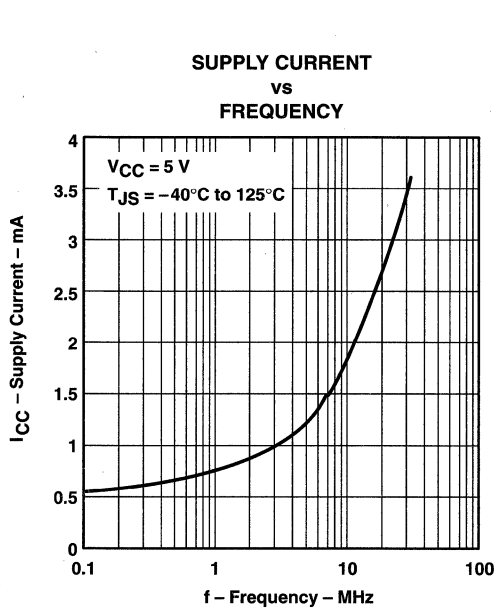


Figure 7

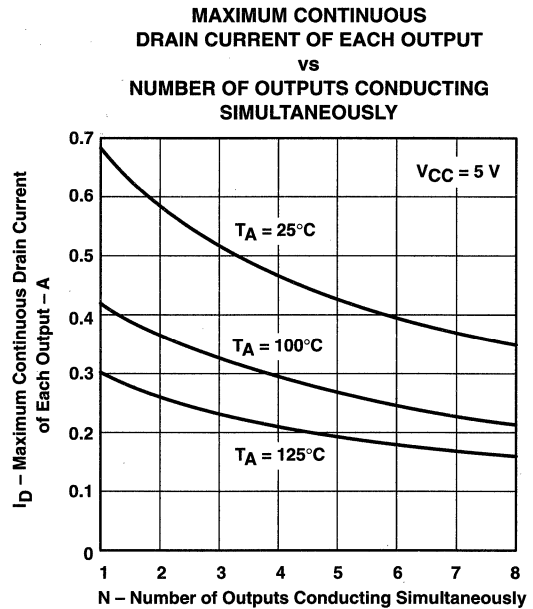


Figure 8

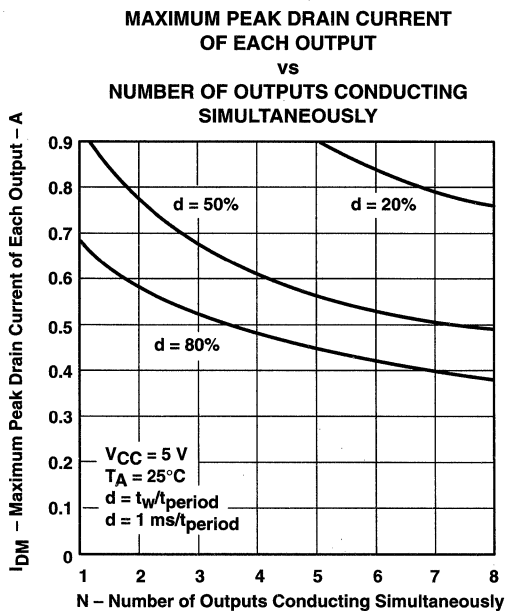


Figure 9

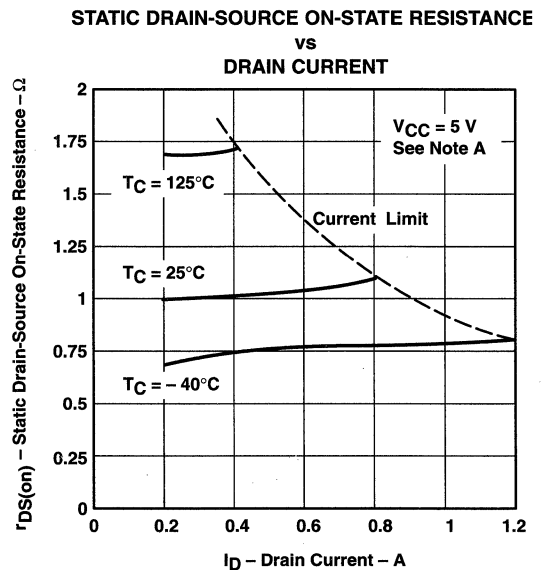


Figure 10

NOTE A: Technique should limit  $T_J - T_C$  to  $10^{\circ}\text{C}$  maximum.



TYPICAL CHARACTERISTICS

STATIC DRAIN-SOURCE ON-STATE RESISTANCE  
vs  
LOGIC SUPPLY VOLTAGE

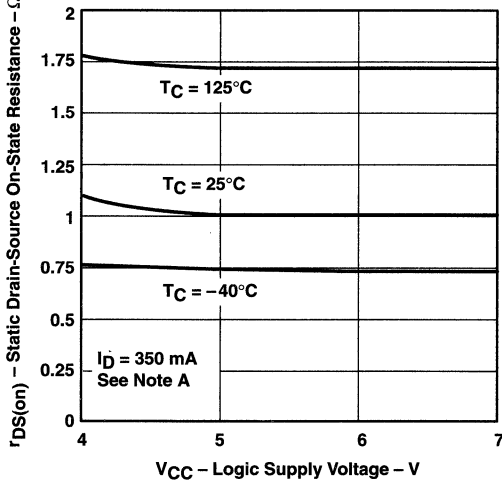


Figure 11

SWITCHING TIME  
vs  
CASE TEMPERATURE

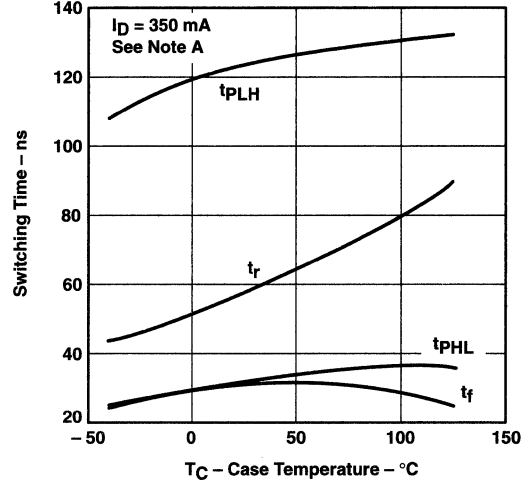


Figure 12

NOTE A: Technique should limit  $T_J - T_C$  to 10°C maximum.

THERMAL INFORMATION

NE PACKAGE  
TRANSIENT THERMAL IMPEDANCE  
vs  
ON TIME

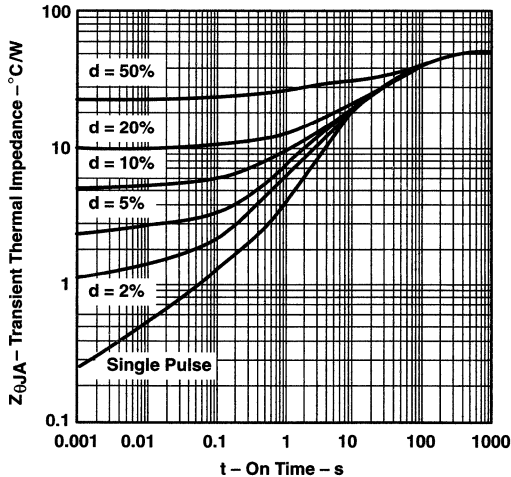


Figure 13

The single-pulse curve represents measured data. The curves for various pulse durations are based on the following equation:

$$Z_{\theta JA} = \left| \frac{t_w}{t_c} \right| R_{\theta JA} + \left| 1 - \frac{t_w}{t_c} \right| Z_{\theta}(t_w + t_c) + Z_{\theta}(t_w) - Z_{\theta}(t_c)$$

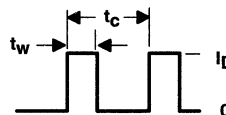
Where:

$Z_{\theta}(t_w)$  = the single-pulse thermal impedance for  $t = t_w$  seconds

$Z_{\theta}(t_c)$  = the single-pulse thermal impedance for  $t = t_c$  seconds

$Z_{\theta}(t_w + t_c)$  = the single-pulse thermal impedance for  $t = t_w + t_c$  seconds

$$d = t_w/t_c$$





# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

- Low  $r_{DS(on)}$  . . . 5  $\Omega$  Typical
- Avalanche Energy . . . 30 mJ
- Eight Power DMOS-Transistor Outputs of 150-mA Continuous Current
- 500-mA Typical Current-Limiting Capability
- Output Clamp Voltage . . . 50 V
- Four Distinct Function Modes
- Low Power Consumption

## description

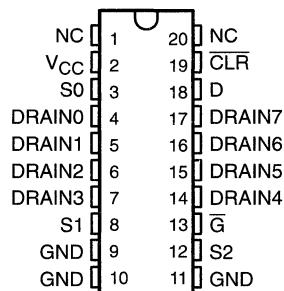
This power logic 8-bit addressable latch controls open-drain DMOS-transistor outputs and is designed for general-purpose storage applications in digital systems. Specific uses include working registers, serial-holding registers, and decoders or demultiplexers. This is a multi-functional device capable of storing single-line data in eight addressable latches and 3-to-8 decoder or demultiplexer with active-low DMOS outputs.

Four distinct modes of operation are selectable by controlling the clear ( $\overline{CLR}$ ) and enable ( $\overline{G}$ ) inputs as enumerated in the function table. In the addressable-latch mode, data at the data-in (D) terminal is written into the addressed latch. The addressed DMOS-transistor output inverts the data input with all unaddressed DMOS-transistor outputs remaining in their previous states. In the memory mode, all DMOS-transistor outputs remain in their previous states and are unaffected by the data or address inputs. To eliminate the possibility of entering erroneous data in the latch, enable  $\overline{G}$  should be held high (inactive) while the address lines are changing. In the 3-to-8 decoding or demultiplexing mode, the addressed output is inverted with respect to the D input and all other outputs are off. In the clear mode, all outputs are off and unaffected by the address and data inputs. When data is low for a given output, the DMOS-transistor output is off. When data is high, the DMOS-transistor output has sink-current capability.

Outputs are low-side, open-drain DMOS transistors with output ratings of 50 V and 150-mA continuous sink-current capability. Each output provides a 500-mA typical current limit at  $T_C = 25^\circ\text{C}$ . The current limit decreases as the junction temperature increases for additional device protection.

The TPIC6B259 is characterized for operation over the operating case temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

DW OR N PACKAGE  
(TOP VIEW)



NC – No internal connection

FUNCTION TABLE

INPUTS			OUTPUT OF ADDRESSED DRAIN	EACH OTHER DRAIN	FUNCTION
$\overline{CLR}$	$\overline{G}$	D			
H	L	H	L	$Q_{i0}$	Addressable Latch
H	L	L	H	$Q_{i0}$	
H	H	X	$Q_{i0}$	$Q_{i0}$	Memory
L	L	H	L	H	8-Line Demultiplexer
L	L	L	H	H	
L	H	X	H	H	Clear

LATCH SELECTION TABLE

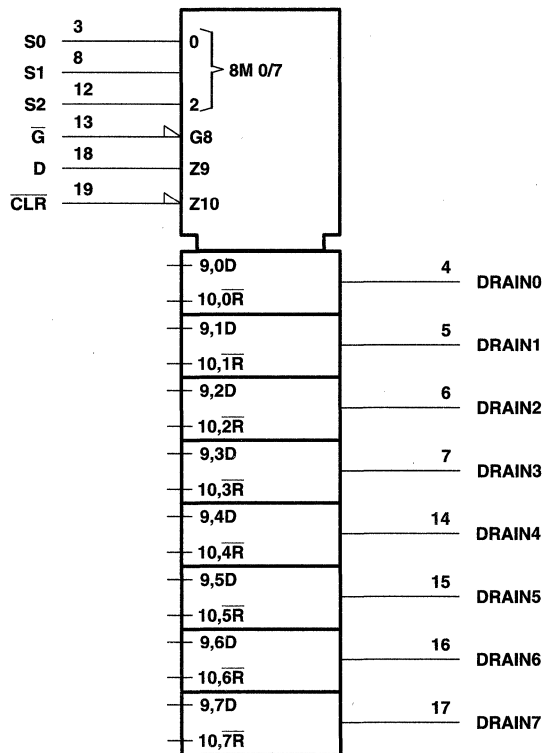
SELECT INPUTS			DRAIN ADDRESSED
S2	S1	S0	
L	L	L	0
L	L	H	1
L	H	L	2
L	H	H	3
H	L	L	4
H	L	H	5
H	H	L	6
H	H	H	7

H = high level, L = low level

# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

## logic symbol†

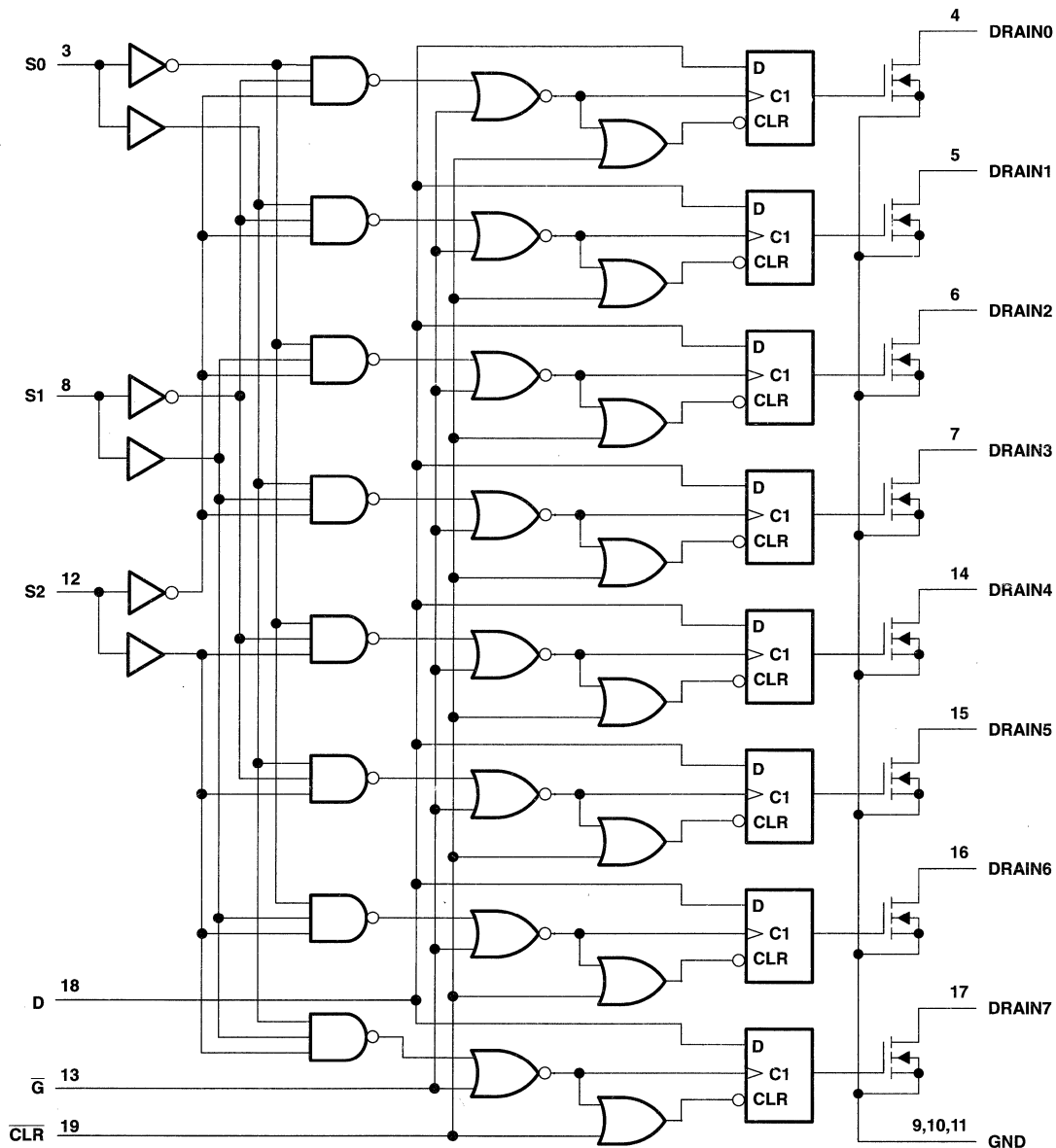


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

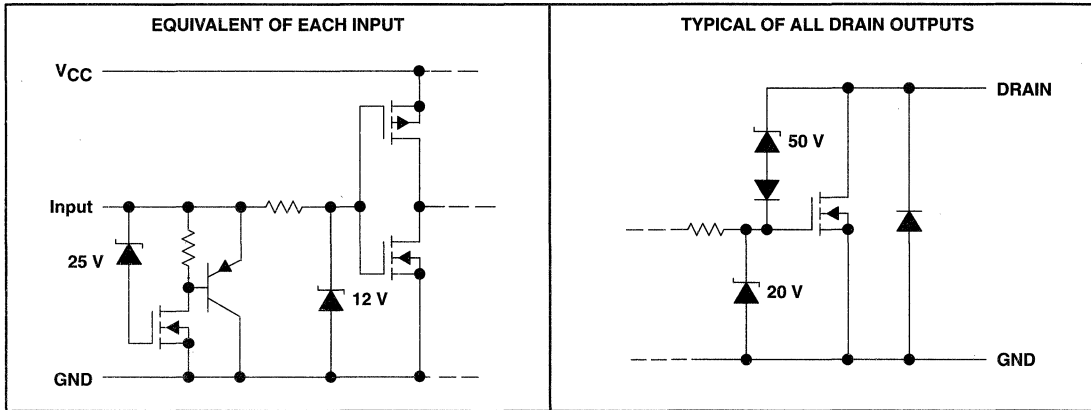
logic diagram (positive logic)



# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

## schematic of inputs and outputs



### absolute maximum ratings over the recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	50 V
Continuous source-to-drain diode anode current	500 mA
Pulsed source-to-drain diode anode current (see Note 3)	1 A
Pulsed drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Continuous drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$	150 mA
Peak drain current single output, $I_{DM}$ , $T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	30 mJ
Avalanche current, $I_{AS}$ (see Note 4)	500 mA
Continuous total dissipation	See Dissipating Rating Table
Operating virtual junction temperature range, $T_J$	-40°C to 150°C
Operating case temperature range, $T_C$	-40°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 are with respect to GND.  
 2. Each power DMOS source is internally connected to GND.  
 3. Pulse duration  $\leq 100 \mu\text{s}$  and duty cycle  $\leq 2\%$ .  
 4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C,  $L = 200 \text{ mH}$ ,  $I_{AS} = 0.5 \text{ A}$  (see Figure 4).

DISSIPATION RATING TABLE

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/°C	278 mW
N	1050 mW	10.5 mW/°C	263 mW

**TPIC6B259**  
**POWER LOGIC 8-BIT ADDRESSABLE LATCH**

SLIS030 – APRIL 1994 – REVISED JULY 1995

**recommended operating conditions**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$		0.15 $V_{CC}$	V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-500	500	mA
Setup time, D high before $\overline{G}\uparrow$ , $t_{SU}$ (see Figure 2)	20		ns
Hold time, D high after $\overline{G}\uparrow$ , $t_H$ (see Figure 2)	20		ns
Pulse duration, $t_W$ (see Figure 2)	40		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$V_{(BR)DSX}$	Drain-to-source breakdown voltage	$I_D = 1\text{ mA}$	50			V	
$V_{SD}$	Source-to-drain diode forward voltage	$I_F = 100\text{ mA}$		0.85	1	V	
$I_{IH}$	High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$	
$I_{IL}$	Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$	
$I_{CC}$	Logic supply current	$V_{CC} = 5.5\text{ V}$	All outputs off		20	100	$\mu\text{A}$
			All outputs on		150	300	
$I_N$	Nominal current	$V_{DS(on)} = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$ , See Notes 5, 6, and 7		90		mA	
$I_{DSX}$	Off-state drain current	$V_{DS} = 40\text{ V}$ , $V_{CC} = 5.5\text{ V}$		0.1	5	$\mu\text{A}$	
		$V_{DS} = 40\text{ V}$ , $V_{CC} = 5.5\text{ V}$ , $T_C = 125^\circ\text{C}$		0.15	8		
$r_{DS(on)}$	Static drain-to-source on-state resistance	$I_D = 100\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	See Notes 5 and 6 and Figures 6 and 7	4.2	5.7	$\Omega$	
		$I_D = 100\text{ mA}$ , $V_{CC} = 4.5\text{ V}$ , $T_C = 125^\circ\text{C}$		6.8	9.5		
		$I_D = 350\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		5.5	8		

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from D	$C_L = 30\text{ pF}$ , $I_D = 100\text{ mA}$ , See Figures 1, 2, and 8		150		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from D			90		ns
$t_r$	Rise time, drain output			200		ns
$t_f$	Fall time, drain output			200		ns
$t_a$	Reverse-recovery-current rise time	$I_F = 100\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3		100		ns
$t_{rF}$	Reverse-recovery time			300		

NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$  and duty cycle  $\leq 2\%$ .

5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .





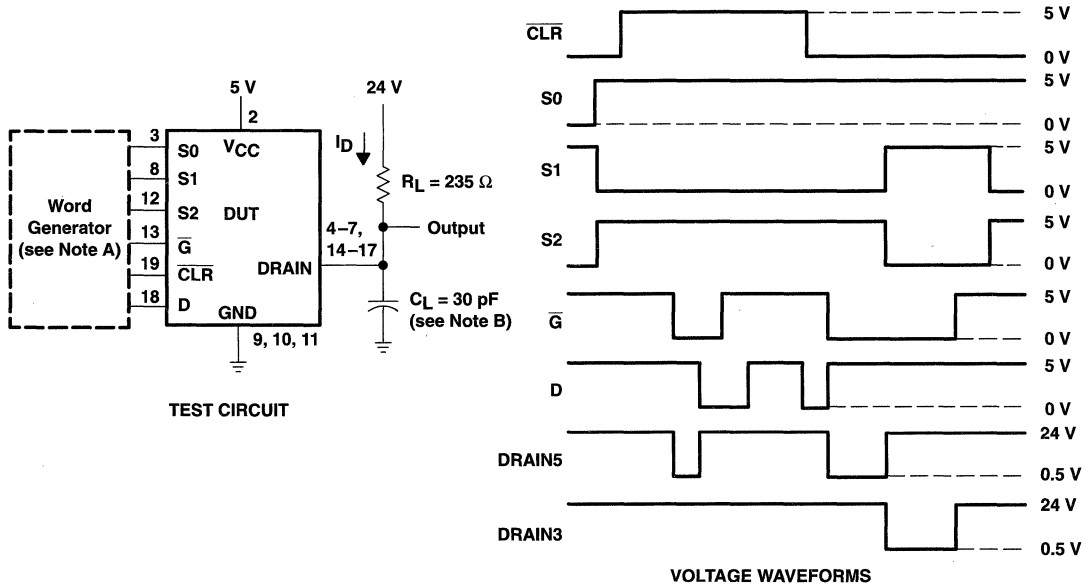
# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

## thermal resistance

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
R <sub>θJA</sub>	Thermal resistance junction-to-ambient	DW package		90	°C/W
		N package		95	

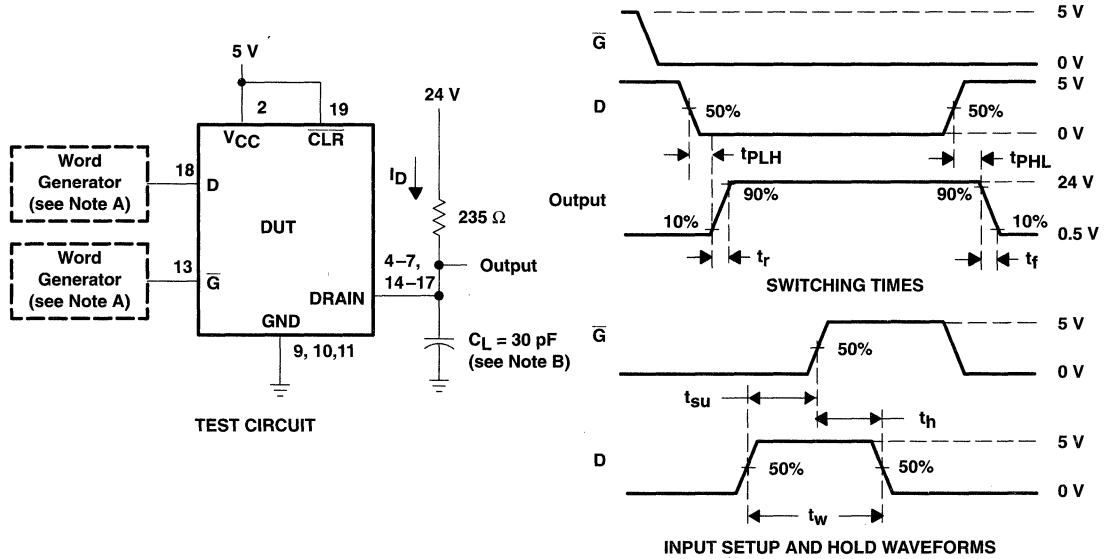
## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50$   $\Omega$ .  
 B. C<sub>L</sub> includes probe and jig capacitance.

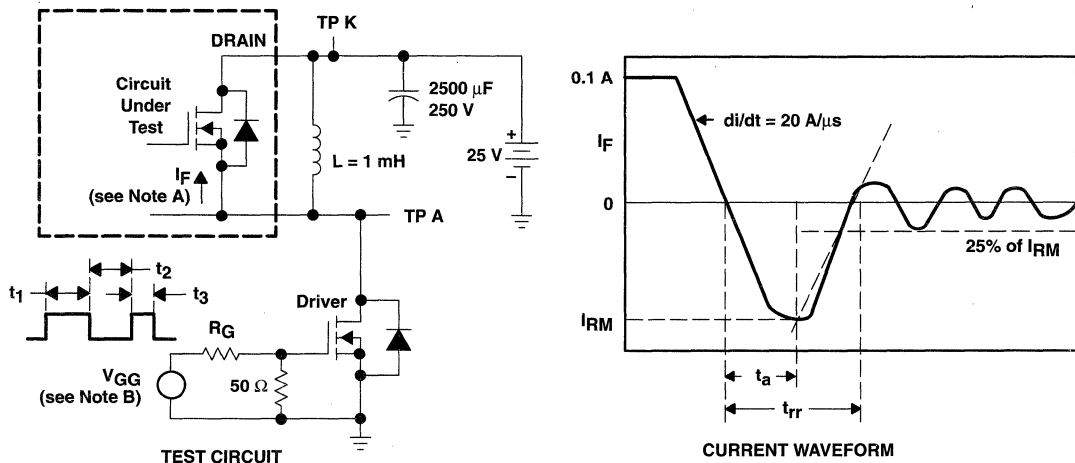
Figure 1. Resistive-Load Test Circuit and Voltage Waveforms

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_0 = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 2. Test Circuit, Switching Times, and Voltage Waveforms



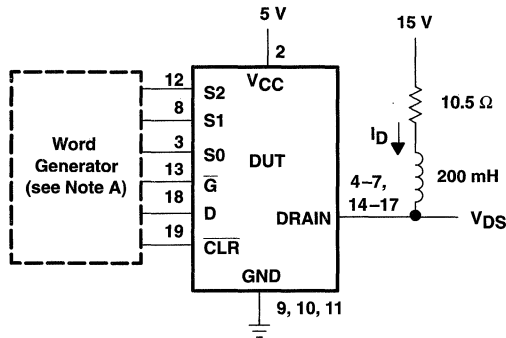
- NOTES: A. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.  
B. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20$  A/ $\mu$ s. A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.1$  A, where  $t_1 = 10 \mu$ s,  $t_2 = 7 \mu$ s, and  $t_3 = 3 \mu$ s.

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-to-Drain Diode

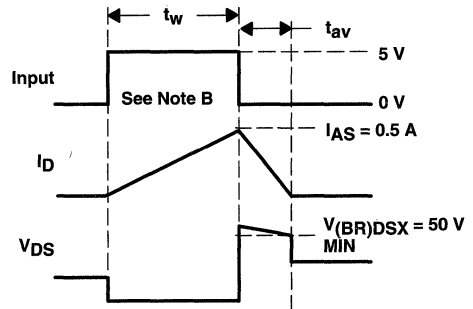
# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 0.5$  A.  
 Energy test level is defined as  $E_{AS} = I_{AS} \times V_{(BR)DSX} \times t_{av}/2 = 30$  mJ.

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

## TYPICAL CHARACTERISTICS

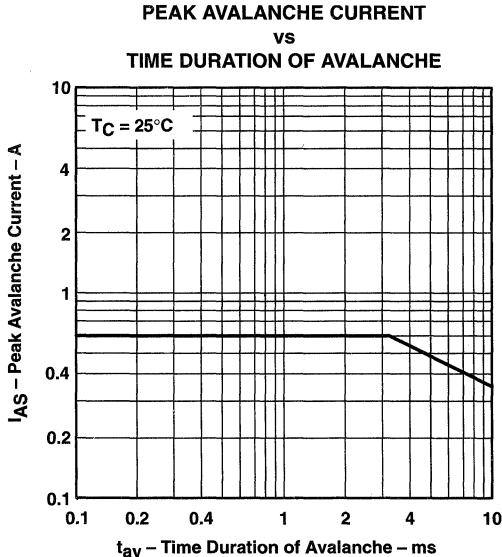
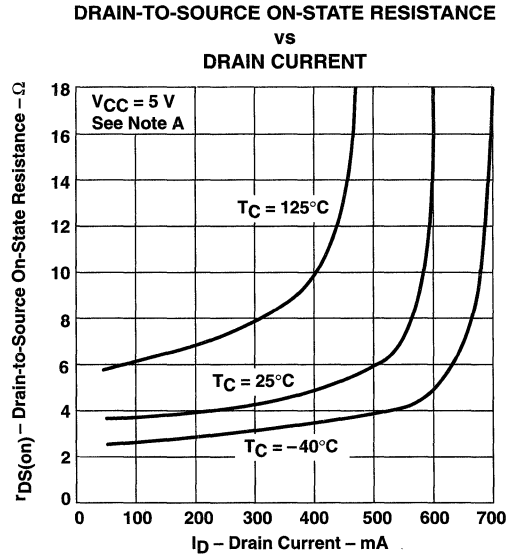


Figure 5



NOTE C. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

Figure 6

TYPICAL CHARACTERISTICS

STATIC DRAIN-TO-SOURCE ON-STATE RESISTANCE  
vs  
LOGIC SUPPLY VOLTAGE

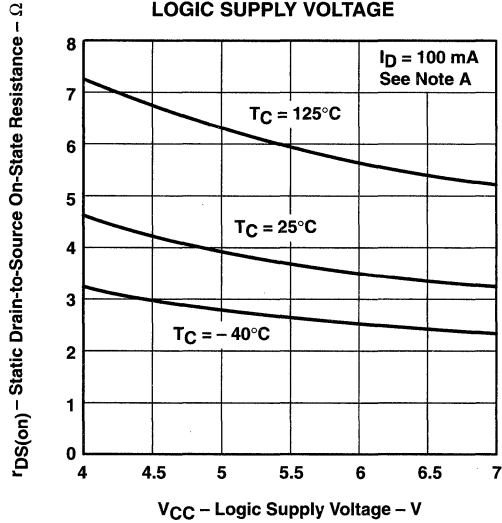


Figure 7

SWITCHING TIME  
vs  
CASE TEMPERATURE

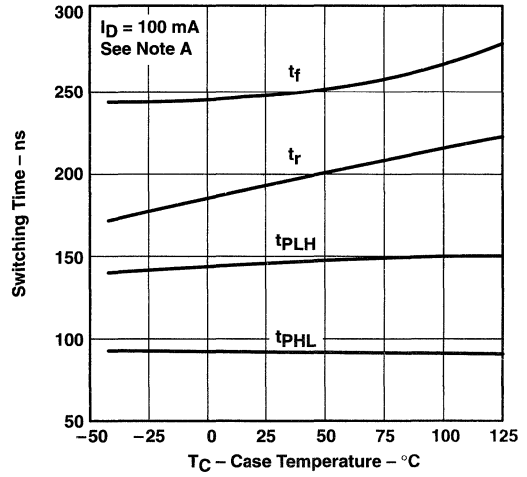


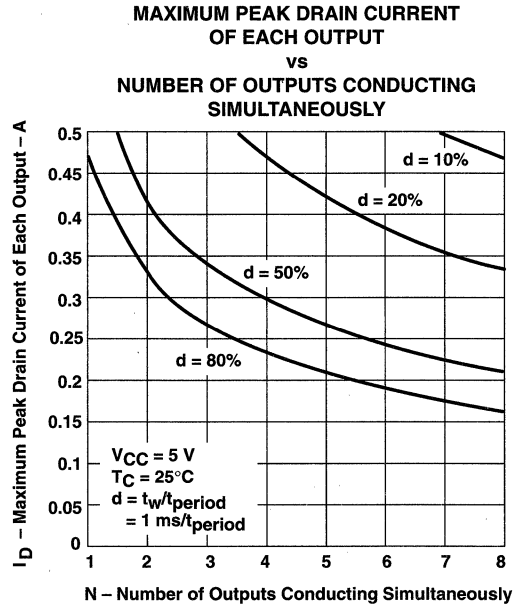
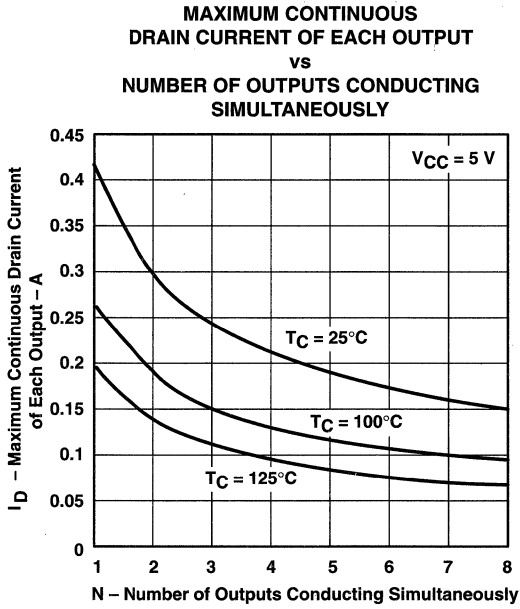
Figure 8

NOTE D. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

# TPIC6B259 POWER LOGIC 8-BIT ADDRESSABLE LATCH

SLIS030 – APRIL 1994 – REVISED JULY 1995

## THERMAL INFORMATION



# TPIC6B273 POWER LOGIC OCTAL D-TYPE LATCH

LSIS031 – APRIL 1994 – REVISED JULY 1995

- Low  $r_{DS(on)}$  . . . 5  $\Omega$  Typical
- Avalanche Energy . . . 30 mJ
- Eight Power DMOS-Transistor Outputs of 150-mA Continuous Current
- 500-mA Typical Current-Limiting Capability
- Output Clamp Voltage . . . 50 V
- Low Power Consumption

## description

The TPIC6B273 is a monolithic, high-voltage, medium-current, power logic octal D-type latch with DMOS-transistor outputs designed for use in systems that require relatively high load power. The device contains a built-in voltage clamp on the outputs for inductive transient protection. Power driver applications include relays, solenoids, and other medium-current or high-voltage loads.

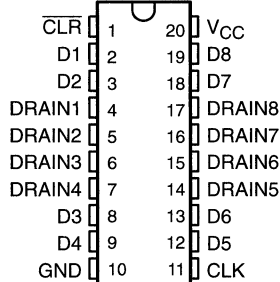
The TPIC6B273 contains eight positive-edge-triggered D-type flip-flops with a direct clear input. Each flip-flop features an open-drain power DMOS-transistor output.

When clear ( $\overline{CLR}$ ) is high, information at the D inputs meeting the setup time requirements is transferred to the DRAIN outputs on the positive-going edge of the clock (CLK) pulse. Clock triggering occurs at a particular voltage level and is not directly related to the transition time of the positive-going pulse. When the clock input (CLK) is at either the high or low level, the D input signal has no effect at the output. An asynchronous  $\overline{CLR}$  is provided to turn all eight DMOS-transistor outputs off. When data is low for a given output, the DMOS-transistor output is off. When data is high, the DMOS-transistor output has sink-current capability.

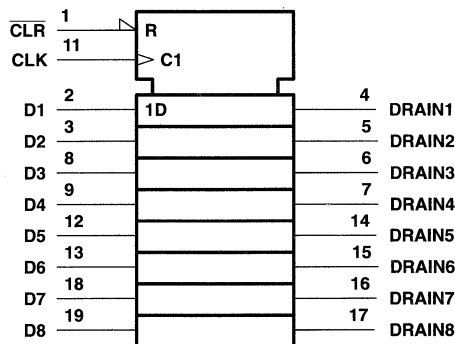
Outputs are low-side, open-drain DMOS transistors with output ratings of 50 V and 150-mA continuous sink-current capability. Each output provides a 500-mA typical current limit at  $T_C = 25^\circ\text{C}$ . The current limit decreases as the junction temperature increases for additional device protection.

The TPIC6B273 is characterized for operation over the operating case temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

DW OR N PACKAGE  
(TOP VIEW)



## logic symbol



† This symbol is in accordance with ANSI/IEEE Standard 91-1984 and IEC Publication 617-12.

FUNCTION TABLE  
(each channel)

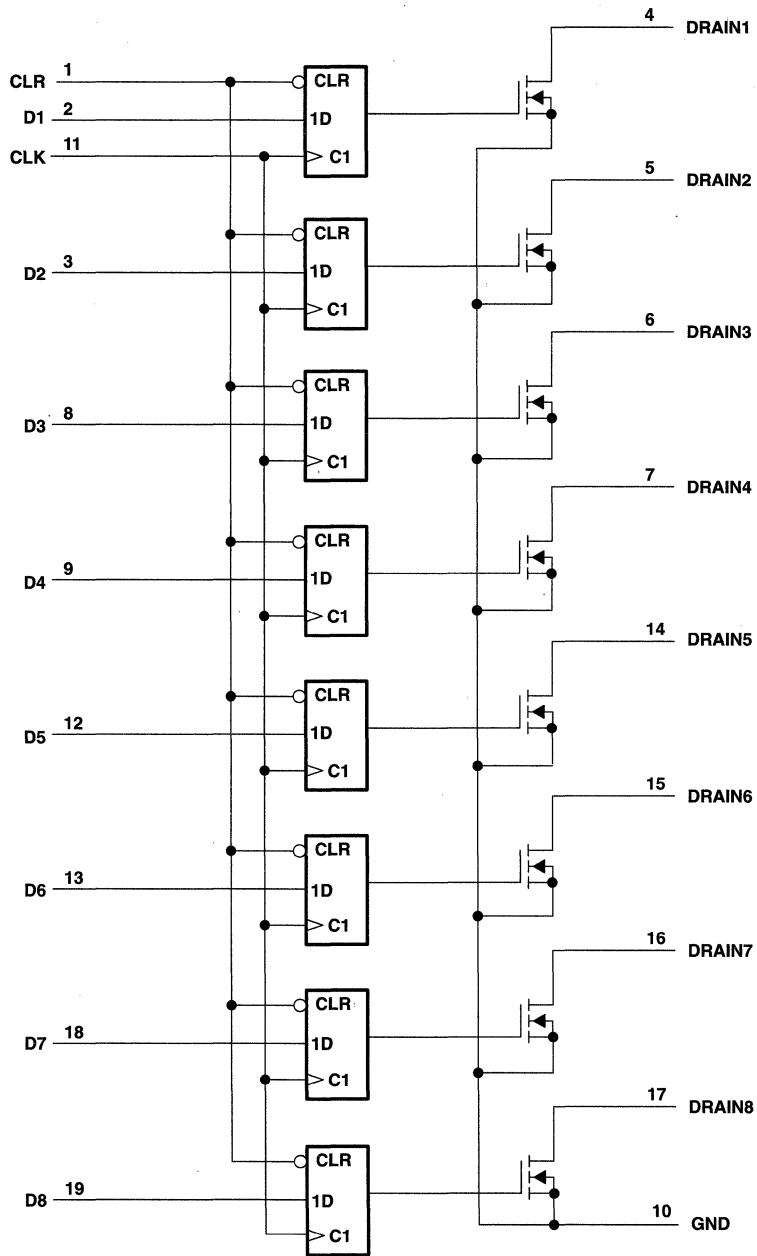
INPUTS			OUTPUT
CLR	CLK	D	DRAIN
L	X	X	H
H	↑	H	L
H	↑	L	H
H	L	X	Latched

H = high level, L = low level, X = irrelevant

# TPIC6B273 POWER LOGIC OCTAL D-TYPE LATCH

SLIS031 – APRIL 1994 – REVISED JULY 1995

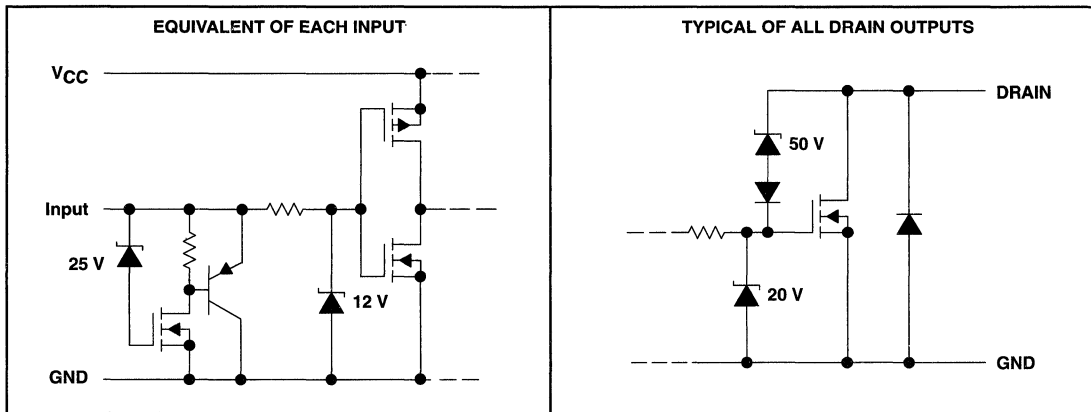
## logic diagram (positive logic)



# TPIC6B273 POWER LOGIC OCTAL D-TYPE LATCH

SLIS031 – APRIL 1994 – REVISED JULY 1995

## schematic of inputs and outputs



## absolute maximum ratings over recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	50 V
Continuous source-to-drain diode anode current	500 mA
Pulsed source-to-drain diode anode current (see Note 3)	1 A
Pulsed drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Continuous drain current, each output, all outputs on, $I_D$ , $T_C = 25^\circ\text{C}$	150 mA
Peak drain current single output, $I_{DM}$ , $T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	30 mJ
Avalanche current, $I_{AS}$ (see Note 4)	500 mA
Continuous total dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°C to 150°C
Operating case temperature range, $T_C$	-40°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 are with respect to GND.  
 2. Each power DMOS source is internally connected to GND.  
 3. Pulse duration  $\leq 100 \mu\text{s}$  and duty cycle  $\leq 2\%$ .  
 4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C,  $L = 200 \text{ mH}$ ,  $I_{AS} = 0.5 \text{ A}$  (see Figure 4).

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/°C	278 mW
N	1050 mW	10.5 mW/°C	263 mW



# TPIC6B273

## POWER LOGIC OCTAL D-TYPE LATCH

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### recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$	0.15 $V_{CC}$		V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-500	500	mA
Setup time, D high before $\text{CLK}\uparrow$ , $t_{SU}$ (see Figure 2)	20		ns
Hold time, D high after $\text{CLK}\uparrow$ , $t_H$ (see Figure 2)	20		ns
Pulse duration, $t_W$ (see Figure 2)	40		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$V_{(BR)DSX}$ Drain-to-source breakdown voltage	$I_D = 1\text{ mA}$	50			V	
$V_{SD}$ Source-to-drain diode forward voltage	$I_F = 100\text{ mA}$	0.85			1	V
$I_{IH}$ High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$				1	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$				-1	$\mu\text{A}$
$I_{CC}$ Logic supply current	$V_{CC} = 5.5\text{ V}$	All outputs off		20	100	$\mu\text{A}$
		All outputs on		150	300	
$I_N$ Nominal current	$V_{DS(on)} = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$ , See Notes 5, 6, and 7	90			mA	
$I_{DSX}$ Off-state drain current	$V_{DS} = 40\text{ V}$ , $V_{CC} = 5.5\text{ V}$	0.1			5	$\mu\text{A}$
	$V_{DS} = 40\text{ V}$ , $V_{CC} = 5.5\text{ V}$ , $T_C = 125^\circ\text{C}$	0.15			8	
$r_{DS(on)}$ Static drain-to-source on-state resistance	$I_D = 100\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	4.2			5.7	$\Omega$
	$I_D = 100\text{ mA}$ , $V_{CC} = 4.5\text{ V}$ , $T_C = 125^\circ\text{C}$	6.8			9.5	
	$I_D = 350\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	5.5			8	

### switching characteristics, $V_{CC} = 5\text{ V}$ , $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output from CLK	$C_L = 30\text{ pF}$ , $I_D = 100\text{ mA}$ , See Figures 1, 2, and 8	150			ns
$t_{PHL}$ Propagation delay time, high-to-low-level output from CLK		90			ns
$t_r$ Rise time, drain output		200			ns
$t_f$ Fall time, drain output		200			ns
$t_a$ Reverse-recovery-current rise time	$I_F = 100\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3	100			ns
$t_{rr}$ Reverse-recovery time		300			

- NOTES:
- Pulse duration  $\leq 100\ \mu\text{s}$  and duty cycle  $\leq 2\%$ .
  - Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.
  - These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.
  - Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of 0.5 V at  $T_C = 85^\circ\text{C}$ .

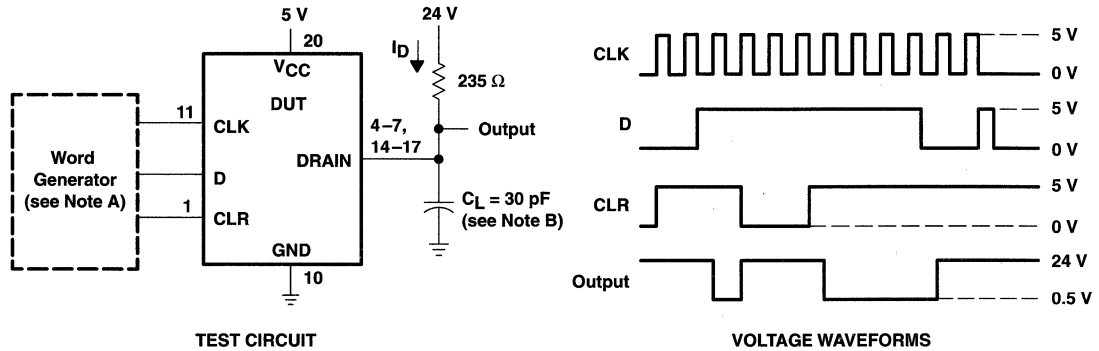
# TPIC6B273 POWER LOGIC OCTAL D-TYPE LATCH

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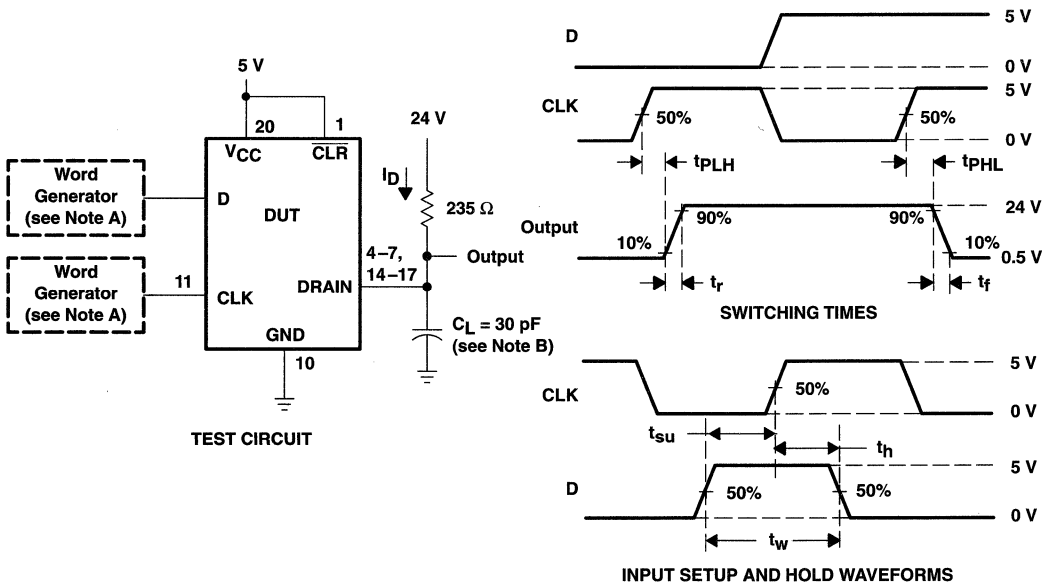
## thermal resistance

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
R <sub>θJA</sub>	Thermal resistance, junction-to-ambient	DW package		90	°C/W
		N package	All 8 outputs with equal power	95	

## PARAMETER MEASUREMENT INFORMATION



**Figure 1. Resistive-Load Test Circuit and Voltage Waveforms**



**Figure 2. Test Circuit, Switching Times, and Voltage Waveforms**

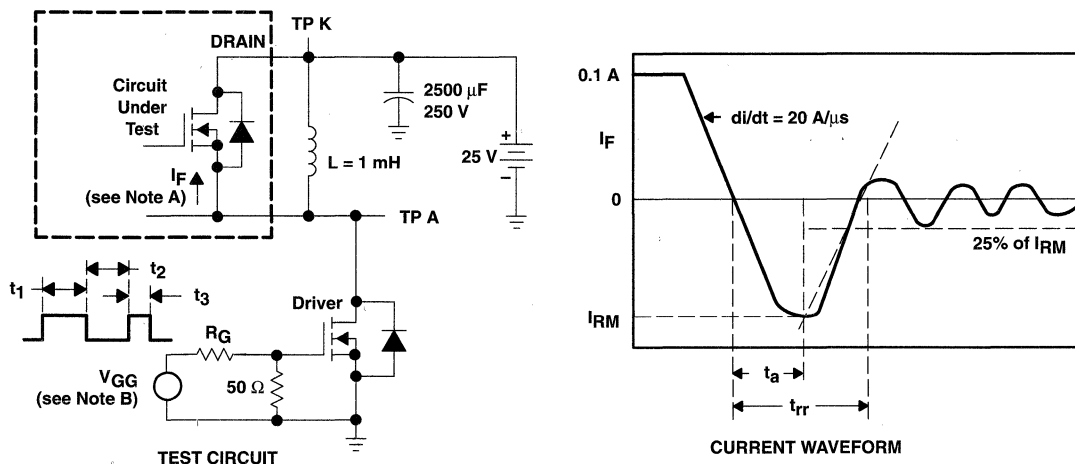
NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 KHz,  $Z_O = 50 \Omega$ .

B.  $C_L$  includes probe and jig capacitance.

# TPIC6B273 POWER LOGIC OCTAL D-TYPE LATCH

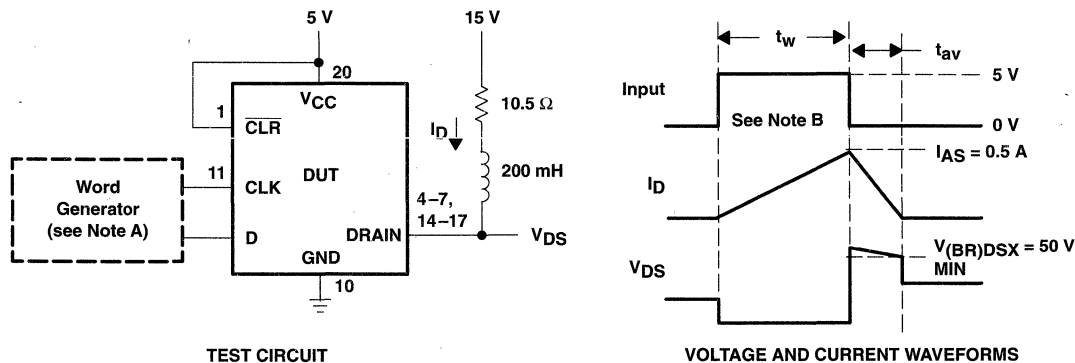
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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.  
 B. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20 \text{ A}/\mu\text{s}$ . A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.1 \text{ A}$ , where  $t_1 = 10 \mu\text{s}$ ,  $t_2 = 7 \mu\text{s}$ , and  $t_3 = 3 \mu\text{s}$ .

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-to-Drain Diode



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $Z_0 = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 0.5 \text{ A}$ .  
 Energy test is defined as  $E_{AS} = I_{AS} \times V_{(BR)DSX} \times t_{av}/2 = 30 \text{ mJ}$ .

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

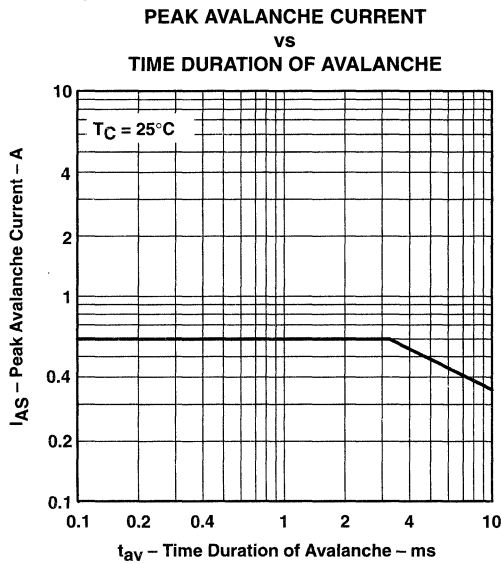


Figure 5

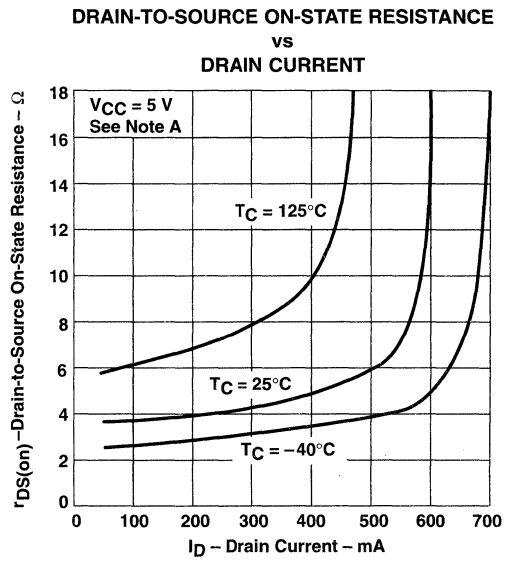


Figure 6

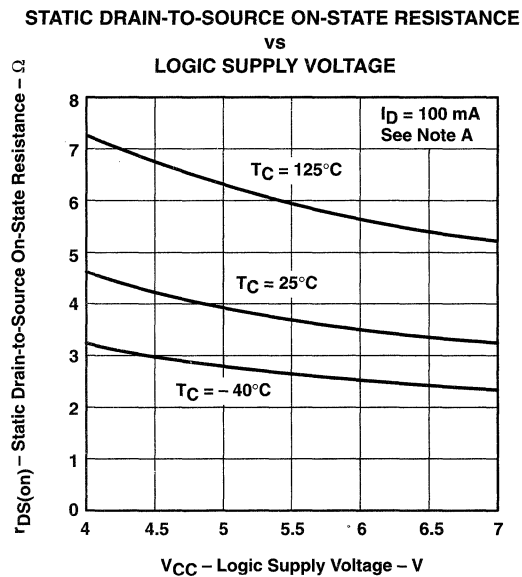


Figure 7

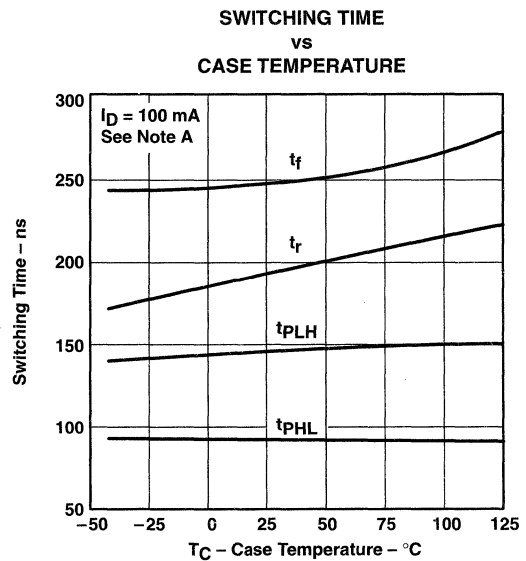


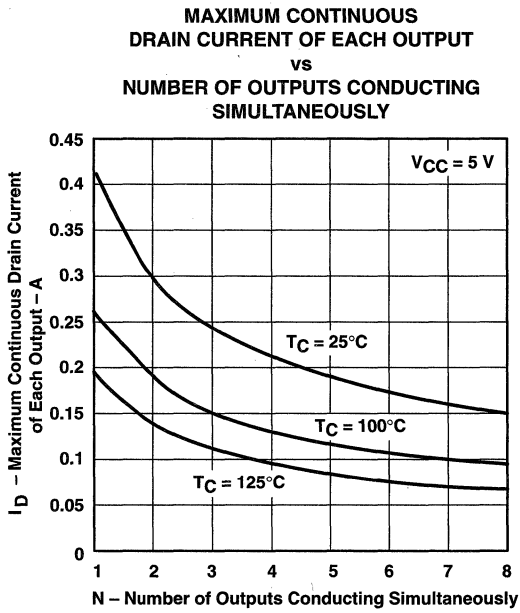
Figure 8

NOTE C. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

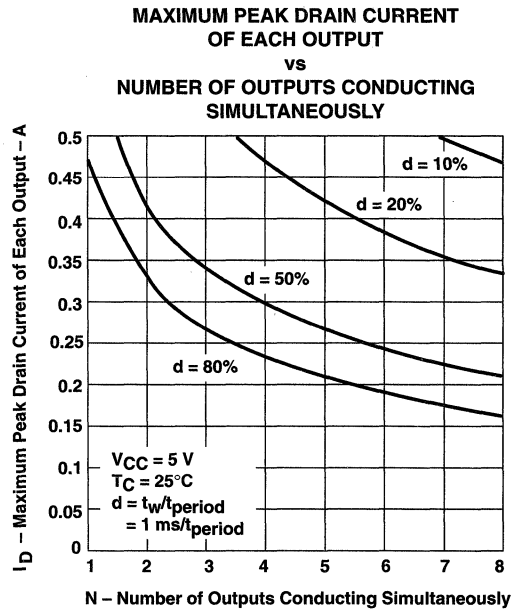
**TPIC6B273**  
**POWER LOGIC OCTAL D-TYPE LATCH**

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**THERMAL INFORMATION**



**Figure 9**



**Figure 10**

# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

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- Low  $r_{DS(on)}$  . . . 5  $\Omega$  Typical
- Avalanche Energy . . . 30 mJ
- Eight Power DMOS-Transistor Outputs of 150-mA Continuous Current
- 500-mA Typical Current-Limiting Capability
- Output Clamp Voltage . . . 50 V
- Devices Are Cascadable
- Low Power Consumption

## description

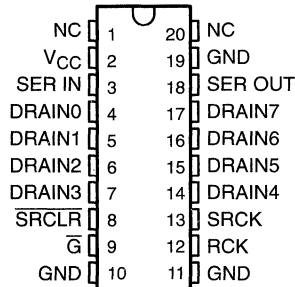
The TPIC6B595 is a monolithic, high-voltage, medium-current power 8-bit shift register designed for use in systems that require relatively high load power. The device contains a built-in voltage clamp on the outputs for inductive transient protection. Power driver applications include relays, solenoids, and other medium-current or high-voltage loads.

This device contains an 8-bit serial-in, parallel-out shift register that feeds an 8-bit D-type storage register. Data transfers through both the shift and storage registers on the rising edge of the shift-register clock (SRCK) and the register clock (RCK), respectively. The storage register transfers data to the output buffer when shift-register clear (SRCLR) is high. When SRCLR is low, the input shift register is cleared. When output enable ( $\bar{G}$ ) is held high, all data in the output buffers is held low and all drain outputs are off. When  $\bar{G}$  is held low, data from the storage register is transparent to the output buffers. When data in the output buffers is low, the DMOS-transistor outputs are off. When data is high, the DMOS-transistor outputs have sink-current capability. The serial output (SER OUT) allows for cascading of the data from the shift register to additional devices.

Outputs are low-side, open-drain DMOS transistors with output ratings of 50 V and 150-mA continuous sink-current capability. Each output provides a 500-mA typical current limit at  $T_C = 25^\circ\text{C}$ . The current limit decreases as the junction temperature increases for additional device protection.

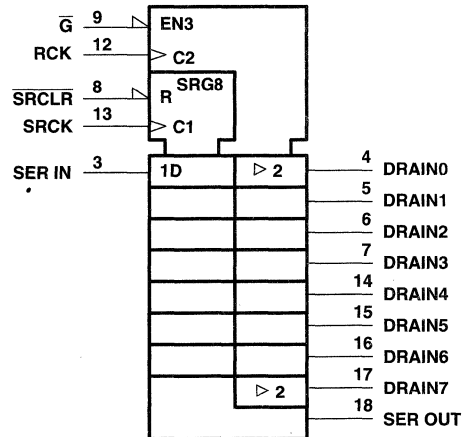
The TPIC6B595 is characterized for operation over the operating case temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

DW OR N PACKAGE  
(TOP VIEW)



NC – No internal connection

## logic symbol

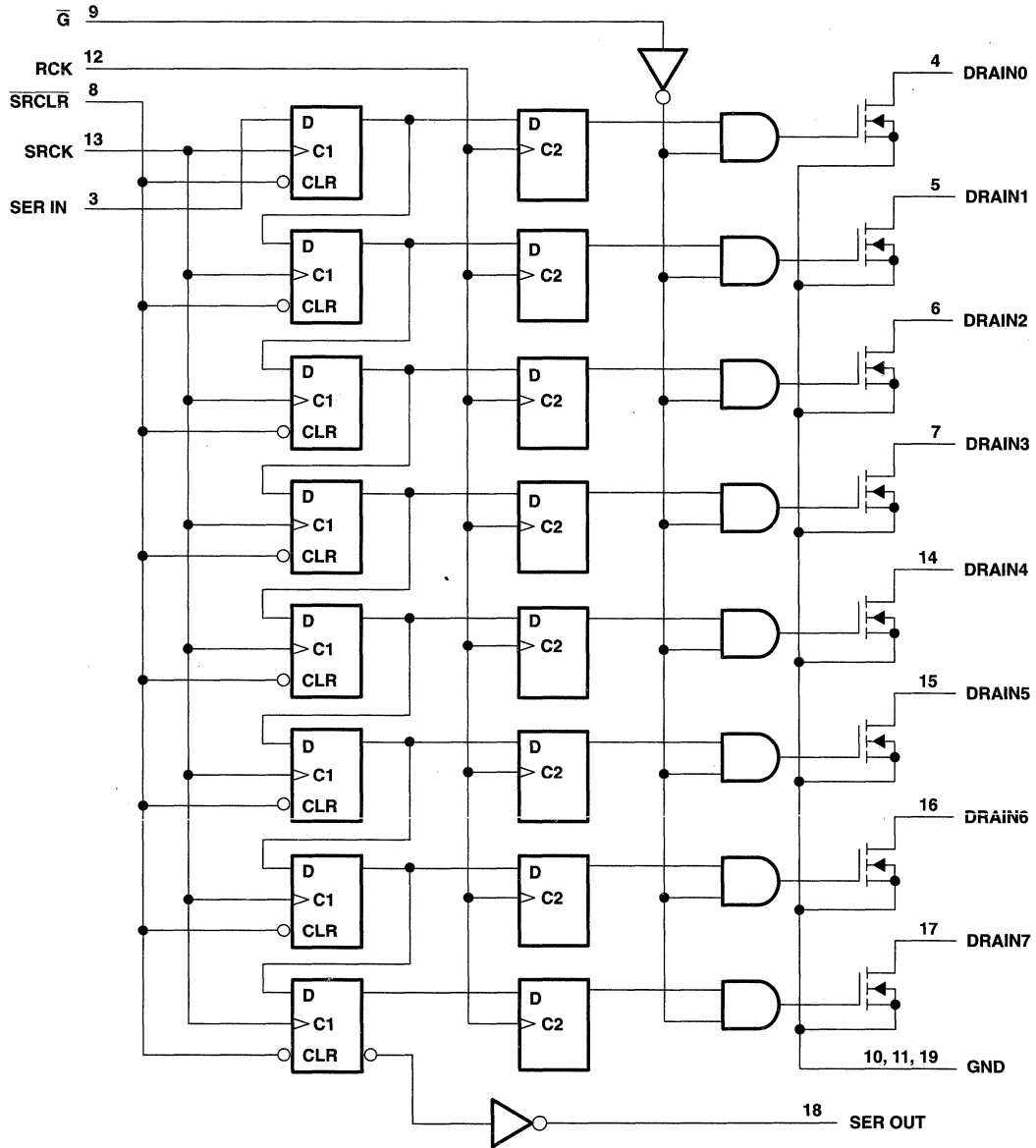


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

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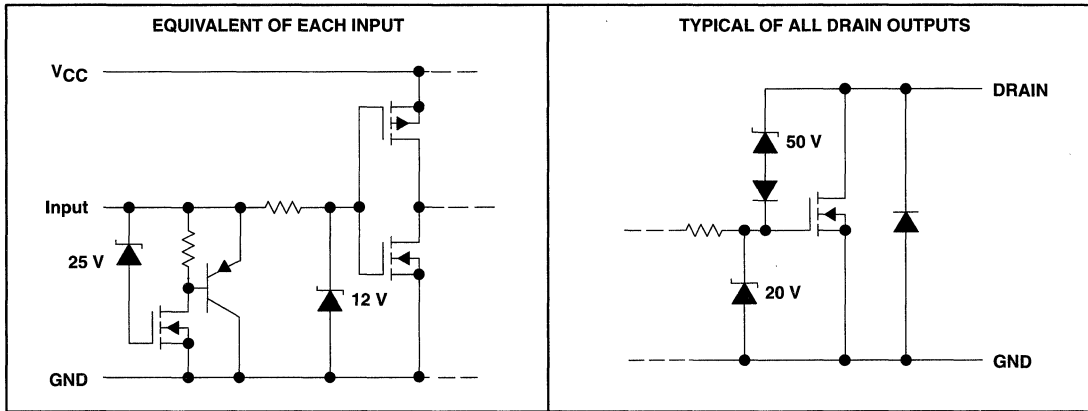
## logic diagram (positive logic)



# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

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## schematic of inputs and outputs



## absolute maximum ratings over recommended operating case temperature range (unless otherwise noted)†

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 2)	50 V
Continuous source-to-drain diode anode current	500 mA
Pulsed source-to-drain diode anode current (see Note 3)	1 A
Pulsed drain current, each output, all outputs on, $I_D, T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Continuous drain current, each output, all outputs on, $I_D, T_C = 25^\circ\text{C}$	150 mA
Peak drain current single output, $I_{DM}, T_C = 25^\circ\text{C}$ (see Note 3)	500 mA
Single-pulse avalanche energy, $E_{AS}$ (see Figure 4)	30 mJ
Avalanche current, $I_{AS}$ (see Note 4)	500 mA
Continuous total dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, $T_J$	-40°C to 150°C
Operating case temperature range, $T_C$	-40°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 are with respect to GND.  
 2. Each power DMOS source is internally connected to GND.  
 3. Pulse duration  $\leq 100 \mu\text{s}$  and duty cycle  $\leq 2\%$ .  
 4. DRAIN supply voltage = 15 V, starting junction temperature ( $T_{JS}$ ) = 25°C,  $L = 200 \text{ mH}$ ,  $I_{AS} = 0.5 \text{ A}$  (see Figure 4).

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
DW	1389 mW	11.1 mW/°C	278 mW
N	1050 mW	10.5 mW/°C	263 mW



# TPIC6B595

## POWER LOGIC 8-BIT SHIFT REGISTER

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### recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$		V
Low-level input voltage, $V_{IL}$	0.15 $V_{CC}$		V
Pulsed drain output current, $T_C = 25^\circ\text{C}$ , $V_{CC} = 5\text{ V}$ (see Notes 3 and 5)	-500	500	mA
Setup time, SER IN high before SRCK $\uparrow$ , $t_{SU}$ (see Figure 2)	20		ns
Hold time, SER IN high after SRCK $\uparrow$ , $t_H$ (see Figure 2)	20		ns
Pulse duration, $t_W$ (see Figure 2)	40		ns
Operating case temperature, $T_C$	-40	125	$^\circ\text{C}$

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT		
$V_{(BR)DSX}$	Drain-to-source breakdown voltage $I_D = 1\text{ mA}$	50			V		
$V_{SD}$	Source-to-drain diode forward voltage $I_F = 100\text{ mA}$	0.85			1	V	
$V_{OH}$	High-level output voltage, SER OUT $I_{OH} = -20\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4.4	4.49		V		
	$I_{OH} = -4\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4	4.2				
$V_{OL}$	Low-level output voltage, SER OUT $I_{OL} = 20\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	0.005			0.1	V	
	$I_{OL} = 4\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	0.3					0.5
$I_{IH}$	High-level input current $V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$				1	$\mu\text{A}$	
$I_{IL}$	Low-level input current $V_{CC} = 5.5\text{ V}$ , $V_I = 0$				-1	$\mu\text{A}$	
$I_{CC}$	Logic supply current $V_{CC} = 5.5\text{ V}$	All outputs off		20	100	$\mu\text{A}$	
		All outputs on		150	300		
$I_{CC}(\text{FRQ})$	Logic supply current at frequency $f_{SRCK} = 5\text{ MHz}$ , $C_L = 30\text{ pF}$ , All outputs off, See Figures 2 and 6	0.4			5	mA	
$I_N$	Nominal current $V_{DS(\text{on})} = 0.5\text{ V}$ , $I_N = I_D$ , $T_C = 85^\circ\text{C}$ See Notes 5, 6, and 7	90				mA	
$I_{DSX}$	Off-state drain current $V_{DS} = 40\text{ V}$ , $V_{CC} = 5.5\text{ V}$	0.1			5	$\mu\text{A}$	
		0.15			8		
$r_{DS(\text{on})}$	Static drain-source on-state resistance $I_D = 100\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	4.2			5.7	$\Omega$	
		See Notes 5 and 6 and Figures 7 and 8	6.8				9.5
			5.5				8

- NOTES: 3. Pulse duration  $\leq 100\ \mu\text{s}$  and duty cycle  $\leq 2\%$ .  
 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.  
 6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.  
 7. Nominal current is defined for a consistent comparison between devices from different sources. It is the current that produces a voltage drop of  $0.5\text{ V}$  at  $T_C = 85^\circ\text{C}$ .



# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

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## switching characteristics, $V_{CC} = 5\text{ V}$ , $T_C = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output from $\bar{G}$	$C_L = 30\text{ pF}$ , $I_D = 100\text{ mA}$ , See Figures 1, 2, and 9		150		ns
$t_{PHL}$ Propagation delay time, high-to-low-level output from $\bar{G}$			90		ns
$t_r$ Rise time, drain output			200		ns
$t_f$ Fall time, drain output			200		ns
$t_a$ Reverse-recovery-current rise time	$I_F = 100\text{ mA}$ , $di/dt = 20\text{ A}/\mu\text{s}$ , See Notes 5 and 6 and Figure 3		100		ns
$t_{rr}$ Reverse-recovery time			300		

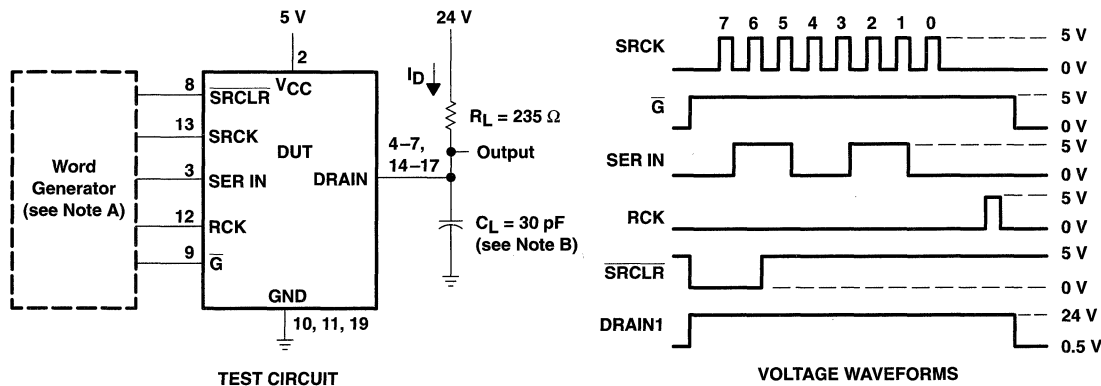
NOTES: 5. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

## thermal resistance

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JA}$ Thermal resistance, junction-to-ambient	DW package		90	$^\circ\text{C}/\text{W}$
	N package	All 8 outputs with equal power	95	

## PARAMETER MEASUREMENT INFORMATION



NOTES: A. The word generator has the following characteristics:  $t_r \leq 10\text{ ns}$ ,  $t_f \leq 10\text{ ns}$ ,  $t_w = 300\text{ ns}$ , pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50\ \Omega$ .

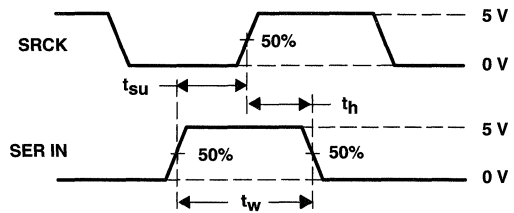
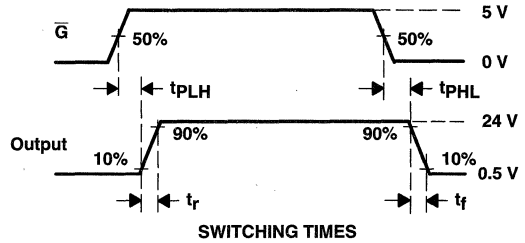
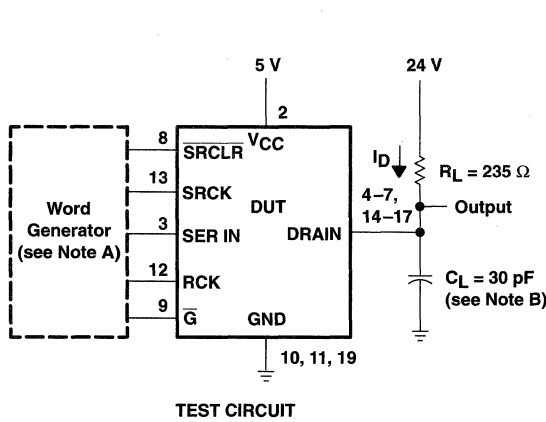
B.  $C_L$  includes probe and jig capacitance.

**Figure 1. Resistive-Load Test Circuit and Voltage Waveforms**

# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

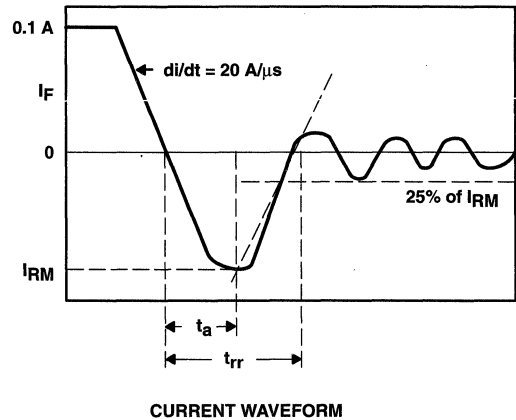
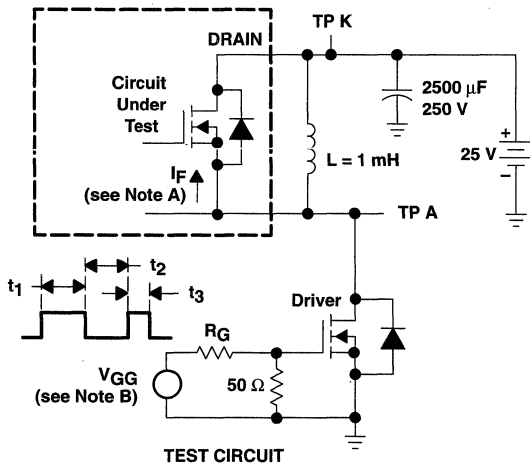
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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50$   $\Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

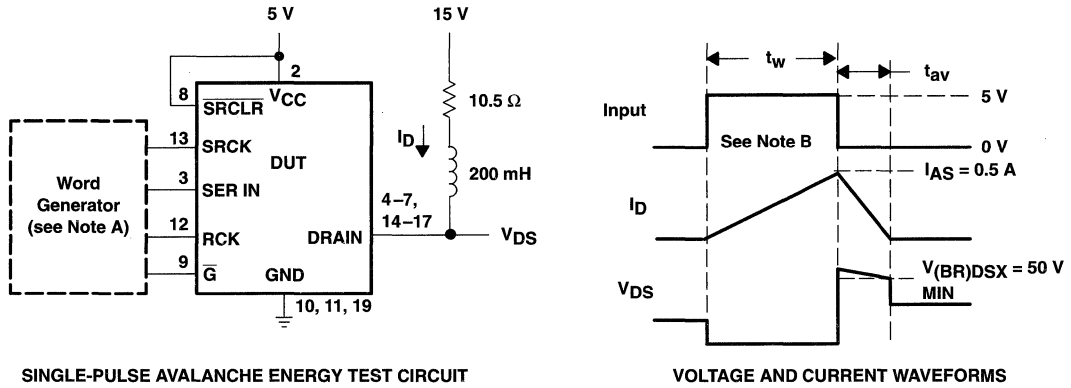
Figure 2. Test Circuit, Switching Times, and Voltage Waveforms



- NOTES: A. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.  
B. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 20$  A/ $\mu$ s. A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.1$  A, where  $t_1 = 10$   $\mu$ s,  $t_2 = 7$   $\mu$ s, and  $t_3 = 3$   $\mu$ s.

Figure 3. Reverse-Recovery-Current Test Circuit and Waveforms of Source-to-Drain Diode

PARAMETER MEASUREMENT INFORMATION



SINGLE-PULSE AVALANCHE ENERGY TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration,  $t_w$ , is increased until peak current  $I_{AS} = 0.5$  A.  
 Energy test level is defined as  $E_{AS} = I_{AS} \times V_{(BR)DSX} \times t_{av}/2 = 30$  mJ.

Figure 4. Single-Pulse Avalanche Energy Test Circuit and Waveforms

TYPICAL CHARACTERISTICS

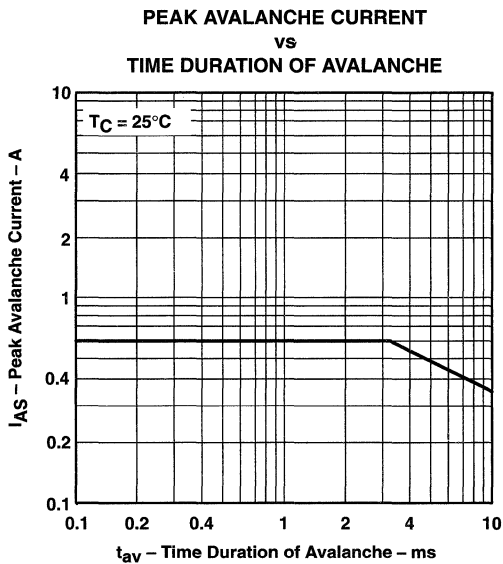


Figure 5

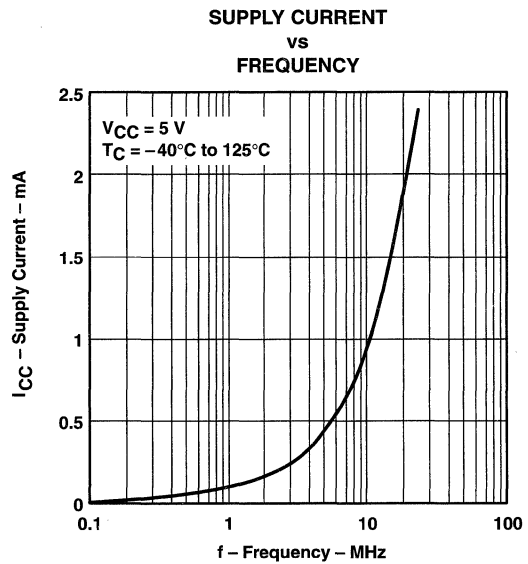


Figure 6

# TPIC6B595 POWER LOGIC 8-BIT SHIFT REGISTER

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## TYPICAL CHARACTERISTICS

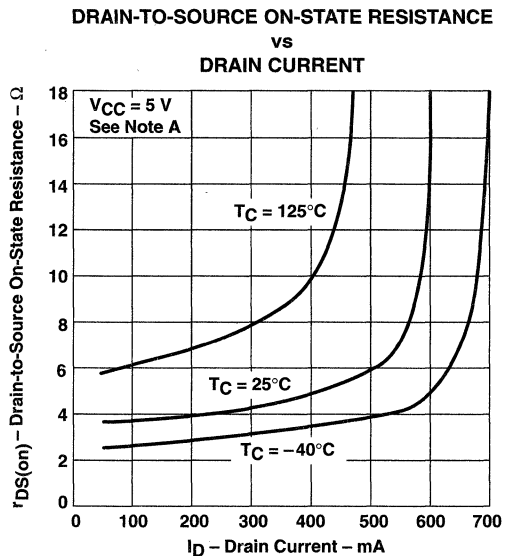


Figure 7

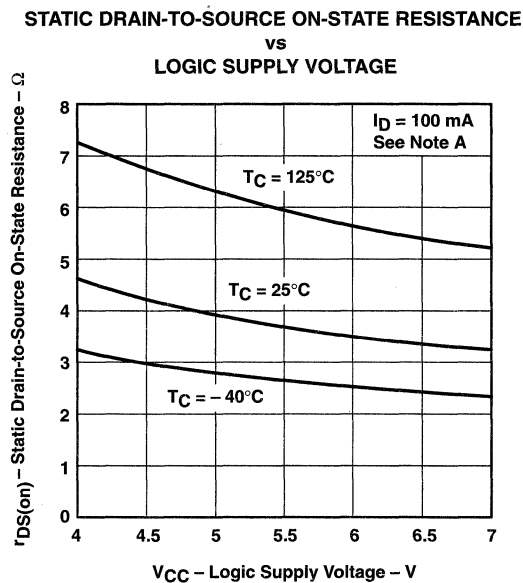


Figure 8

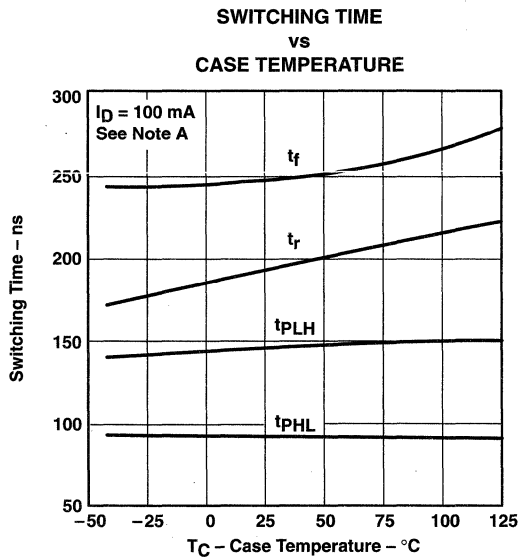


Figure 9

NOTE C. Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

THERMAL INFORMATION

MAXIMUM CONTINUOUS  
DRAIN CURRENT OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

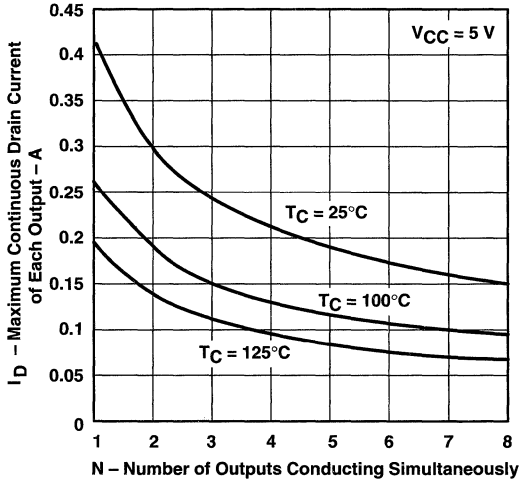


Figure 10

MAXIMUM PEAK DRAIN CURRENT  
OF EACH OUTPUT  
vs  
NUMBER OF OUTPUTS CONDUCTING  
SIMULTANEOUSLY

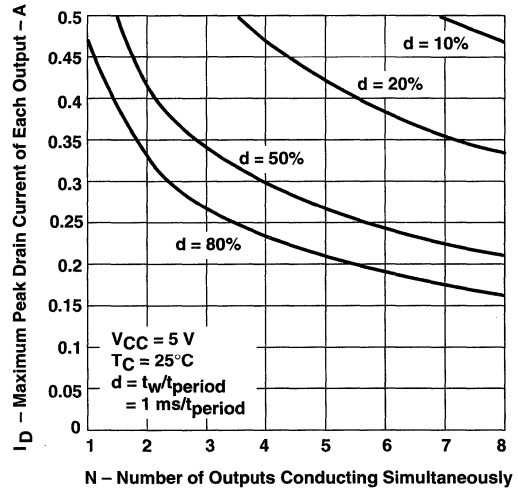


Figure 11



**TPIC6E175**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**QUAD D-TYPE LATCH**

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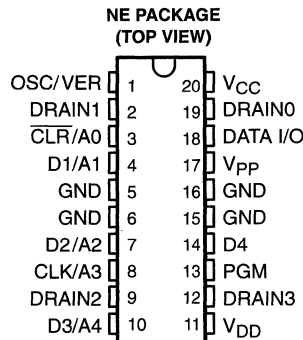
- Programmable-PWM Current Threshold
- Programmable-PWM Frequency Controlled by Internal or External Oscillator
- Integrated Output Recirculation Clamp Diodes
- Low  $r_{DS(on)}$  . . . 1  $\Omega$  Typ
- Four Power MOSFET Outputs
- Integrated Snubbing Clamp Voltage at 40 V
- Low Power Consumption

**description**

The power logic quad D-type latch pulse-width-modulation (PWM) driver controls open-drain DMOS transistor outputs and is designed for applications that require relatively high power. The device contains a built-in snubbing clamp and recirculation clamp on the outputs for inductive transient protection and inductive energy recirculation respectively. Power driver applications include solenoids and other medium-current or high-voltage loads. Each open-drain DMOS transistor features an independent user-programmable PWM circuit that works in conjunction with the recirculation clamping diode in order to control the average current in inductive-load applications. The PWM circuit provides a programmable current-limit threshold that disables the output until the next rising edge of the independent PWM programmable clock. Each clock is generated from a user-programmable internal or external clock reference that in turn is programmed independently for each output through a frequency divide-by circuit.

User-programmable functions are controlled through 32 EEPROM bits. These bits are programmed by placing the TPIC6E175 into program mode by taking PGM high. The address to be programmed is then set up on dual functionality terminals A0–A4 (see Tables 1 and 2). The data bit to be programmed is set up on DATA I/O, and  $V_{PP}$  is then ramped from  $V_{CC}$  to  $V_{PPH}$  and back to  $V_{CC}$  to program the bit. The programming data can then be verified by taking VER high while monitoring DATA I/O, which gives the value of the data at the address selected on A0–A4. For each user-programmable parameter, Table 3 shows the binary programming values and the option selected by each programming value.

The TPIC6E175 contains four positive-edge-triggered D-type flip-flops with direct clear input. Each flip-flop features an open-drain power DMOS-transistor output.



TERMINAL NOMENCLATURE	
OSC/VER	Oscillator/Verify
DRAIN0 – DRAIN3	Drain Output 0 to 3
CLR/A0	Clear/Address 0
D1/A1	Data 1/Address 1
GND	Ground
D2/A2	Data 2/Address 2
D3/A4	Data 3/Address 4
D4	Data 4
VCC	Logic Supply Voltage
DATA I/O	Program Data Input/Output
VPP	Programming Supply Voltage
PGM	Program Enable
VDD	Output Supply Voltage
CLK/A3	Clock/Address 3

**FUNCTION TABLE  
(each channel)**

INPUTS			OUTPUT DRAIN
CLR	CLK	D	
L	X	X	H
H	↑	H	L
H	↑	L	H
H	L	X	Latched

H = high level, L = low level, X = irrelevant

**PRODUCT PREVIEW**



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**description (continued)**

When clear ( $\overline{\text{CLR}}$ ) is high, information at the D inputs meeting the setup time requirements, is transferred to the DRAIN outputs on the positive-going edge of the clock (CLK) pulse. Clock triggering occurs at a particular voltage level and is not directly related to the transition time of the positive-going pulse. When the clock input (CLK) is at either the high or low level, the D input signal has no effect at the output. An asynchronous  $\overline{\text{CLR}}$  is provided to turn all four DMOS-transistor outputs off. When data is low for a given output, the DMOS-transistor output is off. When data is high, the DMOS-transistor output has sink-current capability.

For proper operation,  $V_{\text{DD}}$  must be connected to a voltage source equal to or greater than the maximum drain voltage in the application.

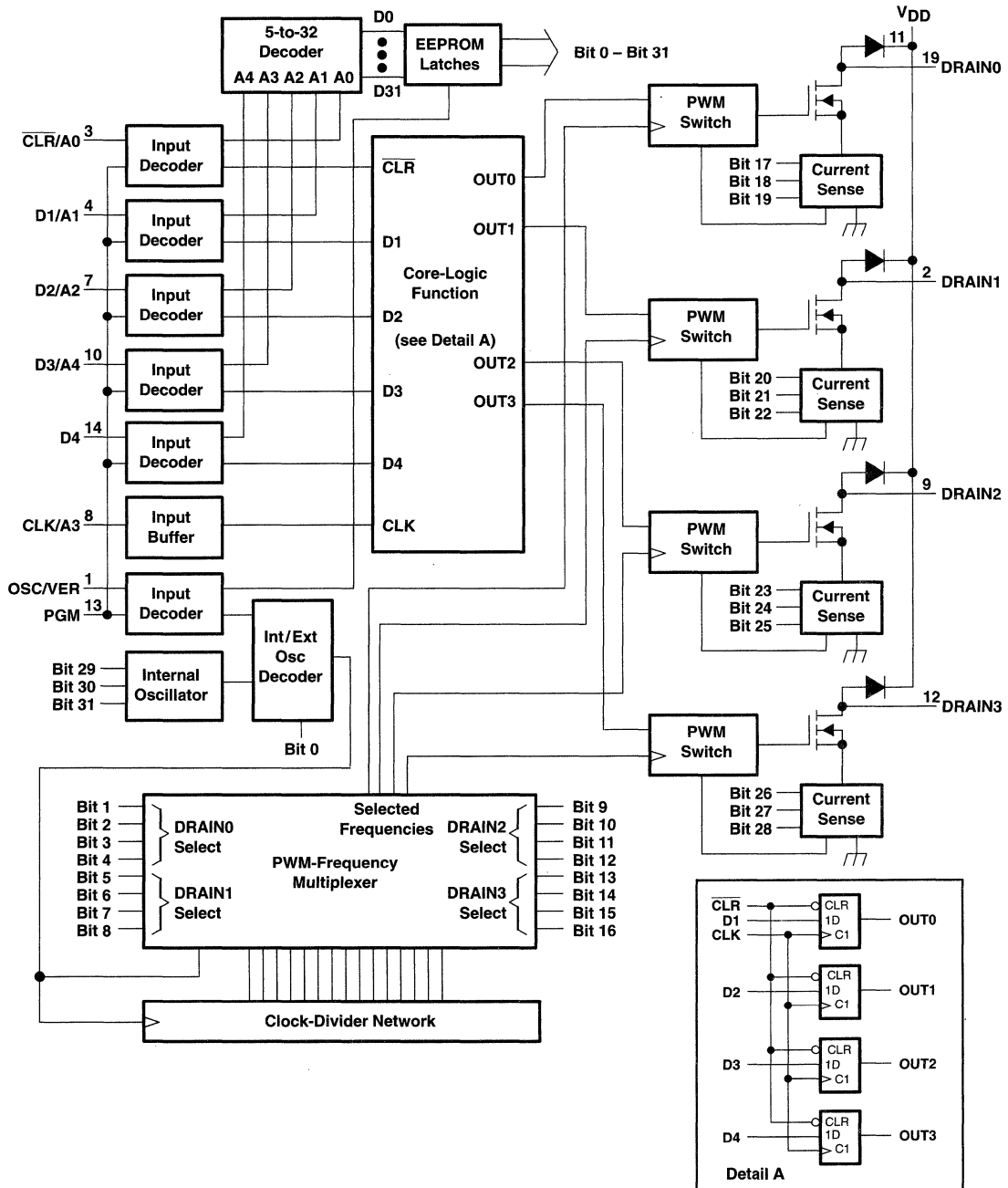
The TPIC6E175 is offered in a 20-pin thermally-enhanced dual-in-line (NE) package and is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**PRODUCT PREVIEW**



**TPIC6E175**  
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functional block diagram

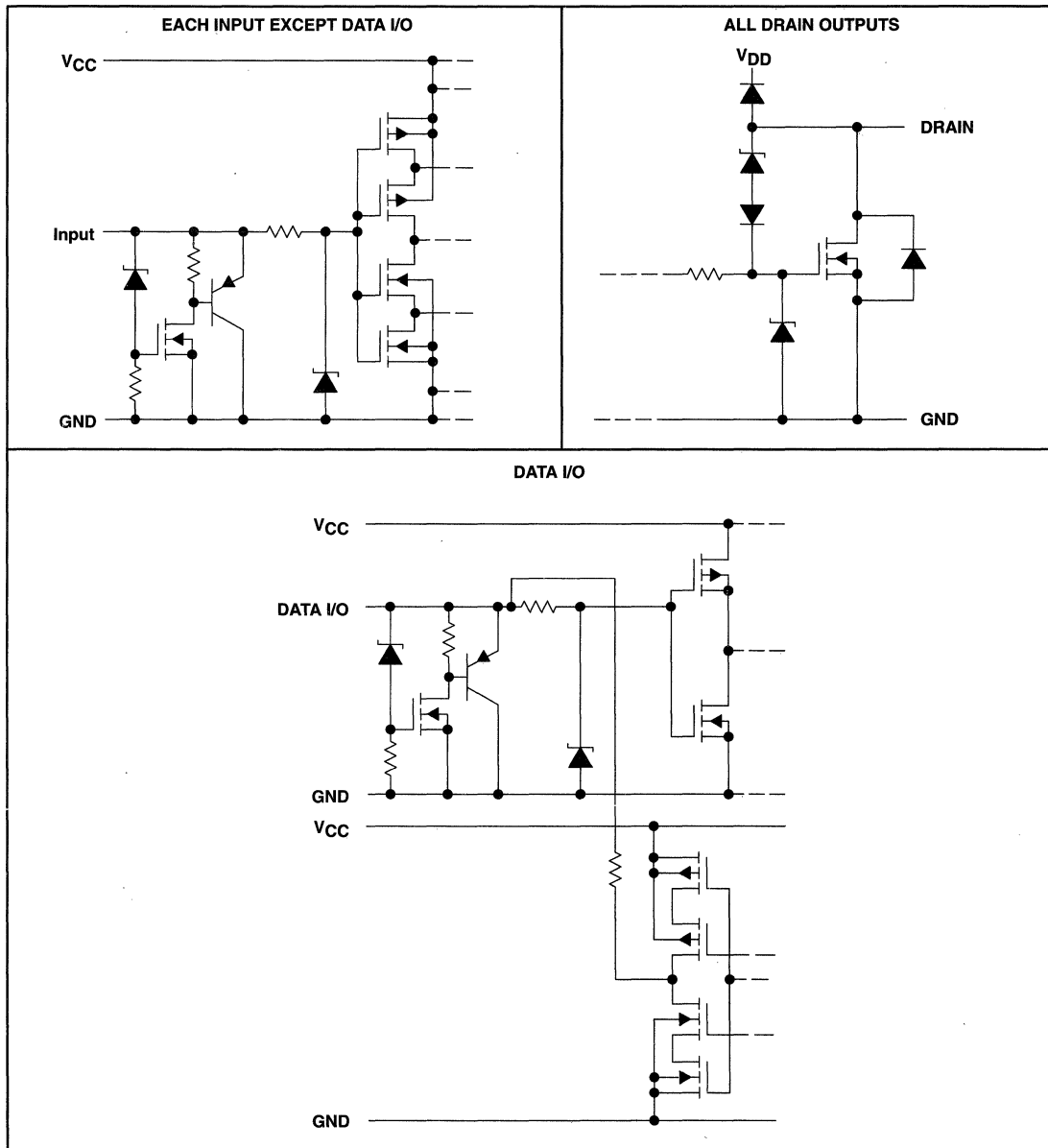


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**QUAD D-TYPE LATCH**

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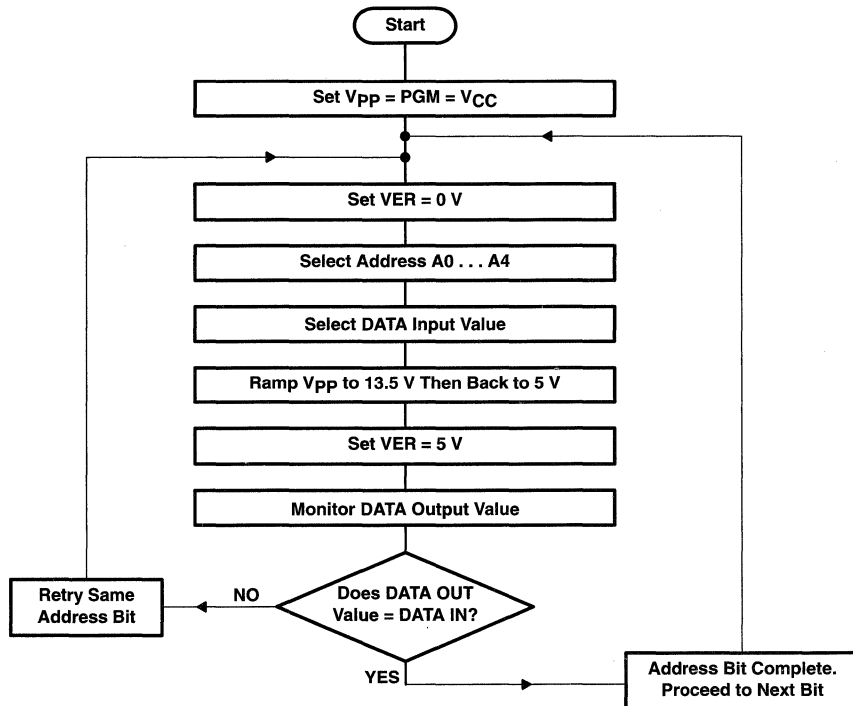
**equivalent inputs and outputs**



**PRODUCT PREVIEW**

**Terminal Functions**

TERMINAL NAME	NO.	I/O	DESCRIPTION
DATA I/O	18	I/O	Programming data input/output
DRAIN0	19	O	Drain outputs 0–3
DRAIN1	2		
DRAIN2	9		
DRAIN3	12		
D2/A2	7	I	Data 2 or Address 2
GND	5, 6, 15, 16	—	Ground
OSC/VER	1	I	Oscillator or Programming verify
PGM	13	I	Program enable
D3/A4	10	I	Data 3 or Address 4
CLR/A0	3	I	Clear or Address 0
CLK/A3	8	O	Clock or Address 3
D1/A1	4	I	Data 1 or Address 1
D4	14	I	Data 4
V <sub>CC</sub>	20	—	Logic supply voltage
V <sub>DD</sub>	11	—	Output supply voltage
V <sub>PP</sub>	17	—	Programming supply voltage



**Figure 1. Recommended EEPROM Programming Sequence**

**PRODUCT PREVIEW**

**TPIC6E175**  
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**Table 1. Function Selection for Dual-Functionality Terminals**

TERMINAL NUMBER	NORMAL MODE (PGM = L)	PROGRAM MODE (PGM = H)
1	OSC	VER
3	CLR	A0
4	D1	A1
7	D2	A2
8	CLK	A3
10	D3	A4

H = high level, L = low level

**Table 2. EEPROM Bit Description**

BIT		USER-PROGRAMMABLE PARAMETER	DESCRIPTION†
NO.	ADDRESS		
0	00000	Internal/External Oscillator	Selects internal or external oscillator to be used for PWM clock
1 (LSB)	00001	DRAIN0 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
2	00010		
3	00011		
4 (MSB)	00100		
5 (LSB)	00101	DRAIN1 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
6	00110		
7	00111		
8 (MSB)	01000		
9 (LSB)	01001	DRAIN2 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
10	01010		
11	01011		
12 (MSB)	01100		
13 (LSB)	01101	DRAIN3 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
14	01110		
15	01111		
16 (MSB)	10000		
17 (LSB)	10001	DRAIN0 Current Sense Adjust	Selects the peak current for the PWM-chop mode
18	10010		
19 (MSB)	10011		
20 (LSB)	10100	DRAIN1 Current Sense Adjust	Selects the peak current for the PWM-chop mode
21	10101		
22 (MSB)	10110		
23 (LSB)	10111	DRAIN2 Current Sense Adjust	Selects the peak current for the PWM-chop mode
24	11000		
25 (MSB)	11001		
26 (LSB)	11010	DRAIN3 Current Sense Adjust	Selects the peak current for the PWM-chop mode
27	11011		
28 (MSB)	11100		
29 (LSB)	11101	Oscillator Frequency Adjust	Selects the frequency of the internal oscillator
30	11110		
31 (MSB)	11111		

† See Table 3

PRODUCT PREVIEW



**Table 3. EEPROM Programming Values**

PROGRAMMABLE PARAMETER	OPTION SELECTED	BINARY VALUE MSB<...>LSB
Internal/External Oscillator	Internal Oscillator	0
	External Oscillator	1
Frequency Multiplexer for All Drain Outputs	Oscillator ÷ 1	0000
	Oscillator ÷ 2	0001
	Oscillator ÷ 4	0010
	Oscillator ÷ 8	0011
	Oscillator ÷ 16	0100
	Oscillator ÷ 32	0101
	Oscillator ÷ 64	0110
	Oscillator ÷ 128	0111
	Oscillator ÷ 256	1000
	Oscillator ÷ 512	1001
	Oscillator ÷ 1024	1010
	Oscillator ÷ 2048	1011
	Oscillator ÷ 4096	1100
	Oscillator ÷ 8192	1101
	Oscillator ÷ 16384	1110
Oscillator ÷ 32768	1111	
Current Sense Adjust for All Drain Outputs	300 mA†	000
	400 mA†	001
	500 mA†	010
	600 mA†	011
	700 mA†	100
	800 mA†	101
	900 mA†	110
	1000 mA†	111
Oscillator Frequency Adjust	Internal Oscillator, Frequency = 1.2 MHz	000
	Internal Oscillator, Frequency = 1.1 MHz	001
	Internal Oscillator, Frequency = 0.9 MHz	010
	Internal Oscillator, Frequency = 0.8 MHz	011
	Internal Oscillator, Frequency = 0.6 MHz	100
	Internal Oscillator, Frequency = 0.5 MHz	101
	Internal Oscillator, Frequency = 0.3 MHz	110
	Internal Oscillator, Frequency = 0.1 MHz	111

† Current target ±20%

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Output supply voltage, $V_{DD}$ (see Note 1)	40 V
Programming supply voltage during programming, $V_{PP}$ (see Notes 1 and 2)	16 V
Programming supply voltage, verify/normal operation, $V_{PP}$	7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 3)	40 V
Continuous source-to-drain diode current	1 A
Pulsed source-to-drain diode current (see Note 3)	1 A
PWM output current, each output, all outputs on, $I_{O(PWM)}$ , $T_A = 25^\circ\text{C}$ , $d = 10\%$ (see Note 4 and Figure 10)	900 mA
PWM output current, each output, all outputs on, $I_{O(PWM)}$ , $T_A = 25^\circ\text{C}$ , $d = 50\%$ (see Note 4 and Figure 9)	800 mA
Peak drain current, single output, $I_{D(PWM)}$ , $T_A = 25^\circ\text{C}$ (see Notes 3 and 4)	1 A
Avalanche current, $I_{(AV)}$ (see Note 5 and Figure 7)	1 A
Single-pulse avalanche energy, $E_A$ (see Note 5 and Figure 7)	100 mJ
Continuous total power dissipation	See Dissipation Rating Table
Operating case temperature range, $T_C$	-40°C to 125°C
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to GND.
  2. For programming waveform, see Figure 2.
  3. Each power DMOS source is internally connected to GND. Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$ .
  4. Output current depends upon program current-sense adjust and load conditions.
  5.  $V_{supply} = 24 \text{ V}$ , starting junction temperature,  $(T_{JS}) = 25^\circ\text{C}$ ,  $L = 87 \text{ mH}$ ,  $I_{AS} = 1 \text{ A}$ .

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	OPERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
NE	2775 mW	20 mW/°C	775 mW
NE on FR-4 PCB	4163 mW	33.3 mW/°C	833 mW

**recommended operating conditions**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
Output supply voltage, $V_{DD}$		40	V
Programming supply voltage during programming, $V_{PP}$	12	15	V
Programming supply voltage during verify or normal operation, $V_{PP}$	$V_{CC} - 0.7$	$V_{CC}$	V
High-level input voltage, $V_{IH}$	$0.85 V_{CC}$	$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	$0.15 V_{CC}$	V
Operating case temperature, $T_C$	-40	125	°C

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-source breakdown voltage	$I_D = 1\text{ mA}$	40			V
$V_{SD}$	Source-drain diode forward voltage	$I_F = 1\text{ A}$		1	1.5	V
$V_{OH}(\text{DATA I/O})$	High-level data output voltage	$I_{OH} = -100\text{ }\mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4.25	4.48		V
$V_{OL}(\text{DATA I/O})$	Low-level data output voltage	$I_{OL} = 100\text{ }\mu\text{A}$ , $V_{CC} = 4.5\text{ V}$		200	250	mV
$V_f$	Forward clamp voltage	$I_f = 1\text{ A}$		1.35	2	V
$I_{IH}$	High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$	Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$	Logic supply current	$I_O = 0$ , All inputs low		1.6	5	mA
$I_{CC}(\text{freq})$	Logic supply current at frequency	SRCK = 5 MHz, $I_O = 0$		5.5		mA
$I_{DS}$	Off-state drain current	$V_{DD} = 40\text{ V}$ , $V_{DS} = 35\text{ V}$		0.2	1	$\mu\text{A}$
		$V_{DD} = 40\text{ V}$ , $V_{DS} = 30\text{ V}$ , $T_C = 125^\circ\text{C}$		1	5	
$r_{DS}(\text{on})$	Static drain-to-source on-state resistance	$I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1	1.5	$\Omega$
		$I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$ , $T_C = 125^\circ\text{C}$		1.6	2.4	
		$I_D = 750\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.1	1.75	

**timing requirements over recommended ranges of supply voltage and operating case temperature**

		MIN	MAX	UNIT
$t_{su}$	Setup time, D high before CLK $\uparrow$ (see Figure 5)	20		ns
$t_{su1}$	Setup time, VER to PGM (see Figure 2)	2		$\mu\text{s}$
$t_{su2}$	Setup time, address and DATA I/O to $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_{su3}$	Setup time, PGM to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{su4}$	Setup time, PGM to address (see Figure 2)	2		$\mu\text{s}$
$t_h$	Hold time, D high before CLK $\uparrow$ (see Figure 5)	20		ns
$t_{h1}$	PGM hold time, DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{h2}$	Hold time, DATA I/O after $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_w$	Pulse duration (see Figure 5)	40		ns
$t_{w1}$	Pulse duration, $V_{pp}$ program (see Figure 2)	5		ms
$t_{pd}$	Propagation delay, VER to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_r$	Rise time, $V_{pp}$ during programming (see Figure 2)	2	3	ms
$t_f$	Fall time, $V_{pp}$ during programming (see Figure 2)	2	3	ms

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from CLK	$C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ , See Figure 5		650		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from CLK			150		ns
$t_{r1}$	Rise time, drain output (see Figure 5)			750		ns
$t_{f1}$	Fall time, drain output (see Figure 5)			425		ns
$t_{rr}$	Reverse-recovery time (see Figure 6)	$I_F = 250\text{ mA}$ , $di/dt = 40\text{ A}/\mu\text{s}$		300		ns
$t_{rra}$	Reverse-recovery current rise time (see Figure 6)			100		ns

**PRODUCT PREVIEW**





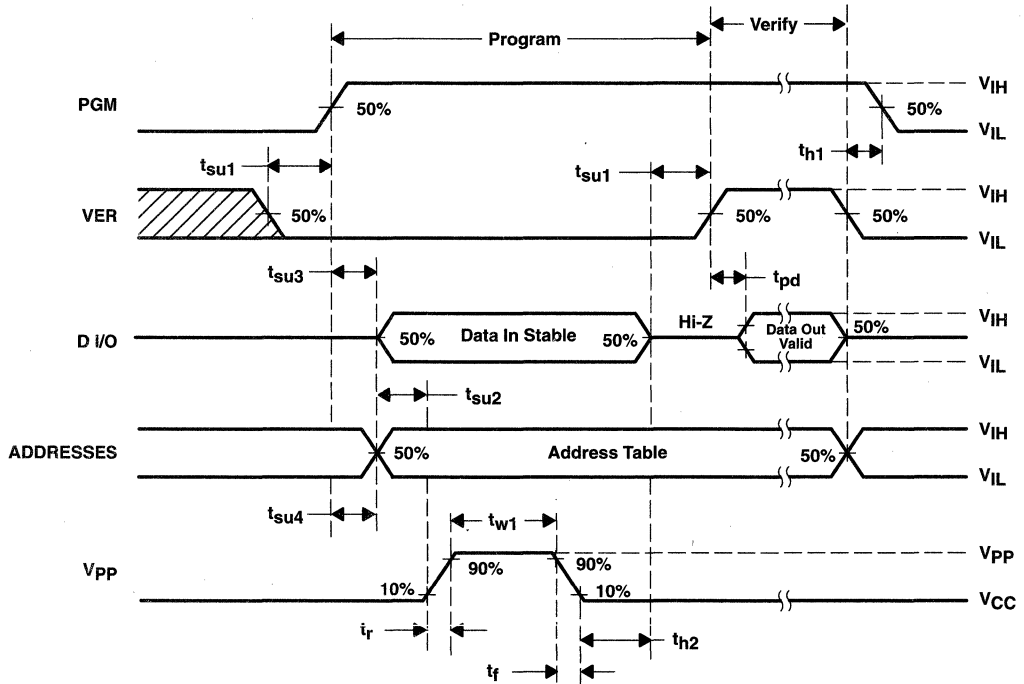
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**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JC}$	Thermal resistance, junction-to-case		8.3	°C/W
$R_{\theta JA}$	Thermal resistance, junction-to-ambient		50	

**PARAMETER MEASUREMENT INFORMATION**

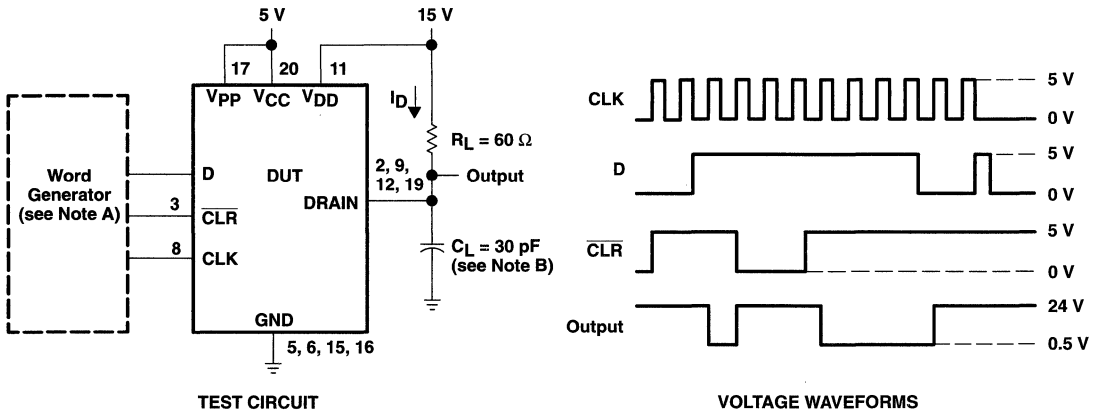


**Figure 2. Programming Waveforms**

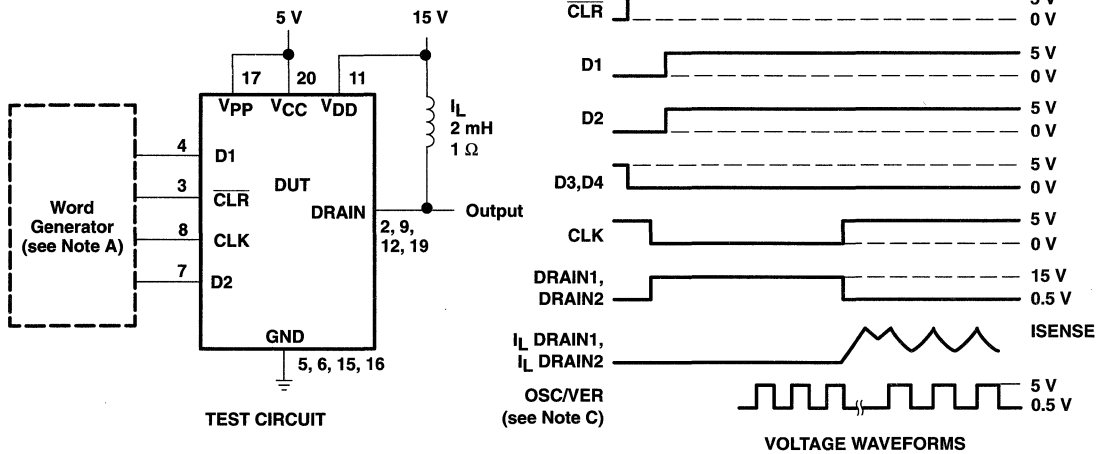
**PRODUCT PREVIEW**



**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Resistive Load Operation**



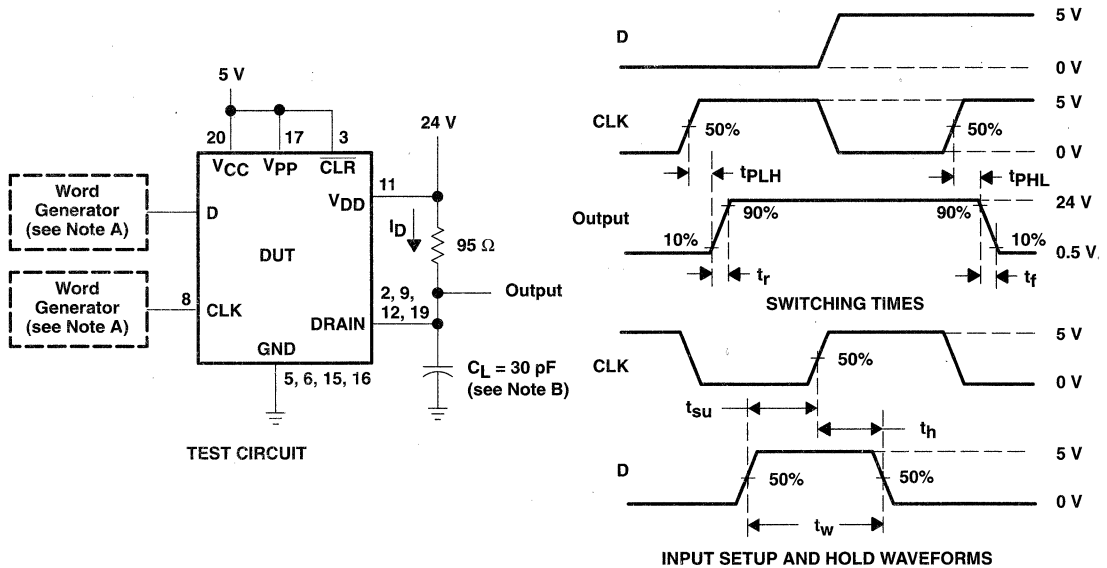
**Figure 4. Inductor Load Operation**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_0 = 50 \Omega$ .
- B.  $C_L$  includes probe and jig capacitance.
- C. DRAIN0 and DRAIN3 remain at 15 V with  $0_A I_L$ .

**PRODUCT PREVIEW**

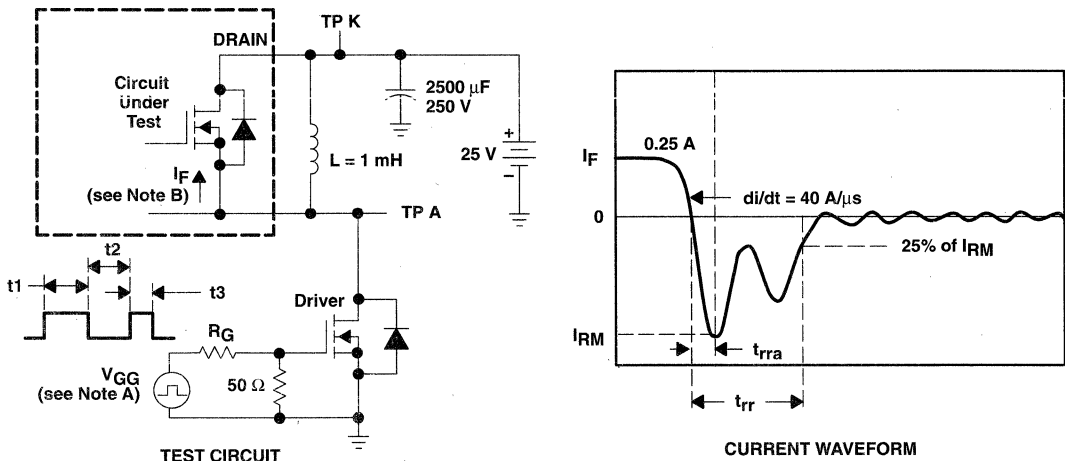
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**PARAMETER MEASUREMENT**



NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

**Figure 5. Test Circuit and Voltage Waveforms, Switching Times**

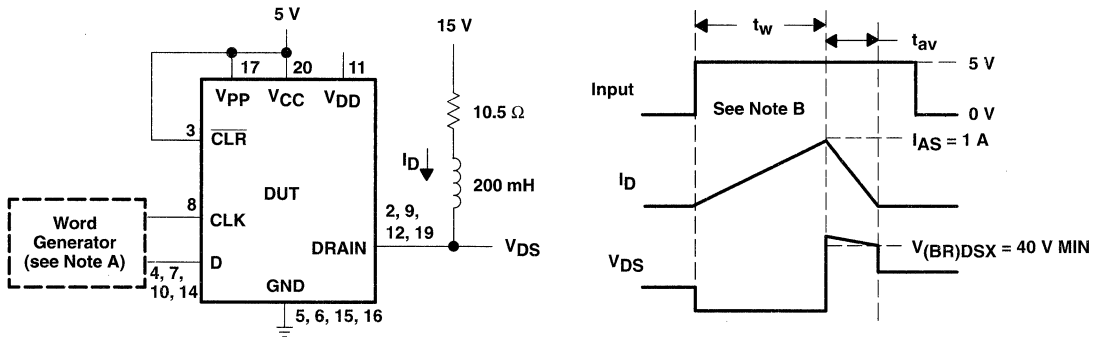


NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 40$  A/ $\mu$ s. A  $V_{GG}$  double-pulse train sets  $I_F = 0.25$  A, where  $t_1 = 15 \mu$ s,  $t_2 = 8.5 \mu$ s, and  $t_3 = 3.5 \mu$ s.  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

**Figure 6. Reverse-Recovery-Current Test Circuit and Waveform of Source Drive Device**

**PRODUCT PREVIEW**

**PARAMETER MEASUREMENT INFORMATION**



**SINGLE-PULSE AVALANCHE-ENERGY TEST CIRCUIT**

**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is controlled by the value of peak current  $I_{AS} = 1$  A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 100$  mJ,  
 where  $t_{av}$  = avalanche time.

**Figure 7. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**PRODUCT PREVIEW**

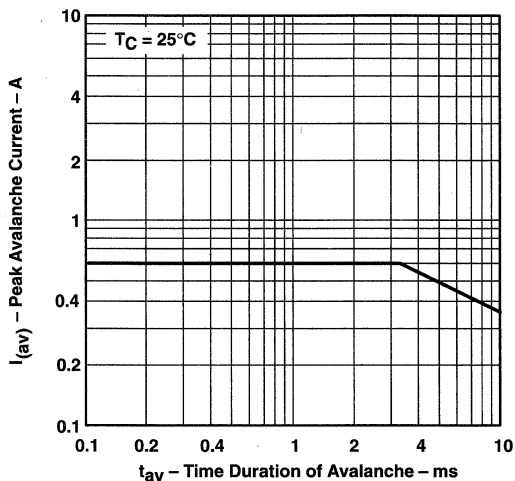
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**TYPICAL CHARACTERISTICS**

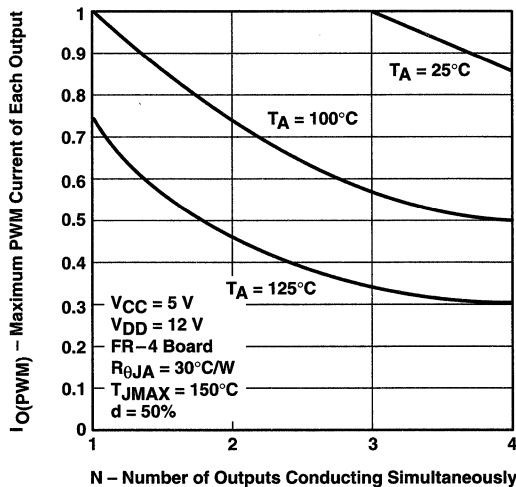
**PRODUCT PREVIEW**

**PEAK AVALANCHE CURRENT**  
**vs**  
**TIME DURATION OF AVALANCHE**



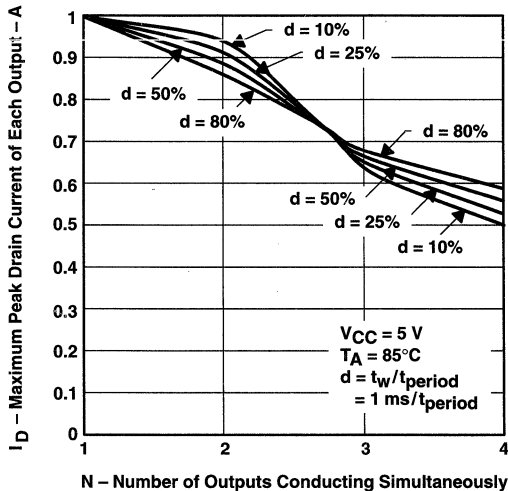
**Figure 8**

**MAXIMUM PWM**  
**CURRENT OF EACH OUTPUT**  
**vs**  
**NUMBER OF OUTPUTS CONDUCTING**  
**SIMULTANEOUSLY**



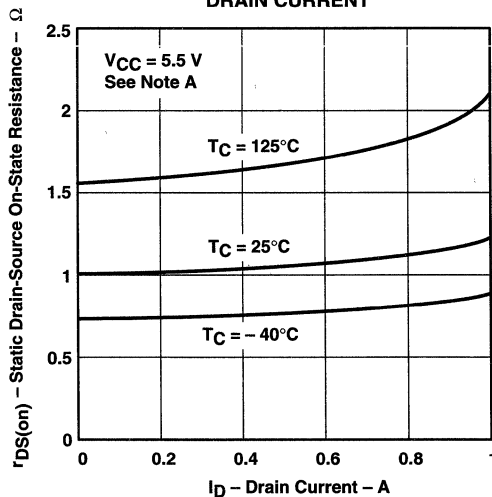
**Figure 9**

**MAXIMUM PEAK DRAIN CURRENT OF EACH OUTPUT**  
**vs**  
**NUMBER OF OUTPUTS CONDUCTING**  
**SIMULTANEOUSLY**



**Figure 10**

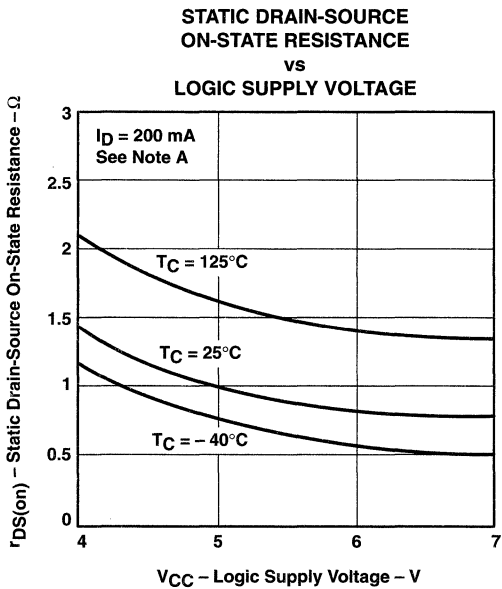
**STATIC DRAIN-SOURCE**  
**ON-STATE RESISTANCE**  
**vs**  
**DRAIN CURRENT**



NOTE A. Technique should limit  $T_J - T_C$  to 10°C maximum.

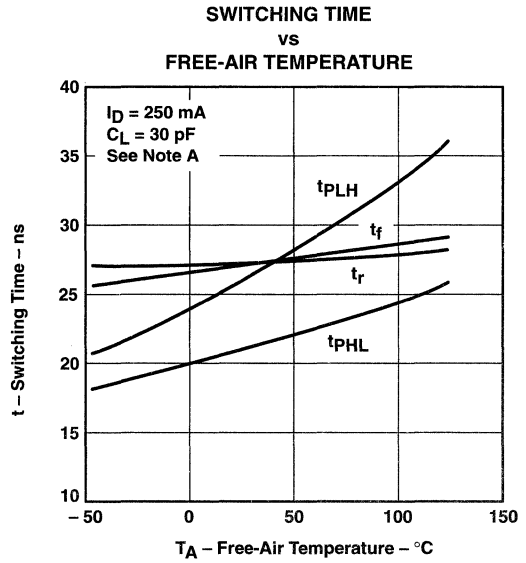
**Figure 11**

**TYPICAL CHARACTERISTICS**



NOTE A: Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

**Figure 12**



**Figure 13**

**PRODUCT PREVIEW**



# TPIC6E261 POWER LOGIC EEPROM-PROGRAMMABLE 4-BIT ADDRESSABLE LATCH

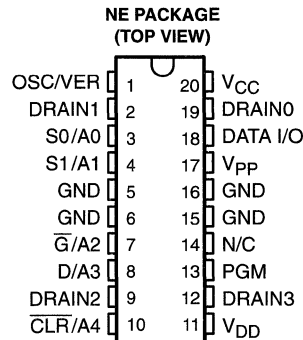
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- Programmable-PWM Current Threshold
- Programmable-PWM Frequency Controlled by Internal or External Oscillator
- Integrated Output Recirculation Clamp Diodes
- Low  $r_{DS(on)}$  . . . 1  $\Omega$  Typ
- Four Power MOSFET Outputs
- Integrated Snubbing Clamp Voltage at 40 V
- Low Power Consumption

## description

The power logic 4-bit addressable latch pulse-width-modulation (PWM) driver controls open-drain DMOS transistor outputs and is designed for applications that require relatively high power. The device contains a built-in snubbing clamp and recirculation clamp on the outputs for inductive transient protection and inductive energy recirculation, respectively. Power driver applications include solenoids and other medium-current or high-voltage loads. Each open-drain DMOS transistor features an independent user-programmable PWM circuit that works in conjunction with the recirculation clamping diode in order to control the average current in inductive-load applications. The PWM circuit provides a programmable current-limit threshold that disables the output until the next rising edge of the independent PWM programmable clock. Each clock is generated from a user-programmable internal or external clock reference that in turn is programmed independently for each output through a frequency divide-by circuit.

User-programmable functions are controlled via 32 EEPROM bits. These bits are programmed by placing the TPIC6E261 into program mode by taking PGM high. The address to be programmed is then set up on dual functionality terminals A0–A4 (see Tables 1 and 2). The data bit to be programmed is set up on DATA I/O, and  $V_{PP}$  is then ramped from  $V_{CC}$  to  $V_{PPH}$  and back to  $V_{CC}$  to program the bit. The programming data can then be verified by taking OSC/VER high while monitoring DATA I/O, which gives the value of the data at the address selected on A0–A4. For each user-programmable parameter, Table 3 shows the binary programming values and the option selected by each programming value.



TERMINAL NOMENCLATURE	
OSC/VER	Oscillator/Verify
DRAIN0 – DRAIN3	Drain Output 0 to 3
S0/A0	Select 0/Address 0
S1/A1	Select 1/Address 1
GND	Ground
$\bar{G}/A2$	Function Select/Address 2
D/A3	Data/Address 3
$\bar{C}LR/A4$	Function Select/Address 4
$V_{CC}$	Logic Supply Voltage
DATA I/O	Program Data Input/Output
$V_{PP}$	Programming Supply Voltage
PGM	Program Enable
$V_{DD}$	Output Supply Voltage

FUNCTION TABLE				
INPUTS	OUTPUT OF ADDRESSED DRAIN		EACH OTHER DRAIN	FUNCTION
	CLR	$\bar{G}$ D		
H L H	L		$Q_{i0}$	Addressable Latch
H L L	H		$Q_{i0}$	
H H X			$Q_{i0}$	Memory
L L H	L		H	8-Line Demultiplexer
L L L	H		H	
L H X	H		H	Clear

LATCH SELECTION TABLE		
SELECT INPUTS		DRAIN ADDRESSED
S1	S0	
L	L	0
L	H	1
H	L	2
H	H	3

PRODUCT PREVIEW



**TPIC6E261**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT ADDRESSABLE LATCH**

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**description (continued)**

Four distinct modes of operation are selectable by controlling the clear ( $\overline{\text{CLR}}$ ) and enable ( $\overline{\text{G}}$ ) inputs as enumerated in the function table. In the addressable-latch mode, data at the data-in (D) terminal is written into the addressed latch. The addressed DMOS-transistor output inverts the data input with all unaddressed DMOS-transistor outputs remaining in their previous states. In the memory mode, all DMOS-transistor outputs remain in their previous states and are unaffected by the data or address inputs. To eliminate the possibility of entering erroneous data in the latch, enable  $\overline{\text{G}}$  should be held high (inactive) while the address lines are changing. In the 3-to-8 decoding or demultiplexing mode, the addressed output is inverted with respect to the D input and all other outputs are off. In the clear mode, all outputs are off and unaffected by the address and data inputs. When data is low for a given output, the DMOS-transistor output is off. When data is high, the DMOS-transistor output has sink-current capability.

For proper operation,  $V_{\text{DD}}$  must be connected to a voltage source equal to or greater than the maximum drain voltage in the application.

The TPIC6E261 is offered in a 20-pin thermally-enhanced dual-in-line (NE) package and is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

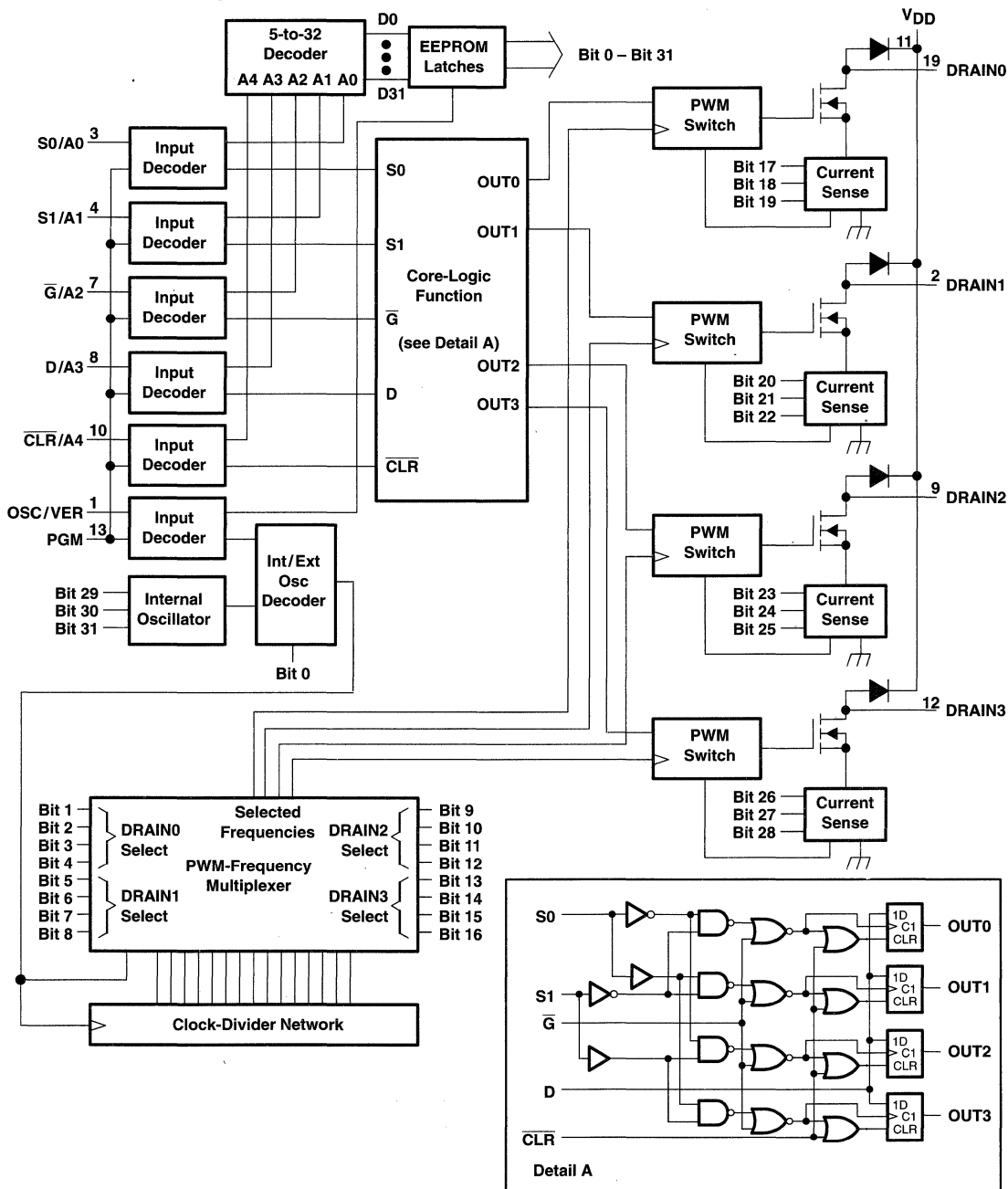
**PRODUCT PREVIEW**



**TPIC6E261**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT ADDRESSABLE LATCH**

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functional block diagram

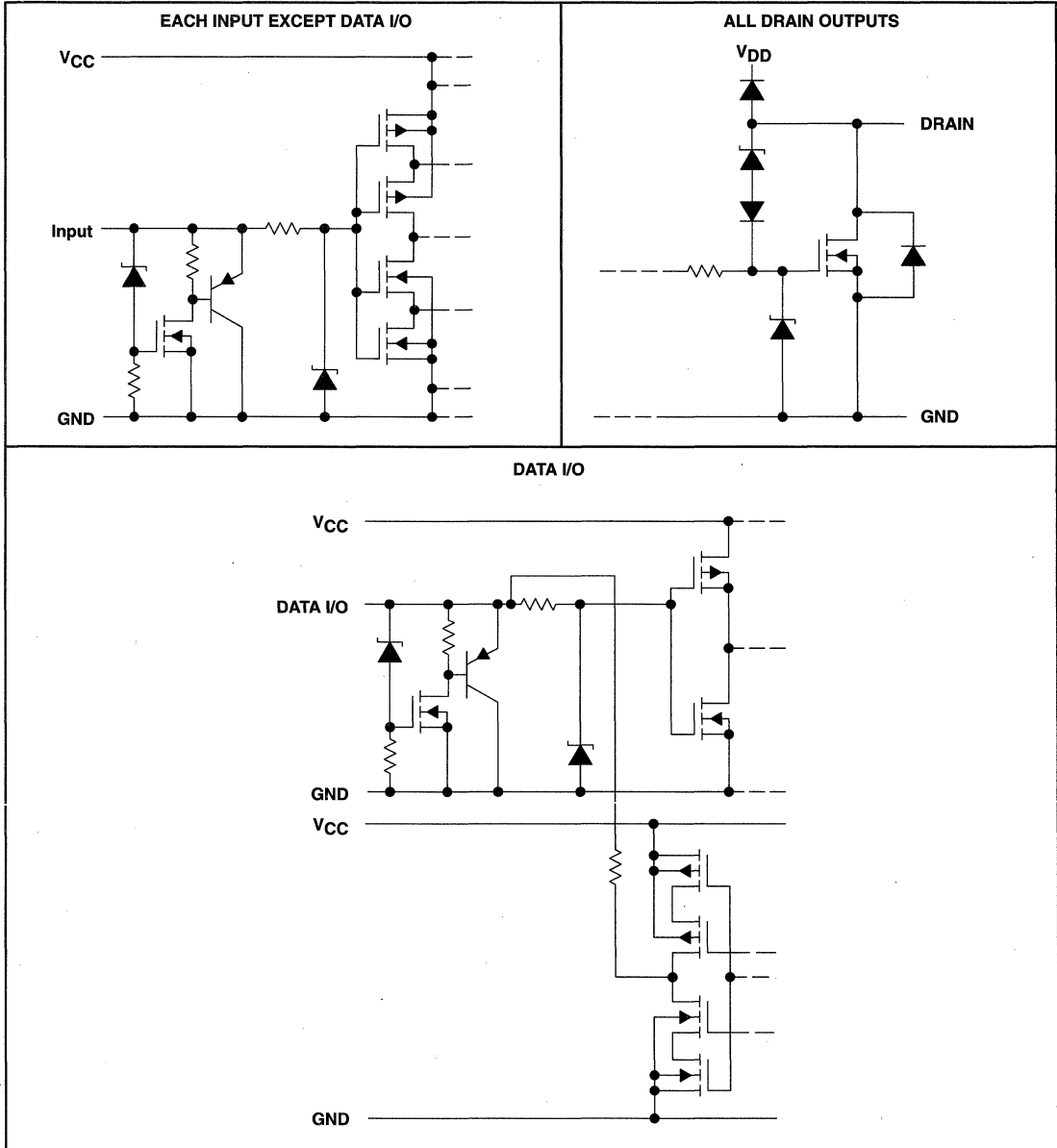


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**TPIC6E261**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT ADDRESSABLE LATCH**

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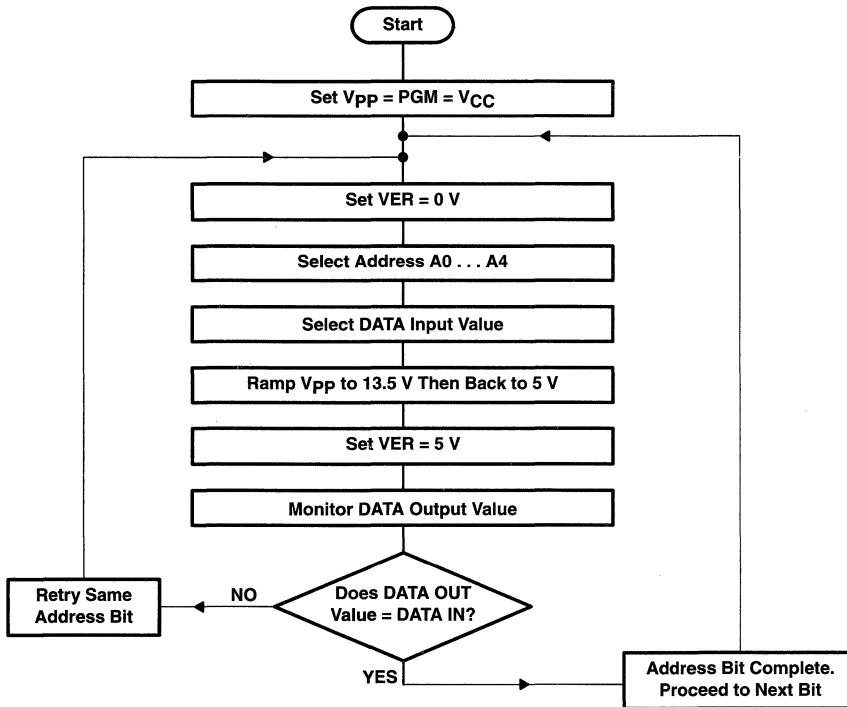
**equivalent inputs and outputs**



**PRODUCT PREVIEW**

**Terminal Functions**

TERMINAL NAME	NO.	I/O	DESCRIPTION
DATA I/O	18	I/O	Programming data input/output
DRAIN0	19	O	Drain outputs 0 to 3
DRAIN1	2		
DRAIN2	9		
DRAIN3	12		
$\bar{G}/A2$	7	I	Function select or Address 2
GND	5, 6, 15, 16	—	Ground
OSC/VER	1	I	Oscillator or Programming verify
PGM	13	I	Program enable
D/A3	8	I	Data or Address 3
S0/A0	3	I	Select 0 or Address 0
S1/A1	4	I	Select 1 or Address 1
$\bar{C}L\bar{R}/A4$	10	I	Function select or Address 4
VCC	20	—	Logic supply voltage
VDD	11	—	Output supply voltage
VPP	17	—	Programming supply voltage



**Figure 1. Recommended EEPROM Programming Sequence**

**PRODUCT PREVIEW**

**TPIC6E261**  
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**4-BIT ADDRESSABLE LATCH**

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**Table 1. Function Selection for Dual-Functionality Terminals**

TERMINAL NUMBER	NORMAL MODE (PGM = L)	PROGRAM MODE (PGM = H)
1	OSC	VER
3	S0	A0
4	S1	A1
7	$\bar{G}$	A2
8	D	A3
10	CLR	A4

H = high level, L = low level

**Table 2. EEPROM Bit Description**

BIT		USER-PROGRAMMABLE PARAMETER	DESCRIPTION†
NO.	ADDRESS		
0	00000	Internal/External Oscillator	Selects internal or external oscillator to be used for PWM clock
1 (LSB)	00001	DRAIN0 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
2	00010		
3	00011		
4 (MSB)	00100		
5 (LSB)	00101	DRAIN1 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
6	00110		
7	00111		
8 (MSB)	01000		
9 (LSB)	01001	DRAIN2 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
10	01010		
11	01011		
12 (MSB)	01100		
13 (LSB)	01101	DRAIN3 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
14	01110		
15	01111		
16 (MSB)	10000		
17 (LSB)	10001	DRAIN0 Current Sense Adjust	Selects the peak current for the PWM-chop mode
18	10010		
19 (MSB)	10011		
20 (LSB)	10100	DRAIN1 Current Sense Adjust	Selects the peak current for the PWM-chop mode
21	10101		
22 (MSB)	10110		
23 (LSB)	10111	DRAIN2 Current Sense Adjust	Selects the peak current for the PWM-chop mode
24	11000		
25 (MSB)	11001		
26 (LSB)	11010	DRAIN3 Current Sense Adjust	Selects the peak current for the PWM-chop mode
27	11011		
28 (MSB)	11100		
29 (LSB)	11101	Oscillator Frequency Adjust	Selects the frequency of the internal oscillator
30	11110		
31 (MSB)	11111		

† See Table 3

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**4-BIT ADDRESSABLE LATCH**

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**Table 3. EEPROM Programming Values**

PROGRAMMABLE PARAMETER	OPTION SELECTED	BINARY VALUE MSB<...>LSB
Internal/External Oscillator	Internal Oscillator	0
	External Oscillator	1
Frequency Multiplexer for All Drain Outputs	Oscillator ÷ 1	0000
	Oscillator ÷ 2	0001
	Oscillator ÷ 4	0010
	Oscillator ÷ 8	0011
	Oscillator ÷ 16	0100
	Oscillator ÷ 32	0101
	Oscillator ÷ 64	0110
	Oscillator ÷ 128	0111
	Oscillator ÷ 256	1000
	Oscillator ÷ 512	1001
	Oscillator ÷ 1024	1010
	Oscillator ÷ 2048	1011
	Oscillator ÷ 4096	1100
	Oscillator ÷ 8192	1101
Oscillator ÷ 16384	1110	
Oscillator ÷ 32768	1111	
Current Sense Adjust for All Drain Outputs	300 mA†	000
	400 mA†	001
	500 mA†	010
	600 mA†	011
	700 mA†	100
	800 mA†	101
	900 mA†	110
	1000 mA†	111
Oscillator Frequency Adjust	Internal Oscillator, Frequency = 1.2 MHz	000
	Internal Oscillator, Frequency = 1.1 MHz	001
	Internal Oscillator, Frequency = 0.9 MHz	010
	Internal Oscillator, Frequency = 0.8 MHz	011
	Internal Oscillator, Frequency = 0.6 MHz	100
	Internal Oscillator, Frequency = 0.5 MHz	101
	Internal Oscillator, Frequency = 0.3 MHz	110
	Internal Oscillator, Frequency = 0.1 MHz	111

† Current target ±20%

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**TPIC6E261**  
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**4-BIT ADDRESSABLE LATCH**

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Output supply voltage, $V_{DD}$ (see Note 1)	40 V
Programming supply voltage during programming, $V_{PP}$ (see Notes 1 and 2)	16 V
Programming supply voltage, verify/normal operation, $V_{PP}$	7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 3)	40 V
Continuous source-to-drain diode current	1 A
Pulsed source-to-drain diode current (see Note 3)	1 A
PWM output current, each output, all outputs on, $I_{O(PWM)}$ , $T_A = 25^\circ\text{C}$ , $d = 10\%$ (see Note 4 and Figure 10)	900 mA
PWM output current, each output, all outputs on, $I_{O(PWM)}$ , $T_A = 25^\circ\text{C}$ , $d = 50\%$ (see Note 4 and Figure 9)	800 mA
Peak drain current, single output, $I_{D(Peak)}$ , $T_A = 25^\circ\text{C}$ (see Notes 3 and 4)	1 A
Peak Avalanche current, $I_{(AV)}$ (see Note 5 and Figure 7)	1 A
Single-pulse avalanche energy, $E_A$ (see Note 5 and Figure 7)	100 mJ
Continuous total power dissipation	See Dissipation Rating Table
Operating case temperature range, $T_C$	-40°C to 125°C
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to GND.
  2. For programming waveform, see Figure 2.
  3. Each power DMOS source is internally connected to GND. Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$ .
  4. Output current depends upon program current-sense adjust and load conditions.
  5.  $V_{supply} = 24 \text{ V}$ , starting junction temperature,  $(T_{JS}) = 25^\circ\text{C}$ ,  $L = 87 \text{ mH}$ ,  $I_{AS} = 1 \text{ A}$ .

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	OPERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
NE	2775 mW	20 mW/°C	775 mW
NE on FR-4 PCB	4163 mW	33.3 mW/°C	833 mW

**recommended operating conditions**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
Output supply voltage, $V_{DD}$		40	V
Programming supply voltage during programming, $V_{pp}$	12	15	V
Programming supply voltage during verify or normal operation, $V_{pp}$	$V_{CC} - 0.7$	$V_{CC}$	V
High-level input voltage, $V_{IH}$	$0.85 V_{CC}$	$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	$0.15 V_{CC}$	V
Operating case temperature, $T_C$	-40	125	°C

**PRODUCT PREVIEW**



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**4-BIT ADDRESSABLE LATCH**

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-source breakdown voltage $I_D = 1\text{ mA}$	40			V
$V_{SD}$	Source-drain diode forward voltage $I_F = 1\text{ A}$		1	1.5	V
$V_{OH}(\text{DATA I/O})$	High-level data output voltage $I_{OH} = -100\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4.25	4.48		V
$V_{OL}(\text{DATA I/O})$	Low-level data output voltage $I_{OL} = 100\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$		200	250	mV
$V_f$	Forward clamp voltage $I_f = 1\text{ A}$		1.35	2	V
$I_{IH}$	High-level input current $V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$	Low-level input current $V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$	Logic supply current $I_O = 0$ , All inputs low		1.6	5	mA
$I_{CC}(\text{freq})$	Logic supply current at frequency SRCK = 5 MHz, $I_O = 0$		5.5		mA
$I_{DS}$	Off-state drain current $V_{DD} = 40\text{ V}$ , $V_{DS} = 35\text{ V}$		0.2	1	$\mu\text{A}$
	$V_{DD} = 40\text{ V}$ , $V_{DS} = 30\text{ V}$ , $T_C = 125^\circ\text{C}$		1	5	
$r_{DS(\text{on})}$	Static drain-to-source on-state resistance $I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1	1.5	$\Omega$
	$I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$ , $T_C = 125^\circ\text{C}$		1.6	2.4	
	$I_D = 750\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.1	1.75	

**timing requirements over recommended ranges of supply voltage and operating case temperature**

	MIN	MAX	UNIT
$t_{su}$ Setup time, D high before $\bar{G}\uparrow$ (see Figure 5)	20		ns
$t_{su1}$ Setup time, VER to PGM (see Figure 2)	2		$\mu\text{s}$
$t_{su2}$ Setup time, address and DATA I/O to $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_{su3}$ Setup time, PGM to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{su4}$ Setup time, PGM to address (see Figure 2)	2		$\mu\text{s}$
$t_h$ Hold time, D high before $\bar{G}\uparrow$ (see Figure 5)	20		ns
$t_{h1}$ PGM hold time, DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{h2}$ Hold time, DATA I/O after $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_w$ Pulse duration (see Figure 5)	40		ns
$t_{w1}$ Pulse duration, $V_{pp}$ program (see Figure 2)	5		ms
$t_{pd}$ Propagation delay, VER to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_r$ Rise time, $V_{pp}$ during programming (see Figure 2)	2	3	ms
$t_f$ Fall time, $V_{pp}$ during programming (see Figure 2)	2	3	ms

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from D $C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ ,		650		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from D See Figure 5		150		ns
$t_{r1}$	Rise time, drain output (see Figure 5)		750		ns
$t_{f1}$	Fall time, drain output (see Figure 5)		425		ns
$t_{rr}$	Reverse-recovery time (see Figure 6)		300		ns
$t_{rra}$	Reverse-recovery current rise time (see Figure 6)	$I_F = 250\text{ mA}$ , $di/dt = 40\text{ A}/\mu\text{s}$	100		ns

PRODUCT PREVIEW





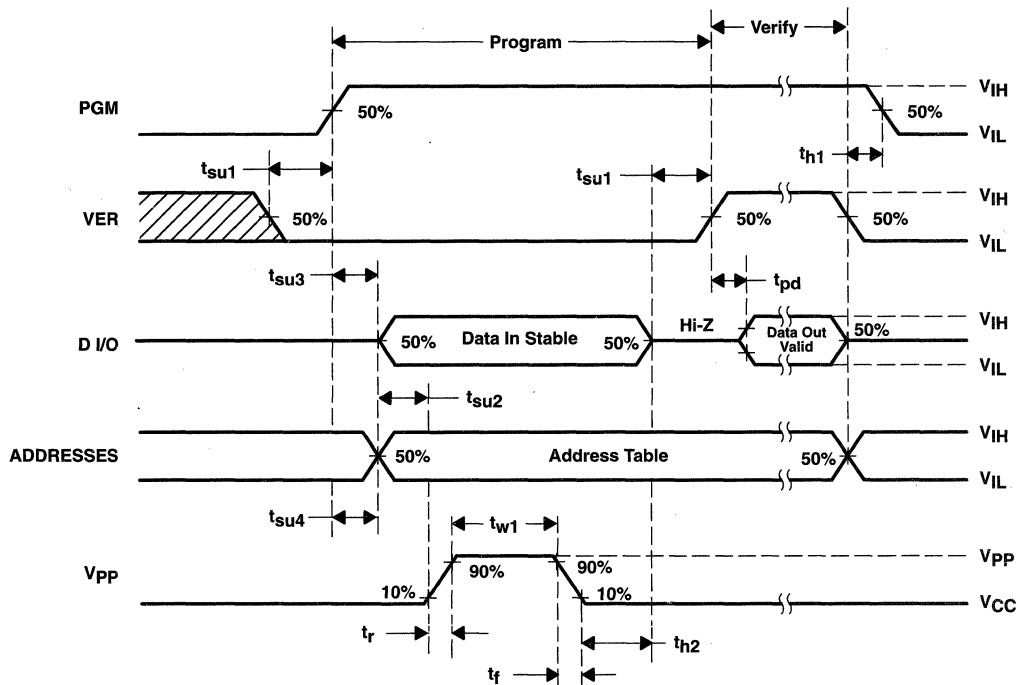
**TPIC6E261**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT ADDRESSABLE LATCH**

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**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
$R_{\theta JC}$	Thermal resistance, junction-to-case		8.3	°C/W
$R_{\theta JA}$	Thermal resistance, junction-to-ambient		50	

**PARAMETER MEASUREMENT INFORMATION**

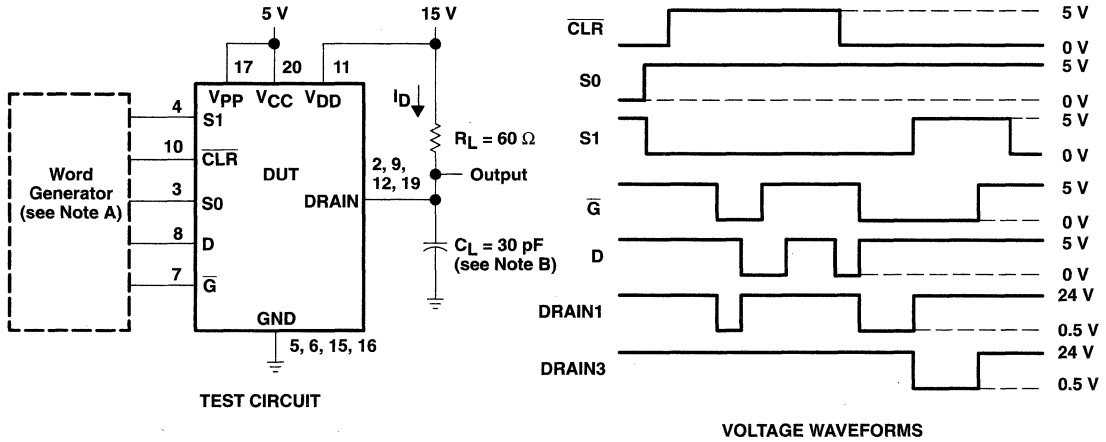


**Figure 2. Programming Waveforms**

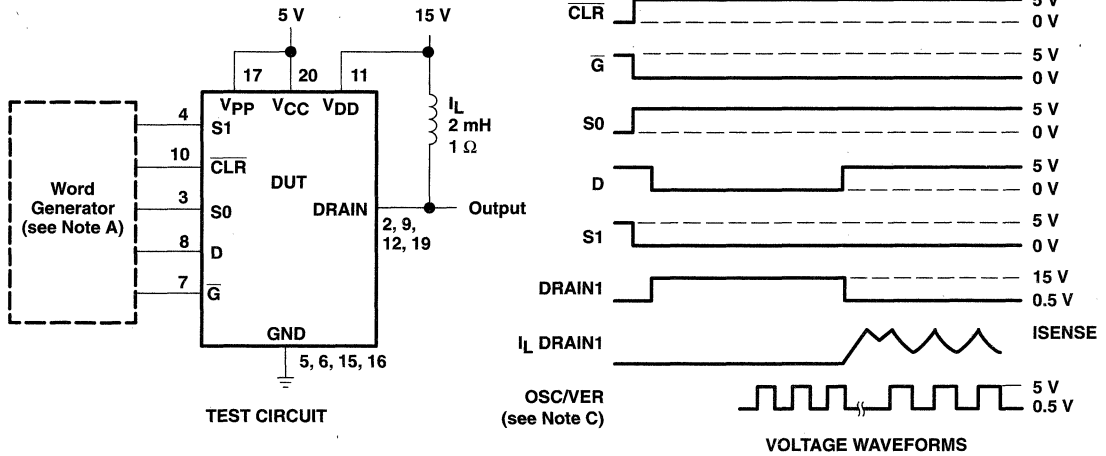
**PRODUCT PREVIEW**



**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Resistive Load Operation**

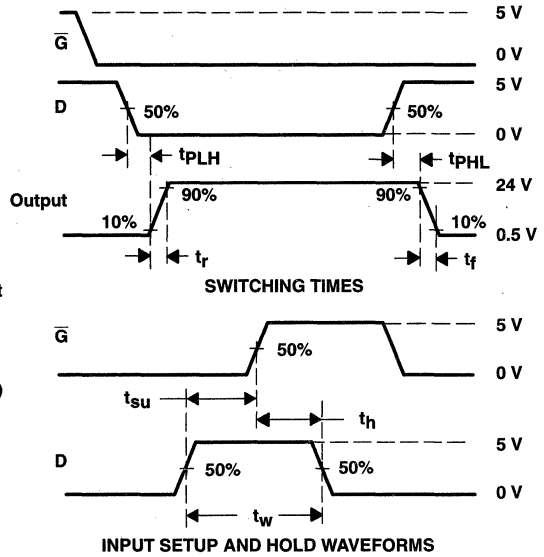
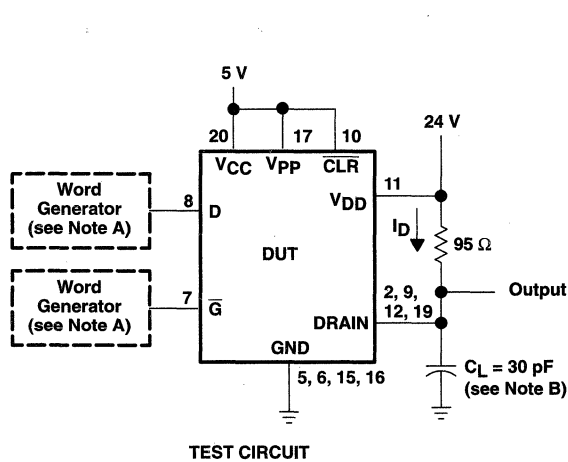


**Figure 4. Inductor Load Operation**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .
- B.  $C_L$  includes probe and jig capacitance.
- C. DRAIN0 and DRAIN3 remain at 15 V with 0A  $I_L$ .

**PRODUCT PREVIEW**

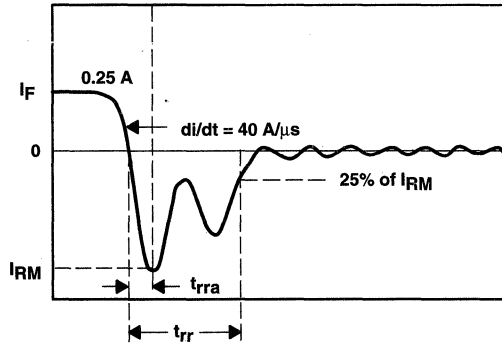
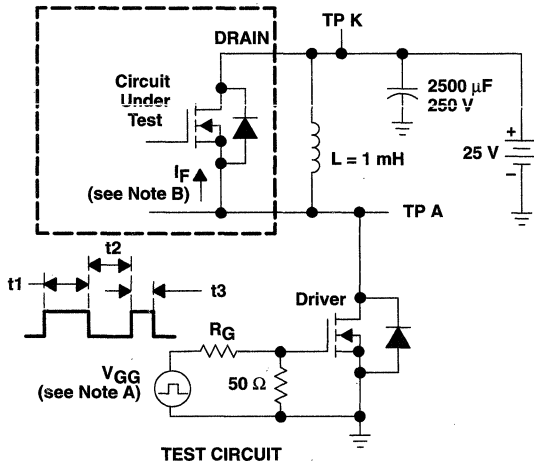
**PARAMETER MEASUREMENT**



**PRODUCT PREVIEW**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

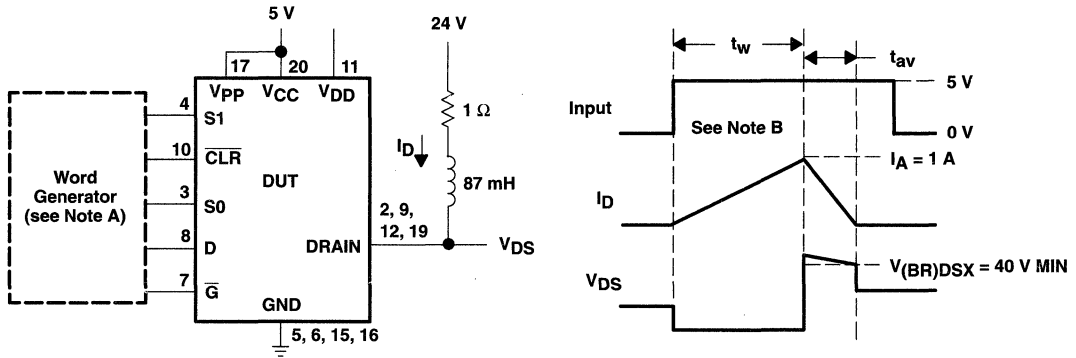
**Figure 5. Test Circuit and Voltage Waveforms, Switching Times**



- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 40$  A/ $\mu$ s. A  $V_{GG}$  double-pulse train sets  $I_F = 0.25$  A, where  $t_1 = 15 \mu$ s,  $t_2 = 8.5 \mu$ s, and  $t_3 = 3.5 \mu$ s.  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

**Figure 6. Reverse-Recovery-Current Test Circuit and Waveform of Source Drive Device**

**PARAMETER MEASUREMENT INFORMATION**



**SINGLE-PULSE AVALANCHE-ENERGY TEST CIRCUIT**

**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is controlled by the value of peak avalanche current  $I_{(av)} = 1$  A.

Energy test level is defined as  $E_A = \frac{I_{(av)} \times V_{(BR)DSX} \times t_{av}}{2} = 100$  mJ,  
 where  $t_{av}$  = avalanche time.

**Figure 7. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**PRODUCT PREVIEW**

TYPICAL CHARACTERISTICS

PRODUCT PREVIEW

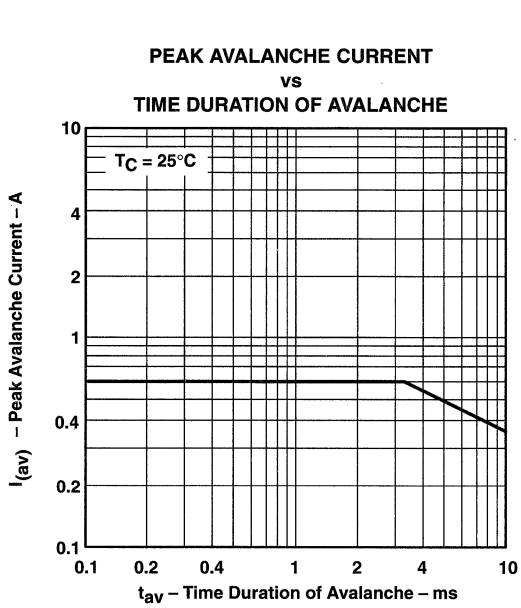


Figure 8

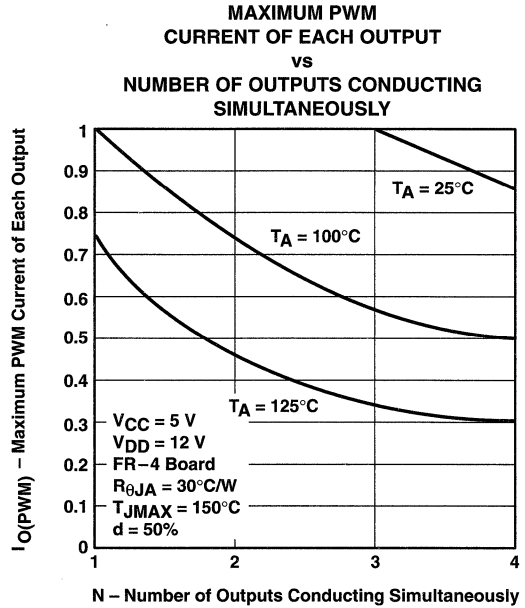


Figure 9

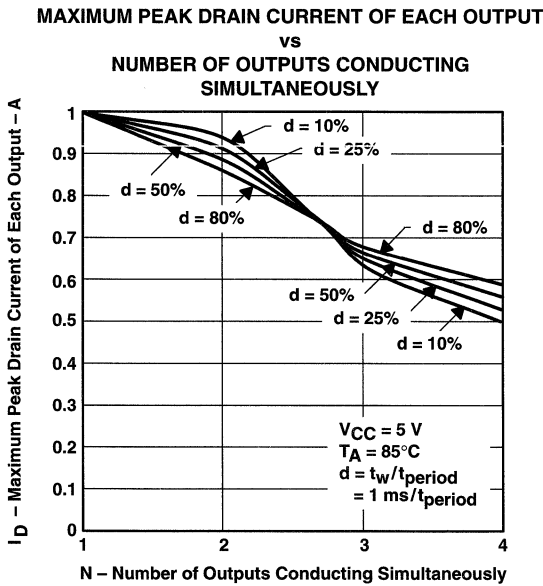
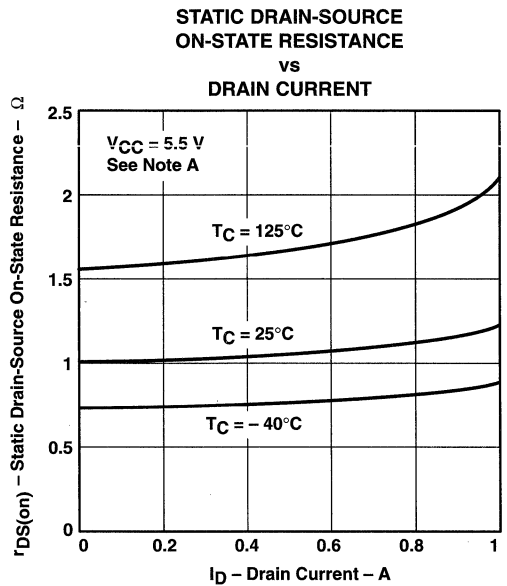


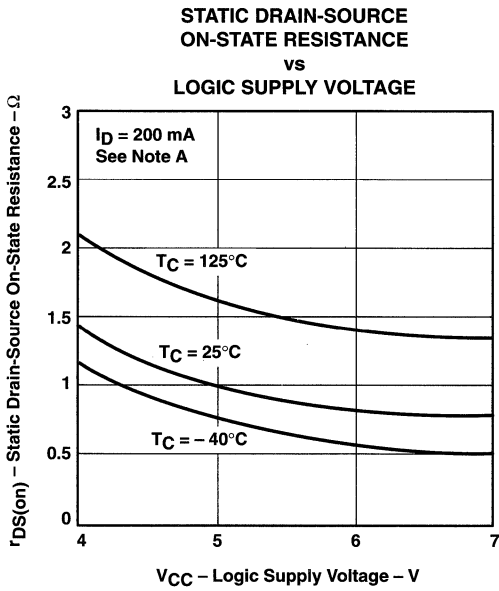
Figure 10



NOTE A: Technique should limit  $T_J - T_C$  to  $10^\circ\text{C}$  maximum.

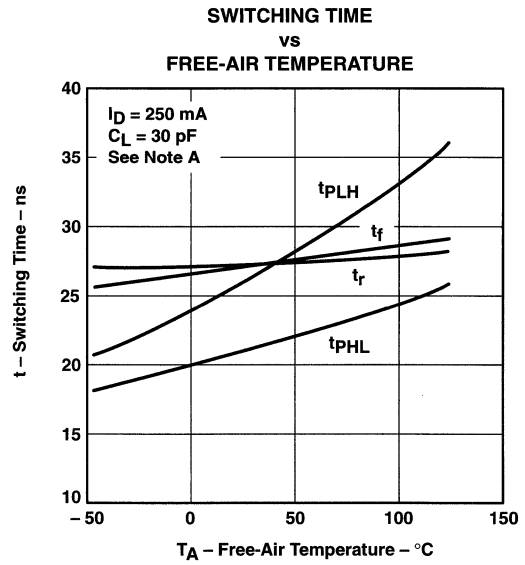
Figure 11

**TYPICAL CHARACTERISTICS**



**Figure 12**

NOTE A: Technique should limit T<sub>J</sub> – T<sub>C</sub> to 10°C maximum.



**Figure 13**

**PRODUCT PREVIEW**



**TPIC6E585**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT SHIFT-REGISTER PWM DRIVER**

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- Programmable-PWM Current Threshold
- Programmable-PWM Frequency Controlled by Internal or External Oscillator
- Integrated Output Recirculation Clamp Diodes
- Low  $r_{DS(on)}$  . . . 1  $\Omega$  Typ
- Four Power MOSFET Outputs
- Integrated Snubbing Clamp Voltage at 40 V
- Low Power Consumption

**description**

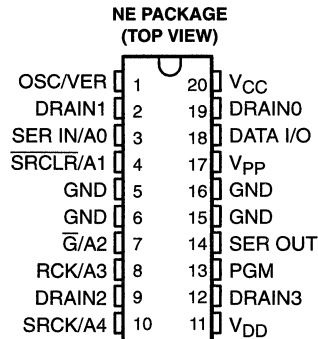
The power logic 4-bit shift-register pulse-width-modulation (PWM) driver controls open-drain DMOS transistor outputs and is designed for applications that require relatively high power. The device contains a built-in snubbing clamp and recirculation clamp on the outputs for inductive transient protection and inductive energy recirculation, respectively. Power driver applications include solenoids and other medium-current or high-voltage loads. Each open-drain DMOS transistor features an independent user-programmable PWM circuit that works in conjunction with the recirculation clamping diode in order to control the average current in inductive-load applications. The PWM circuit provides a programmable current-limit threshold that disables the output until the next rising edge of the independent PWM programmable clock. Each clock is generated from a user-programmable internal or external clock reference that in turn is programmed independently for each output through a frequency divide-by circuit.

User-programmable functions are controlled via 32 EEPROM bits. These bits are programmed by placing the TPIC6E585 into program mode by taking PGM high. The address to be programmed is then set up on dual functionality terminals A0–A4 (see Tables 1 and 2). The data bit to be programmed is set up on DATA I/O, and  $V_{PP}$  is then ramped from  $V_{CC}$  to  $V_{PPH}$  and back to  $V_{CC}$  to program the bit. The programming data can then be verified by taking VER high while monitoring DATA I/O, which gives the value of the data at the address selected on A0–A4. For each user-programmable parameter, Table 3 shows the binary programming values and the option selected by each programming value.

The core logic on this device contains a 4-bit serial-in, parallel-out shift register that feeds a 4-bit D-type register. When the shift register clear (SRCLR) is high, data transfers through the shift register on the rising edge of the shift-register clock (SRCK). It is then transferred to the storage register on the rising edge of the register clock (RCK). When SRCLR is low, the shift register is cleared. When output enable ( $\bar{G}$ ) is held high, all data in the output buffers is held low and all drain outputs are off. When  $\bar{G}$  is held low, data from the storage register is transparent to the output buffers. The serial output (SER OUT) allows for cascading of the data from the shift register to additional devices.

For proper operation,  $V_{DD}$  must be connected to a voltage source equal to or greater than the maximum drain voltage in the application.

The TPIC6E585 is offered in a 20-pin thermally-enhanced dual-in-line (NE) package and is characterized for operation over the operating case temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



TERMINAL NOMENCLATURE	
OSC/VER	Oscillator/Verify
DRAIN0 – DRAIN3	Drain Output
SER IN/A0	Serial Input/Address 0
SRCLR/A1	Shift Register Clear/Address 1
GND	Ground
$\bar{G}$ /A2	Output enable/Address 2
RCK/A3	Register clock/Address 3
SRCK/A4	Shift Register Clock/Address 4
$V_{CC}$	Logic Supply Voltage
DATA I/O	Program Data Input/Output
$V_{PP}$	Programming Supply Voltage
SER OUT	Serial Output
PGM	Program Enable
$V_{DD}$	Output Supply Voltage

**PRODUCT PREVIEW**

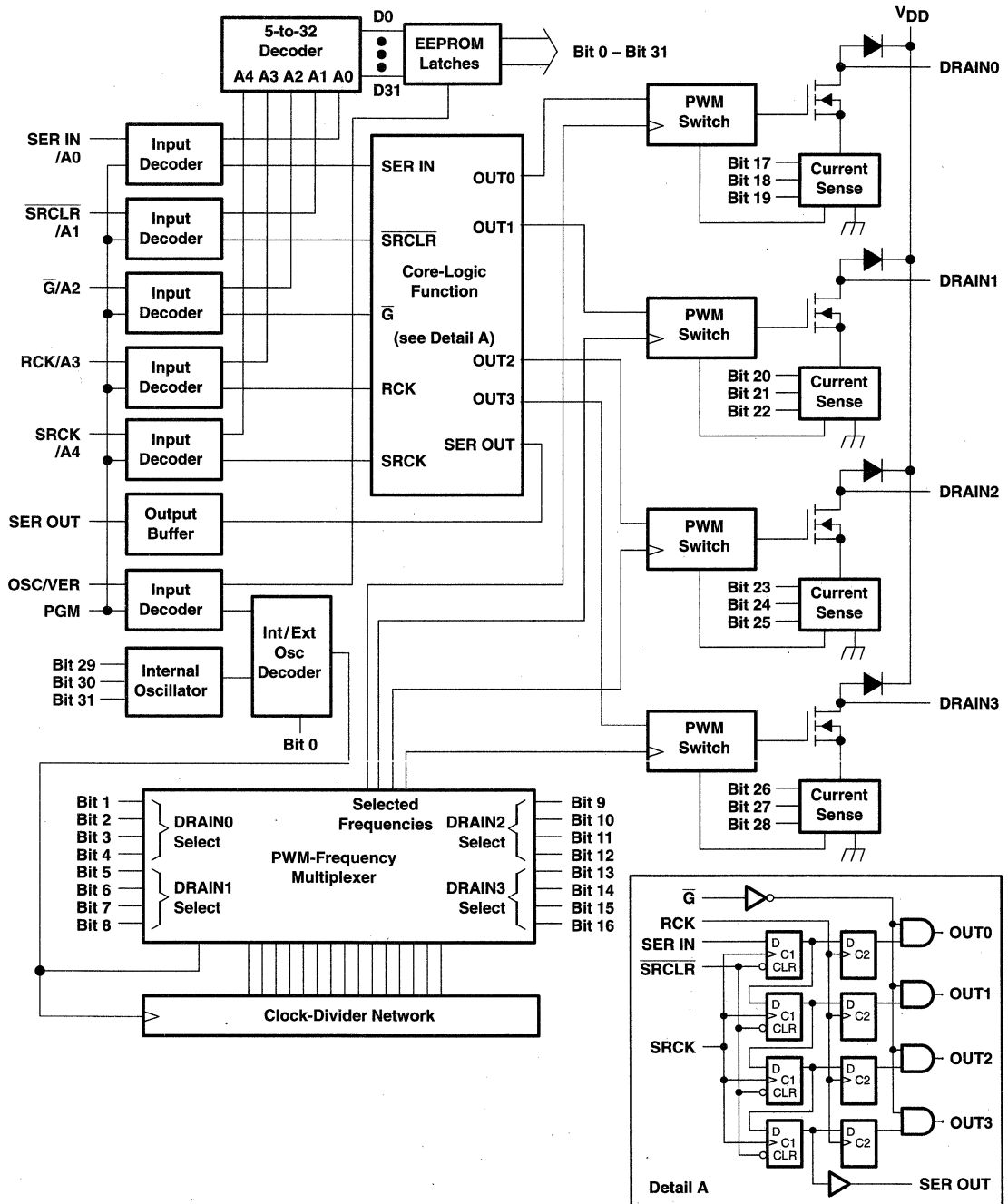


**TPIC6E585**  
**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT SHIFT-REGISTER PWM DRIVER**

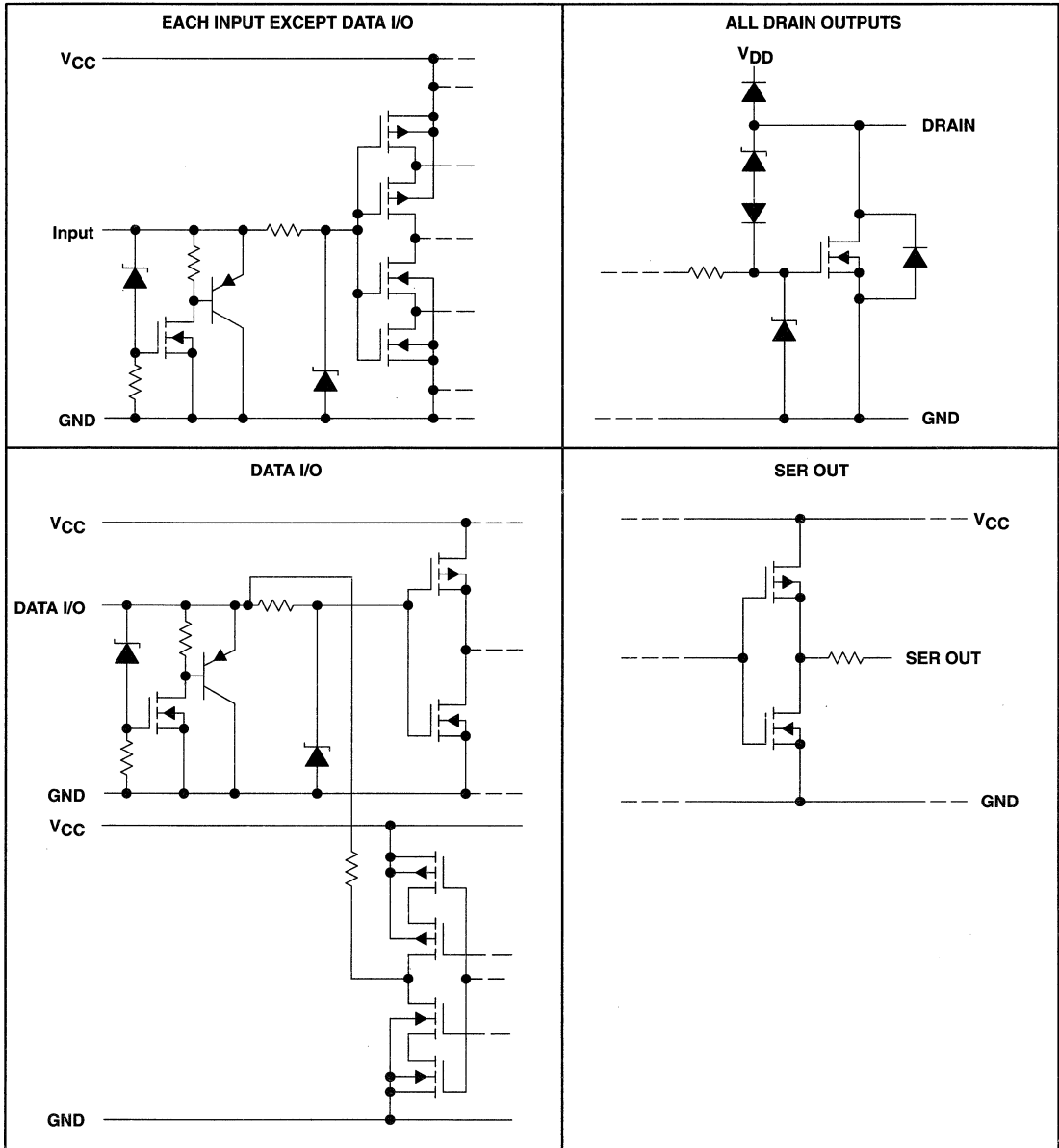
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functional block diagram

**PRODUCT PREVIEW**



**equivalent inputs and outputs**

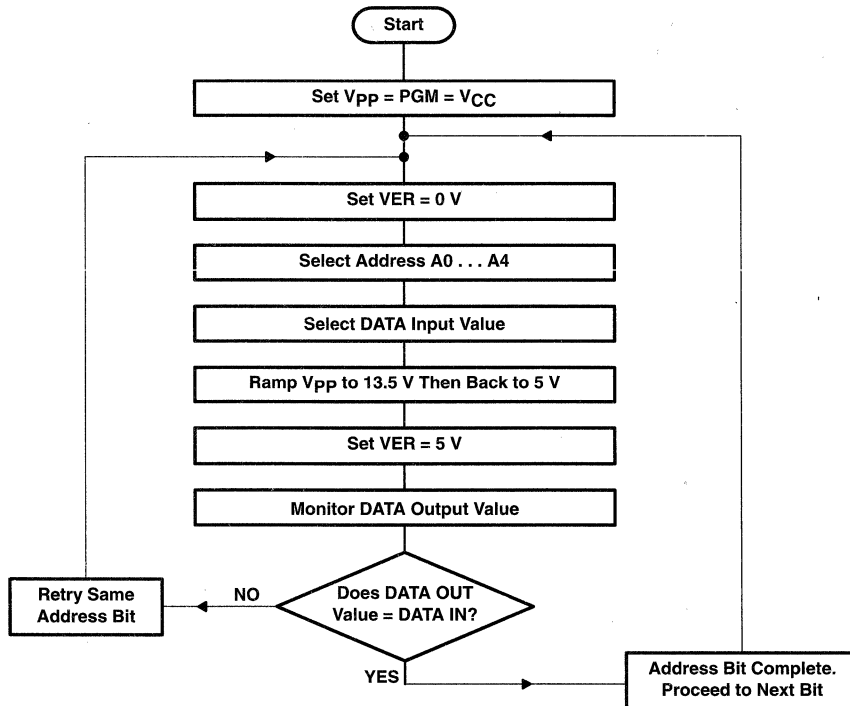


**PRODUCT PREVIEW**

**Terminal Functions**

TERMINAL NAME	NO.	I/O	DESCRIPTION
DATA I/O	18	I/O	Programming data input/output
DRAIN0	19	O	Drain outputs 0–3
DRAIN1	2		
DRAIN2	9		
DRAIN3	12		
$\bar{G}/A2$	7	I	Output Enable or Address 2
GND	5, 6, 15, 16	—	Ground
OSC/VER	1	I	Oscillator or Programming Verify
PGM	13	I	Program enable
RCK/A3	8	I	Register clock or Address 3
SER IN/A0	3	I	Serial input or Address 0
SER OUT	14	O	Serial out
SRCLR/A1	4	I	Shift-register clear or Address 1
SRCK/A4	10	I	Shift-register clock or Address 4
VCC	20	—	Logic supply voltage
VDD	11	—	Output supply voltage
VPP	17	—	Programming supply voltage

**PRODUCT PREVIEW**



**Figure 1. Recommended EEPROM Programming Sequence**

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**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT SHIFT-REGISTER PWM DRIVER**

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**Table 1. Function Selection for Dual-Functionality Terminals**

TERMINAL NUMBER	NORMAL MODE (PGM = L)	PROGRAM MODE (PGM = H)
1	OSC	VER
3	SER IN	A0
4	SRCLR	A1
7	$\bar{G}$	A2
8	RCK	A3
10	SRCK	A4

H = high level, L = low level

**Table 2. EEPROM Bit Description**

BIT NO. ADDRESS		USER-PROGRAMMABLE PARAMETER	DESCRIPTION†
0	00000	Internal/External Oscillator	Selects internal or external oscillator to be used for PWM clock
1 (LSB)	00001	DRAIN0 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
2	00010		
3	00011		
4 (MSB)	00100		
5 (LSB)	00101	DRAIN1 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
6	00110		
7	00111		
8 (MSB)	01000		
9 (LSB)	01001	DRAIN2 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
10	01010		
11	01011		
12 (MSB)	01100		
13 (LSB)	01101	DRAIN3 Frequency Multiplexer	Selects PWM frequency based on internal/external clock frequency and the number of divide-by-2s chosen
14	01110		
15	01111		
16 (MSB)	10000		
17 (LSB)	10001	DRAIN0 Current Sense Adjust	Selects the peak current for the PWM-chop mode
18	10010		
19 (MSB)	10011		
20 (LSB)	10100	DRAIN1 Current Sense Adjust	Selects the peak current for the PWM-chop mode
21	10101		
22 (MSB)	10110		
23 (LSB)	10111	DRAIN2 Current Sense Adjust	Selects the peak current for the PWM-chop mode
24	11000		
25 (MSB)	11001		
26 (LSB)	11010	DRAIN3 Current Sense Adjust	Selects the peak current for the PWM-chop mode
27	11011		
28 (MSB)	11100		
29 (LSB)	11101	Oscillator Frequency Adjust	Selects the frequency of the internal oscillator
30	11110		
31 (MSB)	11111		

† See Table 3

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**4-BIT SHIFT-REGISTER PWM DRIVER**

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**Table 3. EEPROM Programming Values**

PROGRAMMABLE PARAMETER	OPTION SELECTED	BINARY VALUE MSB<...>LSB
Internal/External Oscillator	Internal Oscillator	0
	External Oscillator	1
Frequency Multiplexer for All Drain Outputs	Oscillator ÷ 1	0000
	Oscillator ÷ 2	0001
	Oscillator ÷ 4	0010
	Oscillator ÷ 8	0011
	Oscillator ÷ 16	0100
	Oscillator ÷ 32	0101
	Oscillator ÷ 64	0110
	Oscillator ÷ 128	0111
	Oscillator ÷ 256	1000
	Oscillator ÷ 512	1001
	Oscillator ÷ 1024	1010
	Oscillator ÷ 2048	1011
	Oscillator ÷ 4096	1100
	Oscillator ÷ 8192	1101
Oscillator ÷ 16384	1110	
Oscillator ÷ 32768	1111	
Current Sense Adjust for All Drain Outputs	300 mA†	000
	400 mA†	001
	500 mA†	010
	600 mA†	011
	700 mA†	100
	800 mA†	101
	900 mA†	110
1000 mA†	111	
Oscillator Frequency Adjust	Internal Oscillator, Frequency = 1.2 MHz	000
	Internal Oscillator, Frequency = 1.1 MHz	001
	Internal Oscillator, Frequency = 0.9 MHz	010
	Internal Oscillator, Frequency = 0.8 MHz	011
	Internal Oscillator, Frequency = 0.6 MHz	100
	Internal Oscillator, Frequency = 0.5 MHz	101
	Internal Oscillator, Frequency = 0.3 MHz	110
	Internal Oscillator, Frequency = 0.1 MHz	111

† Current target ±20%

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**POWER LOGIC EEPROM-PROGRAMMABLE**  
**4-BIT SHIFT-REGISTER PWM DRIVER**

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**absolute maximum ratings over operating case temperature range (unless otherwise noted)†**

Logic supply voltage, $V_{CC}$ (see Note 1)	7 V
Logic input voltage range, $V_I$	-0.3 V to 7 V
Output supply voltage, $V_{DD}$ (see Note 1)	40 V
Programming supply voltage during programming, $V_{PP}$ (see Notes 1 and 2)	16 V
Programming supply voltage, verify/normal operation, $V_{PP}$	7 V
Power DMOS drain-to-source voltage, $V_{DS}$ (see Note 3)	40 V
Continuous source-to-drain diode current	1 A
Pulsed source-to-drain diode current (see Note 3)	1 A
PWM output current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$ , $d = 10\%$ (see Note 4 and Figure 10)	900 mA
PWM output current, each output, all outputs on, $I_{Dn}$ , $T_A = 25^\circ\text{C}$ , $d = 50\%$ (see Note 4 and Figure 9)	800 mA
Peak drain current, single output, $I_{Dn}$ , $T_A = 25^\circ\text{C}$ (see Notes 3 and 4)	1 A
Avalanche current, $I_{AS}$ (see Note 5 and Figure 7)	1 A
Single-pulse avalanche energy, $E_{AS}$ (see Note 5 and Figure 7)	100 mJ
Continuous total dissipation	See Dissipation Rating Table
Operating case temperature range, $T_C$	-40°C to 125°C
Operating virtual junction temperature range, $T_J$	-40°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 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 are with respect to GND.
  2. For programming waveform, see Figure 2.
  3. Each power DMOS source is internally connected to GND. Pulse duration  $\leq 100 \mu\text{s}$ , duty cycle  $\leq 2\%$ .
  4. Depends upon program current-sense adjust and load conditions.
  5.  $V_{supply} = 24 \text{ V}$ , starting junction temperature,  $(T_{JS}) = 25^\circ\text{C}$ ,  $L = 87 \text{ mH}$ ,  $I_{AS} = 1 \text{ A}$ .

**DISSIPATION RATING TABLE**

PACKAGE	$T_C \leq 25^\circ\text{C}$ POWER RATING	OPERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$	$T_C = 125^\circ\text{C}$ POWER RATING
NE	2775 mW	20 mW/°C	555 mW
NE on FR-4 PCB	4163 mW	33.3 mW/°C	833 mW

**recommended operating conditions**

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC}$	4.5	5.5	V
Output supply voltage, $V_{DD}$		40	V
Programming supply voltage during programming, $V_{PP}$	12	15	V
Programming supply voltage during verify or normal operation, $V_{PP}$	$V_{CC} - 0.7$	$V_{CC}$	V
High-level input voltage, $V_{IH}$	0.85 $V_{CC}$	$V_{CC}$	V
Low-level input voltage, $V_{IL}$	0	0.15 $V_{CC}$	V
Operating case temperature, $T_C$	-40	125	°C

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**4-BIT SHIFT-REGISTER PWM DRIVER**

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)DSX}$	Drain-source breakdown voltage	$I_D = 1\text{ mA}$	40			V
$V_{SD}$	Source-drain diode forward voltage	$I_F = 1\text{ A}$		1	1.5	V
$V_{OH(SER\ OUT)}$	High-level output voltage	$I_{OH} = -20\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4.4	4.45		V
		$I_{OH} = -4\text{ mA}$ , $V_{CC} = 4.5\text{ V}$	4	4.2		
$V_{OL(SER\ OUT)}$	Low-level output voltage	$I_{OL} = 20\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$		20	100	mV
		$I_{OL} = 4\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		300	600	
$V_{OH(DATA\ I/O)}$	High-level data output voltage	$I_{OH} = -100\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$	4.25	4.48		V
$V_{OL(DATA\ I/O)}$	Low-level data output voltage	$I_{OL} = 100\ \mu\text{A}$ , $V_{CC} = 4.5\text{ V}$		200	250	mV
$V_f$	Forward clamp voltage	$I_f = 1\text{ A}$		1.35	2	V
$I_{IH}$	High-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = V_{CC}$			1	$\mu\text{A}$
$I_{IL}$	Low-level input current	$V_{CC} = 5.5\text{ V}$ , $V_I = 0$			-1	$\mu\text{A}$
$I_{CC}$	Logic supply current	$I_O = 0$ , All inputs low		1.6	5	mA
$I_{CC(freq)}$	Logic supply current at frequency	SRCK = 5 MHz, $I_O = 0$		5.5		mA
$I_{DSX}$	Off-state drain current	$V_{DD} = 40\text{ V}$ , $V_{DS} = 35\text{ V}$		0.2	1	$\mu\text{A}$
		$V_{DD} = 40\text{ V}$ , $V_{DS} = 30\text{ V}$ , $T_C = 125^\circ\text{C}$		1	5	
$r_{DS(on)}$	Static drain-to-source on-state resistance	$I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1	1.5	$\Omega$
		$I_D = 200\text{ mA}$ , $V_{CC} = 4.5\text{ V}$ , $T_C = 125^\circ\text{C}$		1.6	2.4	
		$I_D = 750\text{ mA}$ , $V_{CC} = 4.5\text{ V}$		1.1	1.75	

**timing requirements over recommended ranges of supply voltage and operating case temperature**

		MIN	MAX	UNIT
$t_{su}$	Setup time, SER IN high before SRCK $\uparrow$ (see Figure 5)	20		ns
$t_{su1}$	Setup time, VER to PGM (see Figure 2)	2		$\mu\text{s}$
$t_{su2}$	Setup time, address and DATA I/O to $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_{su3}$	Setup time, PGM to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{su4}$	Setup time, PGM to address (see Figure 2)	2		$\mu\text{s}$
$t_h$	Hold time, SER IN high before SRCK $\uparrow$ (see Figure 5)	20		ns
$t_{h1}$	PGM hold time, DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_{h2}$	Hold time, DATA I/O after $V_{pp}$ (see Figure 2)	2		$\mu\text{s}$
$t_w$	Pulse duration (see Figure 5)	40		ns
$t_{w1}$	Pulse duration, $V_{pp}$ program (see Figure 2)	5		ms
$t_{pd}$	Propagation delay, VER to DATA I/O (see Figure 2)	2		$\mu\text{s}$
$t_r$	Rise time, $V_{pp}$ during programming (see Figure 2)	2	3	ms
$t_f$	Fall time, $V_{pp}$ during programming (see Figure 2)	2	3	ms

**switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_C = 25^\circ\text{C}$**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from $\bar{G}$	$C_L = 30\text{ pF}$ , $I_D = 250\text{ mA}$ , See Figure 5		650		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from $\bar{G}$			150		ns
$t_{r1}$	Rise time, drain output (see Figure 5)			750		ns
$t_{f1}$	Fall time, drain output (see Figure 5)			425		ns
$t_{rr}$	Reverse-recovery time (see Figure 6)			300		ns
$t_{rra}$	Reverse-recovery current rise time (see Figure 6)	$I_F = 250\text{ mA}$ , $di/dt = 40\text{ A}/\mu\text{s}$		100		ns

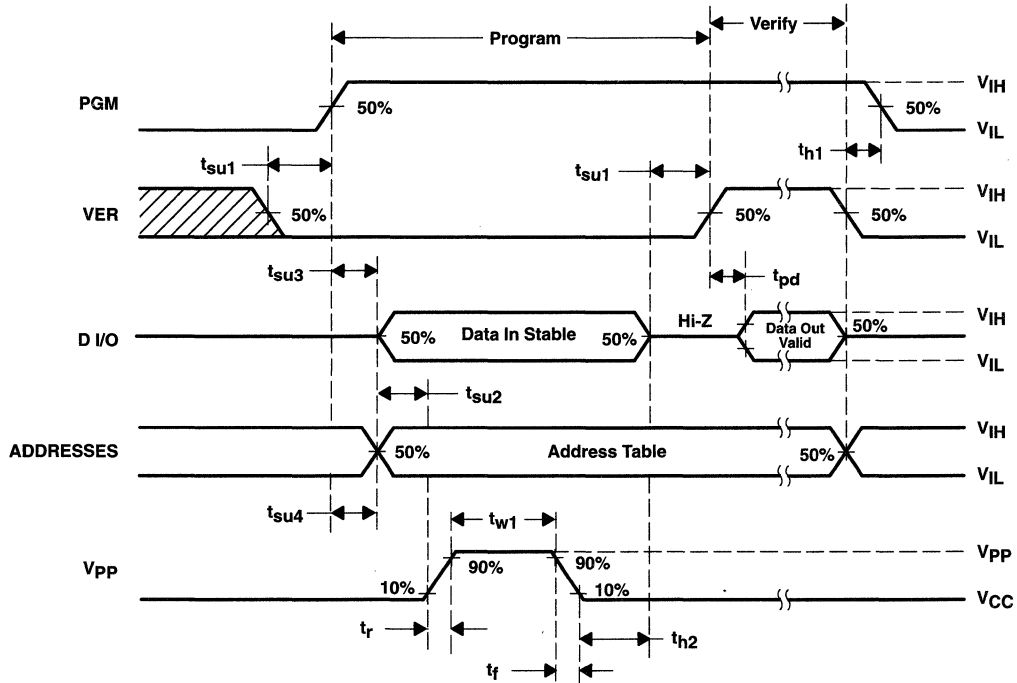
PRODUCT PREVIEW



**thermal resistance**

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
R <sub>θJC</sub> Thermal resistance, junction-to-case	All four outputs with equal power		8.3	°C/W
R <sub>θJA</sub> Thermal resistance, junction-to-ambient	All four outputs with equal power		50	

**PARAMETER MEASUREMENT INFORMATION**



**Figure 2. Programming Waveforms**

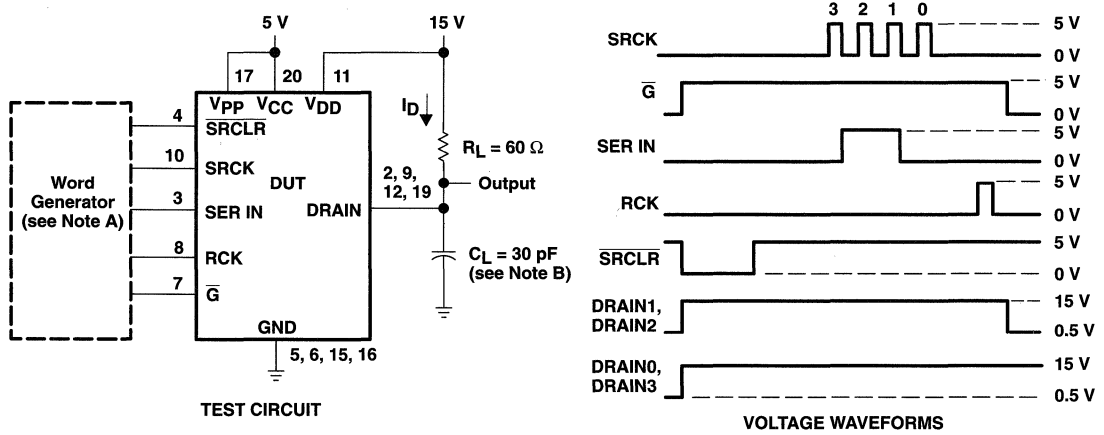
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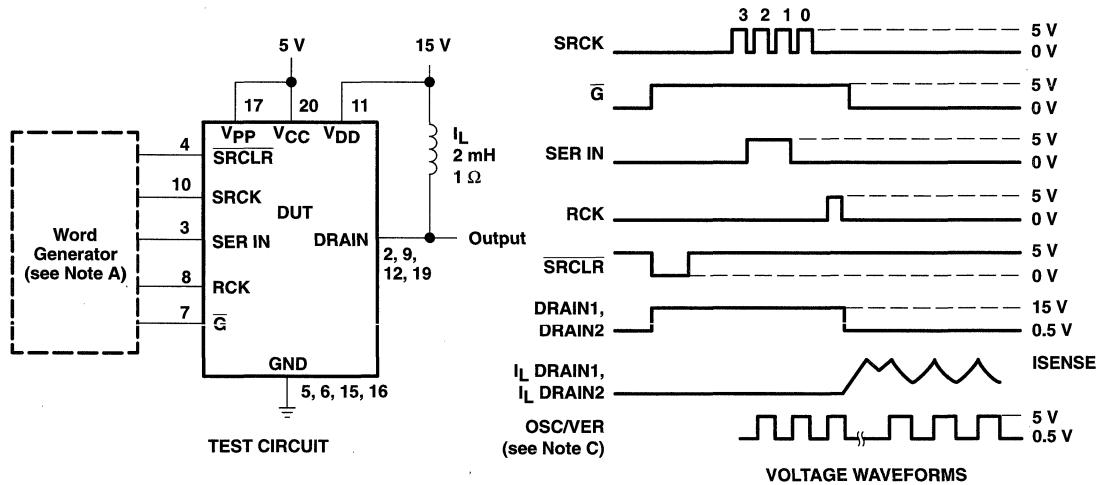
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**PARAMETER MEASUREMENT INFORMATION**



**Figure 3. Resistive Load Operation**

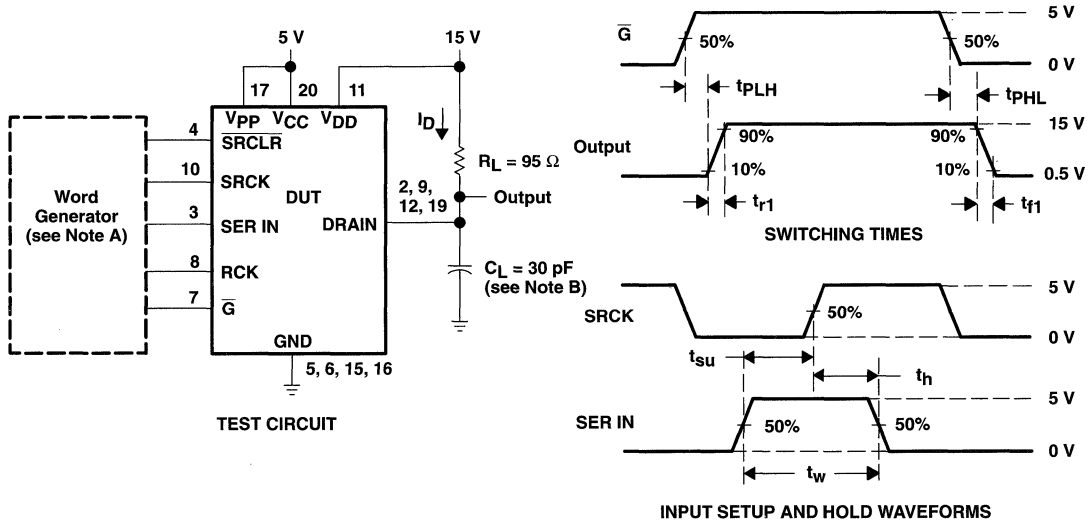


**Figure 4. Inductor Load Operation**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $t_w = 300 \text{ ns}$ , pulsed repetition rate (PRR) = 5 kHz,  $Z_0 = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.  
 C. DRAIN0 and DRAIN3 remain at 15 V with 0A  $I_L$ .

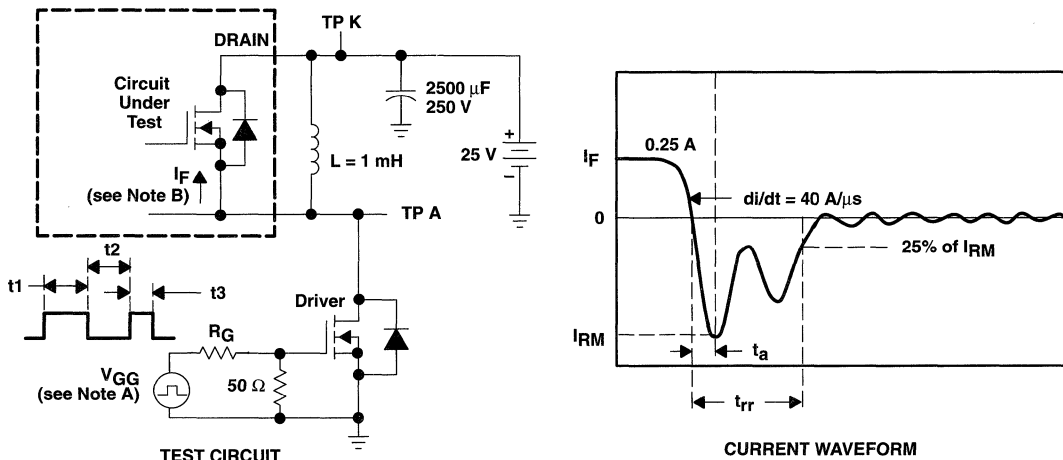
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**PARAMETER MEASUREMENT**



- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $t_w = 300$  ns, pulsed repetition rate (PRR) = 5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

**Figure 5. Test Circuit and Voltage Waveforms, Switching Times**



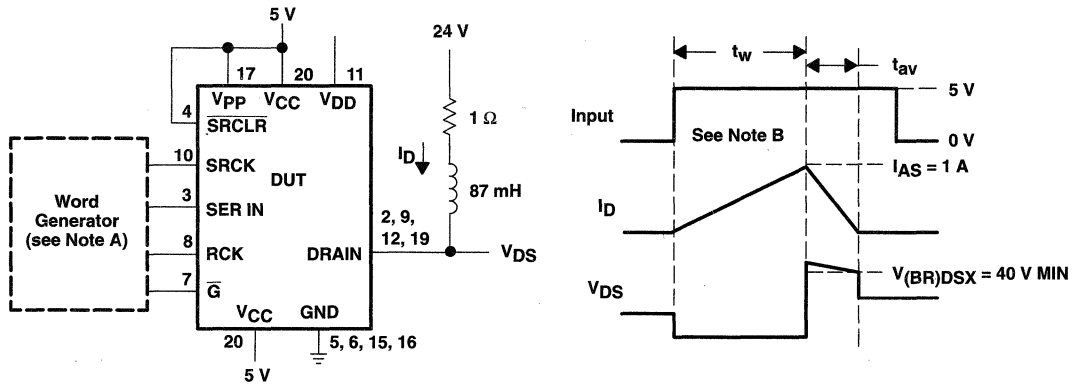
- NOTES: A. The  $V_{GG}$  amplitude and  $R_G$  are adjusted for  $di/dt = 40$  A/ $\mu$ s. A  $V_{GG}$  double-pulse train is used to set  $I_F = 0.25$  A, where  $t_1 = 15 \mu$ s,  $t_2 = 8.5 \mu$ s, and  $t_3 = 3.5 \mu$ s.  
 B. The DRAIN terminal under test is connected to the TP K test point. All other terminals are connected together and connected to the TP A test point.

**Figure 6. Reverse-Recovery-Current Test Circuit and Waveform of Source Drive Device**

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**PARAMETER MEASUREMENT INFORMATION**



**SINGLE-PULSE AVALANCHE-ENERGY TEST CIRCUIT**

**VOLTAGE AND CURRENT WAVEFORMS**

- NOTES: A. The word generator has the following characteristics:  $t_r \leq 10$  ns,  $t_f \leq 10$  ns,  $Z_O = 50 \Omega$ .  
 B. Input pulse duration ( $t_w$ ) is controlled by the value of peak current  $I_{AS} = 1$  A.

Energy test level is defined as  $E_{AS} = \frac{I_{AS} \times V_{(BR)DSX} \times t_{av}}{2} = 100$  mJ,  
 where  $t_{av}$  = avalanche time.

**Figure 7. Single-Pulse Avalanche-Energy Test Circuit and Waveforms**

**PRODUCT PREVIEW**

TYPICAL CHARACTERISTICS

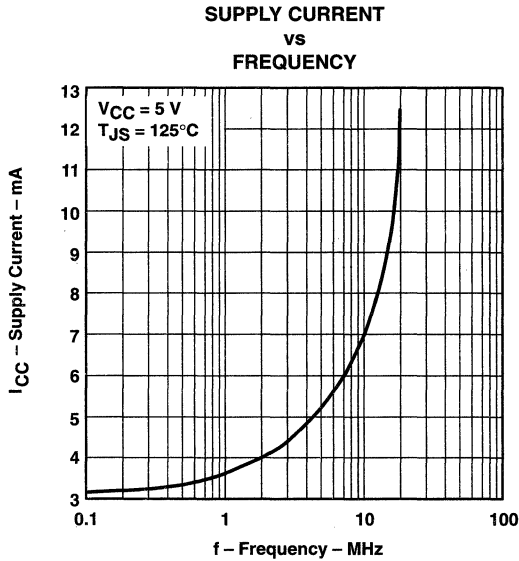


Figure 8

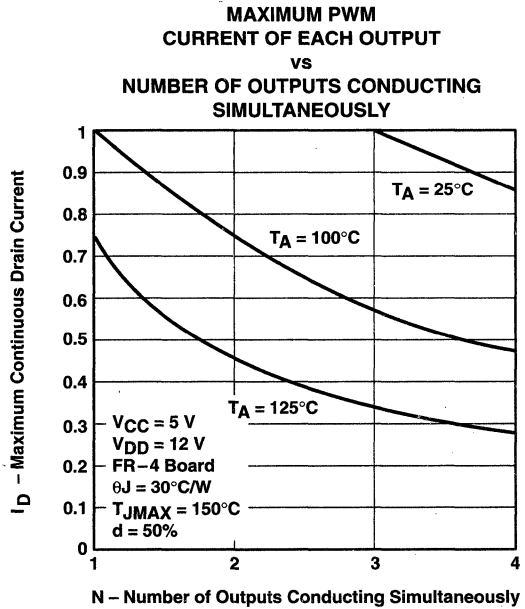


Figure 9

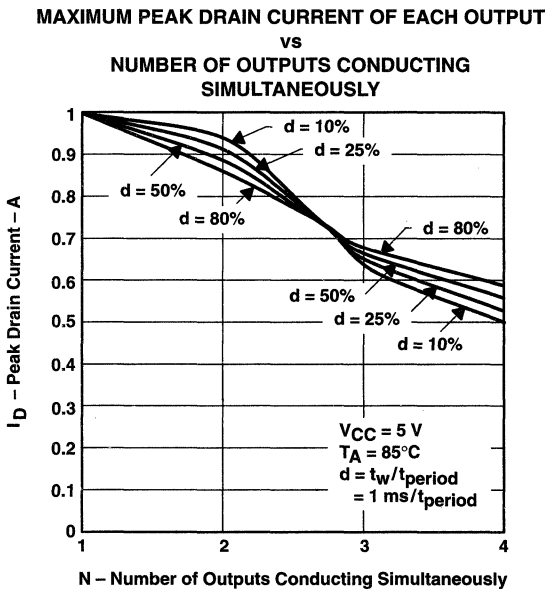


Figure 10

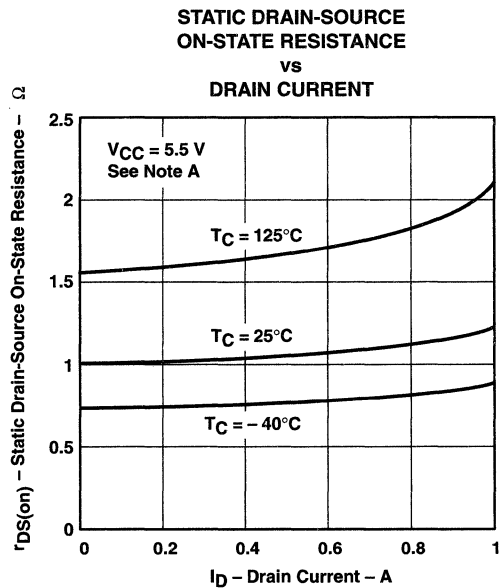


Figure 11

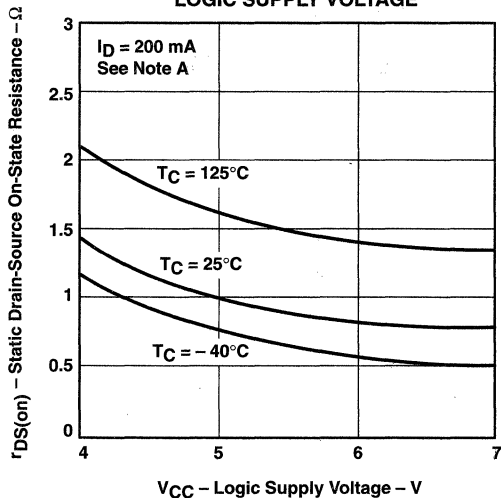
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**4-BIT SHIFT-REGISTER PWM DRIVER**

SLIS025 – SEPTEMBER 1995

**TYPICAL CHARACTERISTICS**

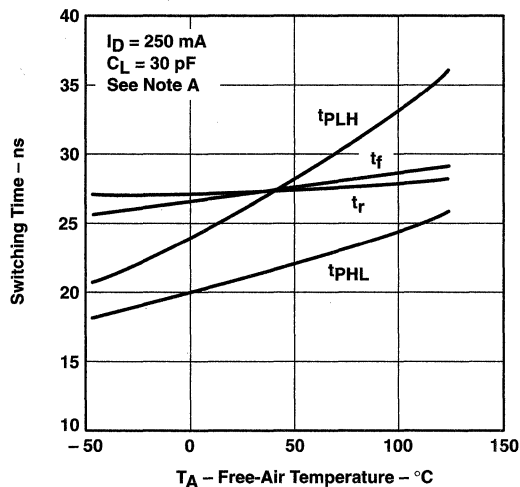
**STATIC DRAIN-SOURCE  
ON-STATE RESISTANCE  
vs  
LOGIC SUPPLY VOLTAGE**



**Figure 12**

NOTE A: Technique should limit T<sub>J</sub> – T<sub>C</sub> to 10°C maximum.

**SWITCHING TIME  
vs  
FREE-AIR TEMPERATURE**



**Figure 13**

**PRODUCT PREVIEW**



<b>General Information</b>	<b>1</b>
<b>Power+™ Products</b>	<b>2</b>
<b>Peripheral Drivers/Actuators</b>	<b>3</b>
<b>Applications</b>	<b>4</b>
<b>Mechanical Data</b>	<b>5</b>

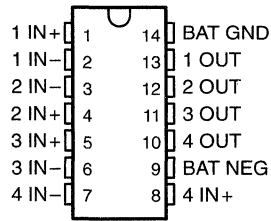
## Peripheral Drivers/Actuators

# DS3680 QUAD TELEPHONE RELAY DRIVER

SLRS014C – MARCH 1986 – REVISED SEPTEMBER 1995

- Designed for –52-V Battery Operation
- 50-mA Output Current Capability
- Input Compatible With TTL and CMOS
- High Common-Mode Input Voltage Range
- Very Low Input Current
- Fail-Safe Disconnect Feature
- Built-in Output Clamp Diode
- Direct Replacement for National DS3680 and Fairchild  $\mu$ A3680

D OR N PACKAGE  
(TOP VIEW)

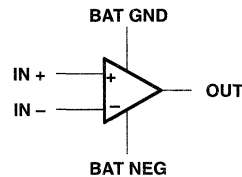


## description

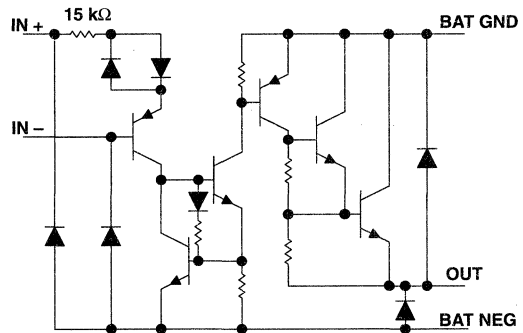
The DS3680 telephone relay driver is a monolithic integrated circuit designed to interface –48-V relay systems to TTL or other systems in telephone applications. It is capable of sourcing up to 50 mA from standard –52-V battery power. To reduce the effects of noise and IR drop between logic ground and battery ground, these drivers are designed to operate with a common-mode input range of  $\pm 20$  V referenced to battery ground. The common-mode input voltages for the four drivers can be different, so a wide range of input elements can be accommodated. The high-impedance inputs are compatible with positive TTL and CMOS levels or negative logic levels. A clamp network is included in the driver outputs to limit high-voltage transients generated by the relay coil during switching. The complementary inputs ensure that the driver output is off as a fail-safe condition when either output is open.

The DS3680 is characterized for operation from 0°C to 70°C.

## symbol (each driver)



## schematic diagram (each driver)



All resistor values shown are nominal.



# DS3680 QUAD TELEPHONE RELAY DRIVER

SLRS014C – MARCH 1986 – REVISED SEPTEMBER 1995

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

Supply voltage range at BAT NEG, $V_{BAT-}$ (see Note 1)	–70 V to 0.5 V
Input voltage range with respect to BAT GND	–70 V to 20 V
Input voltage range with respect to BAT NEG	–0.5 V to 70 V
Differential input voltage, $V_{ID}$ (see Note 2)	±20 V
Output current, $I_O$ : Resistive load	–100 mA
Inductive load	–50 mA
Inductive output load	5 H
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°C
Storage temperature range, $T_{stg}$	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	260°C

- NOTES: 1. All voltages are with respect to BAT GND, unless otherwise specified.  
2. Differential input voltages are at the noninverting input terminal IN+ with respect to the inverting input terminal IN–.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	950 mW	7.6 mW/°C	608 mW
N	1150 mW	9.2 mW/°C	736 mW

## recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, $V_{BAT-}$	–10	–60	V
Input voltage, either input	–20†	20	V
High-level differential input voltage, $V_{IDH}$	2	20	V
Low-level differential input voltage, $V_{IDL}$	–20†	0.8	V
Operating free-air temperature, $T_A$	0	70	°C

† The algebraic convention, in which the less positive (more negative) limit is designated minimum, is used in this data sheet for input voltage levels.

## electrical characteristics over recommended operating free-air temperature range, $V_{BAT-} = -52\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
$I_{IH}$ High-level input current (into IN+)	$V_{ID} = 2\text{ V}$		40	100	$\mu\text{A}$
	$V_{ID} = 7\text{ V}$		375	1000	
$I_{IL}$ Low-level input current (into IN+)	$V_{ID} = 0.4\text{ V}$		0.01	5	$\mu\text{A}$
	$V_{ID} = -7\text{ V}$		–1	–100	
$V_{O(on)}$ On-stage output voltage	$I_O = 50\text{ mA}$ , $V_{ID} = 2\text{ V}$	–1.6		–2.1	V
$I_{O(off)}$ Off-stage output current	$V_O = V_{BAT-}$ Inputs open		–2	–100	$\mu\text{A}$
			–2	–100	
$I_R$ Clamp diode reverse current	$V_O = 0$		2	100	$\mu\text{A}$
$V_{OK}$ Output clamp voltage	$I_O = 50\text{ mA}$		0.9	1.2	V
	$I_O = -50\text{ mA}$ , $V_{BAT-} = 0$		–0.9	–1.2	
$I_{BAT(on)}$ On-state battery current	All drivers on		–2	–4.4	mA
$I_{BAT(off)}$ Off-state battery current	All drivers off		–1	–100	$\mu\text{A}$

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .



# DS3680 QUAD TELEPHONE RELAY DRIVER

SLRS014C – MARCH 1986 – REVISED SEPTEMBER 1995

switching characteristics  $V_{BAT-} = -52\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{on}$ Turn-on time	$V_{ID} = 3\text{-V pulse}$ , $R_L = 1\text{ k}\Omega$ , $L = 1\text{ H}$ , See Figure 2		1	10	$\mu\text{s}$
$t_{off}$ Turn-off time			1	10	$\mu\text{s}$

## PARAMETER MEASUREMENT INFORMATION

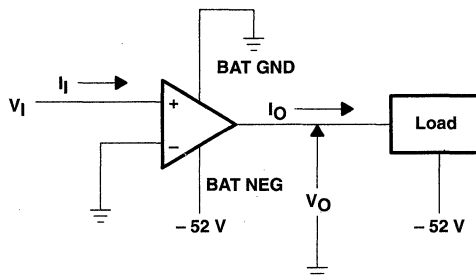


Figure 1. Generalized Test Circuit, Each Driver

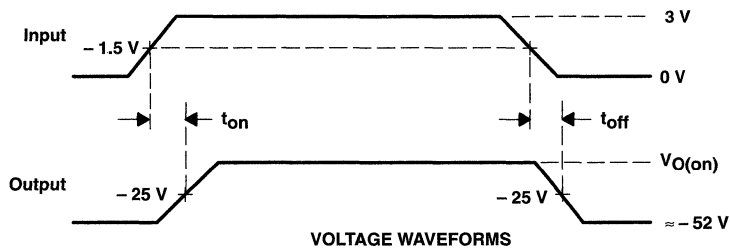
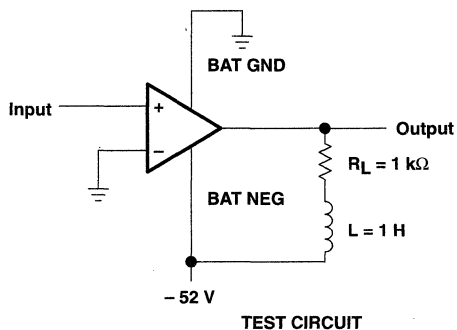


Figure 2. Test Circuit and Voltage Waveforms, Each Driver

# DS3680 QUAD TELEPHONE RELAY DRIVER

SLRS014C – MARCH 1986 – REVISED SEPTEMBER 1995

## APPLICATION INFORMATION

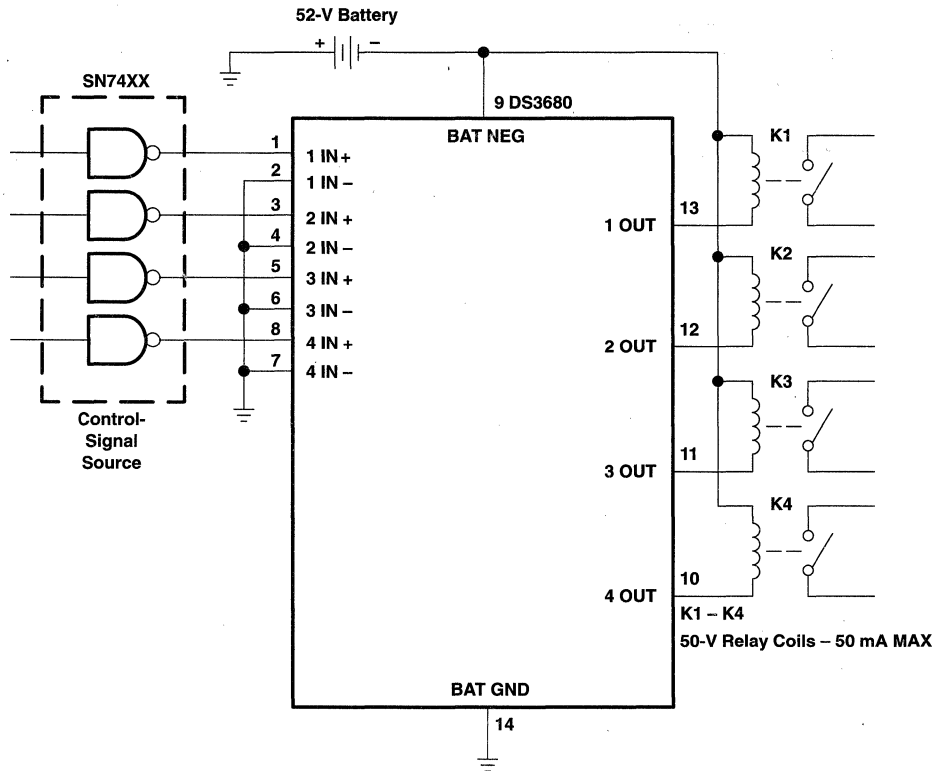


Figure 3. Relay Driver

# L293 QUADRUPLE HALF-H DRIVER

SLRS005 – SEPTEMBER 1986 – REVISED MAY 1990

- 1-A Output Current Capability Per Driver
- Pulsed Current 2-A Driver
- Wide Supply Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- NE Package Designed for Heat Sinking
- Thermal Shutdown
- Internal ESD Protection
- High-Noise-Immunity Inputs
- Functional Replacement for SGS L293

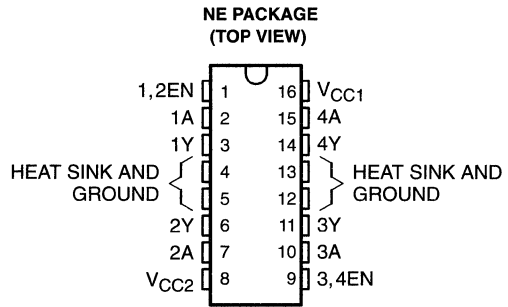
## description

The L293 is a quadruple high-current half-H driver designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. It is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

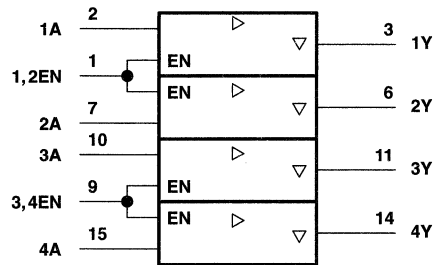
All inputs are TTL compatible. Each output is a complete totem-pole drive circuit with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in a high-impedance state. With the proper data inputs, each pair of drivers form a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

External high-speed output clamp diodes should be used for inductive transient suppression. A  $V_{CC1}$  terminal, separate from  $V_{CC2}$ , is provided for the logic inputs to minimize device power dissipation.

The L293 is designed for operation from 0°C to 70°C.

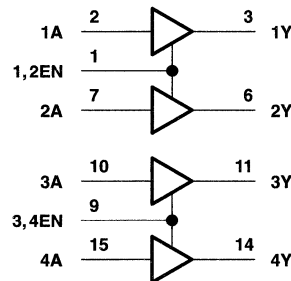


## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

## logic diagram



**FUNCTION TABLE  
(each driver)**

INPUTS‡		OUTPUT
A	EN	Y
H	H	H
L	H	L
X	L	Z

H = high-level, L = low-level,

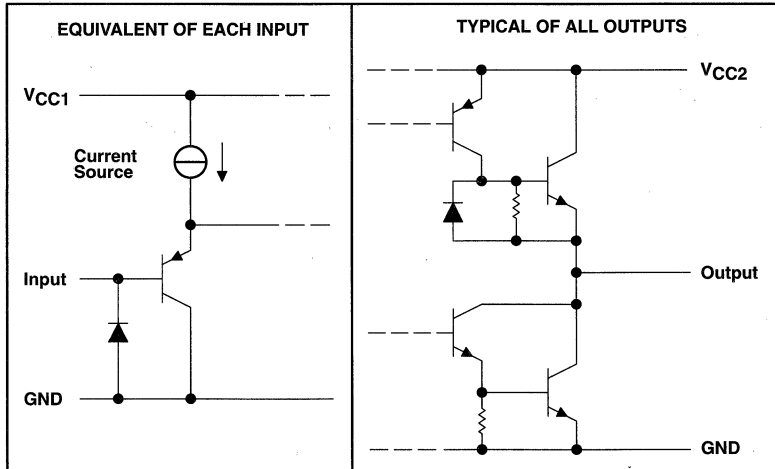
X = irrelevant, Z = high-impedance (off)

‡ In the thermal shutdown mode, the output is in the high-impedance state regardless of the input levels.

# L293 QUADRUPLE HALF-H DRIVER

SLRS005 – SEPTEMBER 1986 – REVISED MAY 1990

## schematics of inputs and outputs



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

Supply voltage, $V_{CC1}$ (see Note 1)	36 V
Output supply voltage range, $V_{CC2}$	36 V
Input voltage range, $V_I$	7 V
Output voltage range, $V_O$	-3 V to $V_{CC2} + 3$ V
Peak output current, $I_O$ (nonrepetitive, $t \leq 5$ ms)	$\pm 2$ A
Continuous output current, $I_O$	$\pm 1$ A
Continuous total dissipation at (or below) 25°C free-air temperature (see Notes 2 and 3)	2075 mW
Continuous total dissipation at 80°C case temperature (see Note 3)	5000 mW
Operating case or virtual junction temperature range, $T_A$	-40°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 seconds	260°C

- NOTES: 1. All voltage values are with respect to the network ground terminal.  
 2. For operation above 25°C free-air temperature, derate linearly at the rate of 16.6 mW/°C.  
 3. For operation above 25°C case temperature, derate linearly at the rate of 71.4 mW/°C. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

## recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC1}$	4.5	7	V
Output supply voltage, $V_{CC2}$		36	V
High-level input voltage, $V_{IH}$	$V_{CC1} \leq 7$ V	2.3	V
	$V_{CC1} \geq 7$ V	2.3	
Low-level output voltage, $V_{IL}$	-0.3 <sup>†</sup>	1.5	V
Operating free-air temperature, $T_A$	0	70	°C

<sup>†</sup> The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

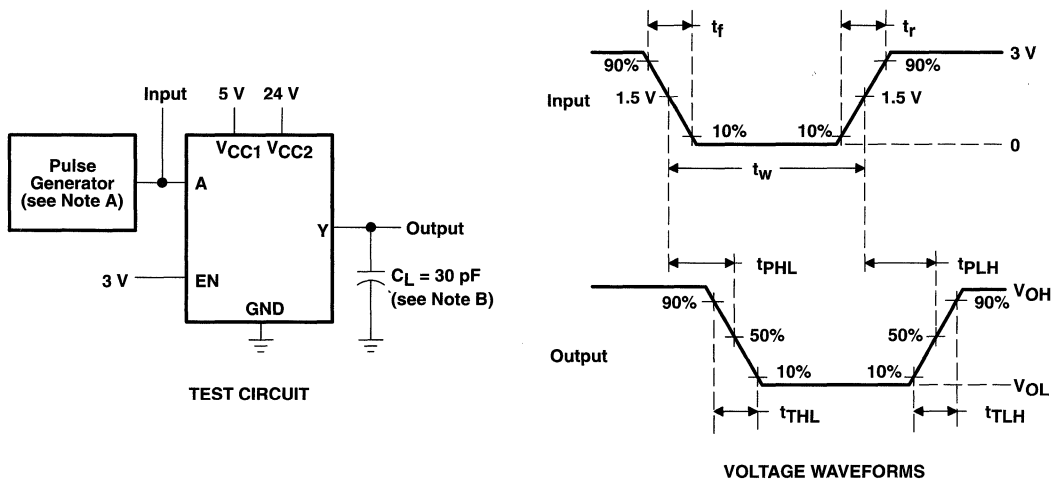
electrical characteristics,  $V_{CC1} = 5\text{ V}$ ,  $V_{CC2} = 24\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{OH}$	High-level output voltage	$I_{OH} = -1\text{ A}$		$V_{CC2} - 1.8$	$V_{CC2} - 1.4$		V
$V_{OL}$	Low-level output voltage	$I_{OL} = 1\text{ A}$			1.2	1.8	V
$I_{IH}$	High-level input current	A	$V_I = 7\text{ V}$		0.2	100	$\mu\text{A}$
		EN			0.2	$\pm 10$	
$I_{IL}$	Low-level input current	A	$V_I = 0$		-3	-10	$\mu\text{A}$
		EN			-2	-100	
$I_{CC1}$	Logic supply current	$I_O = 0$	All outputs at high level		13	22	mA
			All outputs at low level		35	60	
			All outputs at high impedance		8	24	
$I_{CC2}$	Output supply current	$I_O = 0$	All outputs at high level		14	24	mA
			All outputs at low level		2	6	
			All outputs at high impedance		2	4	

switching characteristics,  $V_{CC1} = 5\text{ V}$ ,  $V_{CC2} = 24\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from A input	$C_L = 30\text{ pF}$ , See Figure 1		800		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from A input			400		ns
$t_{TLH}$	Transition time, low-to-high-level output			300		ns
$t_{THL}$	Transition time, high-to-low-level output			300		ns

PARAMETER MEASUREMENT INFORMATION



NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10\text{ ns}$ ,  $t_f \leq 10\text{ ns}$ ,  $t_w = 10\text{ }\mu\text{s}$ , PRR = 5 kHz,  $Z_O = 50\text{ }\Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms

# L293 QUADRUPLE HALF-H DRIVER

SLRS005 – SEPTEMBER 1986 – REVISED MAY 1990

## APPLICATION INFORMATION

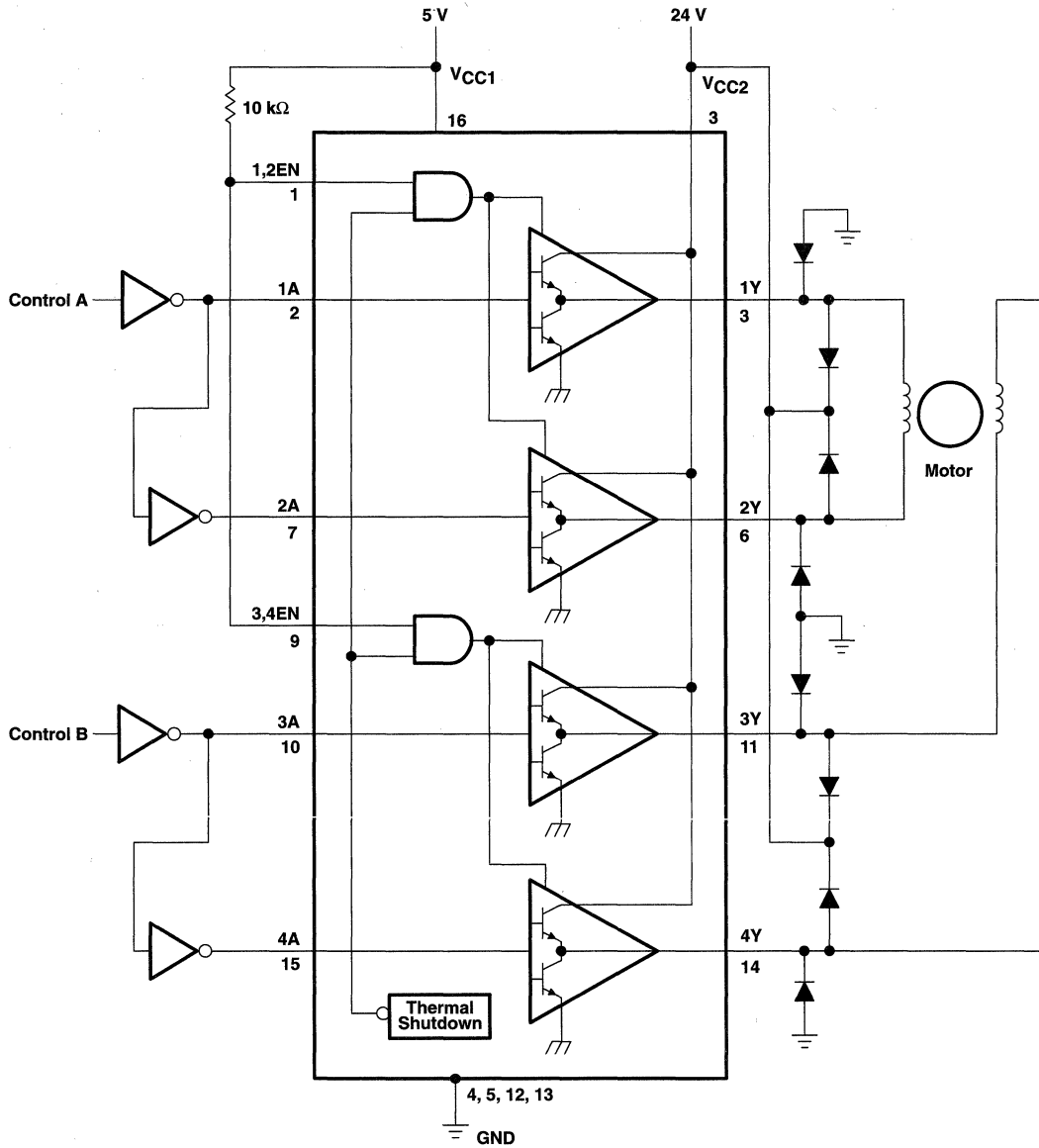


Figure 2. Two-Phase Motor Driver

# L293D QUADRUPLE HALF-H DRIVER

SLRS008A—SEPTEMBER 1986—REVISED MAY 1990

- 600-mA Output Current Capability Per Driver
- Pulsed Current 1.2-A Per Driver
- Output Clamp Diodes for Inductive Transient Suppression
- Wide Supply Voltage Range 4.5 V to 36 V
- Separate Input-Logic Supply
- Thermal Shutdown
- Internal ESD Protection
- High-Noise-Immunity Inputs
- Functional Replacement for SGS L293D

## description

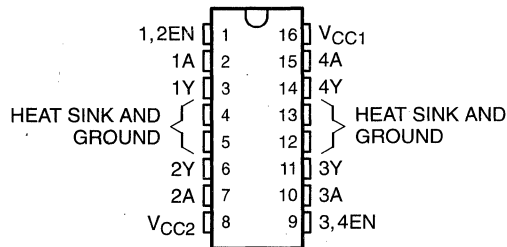
The L293D is a quadruple high-current half-H driver designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. It is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are TTL-compatible. Each output is a complete totem-pole drive circuit with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. External high-speed output clamp diodes should be used for inductive transient suppression. When the enable input is low, those drivers are disabled, and their outputs are off and in a high-impedance state. With the proper data inputs, each pair of drivers form a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

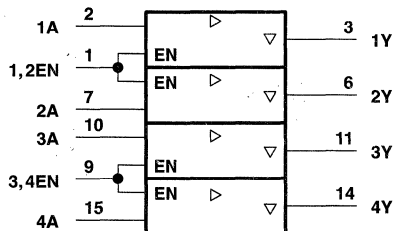
A  $V_{CC1}$  terminal, separate from  $V_{CC2}$ , is provided for the logic inputs to minimize device power dissipation.

The L293D is designed for operation from 0°C to 70°C.

NE PACKAGE  
(TOP VIEW)

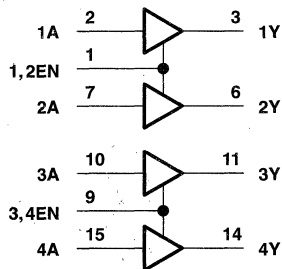


## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## logic diagram



FUNCTION TABLE  
(each driver)

INPUTS‡		OUTPUT
A	EN	Y
H	H	H
L	H	L
X	L	Z

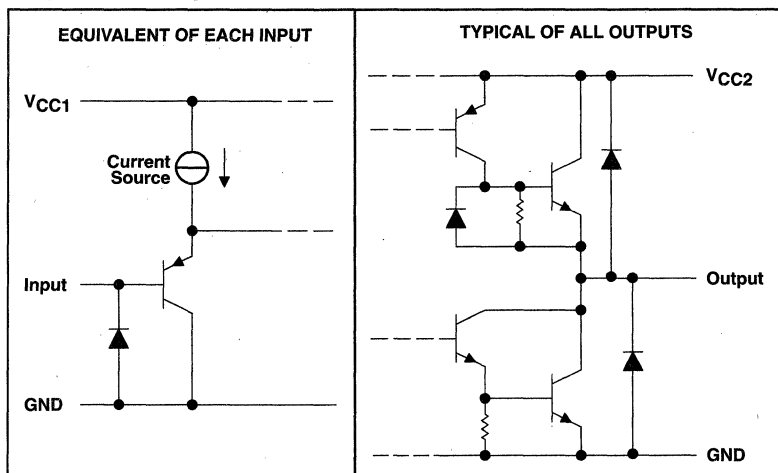
H = high-level, L = low level,  
X = irrelevant, Z = high-impedance (off)  
‡ In the thermal shutdown mode, the output is in the high-impedance state regardless of the input levels.



# L293D QUADRUPLE HALF-H DRIVER

SLRS008A – SEPTEMBER 1986 – REVISED MAY 1990

## schematics of inputs and outputs



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

Logic supply voltage range, $V_{CC1}$ (see Note 1)	36 V
Output supply voltage range, $V_{CC2}$	36 V
Input voltage range, $V_I$	7 V
Output voltage range, $V_O$	-3 V to $V_{CC2} + 3$ V
Peak output current (nonrepetitive, $t \leq 100 \mu\text{s}$ )	$\pm 1.2$ A
Continuous output current, $I_O$	$\pm 600$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Notes 2 and 3)	2075 mW
Continuous total dissipation at 80°C case temperature (see Note 3)	5000 mW
Operating case or virtual junction temperature range, $T_J$	-40°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 seconds	260°C

- NOTES: 1. All voltage values are with respect to the network ground terminal.  
 2. For operation above 25°C free-air temperature, derate linearly at the rate of 16.6 mW/°C.  
 3. For operation above 25°C case temperature, derate linearly at the rate of 71.4 mW/°C. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

## recommended operating conditions

	MIN	MAX	UNIT
Logic supply voltage, $V_{CC1}$	4.5	7	V
Output supply voltage, $V_{CC2}$	$V_{CC1}$	36	V
High-level input voltage, $V_{IH}$	$V_{CC1} \leq 7$ V	2.3 $V_{CC1}$	V
	$V_{CC1} \geq 7$ V	2.3	7
Low-level input voltage, $V_{IL}$	-0.3†	1.5	V
Operating free-air temperature, $T_A$	0	70	°C

† The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels.



# L293D QUADRUPLE HALF-H DRIVER

SLRS008A – SEPTEMBER 1986 – REVISED MAY 1990

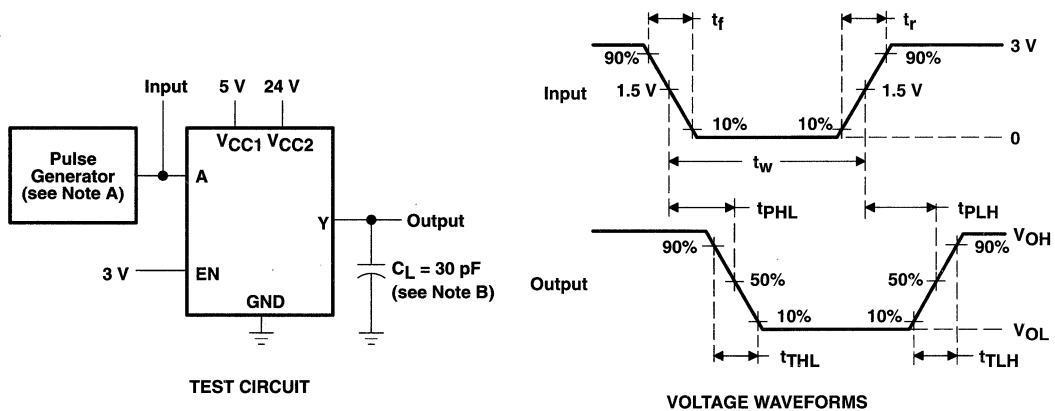
## electrical characteristics, $V_{CC1} = 5\text{ V}$ , $V_{CC2} = 24\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{OH}$	High-level output voltage	$I_{OH} = -0.6\text{ A}$		$V_{CC2} - 1.8$	$V_{CC2} - 1.4$		V
$V_{OL}$	Low-level output voltage	$I_{OL} = 0.6\text{ A}$			1.2	1.8	V
$V_{OKH}$	High-level output clamp voltage	$I_{OK} = -0.6\text{ A}$			$V_{CC2} + 1.3$		V
$V_{OKL}$	Low-level output clamp voltage	$I_{OK} = -0.6\text{ A}$			1.3		V
$I_{IH}$	High-level input current	A	$V_I = 7\text{ V}$		0.2	100	$\mu\text{A}$
		EN			0.2	$\pm 10$	
$I_{IL}$	Low-level input current	A	$V_I = 0$		-3	-10	$\mu\text{A}$
		EN			-2	-100	
$I_{CC1}$	Logic supply current	$I_O = 0$	All outputs at high level		13	22	mA
			All outputs at low level		35	60	
			All outputs at high impedance		8	24	
$I_{CC2}$	Output supply current	$I_O = 0$	All outputs at high level		14	24	mA
			All outputs at low level		2	6	
			All outputs at high impedance		2	4	

## switching characteristics, $V_{CC1} = 5\text{ V}$ , $V_{CC2} = 24\text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output from A input	$C_L = 30\text{ pF}$ See Figure 1		800		ns
$t_{PHL}$	Propagation delay time, high-to-low-level output from A input			400		ns
$t_{TLH}$	Transition time, low-to-high-level output			300		ns
$t_{THL}$	Transition time, high-to-low-level output			300		ns

### PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10\text{ ns}$ ,  $t_f \leq 10\text{ ns}$ ,  $t_w = 10\text{ }\mu\text{s}$ ,  $\text{PRR} = 5\text{ kHz}$ ,  $Z_O = 50\text{ }\Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

**Figure 1. Test Circuit and Voltage Waveforms**

# L293D QUADRUPLE HALF-H DRIVER

SLRS008A – SEPTEMBER 1986 – REVISED MAY 1990

## APPLICATION INFORMATION

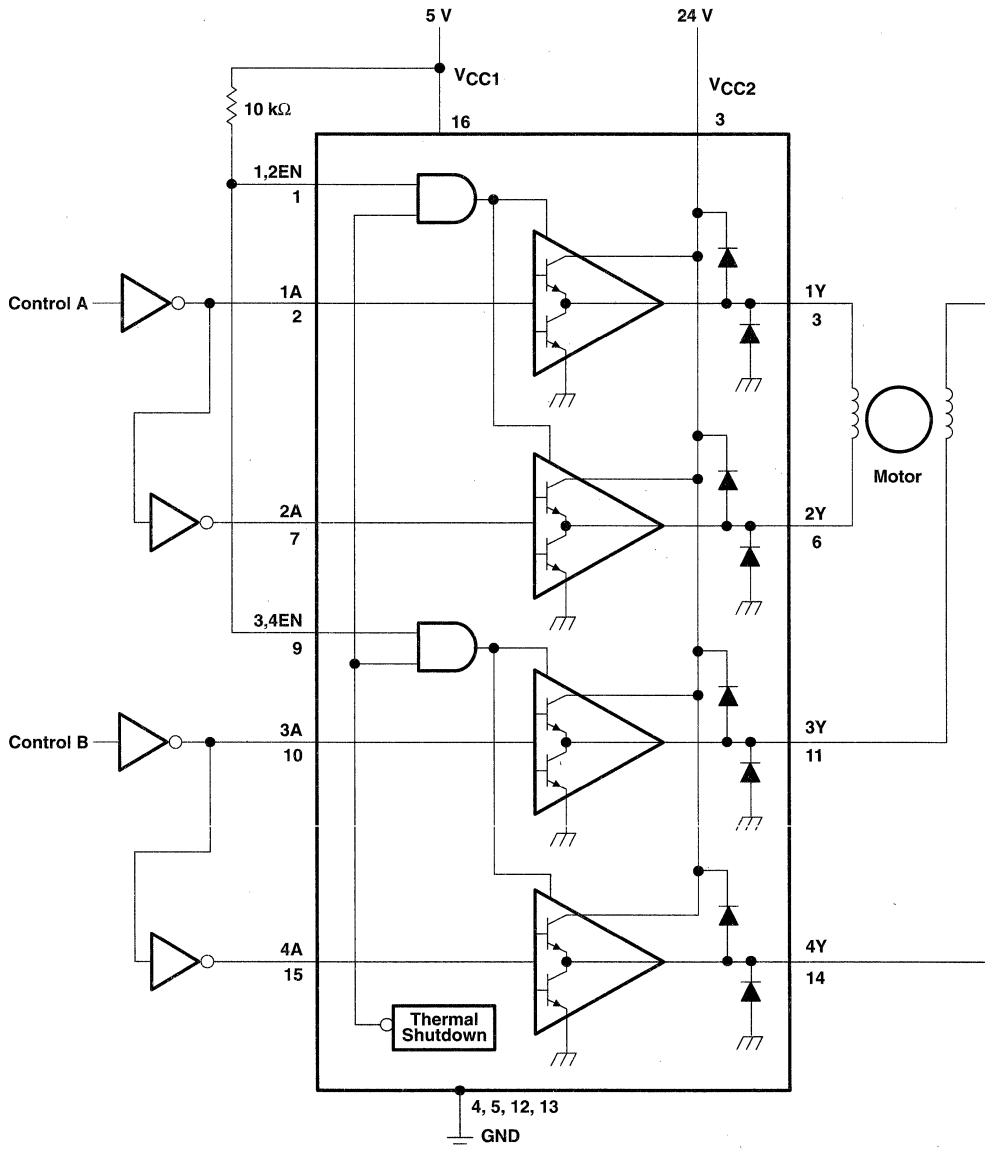


Figure 2. Two-Phase Motor Driver

# SN55451B THRU SN55454B SN75451B THRU SN75454B DUAL PERIPHERAL DRIVERS

SLRS021A – DECEMBER 1976 – REVISED MAY 1993

## PERIPHERAL DRIVERS FOR HIGH-CURRENT SWITCHING AT VERY HIGH SPEEDS

- Characterized for Use to 300 mA
- High-Voltage Outputs
- No Output Latch-Up at 20 V (After Conducting 300 mA)
- High-Speed Switching
- Circuit Flexibility for Varied Applications
- TTL-Compatible Diode-Clamped Inputs
- Standard Supply Voltages
- Plastic DIP (P) With Copper Lead Frame Provides Cooler Operation and Improved Reliability
- Package Options Include Plastic Small-Outline Packages, Ceramic Chip Carriers, and Standard Plastic and Ceramic 300-mil DIPs

SUMMARY OF DEVICES

DEVICE	LOGIC OF COMPLETE CIRCUIT	PACKAGES
SN55451B	AND†	FK, JG
SN55452B	NAND	JG
SN55453B	OR	FK, JG
SN55454B	NOR	JG
SN75451B	AND	D, P
SN75452B	NAND	D, P
SN75453B	OR	D, P
SN75454B	NOR	D, P

† With output transistor base connected externally to output of gate

## description

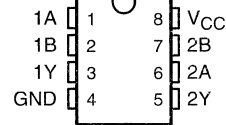
The SN55451B through SN55454B and SN75451B through SN75454B are dual peripheral drivers designed for use in systems that employ TTL logic. This family is functionally interchangeable with and replaces the SN75450 family and the SN75450A family devices manufactured previously. The speed of the devices is equal to that of the SN75450 family, and the parts are designed to ensure freedom from latch-up. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, lamp drivers, MOS drivers, line drivers, and memory drivers.

The SN55451B/SN75451B, SN55452B/SN75452B, SN55453B/SN75453B, and SN55454B/SN75454B are dual peripheral AND, NAND, OR, and NOR drivers, respectively (assuming positive logic), with the output of the logic gates internally connected to the bases of the npn output transistors.

The SN55' drivers are characterized for operation over the full military range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SN75' drivers are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

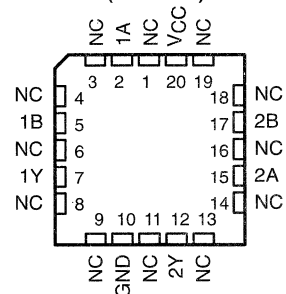
SN55451B, SN55452B,  
SN55453B, SN55454B . . . JG PACKAGE  
SN75451B, SN75452B,  
SN75453B, SN75454B . . . D OR P PACKAGE

(TOP VIEW)



SN55451B, SN55452B  
SN55453B, SN55454B . . . FK PACKAGE

(TOP VIEW)



NC – No internal connection

**SN55451B THRU SN55454B**  
**SN75451B THRU SN75454B**  
**DUAL PERIPHERAL DRIVERS**  
 SLRS021A – DECEMBER 1976 – REVISED MAY 1993

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

	SN55'	SN75'	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	7	7	V
Input voltage, $V_I$	5.5	5.5	V
Inter-emitter voltage (see Note 2)	5.5	5.5	V
Off-state output voltage, $V_O$	30	30	V
Continuous collector or output current, $I_{OK}$ (see Note 3)	400	400	mA
Peak collector or output current, $I_I$ ( $t_W \leq 10$ ms, duty cycle $\leq 50\%$ , see Note 4)	500	500	mA
Continuous total power dissipation	See Dissipation Rating Table		
Operating free-air temperature range, $T_A$	-55 to 125	0 to 70	°C
Storage temperature range, $T_{Stg}$	-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 package	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	°C

- NOTES: 1. Voltage values are with respect to network GND, unless otherwise specified.  
 2. This is the voltage between two emitters of a multiple-emitter transistor.  
 3. This value applies when the base-emitter resistance ( $R_{BE}$ ) is equal to or less than 500  $\Omega$ .  
 4. Both halves of these dual circuits may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous dissipation rating.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	—
FK	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	—

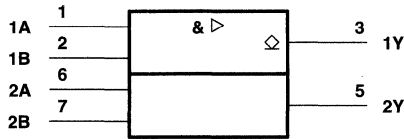
**recommended operating conditions**

	SN55'			SN75'			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.5	5	5.5	4.75	5	5.25	V
High-level input voltage, $V_{IH}$	2			2			V
Low-level input voltage, $V_{IL}$	0.8			0.8			V
Operating free-air temperature, $T_A$	-55			125			°C

# SN55451B THRU SN55454B SN75451B THRU SN75454B DUAL PERIPHERAL DRIVERS

SLRS021A - DECEMBER 1976 - REVISED MAY 1993

## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

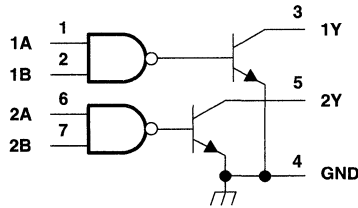
Pin numbers shown are for the D, JG, and P packages.

**FUNCTION TABLE**  
(each driver)

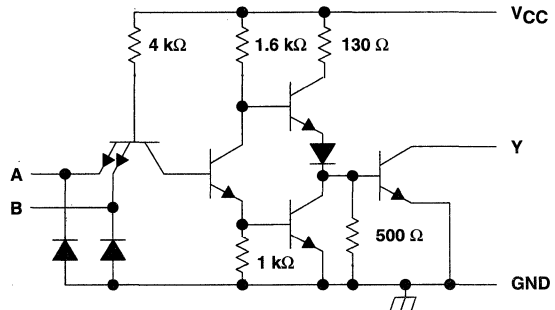
A	B	Y
L	L	L (on state)
L	H	L (on state)
H	L	L (on state)
H	H	H (off state)

positive logic:  
 $Y = AB \text{ or } \overline{A+B}$

## logic diagram (positive logic)



## schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS‡	SN55451B			SN75451B			UNIT
		MIN	TYP§	MAX	MIN	TYP§	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}$ , $I_I = -12 \text{ mA}$	-1.2	-1.5		-1.2	-1.5		V
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 100 \text{ mA}$	0.25	0.5		0.25	0.4		V
	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 300 \text{ mA}$	0.5	0.8		0.5	0.7		
$I_{OH}$ High-level output current	$V_{CC} = \text{MIN}$ , $V_{OH} = 30 \text{ V}$ , $V_{IH} = \text{MIN}$			300			100	$\mu\text{A}$
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}$ , $V_I = 5.5 \text{ V}$			1			1	mA
$I_{IH}$ High-level input current	$V_{CC} = \text{MAX}$ , $V_I = 2.4 \text{ V}$			40			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = \text{MAX}$ , $V_I = 0.4 \text{ V}$	-1	-1.6		-1	-1.6		mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = \text{MAX}$ , $V_I = 5 \text{ V}$	7	11		7	11		mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = \text{MAX}$ , $V_I = 0$	52	65		52	65		mA

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}$ , $R_L = 50 \Omega$ , See Figure 1		18	25	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			18	25	
$t_{TLH}$ Transition time, low-to-high-level output			5	8	
$t_{THL}$ Transition time, high-to-low-level output			7	12	
$V_{OH}$ High-level output voltage after switching	SN55451B	$V_S - 6.5$			mV
	SN75451B	$V_S - 6.5$			

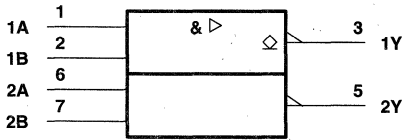
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# SN55451B THRU SN55454B SN75451B THRU SN75454B DUAL PERIPHERAL DRIVERS

SLRS021A - DECEMBER 1976 - REVISED MAY 1993

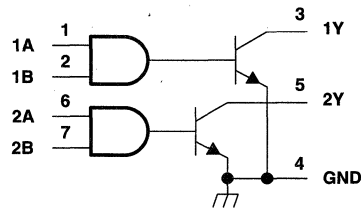
## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

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

## logic diagram (positive logic)



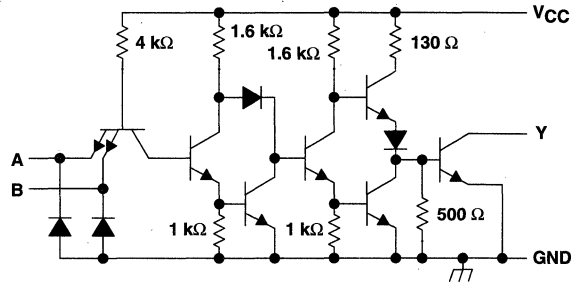
FUNCTION TABLE  
(each driver)

A	B	Y
L	L	H (off state)
L	H	H (off state)
H	L	H (off state)
H	H	L (on state)

positive logic:

$$Y = \overline{AB} \text{ or } \overline{A+B}$$

schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS‡	SN55452B			SN75452B			UNIT
		MIN	TYP§	MAX	MIN	TYP§	MAX	
V <sub>IK</sub> Input clamp voltage	V <sub>CC</sub> = MIN, I <sub>I</sub> = -12 mA	-1.2		-1.5	-1.2		-1.5	V
V <sub>OL</sub> Low-level output voltage	V <sub>CC</sub> = MIN, V <sub>IH</sub> = MIN, I <sub>OL</sub> = 100 mA	0.25		0.5	0.25		0.4	V
	V <sub>CC</sub> = MIN, V <sub>IH</sub> = MIN, I <sub>OL</sub> = 300 mA	0.5		0.8	0.5		0.7	
I <sub>OH</sub> High-level output current	V <sub>CC</sub> = MIN, V <sub>IL</sub> = 0.8 V, V <sub>OH</sub> = 30 V			300			100	μA
I <sub>I</sub> Input current at maximum input voltage	V <sub>CC</sub> = MAX, V <sub>I</sub> = 5.5 V			1			1	mA
I <sub>IH</sub> High-level input current	V <sub>CC</sub> = MAX, V <sub>I</sub> = 2.4 V			40			40	μA
I <sub>IL</sub> Low-level input current	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0.4 V	-1.1		-1.6	-1.1		-1.6	mA
I <sub>CCH</sub> Supply current, outputs high	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0	11		14	11		14	mA
I <sub>CCL</sub> Supply current, outputs low	V <sub>CC</sub> = MAX, V <sub>I</sub> = 5 V	56		71	56		71	mA

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ All typical values are at V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C.

## switching characteristics, V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C

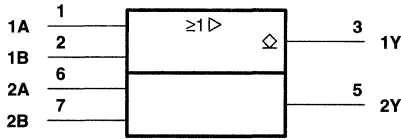
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>PLH</sub> Propagation delay time, low-to-high-level output	I <sub>O</sub> = 200 mA, C <sub>L</sub> = 15 pF, R <sub>L</sub> = 50 Ω, See Figure 1		26	35	ns
t <sub>PHL</sub> Propagation delay time, high-to-low-level output			24	35	
t <sub>TLH</sub> Transition time, low-to-high-level output			5	8	
t <sub>THL</sub> Transition time, high-to-low-level output			7	12	
V <sub>OH</sub> High-level output voltage after switching	SN55452B	V <sub>S</sub> = 20 V, I <sub>O</sub> ≈ 300 mA, See Figure 2			mV
	SN75452B	V <sub>S</sub> - 6.5			

TEXAS  
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# SN55451B THRU SN55454B SN75451B THRU SN75454B DUAL PERIPHERAL DRIVERS

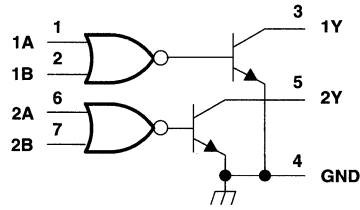
SLRS021A - DECEMBER 1976 - REVISED MAY 1993

## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12. Pin numbers shown are for the D, JG, and P packages.

## logic diagram (positive logic)

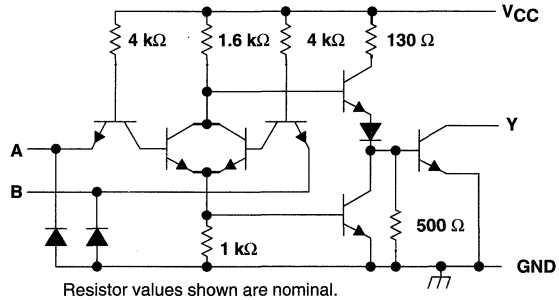


**FUNCTION TABLE**  
(each driver)

A	B	Y
L	L	L (on state)
L	H	H (off state)
H	L	H (off state)
H	H	H (off state)

positive logic:  $Y = A+B$  or  $\overline{A}\overline{B}$

## schematic (each driver)



## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS‡	SN55453B		SN75453B		UNIT		
		MIN	TYP§	MAX	MIN		TYP§	MAX
V <sub>IK</sub> Input clamp voltage	V <sub>CC</sub> = MIN, I <sub>I</sub> = -12 mA	-1.2		-1.5	-1.2		-1.5	V
V <sub>OL</sub> Low-level output voltage	V <sub>CC</sub> = MIN, V <sub>IL</sub> = 0.8 V, I <sub>OL</sub> = 100 mA	0.25		0.5	0.25		0.4	V
	V <sub>CC</sub> = MIN, V <sub>IL</sub> = 0.8 V, I <sub>OL</sub> = 300 mA	0.5		0.8	0.5		0.7	
I <sub>OH</sub> High-level output current	V <sub>CC</sub> = MIN, V <sub>OH</sub> = 30 V, V <sub>IH</sub> = MIN			300			100	μA
I <sub>I</sub> Input current at maximum input voltage	V <sub>CC</sub> = MAX, V <sub>I</sub> = 5.5 V			1			1	mA
I <sub>IH</sub> High-level input current	V <sub>CC</sub> = MAX, V <sub>I</sub> = 2.4 V			40			40	μA
I <sub>IL</sub> Low-level input current	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0.4 V	-1		-1.6	-1		-1.6	mA
I <sub>CCH</sub> Supply current, outputs high	V <sub>CC</sub> = MAX, V <sub>I</sub> = 5 V	8		11	8		11	mA
I <sub>CCL</sub> Supply current, outputs low	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0	54		68	54		68	mA

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ All typical values are at V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C.

## switching characteristics, V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C

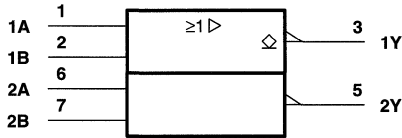
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>PLH</sub> Propagation delay time, low-to-high-level output	I <sub>O</sub> ≈ 200 mA, C <sub>L</sub> = 15 pF, R <sub>L</sub> = 50 Ω, See Figure 1		18	25	ns
t <sub>PHL</sub> Propagation delay time, high-to-low-level output			18	25	
t <sub>TLH</sub> Transition time, low-to-high-level output			5	8	
t <sub>THL</sub> Transition time, high-to-low-level output			7	12	
V <sub>OH</sub> High-level output voltage after switching	SN55453B	V <sub>S</sub> = 20 V, I <sub>O</sub> ≈ 300 mA, See Figure 2		V <sub>S</sub> - 6.5	mV
	SN75453B			V <sub>S</sub> - 6.5	



# SN55451B THRU SN55454B SN75451B THRU SN75454B DUAL PERIPHERAL DRIVERS

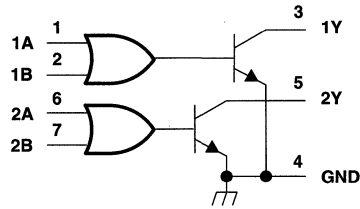
SLRS021A—DECEMBER 1976—REVISED MAY 1993

## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12. Pin numbers shown are for the D, JG, and P packages.

## logic diagram (positive logic)

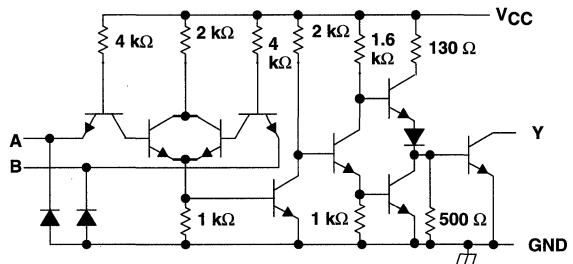


**FUNCTION TABLE**  
(each driver)

A	B	Y
L	L	H (off state)
L	H	L (on state)
H	L	L (on state)
H	H	L (on state)

positive logic:  
 $Y = \overline{A+B}$  or  $\overline{AB}$

## schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS‡	SN55454B		SN75454B		UNIT		
		MIN	TYP§	MAX	MIN		TYP§	MAX
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}$ , $I_I = -12 \text{ mA}$	-1.2		-1.5	-1.2		V	
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}$ , $V_{IH} = \text{MIN}$ , $I_{OL} = 100 \text{ mA}$		0.25	0.5		0.25	0.4	V
	$V_{CC} = \text{MIN}$ , $V_{IH} = \text{MIN}$ , $I_{OL} = 300 \text{ mA}$		0.5	0.8		0.5	0.7	V
$I_{OH}$ High-level output current	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $V_{OH} = 30 \text{ V}$			300			100	$\mu\text{A}$
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}$ , $V_I = 5.5 \text{ V}$			1			1	mA
$I_{IH}$ High-level input current	$V_{CC} = \text{MAX}$ , $V_I = 2.4 \text{ V}$			40			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = \text{MAX}$ , $V_I = 0.4 \text{ V}$			-1			-1.6	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = \text{MAX}$ , $V_I = 0$		13	17		13	17	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = \text{MAX}$ , $V_I = 5 \text{ V}$		61	79		61	79	mA

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

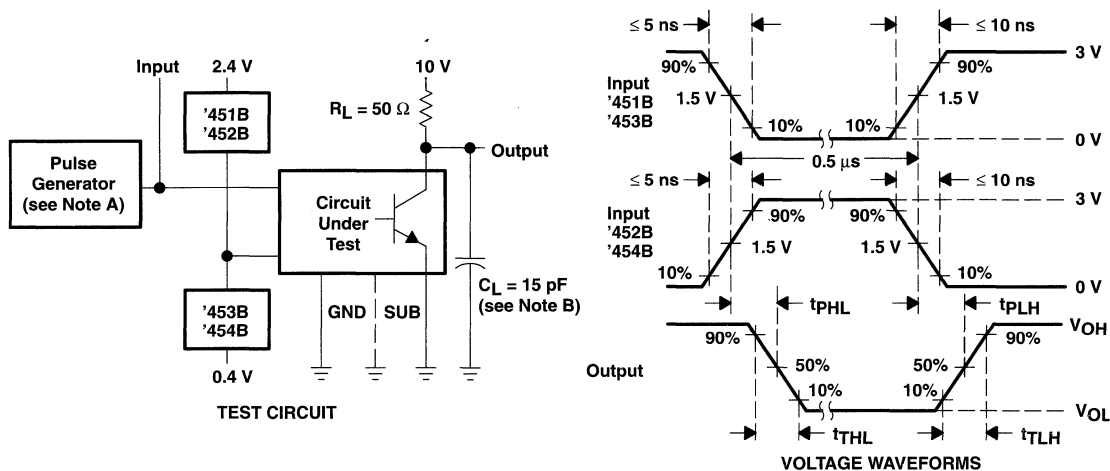
§ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}$ , $C_L = 15 \text{ pF}$ , $R_L = 50 \Omega$ , See Figure 1		27	35	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			24	35	
$t_{TLH}$ Transition time, low-to-high-level output			5	8	
$t_{THL}$ Transition time, high-to-low-level output			7	12	
$V_{OH}$ High-level output voltage after switching	SN55454B	$V_S = 20 \text{ V}$ , $I_O \approx 300 \text{ mA}$ , See Figure 2	$V_S - 6.5$		mV
	SN75454B		$V_S - 6.5$		

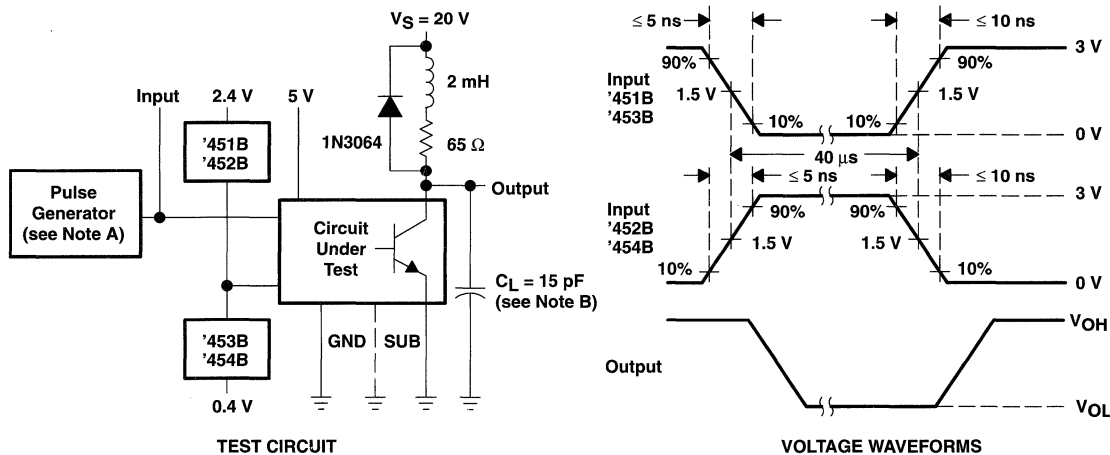
TEXAS  
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PARAMETER MEASUREMENT INFORMATION



NOTES: A. The pulse generator has the following characteristics: PRR  $\leq$  1 MHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms, Complete Drivers

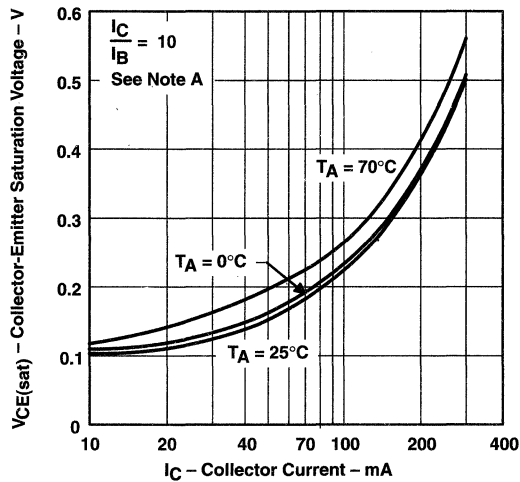


NOTES: A. The pulse generator has the following characteristics: PRR  $\leq$  12.5 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 2. Test Circuit and Voltage Waveforms for Latch-Up Test of Complete Drivers

TYPICAL CHARACTERISTICS

TRANSISTOR  
COLLECTOR-EMITTER SATURATION VOLTAGE  
vs  
COLLECTOR CURRENT



NOTE A: These parameters must be measured using pulse techniques,  $t_w = 300 \mu\text{s}$ , duty cycle  $\leq 2\%$ .

Figure 3

# SN55461 THRU SN55463 SN75461 THRU SN75463 DUAL PERIPHERAL DRIVERS

SLRS022A – DECEMBER 1976 – REVISED OCTOBER 1995

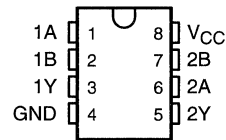
## PERIPHERAL DRIVERS FOR HIGH-VOLTAGE, HIGH-CURRENT DRIVER APPLICATIONS

- Characterized for Use to 300 mA
- High-Voltage Outputs
- No Output Latch-Up at 30 V (After Conducting 300 mA)
- Medium-Speed Switching
- Circuit Flexibility for Varied Applications and Choice of Logic Function
- TTL-Compatible Diode-Clamped Inputs
- Standard Supply Voltages
- Plastic DIP (P) With Copper Lead Frame for Cooler Operation and Improved Reliability
- Package Options Include Plastic Small Outline Packages, Ceramic Chip Carriers, and Standard Plastic and Ceramic 300-mil DIPs

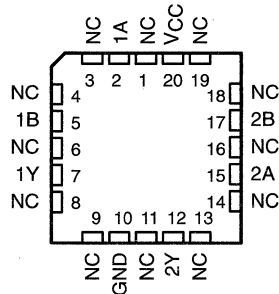
### SUMMARY OF SERIES 55461/75461

DEVICE	LOGIC	PACKAGES
SN55461	AND	FK, JG
SN55462	NAND	FK, JG
SN55463	OR	FK, JG
SN75461	AND	D, P
SN75462	NAND	D, P
SN75463	OR	D, P

SN55461, SN55462, SN55463 . . . JG PACKAGE  
SN75461, SN75462, SN75463 . . . D OR P PACKAGE  
(TOP VIEW)



SN55461, SN55462, SN55463 . . . FK PACKAGE  
(TOP VIEW)



NC – No internal connection

## description

These dual peripheral drivers are functionally interchangeable with SN55451B through SN55453B and SN75451B through SN75453B peripheral drivers, but are designed for use in systems that require higher breakdown voltages than those devices can provide at the expense of slightly slower switching speeds. Typical applications include logic buffers, power drivers, relay drivers, lamp drivers, MOS drivers, line drivers, and memory drivers.

The SN55461/SN75461, SN55462/SN75462, and SN55463/SN75463 are dual peripheral AND, NAND, and OR drivers respectively (assuming positive logic), with the output of the gates internally connected to the bases of the npn output transistors.

Series SN55461 drivers are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Series SN75461 drivers are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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**SN55461 THRU SN55463**  
**SN75461 THRU SN75463**  
**DUAL PERIPHERAL DRIVERS**

SLRS022A – DECEMBER 1976 – REVISED OCTOBER 1995

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

	SN55'	SN75'	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	7	7	V
Input voltage, $V_I$	5.5	5.5	V
Intermitter voltage (see Note 2)	5.5	5.5	V
Off-state output voltage, $V_O$	35	35	V
Continuous collector or output current (see Note 3)	400	400	mA
Peak collector or output current ( $t_w \leq 10$ ms, duty cycle $\leq 50\%$ , see Note 4)	500	500	mA
Continuous total power dissipation	See Dissipation Rating Table		
Operating free-air temperature range, $T_A$	-55 to 125	0 to 70	°C
Storage temperature range, $T_{stg}$	-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	JG package	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P 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. Voltage values are with respect to network GND unless otherwise specified.
  2. This is the voltage between two emitters A and B.
  3. This value applies when the base-emitter resistance ( $R_{BE}$ ) is equal to or less than 500  $\Omega$ .
  4. Both halves of these dual circuits may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous dissipation rating.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	–
FK	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	–

**recommended operating conditions**

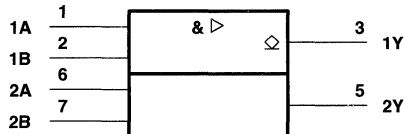
	SN55'			SN75'			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.5	5	5.5	4.75	5	5.25	V
High-level input voltage, $V_{IH}$	2			2			V
Low-level input voltage, $V_{IL}$				0.8			V
Operating free-air temperature, $T_A$	-55			125			°C



# SN55461 THRU SN55463 SN75461 THRU SN75463 DUAL PERIPHERAL DRIVERS

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## logic symbol†



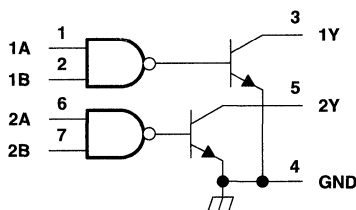
† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.  
Pin numbers shown are for D, JG, and P packages.

FUNCTION TABLE  
(each driver)

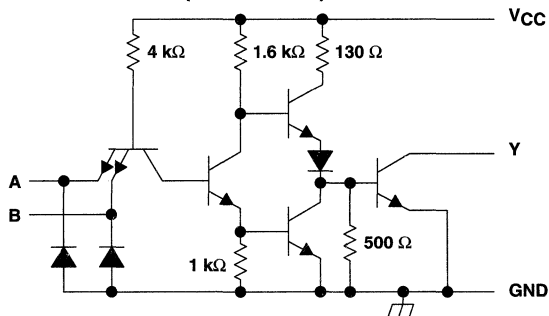
A	B	Y
L	L	L (on state)
L	H	L (on state)
H	L	L (on state)
H	H	H (off state)

positive logic:  
 $Y = AB \text{ or } A + B$

## logic diagram (positive logic)



## schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS†	SN55461		SN75461		UNIT
		MIN	TYP‡	MAX	MIN	
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}$ , $I_I = -12 \text{ mA}$	-1.2	-1.5	-1.2	-1.5	V
$I_{OH}$ High-level output current	$V_{CC} = \text{MIN}$ , $V_{IH} = \text{MIN}$ , $V_{OH} = 35 \text{ V}$		300		100	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 100 \text{ mA}$	0.25	0.5	0.25	0.4	V
	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 300 \text{ mA}$	0.5	0.8	0.5	0.7	
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}$ , $V_I = 5.5 \text{ V}$		1		1	mA
$I_{IH}$ High-level input current	$V_{CC} = \text{MAX}$ , $V_I = 2.4 \text{ V}$		40		40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = \text{MAX}$ , $V_I = 0.4 \text{ V}$	-1	-1.6	-1	-1.6	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = \text{MAX}$ , $V_I = 5 \text{ V}$	8	11	8	11	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = \text{MAX}$ , $V_I = 0$	56	76	56	76	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

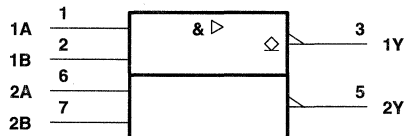
## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}$ , $C_L = 15 \text{ pF}$ , $R_L = 50 \Omega$ , See Figure 1		30	55	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			25	40	
$t_{TLH}$ Transition time, low-to-high-level output			8	20	
$t_{THL}$ Transition time, high-to-low-level output			10	20	
$V_{OH}$ High-level output voltage after switching	SN55461	$V_S = 30 \text{ V}$ , $I_O = 300 \text{ mA}$ , See Figure 2		$V_S - 10$	mV
	SN75461			$V_S - 10$	

# SN55461 THRU SN55463 SN75461 THRU SN75463 DUAL PERIPHERAL DRIVERS

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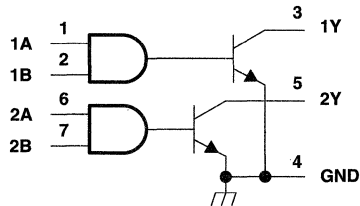
## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

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

## logic diagram (positive logic)



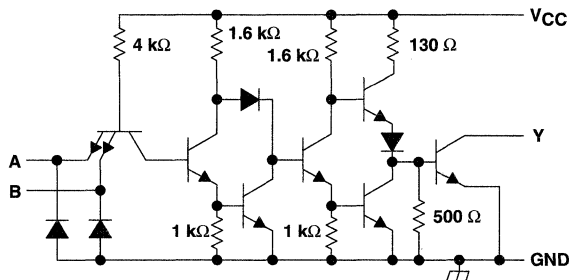
**FUNCTION TABLE**  
(each driver)

A	B	Y
L	L	H (off state)
L	H	H (off state)
H	L	H (off state)
H	H	L (on state)

positive logic:

$$Y = \overline{AB} \text{ or } \overline{A} + \overline{B}$$

## schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS†	SN55462			SN75462			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}$ , $I_I = -12 \text{ mA}$	-1.2	-1.5		-1.2	-1.5		V
$I_{OH}$ High-level output current	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8 \text{ V}$ , $V_{OH} = 35 \text{ V}$			300			100	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}$ , $V_{IH} = \text{MIN}$ , $I_{OL} = 100 \text{ mA}$		0.25	0.5		0.25	0.4	V
	$V_{CC} = \text{MIN}$ , $V_{IH} = \text{MIN}$ , $I_{OL} = 300 \text{ mA}$		0.5	0.8		0.5	0.7	
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}$ , $V_I = 5.5 \text{ V}$			1			1	mA
$I_{IH}$ High-level input current	$V_{CC} = \text{MAX}$ , $V_I = 2.4 \text{ V}$			40			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = \text{MAX}$ , $V_I = 0.4 \text{ V}$		-1.1	-1.6		-1.1	-1.6	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = \text{MAX}$ , $V_I = 0$		13	17		13	17	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = \text{MAX}$ , $V_I = 5 \text{ V}$		61	76		61	76	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

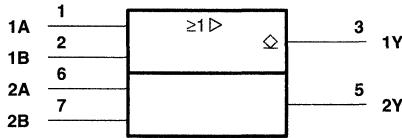
## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}$ , $C_L = 15 \text{ pF}$ , $R_L = 50 \Omega$ , See Figure 1		45	65	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			30	50	
$t_{TLH}$ Transition time, low-to-high-level output			13	25	
$t_{THL}$ Transition time, high-to-low-level output			10	20	
$V_{OH}$ High-level output voltage after switching	SN55462	$V_S = 30 \text{ V}$ , See Figure 2	$I_O \approx 300 \text{ mA}$ ,	$V_S - 10$	mV
	SN75462			$V_S - 10$	

SN55461 THRU SN55463  
SN75461 THRU SN75463  
DUAL PERIPHERAL DRIVERS

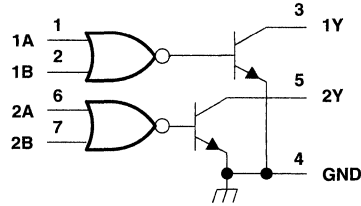
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logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12. Pin numbers shown are for D, JG, and P packages.

logic diagram (positive logic)



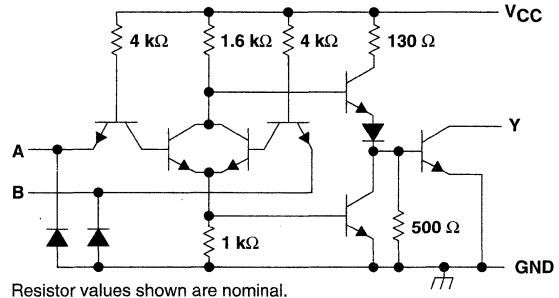
FUNCTION TABLE  
(each driver)

A	B	Y
L	L	L (on state)
L	H	H (off state)
H	L	H (off state)
H	H	H (off state)

positive logic:

$$Y = A + B \text{ or } \overline{A\overline{B}}$$

schematic (each driver)



electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS†	SN55463			SN75463			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}, I_I = -12 \text{ mA}$	-1.2	-1.5		-1.2	-1.5		V
$I_{OH}$ High-level output current	$V_{CC} = \text{MIN}, V_{IH} = \text{MIN}, V_{OH} = 35 \text{ V}$			300			100	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}, V_{IL} = 0.8 \text{ V}, I_{OL} = 100 \text{ mA}$		0.25	0.5		0.25	0.4	V
	$V_{CC} = \text{MIN}, V_{IL} = 0.8 \text{ V}, I_{OL} = 300 \text{ mA}$		0.5	0.8		0.5	0.7	
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}, V_I = 5.5 \text{ V}$			1			1	mA
$I_{IH}$ High-level input current	$V_{CC} = \text{MAX}, V_I = 2.4 \text{ V}$			40			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = \text{MAX}, V_I = 0.4 \text{ V}$		-1	-1.6		-1	-1.6	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = \text{MAX}, V_I = 5 \text{ V}$		8	11		8	11	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = \text{MAX}, V_I = 0$		58	76		58	76	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values are at  $V_{CC} = 5 \text{ V}, T_A = 25^\circ\text{C}$ .

switching characteristics,  $V_{CC} = 5 \text{ V}, T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}, C_L = 15 \text{ pF}, R_L = 50 \Omega,$ See Figure 1		30	55	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			25	40	
$t_{TLH}$ Transition time, low-to-high-level output			8	25	
$t_{THL}$ Transition time, high-to-low-level output			10	25	
$V_{OH}$ High-level output voltage after switching	SN55463	$V_S - 10$			mV
	SN75463	$V_S - 10$			

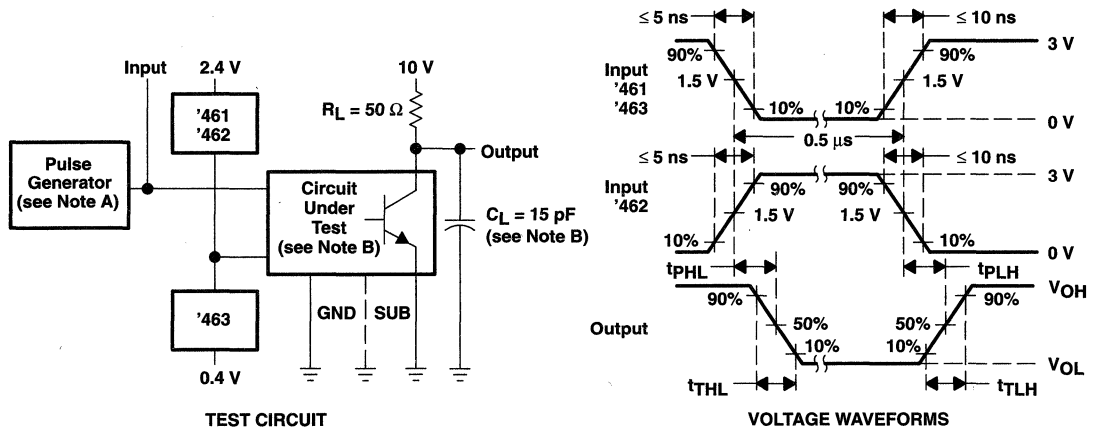




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SN75461 THRU SN75463  
DUAL PERIPHERAL DRIVERS**

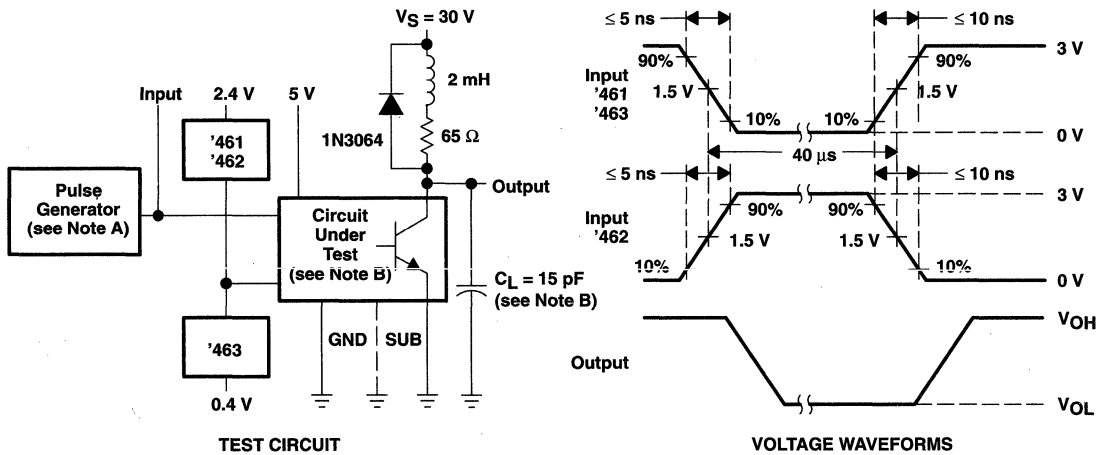
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**PARAMETER MEASUREMENT INFORMATION**



NOTES: A. The pulse generator has the following characteristics: PRR  $\leq$  1 MHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

**Figure 1. Test Circuit and Voltage Waveforms for Switching Times**



NOTES: A. The pulse generator has the following characteristics: PRR  $\leq$  12.5 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

**Figure 2. Test Circuit and Voltage Waveforms for Latch-Up Test**

# SN75372 DUAL MOSFET DRIVER

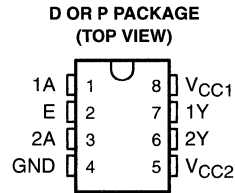
SLLS025A - JULY 1986

- Dual Circuits Capable of Driving High-Capacitance Loads at High Speeds
- Output Supply Voltage Range up to 24 V
- Low Standby Power Dissipation

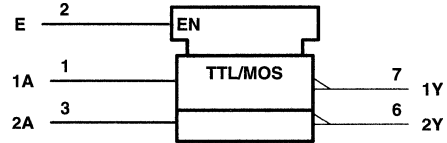
## description

The SN75372 is a dual NAND gate interface circuit designed to drive power MOSFETs from TTL inputs. It provides high current and voltage levels necessary to drive large capacitive loads at high speeds. The device operates from a  $V_{CC1}$  of 5 V and a  $V_{CC2}$  of up to 24 V.

The SN75372 is characterized for operation from 0°C to 70°C.

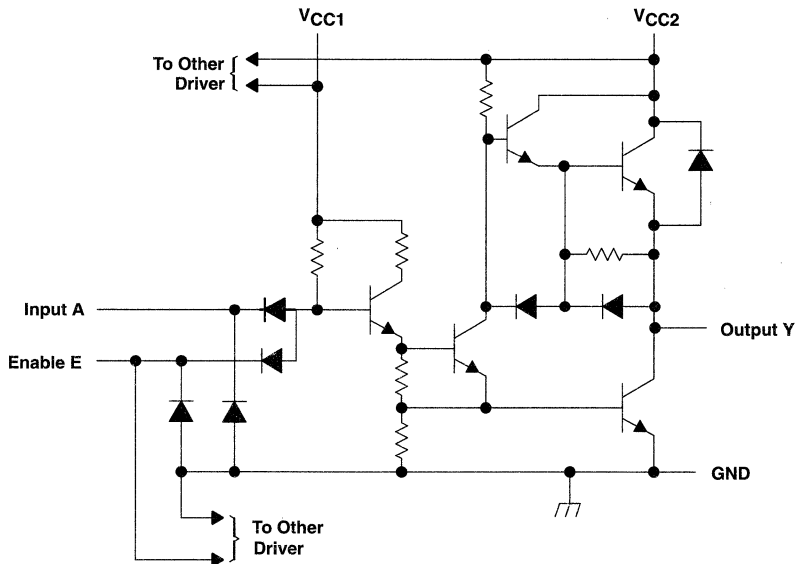


## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## schematic (each driver)



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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# SN75372 DUAL MOSFET DRIVER

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

Supply voltage range, $V_{CC1}$ (see Note 1)	-0.5 V to 7 V
Supply voltage range, $V_{CC2}$	-0.5 V to 25 V
Input voltage, $V_I$	5.5 V
Peak output current, $I_O$ ( $t_w < 10$ ms, duty cycle $< 50\%$ )	500 mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°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.

NOTE 1: Voltage values are with respect to network GND.

DISSIPATION RATING TABLE

PACKAGE	$T_A = 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC1}$	4.75	5	5.25	V
Supply voltage, $V_{CC2}$	4.75	20	24	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
High-level output current, $I_{OH}$			-10	mA
Low-level output current, $I_{OL}$			40	mA
Operating free-air temperature, $T_A$	0		70	°C

# SN75372 DUAL MOSFET DRIVER

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**electrical characteristics over recommended ranges of  $V_{CC1}$ ,  $V_{CC2}$ , and operating free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP†	MAX	UNIT
$V_{IK}$	Input clamp voltage	$I_I = -12 \text{ mA}$				-1.5	V
$V_{OH}$	High-level output voltage	$V_{IL} = 0.8 \text{ V}$ ,	$I_{OH} = -50 \mu\text{A}$	$V_{CC2} - 1.3$	$V_{CC2} - 0.8$		V
		$V_{IL} = 0.8 \text{ V}$ ,	$I_{OH} = -10 \text{ mA}$	$V_{CC2} - 2.5$	$V_{CC2} - 1.8$		
$V_{OL}$	Low-level output voltage	$V_{IH} = 2 \text{ V}$ ,	$I_{OL} = 10 \text{ mA}$		0.15	0.3	V
		$V_{CC2} = 15 \text{ V to } 24 \text{ V}$ ,	$V_{IH} = 2 \text{ V}$ ,		0.25	0.5	
$V_F$	Output clamp-diode forward voltage	$V_I = 0$ ,	$I_F = 20 \text{ mA}$			1.5	V
$I_I$	Input current at maximum input voltage	$V_I = 5.5 \text{ V}$				1	mA
$I_{IH}$	High-level input current	Any A	$V_I = 2.4 \text{ V}$			40	$\mu\text{A}$
		Any E		80			
$I_{IL}$	Low-level input current	Any A	$V_I = 0.4 \text{ V}$			-1	mA
		Any E		-2	-3.2		
$I_{CC1(H)}$	Supply current from $V_{CC1}$ , both outputs high	$V_{CC1} = 5.25 \text{ V}$ , All inputs at 0 V,	$V_{CC2} = 24 \text{ V}$ , No load		2	4	mA
$I_{CC2(H)}$	Supply current from $V_{CC2}$ , both outputs high			0.5	mA		
$I_{CC1(L)}$	Supply current from $V_{CC1}$ , both outputs low	$V_{CC1} = 5.25 \text{ V}$ , All inputs at 5 V,	$V_{CC2} = 24 \text{ V}$ , No load		16	24	mA
$I_{CC2(L)}$	Supply current from $V_{CC2}$ , both outputs low			7	13	mA	
$I_{CC2(S)}$	Supply current from $V_{CC2}$ , standby condition	$V_{CC1} = 0$ , All inputs at 5 V,	$V_{CC2} = 24 \text{ V}$ , No load			0.5	mA

† All typical values are at  $V_{CC1} = 5 \text{ V}$ ,  $V_{CC2} = 20 \text{ V}$ , and  $T_A = 25^\circ\text{C}$ .

**switching characteristics,  $V_{CC1} = 5 \text{ V}$ ,  $V_{CC2} = 20 \text{ V}$ ,  $T_A = 25^\circ\text{C}$**

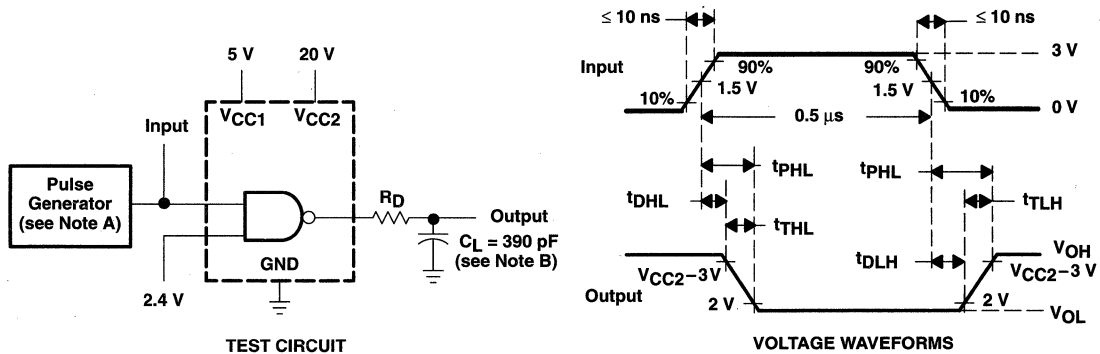
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
$t_{DLH}$	Delay time, low-to-high-level output	$C_L = 390 \text{ pF}$ , $R_D = 10 \Omega$ , See Figure 1			20	35	ns	
$t_{DHL}$	Delay time, high-to-low-level output				10	20	ns	
$t_{TLH}$	Transition time, low-to-high-level output				20	30	ns	
$t_{THL}$	Transition time, high-to-low-level output				20	30	ns	
$t_{PLH}$	Propagation delay time, low-to-high-level output				10	40	65	ns
$t_{PHL}$	Propagation delay time, high-to-low-level output				10	30	50	ns



# SN75372 DUAL MOSFET DRIVER

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## PARAMETER MEASUREMENT INFORMATION



NOTES: A. The pulse generator has the following characteristics: PRR = 1 MHz,  $Z_0 \approx 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms, Each Driver

## TYPICAL CHARACTERISTICS

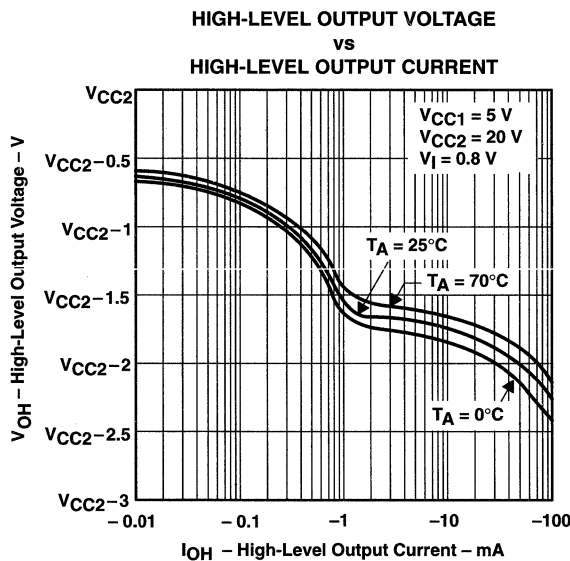


Figure 2

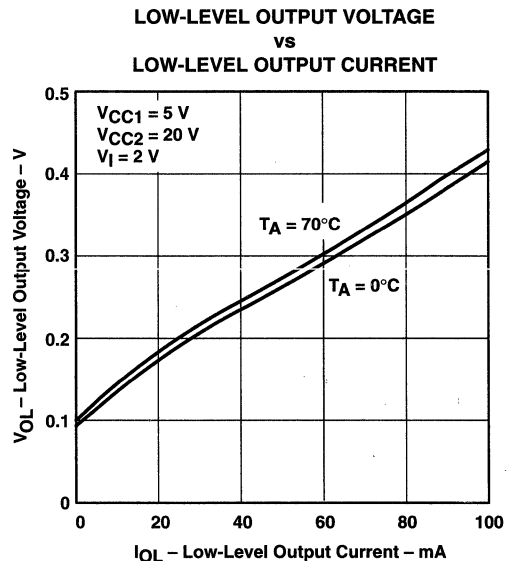


Figure 3

TYPICAL CHARACTERISTICS

VOLTAGE TRANSFER CHARACTERISTICS

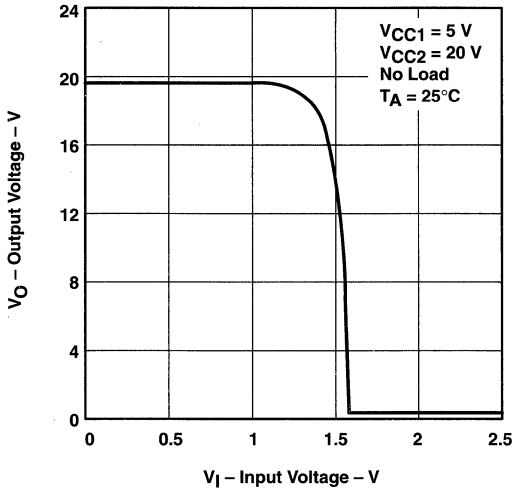


Figure 4

POWER DISSIPATION (BOTH DRIVERS)  
VS  
FREQUENCY

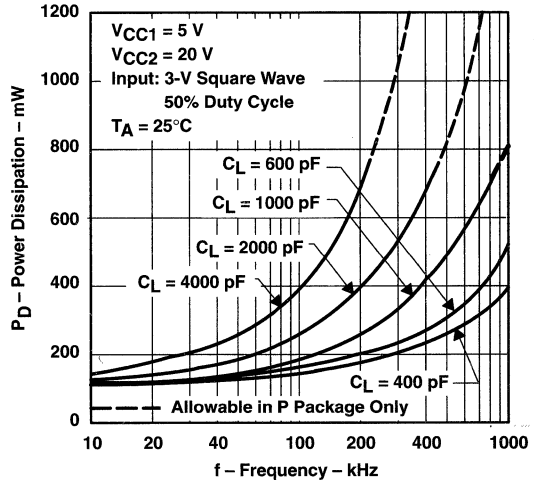


Figure 5

PROPAGATION DELAY TIME,  
LOW-TO-HIGH-LEVEL OUTPUT  
vs  
FREE-AIR TEMPERATURE

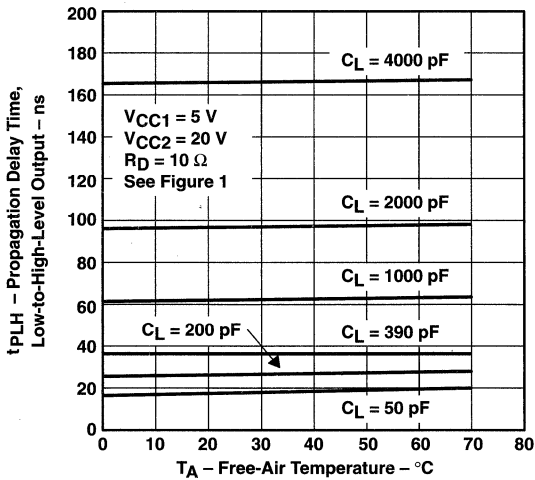


Figure 6

PROPAGATION DELAY TIME,  
HIGH-TO-LOW-LEVEL OUTPUT  
vs  
FREE-AIR TEMPERATURE

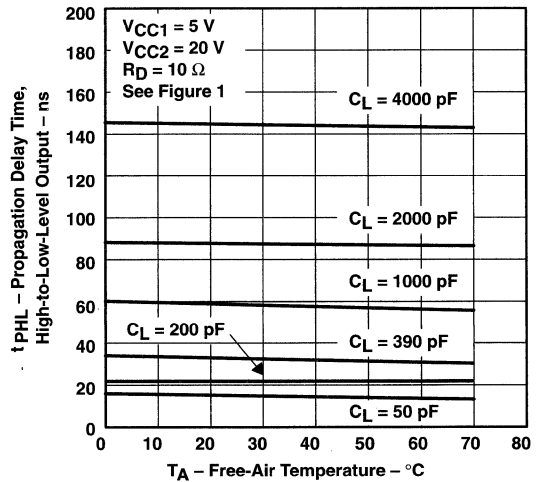


Figure 7

# SN75372 DUAL MOSFET DRIVER

SLLS025A - JULY 1986

## TYPICAL CHARACTERISTICS

PROPAGATION DELAY TIME,  
LOW-TO-HIGH-LEVEL OUTPUT  
vs  
VCC2 SUPPLY VOLTAGE

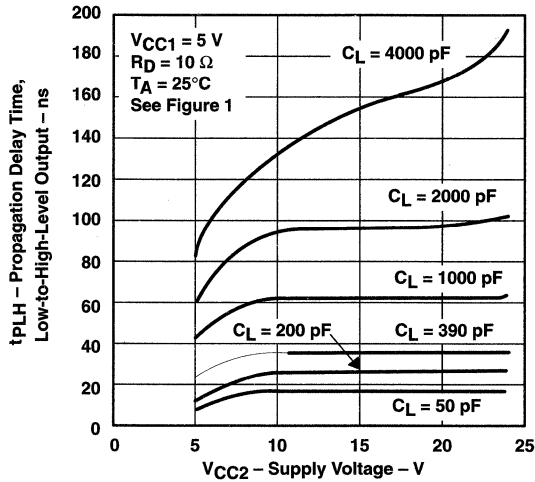


Figure 8

PROPAGATION DELAY TIME,  
HIGH-TO-LOW-LEVEL OUTPUT  
vs  
VCC2 SUPPLY VOLTAGE

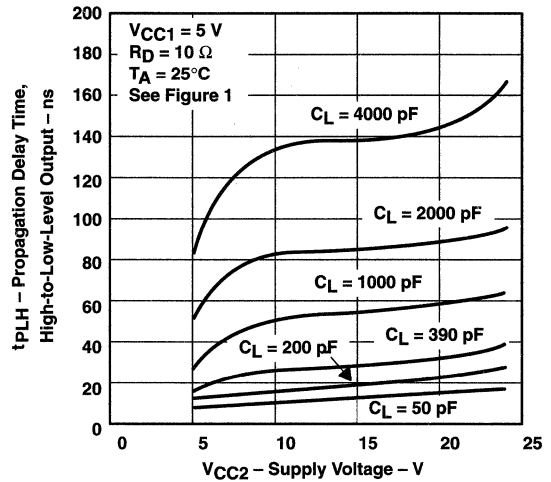


Figure 9

PROPAGATION DELAY TIME,  
LOW-TO-HIGH-LEVEL OUTPUT  
vs  
LOAD CAPACITANCE

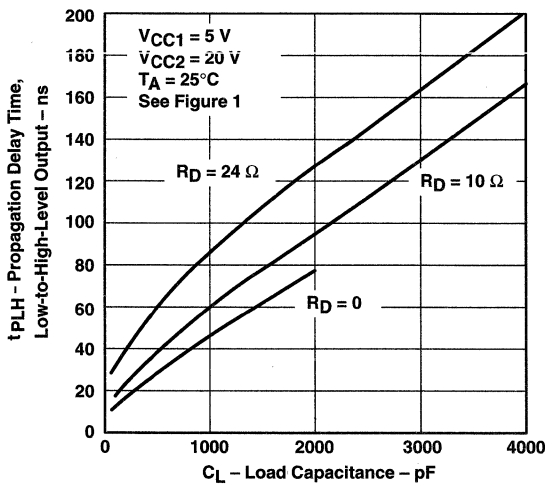


Figure 10

PROPAGATION DELAY TIME,  
HIGH-TO-LOW-LEVEL OUTPUT  
vs  
LOAD CAPACITANCE

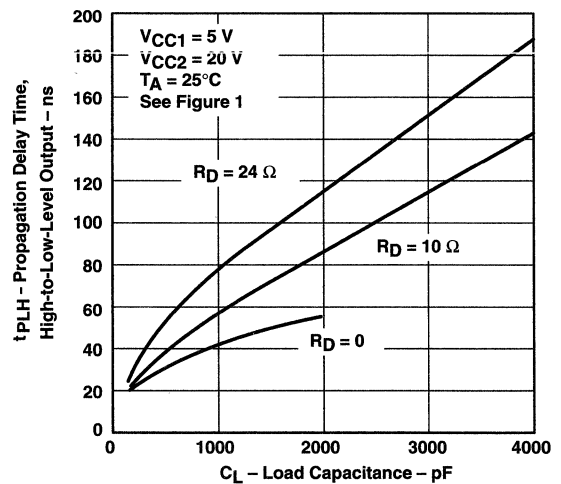


Figure 11

NOTE: For RD = 0, operation with CL > 2000 pF violates absolute maximum current rating.



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THERMAL INFORMATION

power dissipation precautions

Significant power may be dissipated in the SN75372 driver when charging and discharging high-capacitance loads over a wide voltage range at high frequencies. Figure 5 shows the power dissipated in a typical SN75372 as a function of load capacitance and frequency. Average power dissipated by this driver is derived from the equation

$$P_{T(AV)} = P_{DC(AV)} + P_{C(AV)} = P_{S(AV)}$$

where  $P_{DC(AV)}$  is the steady-state power dissipation with the output high or low,  $P_{C(AV)}$  is the power level during charging or discharging of the load capacitance, and  $P_{S(AV)}$  is the power dissipation during switching between the low and high levels. None of these include energy transferred to the load, and all are averaged over a full cycle.

The power components per driver channel are

$$P_{DC(AV)} = \frac{P_H t_H + P_L t_L}{T}$$

$$P_{C(AV)} \approx C V_C^2 f$$

$$P_{S(AV)} = \frac{P_{LH} t_{LH} + P_{HL} t_{HL}}{T}$$

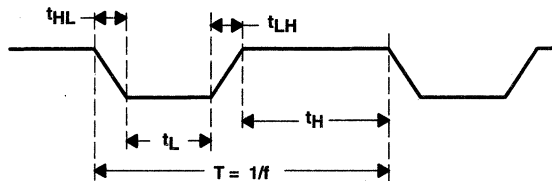


Figure 12. Output Voltage Waveform

where the times are as defined in Figure 14.

$P_L$ ,  $P_H$ ,  $P_{LH}$ , and  $P_{HL}$  are the respective instantaneous levels of power dissipation,  $C$  is the load capacitance.  $V_C$  is the voltage across the load capacitance during the charge cycle shown by the equation

$$V_C = V_{OH} - V_{OL}$$

$P_{S(AV)}$  may be ignored for power calculations at low frequencies.

In the following power calculation, both channels are operating under identical conditions:

$V_{OH} = 19.2$  V and  $V_{OL} = 0.15$  V with  $V_{CC1} = 5$  V,  $V_{CC2} = 20$  V,  $V_C = 19.05$  V,  $C = 1000$  pF, and the duty cycle = 60%. At 0.5 MHz,  $P_{S(AV)}$  is negligible and can be ignored. When the output voltage is high,  $I_{CC2}$  is negligible and can be ignored.

On a per-channel basis using data sheet values,

$$P_{DC(AV)} = \left[ (5 \text{ V}) \left( \frac{2 \text{ mA}}{2} \right) + (20 \text{ V}) \left( \frac{0 \text{ mA}}{2} \right) \right] (0.6) + \left[ (5 \text{ V}) \left( \frac{16 \text{ mA}}{2} \right) + (20 \text{ V}) \left( \frac{7 \text{ mA}}{2} \right) \right] (0.4)$$

$$P_{DC(AV)} = 47 \text{ mW per channel}$$

Power during the charging time of the load capacitance is

$$P_{C(AV)} = (1000 \text{ pF}) (19.05 \text{ V})^2 (0.5 \text{ MHz}) = 182 \text{ mW per channel}$$

Total power for each driver is

$$P_{T(AV)} = 47 \text{ mW} + 182 \text{ mW} = 229 \text{ mW}$$

and total package power is

$$P_{T(AV)} = (229) (2) = 458 \text{ mW.}$$



# SN75372 DUAL MOSFET DRIVER

SLLS025A – JULY 1986

## APPLICATION INFORMATION

### driving power MOSFETs

The drive requirements of power MOSFETs are much lower than comparable bipolar power transistors. The input impedance of a FET consists of a reverse biased PN junction that can be described as a large capacitance in parallel with a very high resistance. For this reason, the commonly used open-collector driver with a pullup resistor is not satisfactory for high-speed applications. In Figure 12(a), an IRF151 power MOSFET switching an inductive load is driven by an open-collector transistor driver with a 470- $\Omega$  pullup resistor. The input capacitance ( $C_{iss}$ ) specification for an IRF151 is 4000 pF maximum. The resulting long turn-on time due to the combination of  $C_{iss}$  and the pullup resistor is shown in Figure 12(b).

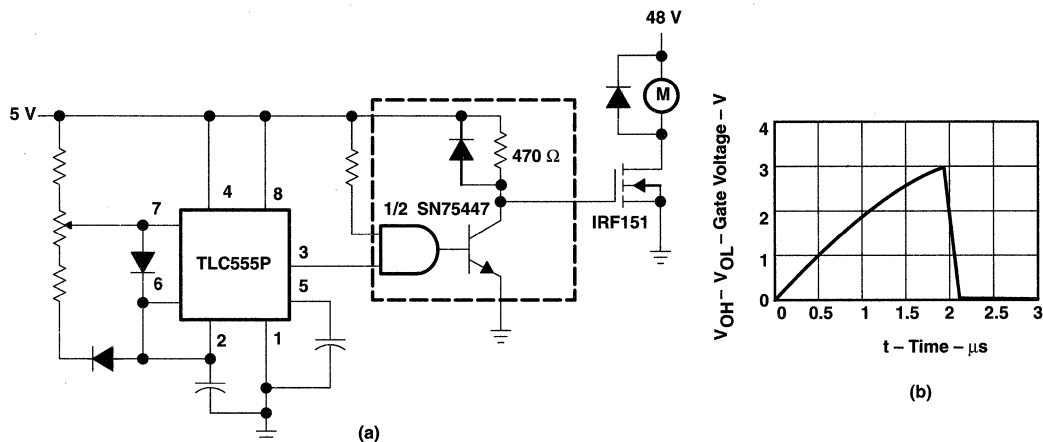
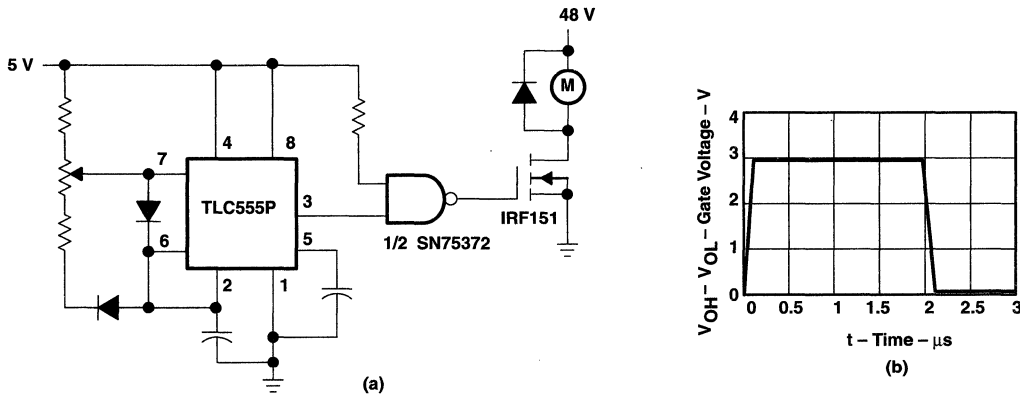


Figure 13. Power MOSFET Drive Using SN75447

**APPLICATION INFORMATION**

A faster, more efficient drive circuit uses an active pullup as well as an active pulldown output configuration, referred to as a totem-pole output. The SN75372 driver provides the high speed, totem-pole drive desired in an application of this type, see Figure 13(a). The resulting faster switching speeds are shown in Figure 13(b).



**Figure 14. Power MOSFET Drive Using SN75372**

Power MOSFET drivers must be capable of supplying high peak currents to achieve fast switching speeds as shown by the equation

$$I_{pk} = \frac{VC}{t_r}$$

where C is the capacitive load, and  $t_r$  is the desired drive time. V is the voltage that the capacitance is charged to. In the circuit shown in Figure 13(a), V is found by the equation

$$V = V_{OH} - V_{OL}$$

Peak current required to maintain a rise time of 100 ns in the circuit of Figure 13(a) is

$$I_{PK} = \frac{(3 - 0)4(10^{-9})}{100(10^{-9})} = 120 \text{ mA}$$

Circuit capacitance can be ignored because it is very small compared to the input capacitance of the IRF151. With a  $V_{CC}$  of 5 V, and assuming worst-case conditions, the gate drive voltage is 3 V.

For applications in which the full voltage of  $V_{CC2}$  must be supplied to the MOSFET gate, the SN75374 quad MOSFET driver should be used.



# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 - SEPTEMBER 1988

- **Quadruple Circuits Capable of Driving High-Capacitance Loads at High Speeds**
- **Output Supply Voltage Range From 5 V to 24 V**
- **Low Standby Power Dissipation**
- **V<sub>CC3</sub> Supply Maximizes Output Source Voltage**

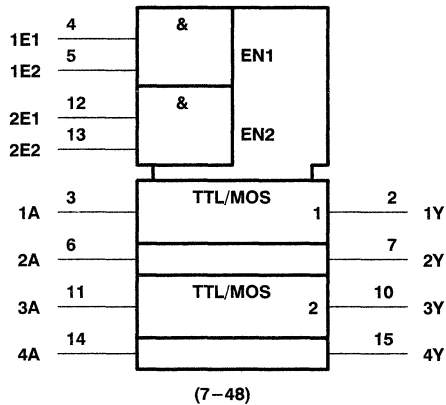
## description

The SN75374 is a quadruple NAND interface circuit designed to drive power MOSFETs from TTL inputs. It provides the high current and voltage necessary to drive large capacitive loads at high speeds.

The outputs can be switched very close to the V<sub>CC2</sub> supply rail when V<sub>CC3</sub> is about 3 V higher than V<sub>CC2</sub>. V<sub>CC3</sub> can also be tied directly to V<sub>CC2</sub> when the source voltage requirements are lower.

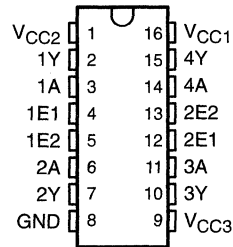
The SN75374 is characterized for operation from 0°C to 70°C.

## logic symbol†

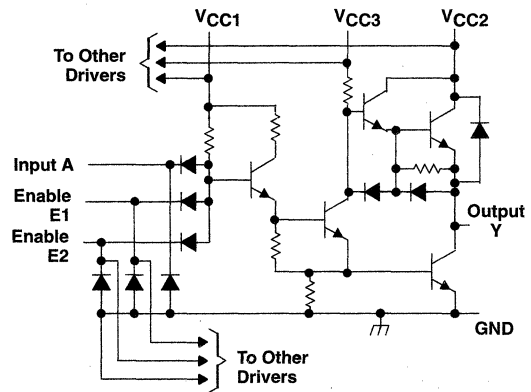


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12

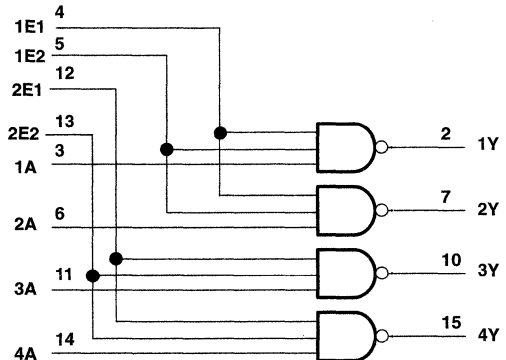
**D OR N PACKAGE  
(TOP VIEW)**



## schematic (each driver)



## logic diagram (positive logic)



# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 – SEPTEMBER 1988

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

Supply voltage range of $V_{CC1}$ (see Note 1)	-0.5 V to 7 V
Supply voltage range of $V_{CC2}$	-0.5 V to 25 V
Supply voltage range of $V_{CC3}$	-0.5 V to 30 V
Input voltage, $V_I$	5.5 V
Peak output current, $I_I$ ( $t_w < 10$ ms, duty cycle $< 50\%$ )	500 mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°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

NOTE 1: Voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	950 mW	7.6 mW/°C	608 mW
N	1150 mW	9.2 mW/°C	736 mW

## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC1}$	4.75	5	5.25	V
Supply voltage, $V_{CC2}$	4.75	20	24	V
Supply voltage, $V_{CC3}$	$V_{CC2}$	24	28	V
Voltage difference between supply voltages: $V_{CC3} - V_{CC2}$	0	4	10	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
High-level output current, $I_{OH}$			-10	mA
High-level output current, $I_{OL}$			40	mA
Operating free-air temperature, $T_A$	0		70	°C

# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 – SEPTEMBER 1988

**electrical characteristics over recommended ranges of  $V_{CC1}$ ,  $V_{CC2}$ ,  $V_{CC3}$ , and operating free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
$V_{IK}$	Input clamp voltage	$I_I = -12 \text{ mA}$			-1.5	V
$V_{OH}$	High-level output voltage	$V_{CC3} = V_{CC2} + 3 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OH} = -100 \mu\text{A}$	$V_{CC2} - 0.3$	$V_{CC2} - 0.1$		V
		$V_{CC3} = V_{CC2} + 3 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OH} = -10 \text{ mA}$	$V_{CC2} - 1.3$	$V_{CC2} - 0.9$		
		$V_{CC3} = V_{CC2}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OH} = -50 \mu\text{A}$	$V_{CC2} - 1$	$V_{CC2} - 0.7$		
		$V_{CC3} = V_{CC2}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OH} = -10 \text{ mA}$	$V_{CC2} - 2.5$	$V_{CC2} - 1.8$		
$V_{OL}$	Low-level output voltage	$V_{IH} = 2 \text{ V}$ , $I_{OL} = 10 \text{ mA}$		0.15	0.3	V
		$V_{CC2} = 15 \text{ V to } 28 \text{ V}$ , $V_{IH} = 2 \text{ V}$ , $I_{OL} = 40 \text{ mA}$		0.25	0.5	
$V_F$	Output clamp-diode forward voltage	$V_I = 0$ , $I_F = 20 \text{ mA}$			1.5	V
$I_I$	Input current at maximum input voltage	$V_I = 5.5 \text{ V}$			1	mA
$I_{IH}$	High-level input current	Any A Any E $V_I = 2.4 \text{ V}$		40		$\mu\text{A}$
				80		
$I_{IL}$	low-level input current	Any A Any E $V_I = 0.4 \text{ V}$		-1	-1.6	mA
				-2	-3.2	
$I_{CC1(H)}$	Supply current from $V_{CC1}$ , all outputs high	$V_{CC1} = 5.25 \text{ V}$ , All inputs at 0 V, $V_{CC2} = 24 \text{ V}$ , $V_{CC3} = 28 \text{ V}$ , No load		4	8	mA
$I_{CC2(H)}$	Supply current from $V_{CC2}$ , all outputs high			-2.2	0.25	
$I_{CC3(H)}$	Supply current from $V_{CC3}$ , all outputs high			2.2	3.5	
$I_{CC1(L)}$	Supply current from $V_{CC1}$ , all outputs low	$V_{CC1} = 5.25 \text{ V}$ , All inputs at 5 V, $V_{CC2} = 24 \text{ V}$ , $V_{CC3} = 28 \text{ V}$ , No load		31	47	mA
	$I_{CC2(L)}$		Supply current from $V_{CC2}$ , all outputs low		2	
	$I_{CC3(L)}$		Supply current from $V_{CC1}$ , all outputs low		16	
$I_{CC2(H)}$	Supply current from $V_{CC2}$ , all outputs high	$V_{CC1} = 5.25 \text{ V}$ , All inputs at 0 V, $V_{CC2} = 24 \text{ V}$ , $V_{CC3} = 24 \text{ V}$ , No load		0.25		mA
$I_{CC3(H)}$	Supply current from $V_{CC3}$ , all outputs high			0.5		
$I_{CC2(S)}$	Supply current from $V_{CC2}$ , standby condition	$V_{CC1} = 0$ , All inputs at 0 V, $V_{CC2} = 24 \text{ V}$ , $V_{CC3} = 24 \text{ V}$ , No load		0.25		mA
$I_{CC3(S)}$	Supply current from $V_{CC3}$ , standby condition			0.5		

† All typical values are at  $V_{CC1} = 5 \text{ V}$ ,  $V_{CC2} = 20 \text{ V}$ ,  $V_{CC3} = 24 \text{ V}$ , and  $T_A = 25^\circ\text{C}$  except for  $V_{OH}$  for which  $V_{CC2}$  and  $V_{CC3}$  are as stated under test conditions.

**switching characteristics,  $V_{CC1} = 5 \text{ V}$ ,  $V_{CC2} = 20 \text{ V}$ ,  $V_{CC3} = 24 \text{ V}$ ,  $T_A = 25^\circ\text{C}$**

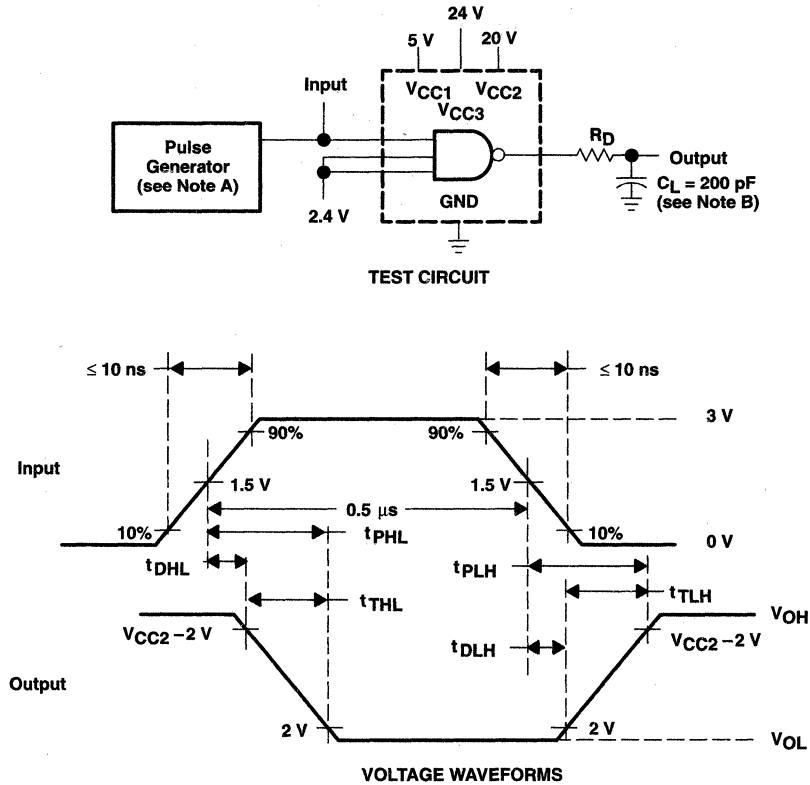
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
$t_{DLH}$	Delay time, low-to-high-level output	$C_L = 200 \text{ pF}$ $R_D = 24 \Omega$ , See Figure 1		20	30	ns	
$t_{DHL}$	Delay time, high-to-low-level output			10	20	ns	
$t_{PLH}$	Propagation delay time, low-to-high-level output			10	40	60	ns
$t_{PHL}$	Propagation delay time, high-to-low-level output			10	30	50	ns
$t_{TLH}$	Transition time, low-to-high-level output				20	30	ns
$t_{THL}$	Transition time, high-to-low-level output				20	30	ns



# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 – SEPTEMBER 1988

## PARAMETER MEASUREMENT INFORMATION



**Figure 1. Test Circuit and Voltage Waveforms, Each Driver**

- NOTES: A. The pulse generator has the following characteristics: PRR = 1 MHz,  $Z_O \approx 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

TYPICAL CHARACTERISTICS

HIGH-LEVEL OUTPUT VOLTAGE  
 vs  
 HIGH-LEVEL OUTPUT CURRENT

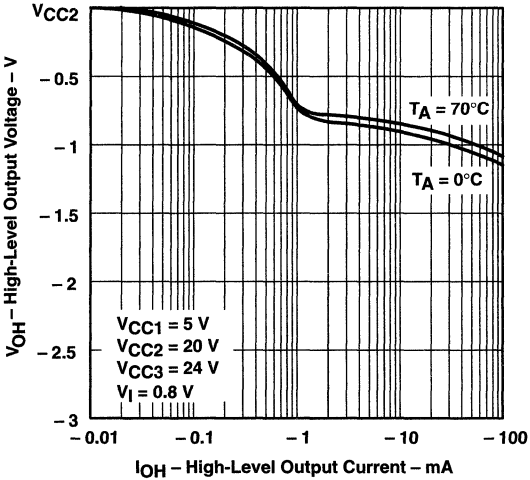


Figure 2

HIGH-LEVEL OUTPUT VOLTAGE  
 vs  
 HIGH-LEVEL OUTPUT CURRENT

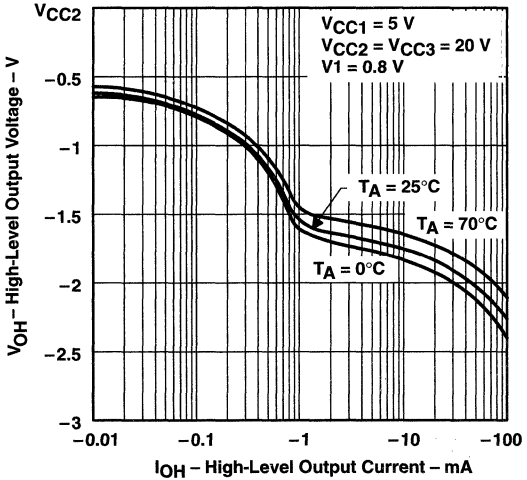


Figure 3

LOW-LEVEL OUTPUT VOLTAGE  
 vs  
 LOW-LEVEL OUTPUT CURRENT

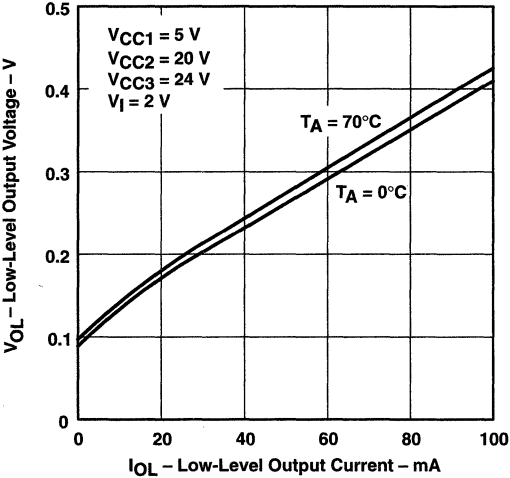


Figure 4

VOLTAGE TRANSFER CHARACTERISTICS

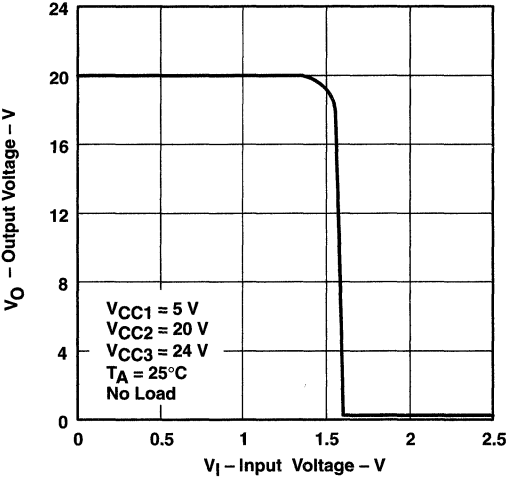


Figure 5





# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 – SEPTEMBER 1988

## TYPICAL CHARACTERISTICS

PROPAGATION DELAY TIME  
LOW-TO-HIGH-LEVEL OUTPUT  
vs  
FREE-AIR TEMPERATURE

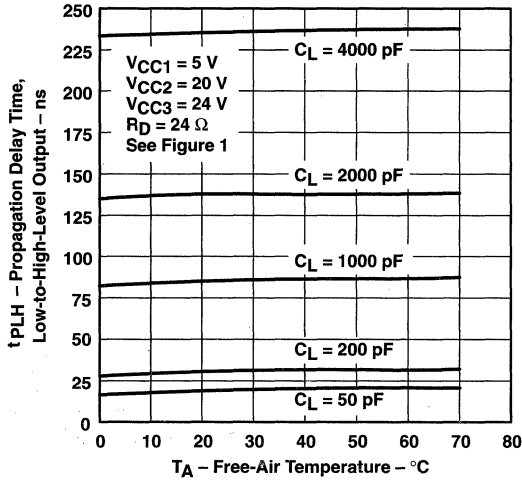


Figure 6

PROPAGATION DELAY TIME  
HIGH-TO-LOW-LEVEL OUTPUT  
vs  
FREE-AIR TEMPERATURE

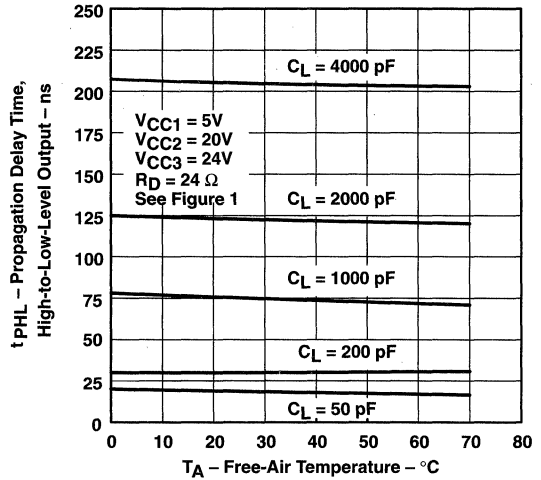


Figure 7

PROPAGATION DELAY TIME  
LOW-TO-HIGH-LEVEL OUTPUT  
vs  
VCC2 SUPPLY VOLTAGE

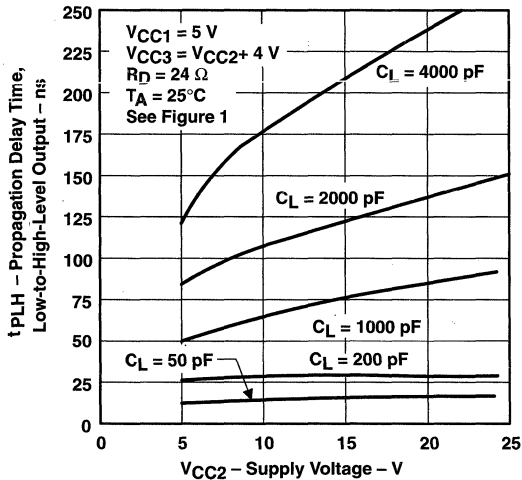


Figure 8

PROPAGATION DELAY TIME  
HIGH-TO-LOW-LEVEL OUTPUT  
vs  
VCC2 SUPPLY VOLTAGE

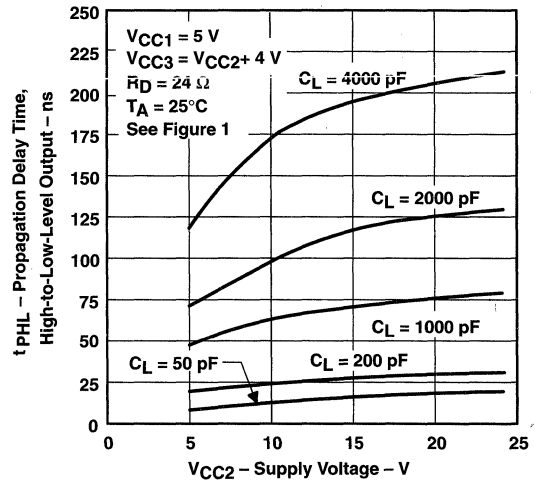


Figure 9



TYPICAL CHARACTERISTICS

PROPAGATION DELAY TIME  
 LOW-TO-HIGH-LEVEL OUTPUT  
 vs  
 LOAD CAPACITANCE

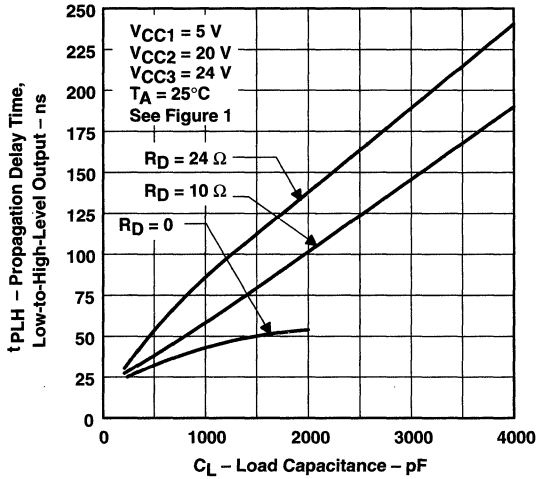


Figure 10

PROPAGATION DELAY TIME  
 HIGH-TO-LOW-LEVEL OUTPUT  
 vs  
 LOAD CAPACITANCE

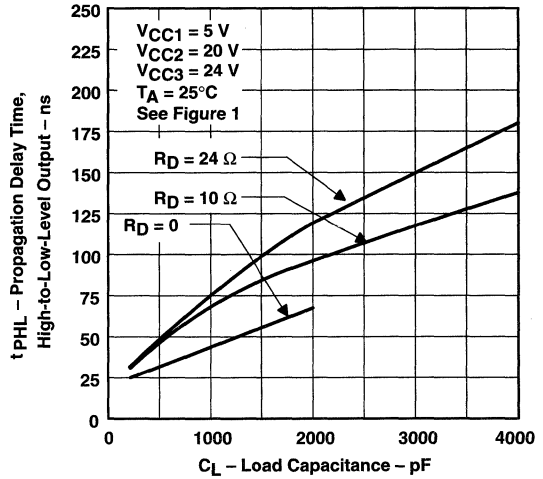


Figure 11

POWER DISSIPATION (ALL DRIVERS)  
 vs  
 FREQUENCY

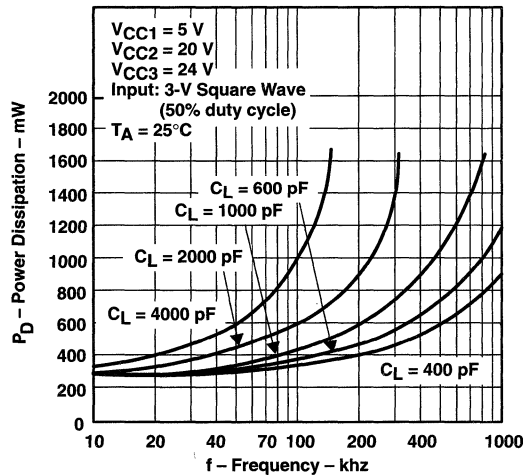


Figure 12

NOTE: For  $R_D = 0$ , operation with  $C_L > 2000$  pF violates absolute maximum current rating.

# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 - SEPTEMBER 1988

## THERMAL INFORMATION

### power dissipation precautions

Significant power may be dissipated in the SN75374 driver when charging and discharging high-capacitance loads over a wide voltage range at high frequencies. Figure 12 shows the power dissipated in a typical SN75374 as a function of frequency and load capacitance. Average power dissipated by this driver is derived from the equation

$$P_{T(AV)} = P_{DC(AV)} + P_{C(AV)} + P_{S(AV)}$$

where  $P_{DC(AV)}$  is the steady-state power dissipation with the output high or low,  $P_{C(AV)}$  is the power level during charging or discharging of the load capacitance, and  $P_{S(AV)}$  is the power dissipation during switching between the low and high levels. None of these include energy transferred to the load and all are averaged over a full cycle.

The power components per driver channel are

$$P_{DC(AV)} = \frac{P_H t_H + P_L t_L}{T}$$

$$P_{C(AV)} \approx C V^2 c f$$

$$P_{S(AV)} = \frac{P_{LH} t_{LH} + P_{HL} t_{HL}}{T}$$

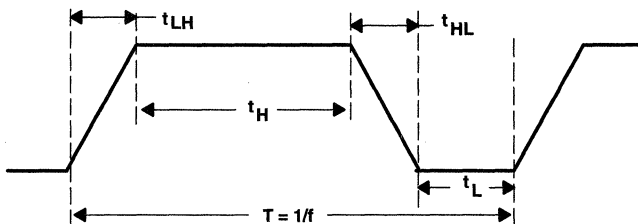


Figure 13. Output Voltage Waveform

where the times are as defined in Figure 15.

### THERMAL INFORMATION

$P_L$ ,  $P_H$ ,  $P_{LH}$ , and  $P_{HL}$  are the respective instantaneous levels of power dissipation,  $C$  is the load capacitance.  $V_C$  is the voltage across the load capacitance during the charge cycle shown by the equation

$$V_C = V_{OH} - V_{OL}$$

$P_{S(AV)}$  may be ignored for power calculations at low frequencies.

In the following power calculation, all four channels are operating under identical conditions:  $f = 0.2$  MHz,  $V_{OH} = 19.9$  V and  $V_{OL} = 0.15$  V with  $V_{CC1} = 5$  V,  $V_{CC2} = 20$  V,  $V_{CC3} = 24$  V,  $V_C = 19.75$  V,  $C = 1000$  pF, and the duty cycle = 60%. At 0.2 MHz for  $C_L < 2000$  pF,  $P_{S(AV)}$  is negligible and can be ignored. When the output voltage is low,  $I_{CC2}$  is negligible and can be ignored.

On a per-channel basis using data sheet values,

$$P_{DC(AV)} = \left[ (5 \text{ V}) \left( \frac{4 \text{ mA}}{4} \right) + (20 \text{ V}) \left( \frac{-2.2 \text{ mA}}{4} \right) + (24 \text{ V}) \left( \frac{2.2 \text{ mA}}{4} \right) \right] (0.6) + \left[ (5 \text{ V}) \left( \frac{31 \text{ mA}}{4} \right) + (20 \text{ V}) \left( \frac{0 \text{ mA}}{4} \right) + (24 \text{ V}) \left( \frac{16 \text{ mA}}{4} \right) \right] (0.4)$$

$$P_{DC(AV)} = 58.2 \text{ mW per channel}$$

Power during the charging time of the load capacitance is

$$P_{C(AV)} = (1000 \text{ pF}) (19.75 \text{ V})^2 (0.2 \text{ MHz}) = 78 \text{ mW per channel}$$

Total power for each driver is

$$P_{T(AV)} = 58.2 \text{ mW} + 78 \text{ mW} = 136.2 \text{ mW}$$

The total package power is

$$P_{T(AV)} = (136.2) (4) = 544.8 \text{ mW}$$

# SN75374 QUADRUPLE MOSFET DRIVER

SLRS028 – SEPTEMBER 1988

## APPLICATION INFORMATION

### driving power MOSFETs

The drive requirements of power MOSFETs are much lower than comparable bipolar power transistors. The input impedance of a FET consists of a reverse biased PN junction that can be described as a large capacitance in parallel with a very high resistance. For this reason, the commonly used open-collector driver with a pullup resistor is not satisfactory for high-speed applications. In Figure 13(a), an IRF151 power MOSFET switching an inductive load is driven by an open-collector transistor driver with a 470-Ω pullup resistor. The input capacitance ( $C_{ISS}$ ) specification for an IRF151 is 4000 pF maximum. The resulting long turn-on time due to the product of input capacitance and the pullup resistor is shown in Figure 13(b).

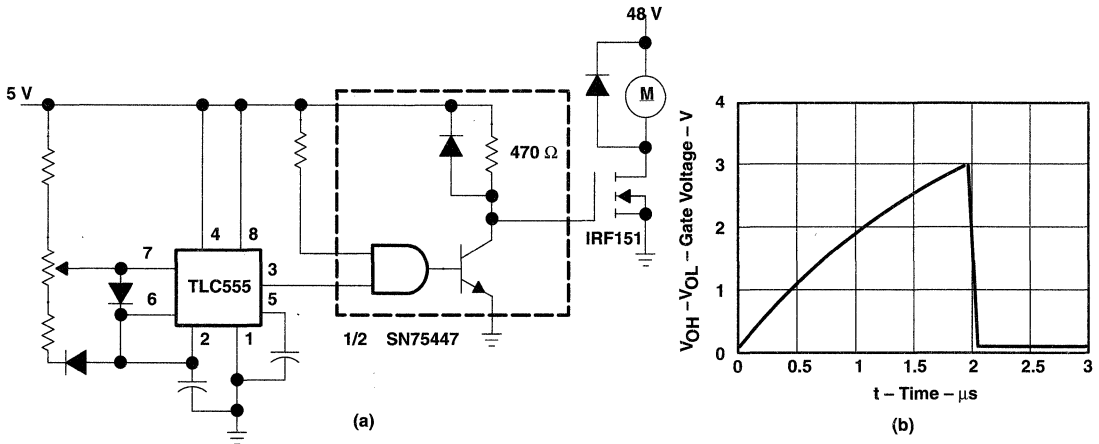


Figure 14. Power MOSFET Drive Using SN75447

A faster, more efficient drive circuit uses an active pull-up as well as an active pull-down output configuration, referred to as a totem-pole output. The SN75374 driver provides the high-speed totem-pole drive desired in an application of this type, see Figure 14(a). The resulting faster switching speeds are shown in Figure 14(b).

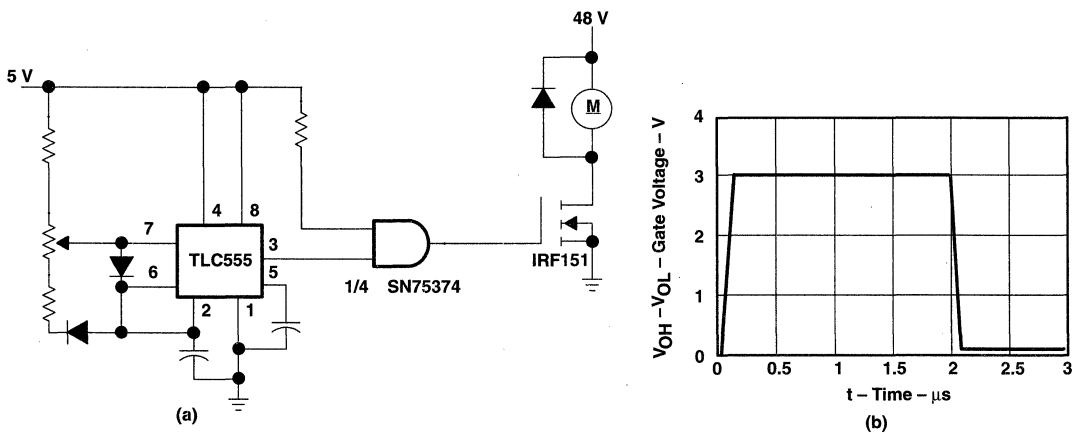


Figure 15. Power MOSFET Drive Using SN75374

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### APPLICATION INFORMATION

Power MOSFET drivers must be capable of supplying high peak currents to achieve fast switching speeds as shown by the equation

$$I_{PK} = \frac{VC}{t_r}$$

where C is the capacitive load, and  $t_r$  is the desired rise time. V is the voltage that the capacitance is charged to. In the circuit shown in Figure 14(a), V is found by the equation

$$V = V_{OH} - V_{OL}$$

Peak current required to maintain a rise time of 100 ns in the circuit of Figure 14(a) is

$$I_{PK} = \frac{(3 - 0)4(10^{-9})}{100(10^{-9})} = 120 \text{ mA}$$

Circuit capacitance can be ignored because it is very small compared to the input capacitance of the IRF151. With a  $V_{CC}$  of 5 V and assuming worst-case conditions, the gate drive voltage is 3 V.

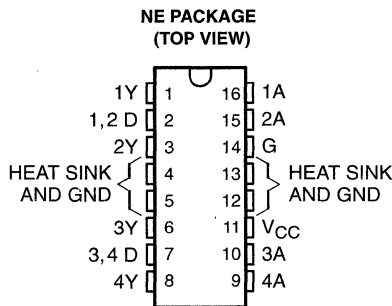
For applications in which the full voltage of  $V_{CC2}$  must be supplied to the MOSFET gate,  $V_{CC3}$  should be at least 3 V higher than  $V_{CC2}$ .



# SN75436, SN75437A QUADRUPLE PERIPHERAL DRIVERS

SLRS019A – DECMEBER 1986 – REVISED OCTOBER 1995

- Saturating Outputs With Low On-State Resistance
- High-Impedance Inputs Compatible With CMOS and TTL Levels
- Very Low Standby Power . . . 21 mW Max
- High-Voltage Outputs . . . 70 V Min
- No Power-Up or Power-Down Output Glitch
- No Latch-Up Within Recommended Operating Conditions
- Output-Clamp Diodes for Transient Suppression
- 2-W Power Package

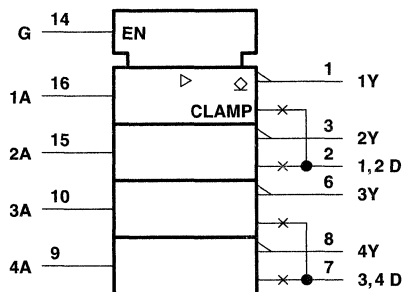


## description

The SN75436 and SN75437A quadruple peripheral drivers are designed for use in systems requiring high current, high voltage, and high load power. Each device features four inverting open-collector outputs with a common-enable input that, when taken low, disables all four outputs. The envelope of 1-V characteristics exceeds the specifications sufficiently to avoid high-current latch-up. Applications include driving relays, lamps, solenoids, motors, LEDs, transmission lines, hammers, and other high-power-demand devices.

The SN75436 and SN75437A are offered in a 16-pin wide-body surface-mount (NE) package and is characterized for operation over the free-air temperature of 0°C to 70°C.

## logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

FUNCTION TABLE  
(each NAND driver)

INPUTS		OUTPUT
A	G	Y
H	H	L
L	X	H
X	L	H

H = high level, L = low level,  
X = irrelevant

## SELECTION GUIDE

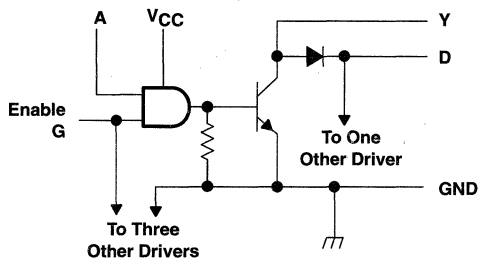
FEATURE	SN75436	SN75437A	UNIT
Maximum recommended output current	0.5	0.5	A
Maximum $V_{OL}$ at maximum $I_{OL}$	0.5	0.5	V
Maximum recommended output supply voltage in an inductive switching circuit, $V_S$	50	35	V



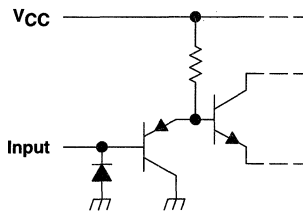
# SN75436, SN75437A QUADRUPLE PERIPHERAL DRIVERS

SLRS019A – DECMEBER 1986 – REVISED OCTOBER 1995

## logic diagram (positive logic, each driver)



## equivalent schematic of each input



## absolute maximum ratings over operating temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$	7 V
Input voltage, $V_I$	30 V
Output current (see Note 1)	0.75 A
Output clamp-diode current, $I_{OK}$	1.25 A
Output voltage, $V_O$ (off state)	70 V
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 2)	2075 mW
Operating free-air temperature range, $T_A$	0°C to 70°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

- NOTES: 1. All four sections of these circuits may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous dissipation ratings.  
2. For operation above 25°C free-air temperature, derate linearly to 1328 mW at 70°C at the rate of 16.6 mW/°C.

## recommended operating conditions

PARAMETER	SN75436			SN75437A			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.75	5	5.25	4.75	5	5.25	V
High-level input voltage, $V_{IH}$	2			2			V
Low-level input voltage, $V_{IL}$			0.8			0.8	V
Output supply voltage in inductive switching circuit (see Figure 2), $V_S$			50			35	V
Output current, $I_O$			0.5			0.5	A
Operating free-air temperature, $T_A$	0		70	0		70	°C

# SN75436, SN75437A QUADRUPLE PERIPHERAL DRIVERS

SLRS019A – DECEMBER 1986 – REVISED OCTOBER 1995

**electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
V <sub>IK</sub>	Input clamp voltage	V <sub>CC</sub> = 4.75 V, I <sub>I</sub> = -12 mA	-0.9	-1.5		V
V <sub>OL</sub>	Low-level output voltage	V <sub>CC</sub> = 4.75 V, I <sub>OL</sub> = 250 mA	0.14	0.25		V
		V <sub>IH</sub> = 2 V, I <sub>OL</sub> = 500 mA	0.28	0.5		
V <sub>R(K)</sub>	Output clamp-diode reverse voltage	V <sub>CC</sub> = 4.75 V, I <sub>R</sub> = 100 μA	70	100		V
V <sub>F(K)</sub>	Output clamp-diode forward voltage	I <sub>F</sub> = 500 mA		1	1.6	V
I <sub>OH</sub>	High-level output current	V <sub>CC</sub> = 4.75 V, V <sub>IH</sub> = 2 V, V <sub>IL</sub> = 0.8 V, V <sub>OH</sub> = 70 V		1	100	μA
I <sub>IH</sub>	High-level input current	V <sub>CC</sub> = 5.25 V, V <sub>I</sub> = 5.25 V		0.1	10	μA
I <sub>IL</sub>	Low-level input current	V <sub>CC</sub> = 5.25 V, V <sub>I</sub> = 0.8 V	-0.25	-10		μA
I <sub>CCH</sub>	Supply current, outputs high	V <sub>CC</sub> = 5.25 V, V <sub>I</sub> = 0		1	4	mA
I <sub>CCL</sub>	Supply current, outputs low	V <sub>CC</sub> = 5.25 V, V <sub>I</sub> = 5 V		45	65	mA

† All typical values are at V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C.

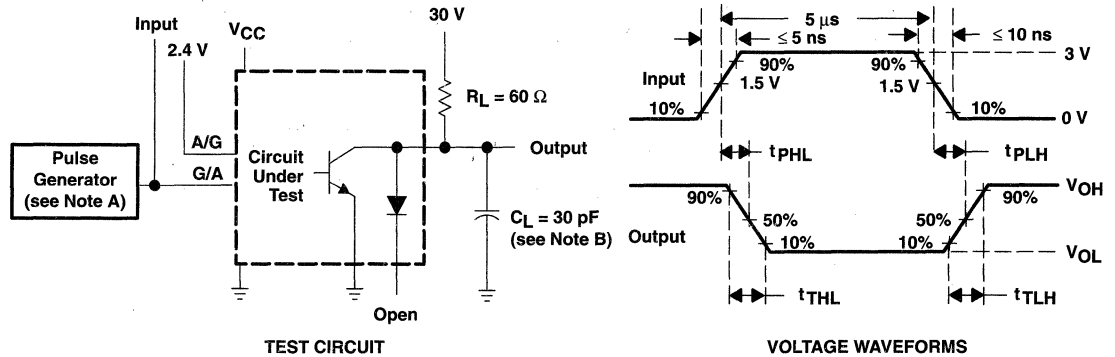
## switching characteristics, V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>PLH</sub>	Propagation delay time, low-to-high-level output	C <sub>L</sub> = 30 pF, R <sub>L</sub> = 60 Ω, See Figure 1		1950	5000	ns
t <sub>PHL</sub>	Propagation delay time, high-to-low-level output			150	500	ns
t <sub>TLH</sub>	Transition time, low-to-high-level output			40		ns
t <sub>THL</sub>	Transition time, high-to-low-level output			36		ns
V <sub>OH</sub>	High-level output voltage after switching	SN75436 V <sub>S</sub> = 50 V, R <sub>L</sub> = 100 Ω, I <sub>O</sub> = 500 mA, See Figure 2	V <sub>S</sub> -10			mV
		SN75437A V <sub>S</sub> = 35 V, R <sub>L</sub> = 70 Ω, I <sub>O</sub> = 500 mA, See Figure 2	V <sub>S</sub> -10			mV

# SN75436, SN75437A QUADRUPLE PERIPHERAL DRIVERS

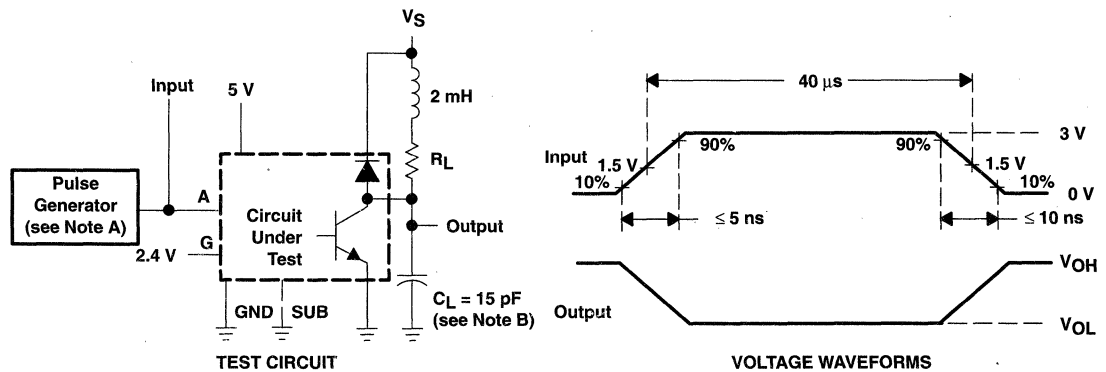
SLRS019A – DECEMBER 1986 – REVISED OCTOBER 1995

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The pulse generator has the following characteristics: PRR = 100 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms



- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 2. Latch-Up Test Circuit and Voltage Waveforms

# SN75439 QUADRUPLE PERIPHERAL DRIVER

SLRS013A – MAY 1988 – REVISED NOVEMBER 1989

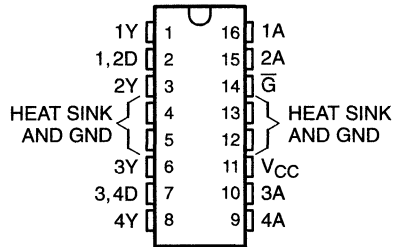
- 1.3-A Current Capability Each Channel
- Saturating Outputs With Low On-State Resistance
- Two Inverting and Two Noninverting Driver Channels With Common Active-Low Enable Input
- Key Application Is as a Complete Full-Step 4-Phase DC Stepper Motor Driver Using Only Three Directly Connected Logic Control Signal Lines From Standard Microprocessors
- High-Impedance Inputs Compatible With TTL or CMOS Levels
- Very Low Standby Power . . . 10 mW Typ
- 50-V Noninductive Switching Voltage Capability
- 40-V Inductive Switching Voltage Capability
- Output Clamp Diodes for Inductive Transient Protection
- 2-W Power Package

## description

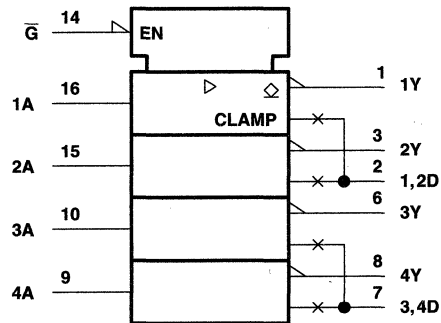
The SN75439 quadruple peripheral driver is designed for use in systems requiring high current, high voltage, and high load power. The device features two inverting and two noninverting open-collector outputs with a common-enable input that, when taken high, disables all four outputs. By pairing each inverting channel with a corresponding noninverting channel (such as channel 1 paired with channel 2 and channel 3 paired with channel 4), the device may be used as a complete full-step 4-phase dc stepper-motor driver using only two input logic control signals plus the enable signal, as shown in Figure 3. Other applications include driving relays, lamps, solenoids, motors, LEDs, transmission lines, hammers, and other high-power-demand loads.

The SN75439 is characterized for operation from 0°C to 70°C.

NE PACKAGE  
(TOP VIEW)



## logic symbol



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

## Function Tables

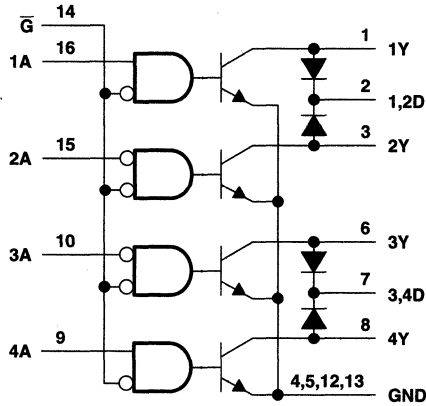
EACH CHANNEL 1 OR CHANNEL 4 DRIVER			EACH CHANNEL 2 OR CHANNEL 3 DRIVER		
INPUTS		OUTPUT	INPUTS		OUTPUT
A	G	Y	A	G	Y
H	L	L	L	L	L
L	X	H	H	X	H
X	H	H	X	H	H

H = high level, L = low level X = irrelevant

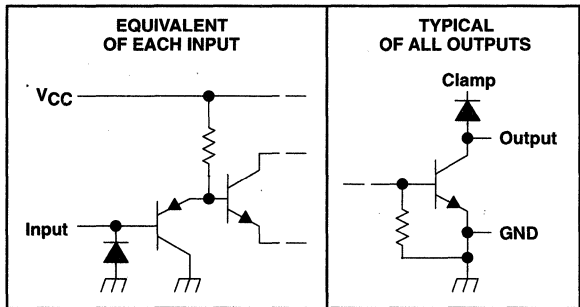
# SN75439 QUADRUPLE PERIPHERAL DRIVER

SLRS013A – MAY 1988 – REVISED NOVEMBER 1989

## logic diagram (positive logic)



## schematics of inputs and outputs



## absolute maximum ratings over operating temperature range (unless otherwise noted)

Supply voltage range, $V_{CC}$ (see Note 1)	−0.3 V to 7 V
Input voltage, $V_I$	7 V
Output voltage range, $V_O$	−0.3 V to 52 V
Output voltage, $V_O$ (inductive load)	43 V
Output clamp-diode terminal voltage range, $V_{OK}$	−0.3 V to 52 V
Input current, $I_I$	−15 mA
Peak sink output current, $I_{OM}$ (nonrepetitive, $t_w \leq 0.1$ ms) (see Note 2)	1.5 A
(repetitive, $t_w \leq 10$ ms, duty cycle $\leq 50\%$ )	1.4 A
Continuous sink output current, $I_O$ (see Note 2)	1.3 A
Peak output clamp diode current, $I_{OKM}$ (nonrepetitive, $t_w \leq 0.1$ ms) (see Note 2)	1.5 A
(repetitive, $t_w \leq 10$ ms, duty cycle $\leq 50\%$ )	1.3 A
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 3)	2075 mW
Continuous total dissipation at (or below) 65°C case temperature (see Note 3)	5000 mW
Operating case or virtual junction temperature range	−55°C to 150°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 are with respect to the network GND (unless otherwise specified).  
 2. All four channels of this device may conduct rated current simultaneously; however, power dissipation average over a short time interval must fall within the continuous dissipation range.  
 3. For operation above 25°C free-air temperature, derate linearly at the rate of 16.6 mW/°C. For operation above 65°C case temperature, derate linearly at the rate of 59 mW/°C. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded.

# SN75439 QUADRUPLE PERIPHERAL DRIVER

SLRS013A – MAY 1988 – REVISED NOVEMBER 1989

## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.75	5	5.25	V
Output supply voltage in inductive switching circuit, $V_S$ (see Figure 2)			40	V
High-level input voltage, $V_{IH}$	2		5.25	V
Low-level input voltage, $V_{IL}$	-0.3 <sup>†</sup>		0.8	V
Low-level output current, $I_{OL}$			1.3	A
Operating free-air temperature, $T_A$	0	25	70	°C

<sup>†</sup> The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels.

## electrical characteristics over recommended ranges of operating free-air temperature and supply voltages (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{IK}$ Input clamp voltage	$I_I = -12$ mA	-0.9	-1.5		V
$V_{OL}$ Low-level output voltage	$I_{OL} = 0.5$ A		0.2	0.35	V
	$I_{OL} = 1$ A		0.4	0.7	
	$I_{OL} = 1.3$ A		0.5	0.9	
$V_{F(K)}$ Output clamp-diode forward voltage	$I_F = 0.5$ A		1.1	1.9	V
	$I_F = 1$ A		1.3	2.2	
	$I_F = 1.3$ A		1.4	2.4	
$I_{OH}$ High-level output current	$V_{OH} = 50$ V, $V_{OK} = 50$ V			100	$\mu$ A
$I_{IH}$ High-level input current	$V_I = V_{IH}$			10	$\mu$ A
$I_{IL}$ Low-level input current	$V_I = 0$ to 0.8 V			-10	$\mu$ A
$I_{R(K)}$ Output clamp-diode reverse current (at Y output)	$V_R = 50$ V, $V_O = 0$			100	$\mu$ A
$I_{CC}$ Supply current	All outputs at high level (off)		2	8	mA
	All outputs at low level (on)		140	200	
	Two outputs at high level (off) and two outputs at low level (on)		70	110	

<sup>†</sup> All typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTE 4: These parameters must be measured using pulse techniques,  $t_w = 1$  ms, duty cycle  $\leq 10\%$ .

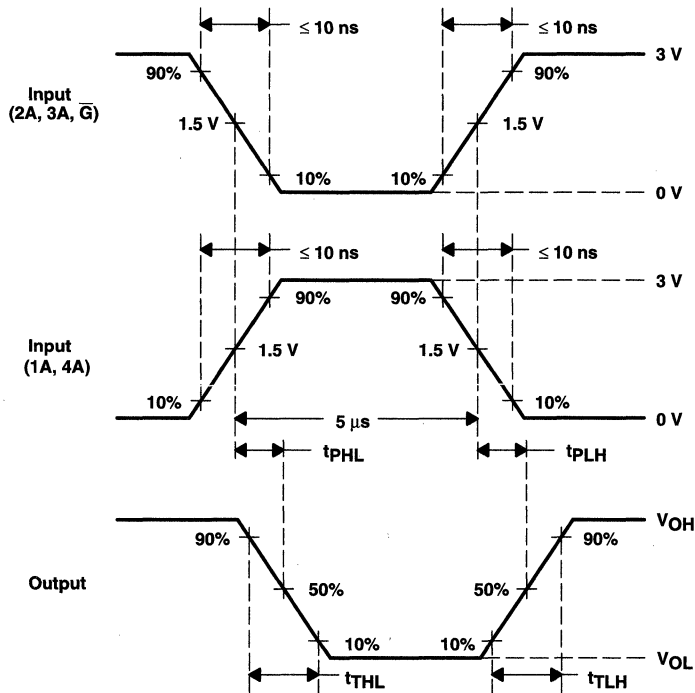
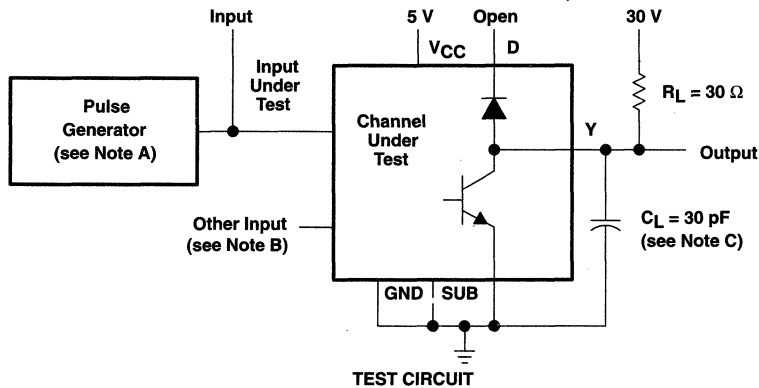
## switching characteristics, $V_{CC} = 5$ V, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output			1500		ns
$t_{PHL}$ Propagation delay time, high-to-low-level output	$I_{OL} \approx 1$ A, $C_L = 30$ pF, $R_L = 30 \Omega$ , See Figure 1		100		ns
$t_{TLH}$ Transition time, low-to-high-level output			170		ns
$t_{THL}$ Transition time, high-to-low-level output			50		ns
$V_{OH}$ High-level output voltage (after switching inductive load)		$V_S = 40$ V, $R_L = 31 \Omega$ , $I_O \approx 1.3$ A, See Figure 2	$V_S - 100$		

# SN75439 QUADRUPLE PERIPHERAL DRIVER

SLRS013A - MAY 1988 - REVISED NOVEMBER 1989

## PARAMETER MEASUREMENT INFORMATION



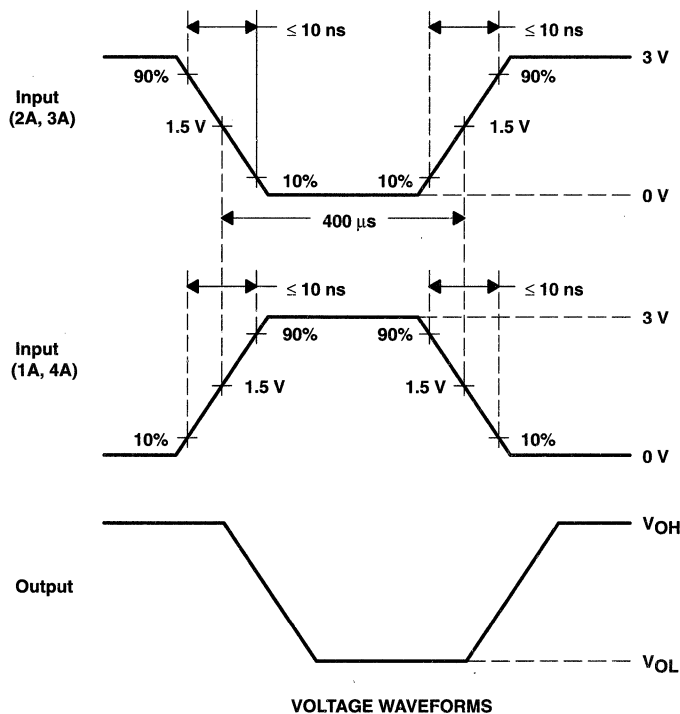
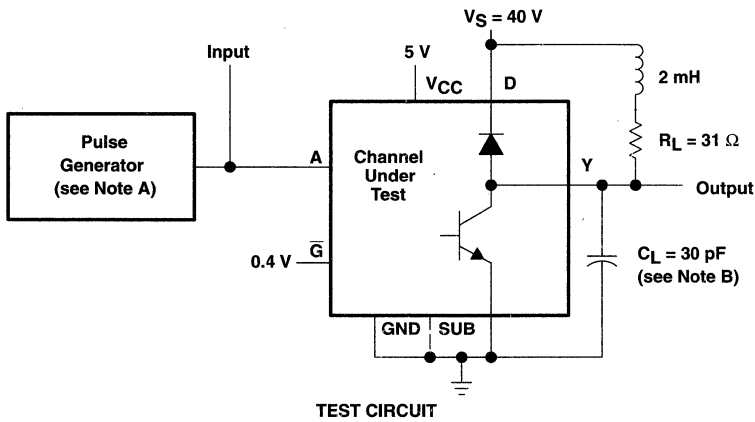
### VOLTAGE WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics: duty cycle  $\leq 1\%$ ,  $Z_O = 50 \Omega$ .  
 B. Enable input  $\bar{G}$  is at 0 V if input A is used as the switching input. When  $\bar{G}$  is used as the switching input, the corresponding A input is at 0 V if testing channel 2 or channel 3 or at 3 V if testing channel 1 or channel 4.  
 C.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms, Switching Characteristics



PARAMETER MEASUREMENT INFORMATION



NOTES: A. The pulse generator has the following characteristics: duty cycle  $\leq 1\%$ ,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 2. Output Latch-Up Test Circuit and Voltage Waveforms



# SN75439 QUADRUPLE PERIPHERAL DRIVER

SLRS013A – MAY 1988 – REVISED NOVEMBER 1989

## APPLICATION INFORMATION

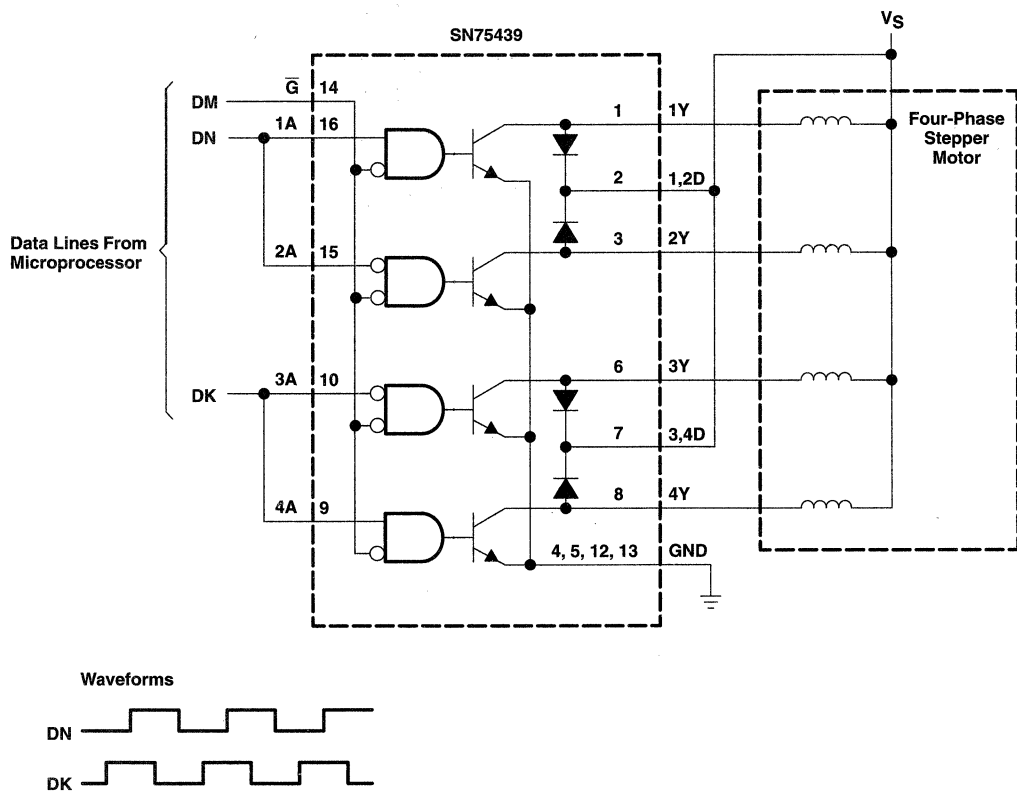


Figure 3. Full-Step Four-Phase Stepper-Motor Driver

# SN754410 QUADRUPLE HALF-H DRIVER

SLRS007B – NOVEMBER 1986 – REVISED NOVEMBER 1995

- 1-A Output-Current Capability Per Driver
- Applications Include Half-H and Full-H Solenoid Drivers and Motor Drivers
- Designed for Positive-Supply Applications
- Wide Supply-Voltage Range of 4.5 V to 36 V
- TTL- and CMOS-Compatible High-Impedance Diode-Clamped Inputs
- Separate Input-Logic Supply
- Thermal Shutdown
- Internal ESD Protection
- Input Hysteresis Improves Noise Immunity
- 3-State Outputs
- Minimized Power Dissipation
- Sink/Source Interlock Circuitry Prevents Simultaneous Conduction
- No Output Glitch During Power Up or Power Down
- Improved Functional Replacement for the SGS L293

## description

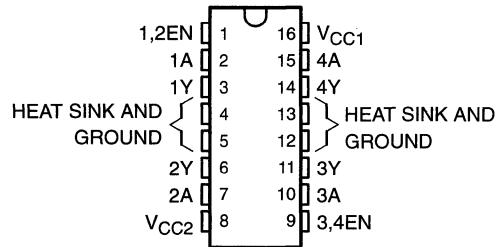
The SN754410 is a quadruple high-current half-H driver designed to provide bidirectional drive currents up to 1 A at voltages from 4.5 V to 36 V. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are compatible with TTL-and low-level CMOS logic. Each output (Y) is a complete totem-pole driver with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs become active and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in a high-impedance state. With the proper data inputs, each pair of drivers form a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

A separate supply voltage ( $V_{CC1}$ ) is provided for the logic input circuits to minimize device power dissipation. Supply voltage  $V_{CC2}$  is used for the output circuits.

The SN754410 is designed for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

NE PACKAGE  
(TOP VIEW)



FUNCTION TABLE  
(each driver)

INPUTS <sup>†</sup>		OUTPUT
A	EN	Y
H	H	H
L	H	L
X	L	Z

H = high-level, L = low-level

X = irrelevant

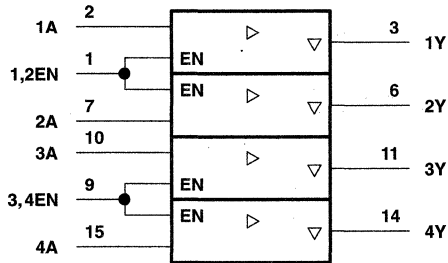
Z = high-impedance (off)

<sup>†</sup>In the thermal shutdown mode, the output is in a high-impedance state regardless of the input levels.

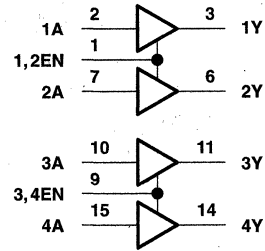
# SN754410 QUADRUPLE HALF-H DRIVER

SLRS007B – NOVEMBER 1986 – REVISED NOVEMBER 1995

## logic symbol†

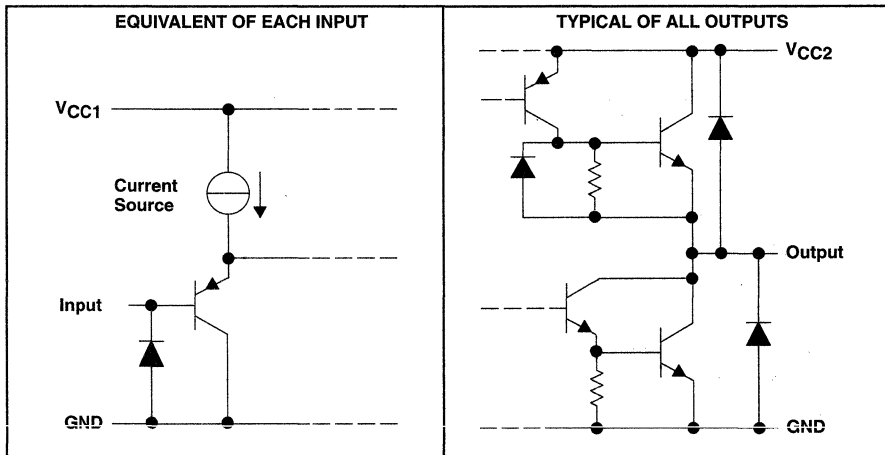


## logic diagram



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## schematics of inputs and outputs



# SN754410 QUADRUPLE HALF-H DRIVER

SLRS007B – NOVEMBER 1986 – REVISED NOVEMBER 1995

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

Output supply voltage range, $V_{CC1}$ (see Note 1)	–0.5 V to 36 V
Output supply voltage range, $V_{CC2}$	–0.5 V to 36 V
Input voltage, $V_I$	36 V
Output voltage range, $V_O$	–3 V to $V_{CC2} + 3$ V
Peak output current (nonrepetitive, $t_w \leq 5$ ms)	$\pm 2$ A
Continuous output current, $I_O$	$\pm 1.1$ A
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 2)	2075 mW
Operating free-air temperature range, $T_A$	–40°C to 85°C
Operating virtual junction temperature range, $T_J$	–40°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 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 are with respect to network GND.

2. For operation above 25°C free-air temperature, derate linearly at the rate of 16.6 mW/°C. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection can be activated at power levels slightly above or below the rated dissipation.

## recommended operating conditions

	MIN	MAX	UNIT
Output supply voltage, $V_{CC1}$	4.5	5.5	V
Output supply voltage, $V_{CC2}$	4.5	36	V
High-level input voltage, $V_{IH}$	2	5.5	V
Low-level input voltage, $V_{IL}$	–0.3‡	0.8	V
Operating virtual junction temperature, $T_J$	–40	125	°C
Operating free-air temperature, $T_A$	–40	85	°C

‡ The algebraic convention, in which the least positive (most negative) limit is designated as minimum, is used in this data sheet for logic voltage levels.

# SN754410 QUADRUPLE HALF-H DRIVER

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**electrical characteristics over recommended ranges of supply voltage and free-air temperature (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
V <sub>IK</sub>	Input clamp voltage	I <sub>I</sub> = -12 mA		-0.9	-1.5	V
V <sub>OH</sub>	High-level output voltage	I <sub>OH</sub> = -0.5 A	V <sub>CC2</sub> -1.5	V <sub>CC2</sub> -1.1		V
		I <sub>OH</sub> = -1 A	V <sub>CC2</sub> -2			
		I <sub>OH</sub> = -1 A, T <sub>J</sub> = 25°C	V <sub>CC2</sub> -1.8	V <sub>CC2</sub> -1.4		
V <sub>OL</sub>	Low-level output voltage	I <sub>OL</sub> = 0.5 A		1	1.4	V
		I <sub>OL</sub> = 1 A			2	
		I <sub>OL</sub> = 1 A, T <sub>J</sub> = 25°C		1.2	1.8	
V <sub>OKH</sub>	High-level output clamp voltage	I <sub>OK</sub> = -0.5 A	V <sub>CC2</sub> +1.4	V <sub>CC2</sub> +2		V
		I <sub>OK</sub> = 1 A	V <sub>CC2</sub> +1.9	V <sub>CC2</sub> +2.5		
V <sub>OKL</sub>	Low-level output clamp voltage	I <sub>OK</sub> = 0.5 A		-1.1	-2	V
		I <sub>OK</sub> = -1 A		-1.3	-2.5	
I <sub>OZ(off)</sub>	Off-state high-impedance-state output current	V <sub>O</sub> = V <sub>CC2</sub>			500	μA
		V <sub>O</sub> = 0			-500	
I <sub>IH</sub>	High-level input current	V <sub>I</sub> = 5.5 V			10	μA
I <sub>IL</sub>	Low-level input current	V <sub>I</sub> = 0			-10	μA
I <sub>CC1</sub>	Output supply current	I <sub>O</sub> = 0	All outputs at high level		38	mA
			All outputs at low level		70	
			All outputs at high impedance		25	
I <sub>CC2</sub>	Output supply current	I <sub>O</sub> = 0	All outputs at high level		33	mA
			All outputs at low level		20	
			All outputs at high impedance		5	

† All typical values are at V<sub>CC1</sub> = 5 V, V<sub>CC2</sub> = 24 V, T<sub>A</sub> = 25°C.

**switching characteristics, V<sub>CC1</sub> = 5 V, V<sub>CC2</sub> = 24 V, C<sub>L</sub> = 30 pF, T<sub>A</sub> = 25°C**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>d1</sub>	Delay time, high-to-low-level output from A input	See Figure 1		400		ns
t <sub>d2</sub>	Delay time, low-to-high-level output from A input			800		ns
t <sub>TLH</sub>	Transition time, low-to-high-level output			300		ns
t <sub>THL</sub>	Transition time, high-to-low-level output			300		ns
t <sub>r</sub>	Rise time, pulse input					
t <sub>f</sub>	Fall time, pulse input					
t <sub>w</sub>	Pulse duration					
t <sub>en1</sub>	Enable time to the high level	See Figure 2		700		ns
t <sub>en2</sub>	Enable time to the low level			400		ns
t <sub>dis1</sub>	Disable time from the high level			900		ns
t <sub>dis2</sub>	Disable time from the low level			600		ns



# SN754410 QUADRUPLE HALF-H DRIVER

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## PARAMETER MEASUREMENT INFORMATION

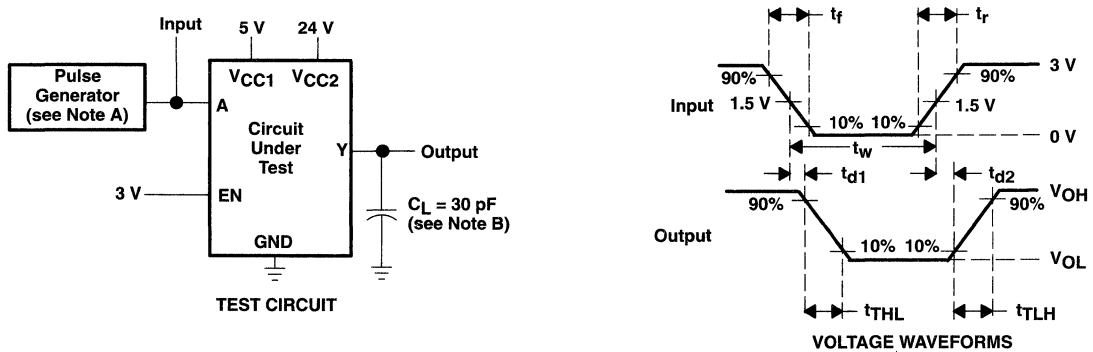


Figure 1. Test Circuit and Switching Times From Data Inputs

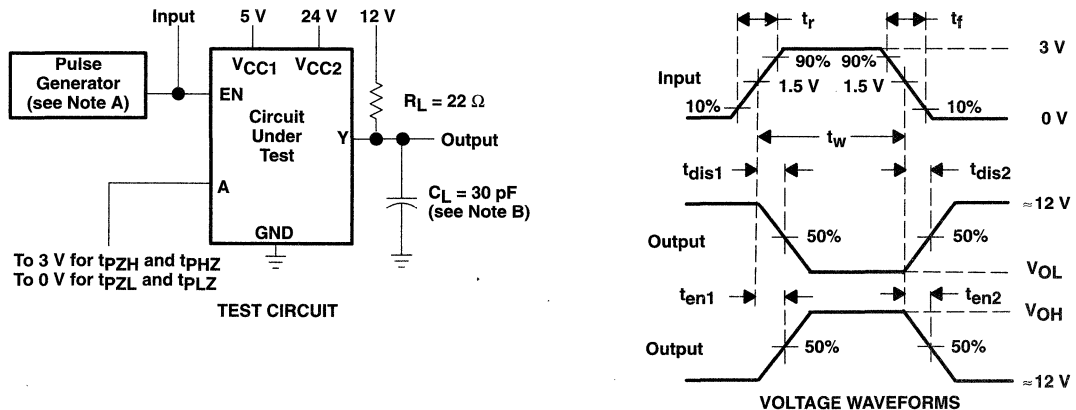


Figure 2. Test Circuit and Switching Times From Enable Inputs

- NOTES: A. The pulse generator has the following characteristics:  $t_r \leq 10 \text{ ns}$ ,  $t_f \leq 10 \text{ ns}$ ,  $t_w = 10 \mu\text{s}$ ,  $\text{PRR} = 5 \text{ kHz}$ ,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

# SN754410 QUADRUPLE HALF-H DRIVER

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## APPLICATION INFORMATION

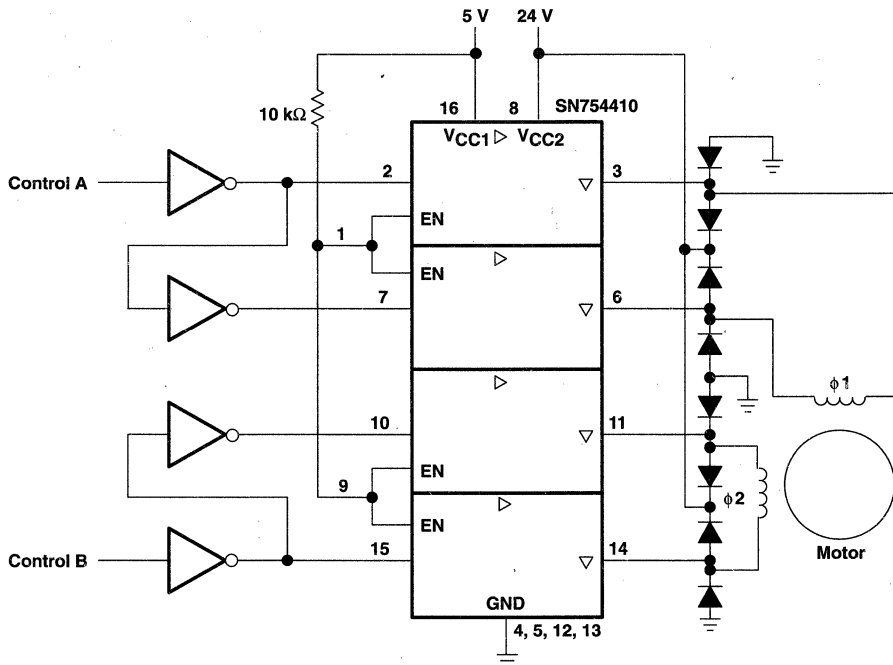


Figure 3. Two-Phase Motor Driver

# SN75446, SN75447 DUAL PERIPHERAL DRIVERS

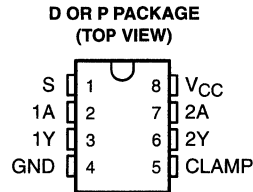
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- Very Low Power Requirements
- Very Low Input Current
- Characterized for Use to 350 mA
- No Output Latch-Up at 50 V (After Conducting 300 mA)
- High-Voltage Outputs (70 V Min)
- Output Clamp Diodes for Transient Suppression (350 mA, 70 V)
- TTL- or MOS-Compatible Diode-Clamped Inputs
- Standard Supply Voltage
- Suitable for Hammer-Driver Applications

## description

The SN75446 and SN75447 dual peripheral drivers are designed for use in systems that require high current, high voltage, and fast switching times. The SN75446 and SN75447 provide AND and NAND drivers, respectively. These devices have diode-clamped inputs as well as high-current, high-voltage inductive-clamp diodes on the outputs.

The SN75446 and SN75447 drivers are characterized for operation from 0°C to 70°C.



## Function Tables

**SN75446**  
(each AND driver)

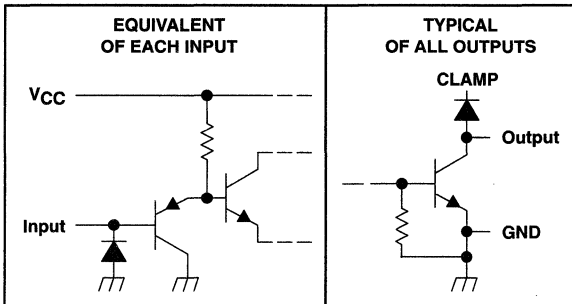
INPUTS		OUTPUT
A	S	Y
H	H	H
L	X	L
X	L	L

**SN75447**  
(each NAND driver)

INPUTS		OUTPUT
A	S	Y
H	H	L
L	X	H
X	L	H

H = high level, L = low level  
X = irrelevant

## schematics of inputs and outputs

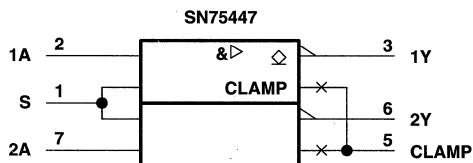
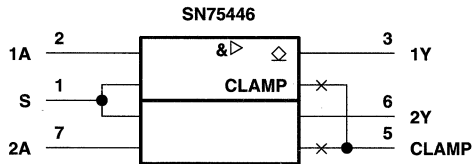




# SN75446, SN75447 DUAL PERIPHERAL DRIVERS

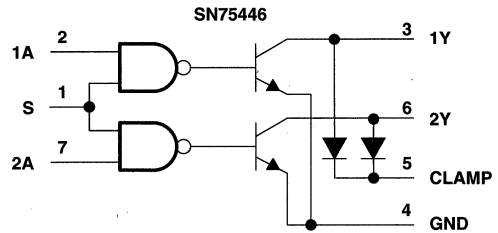
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## logic symbols†

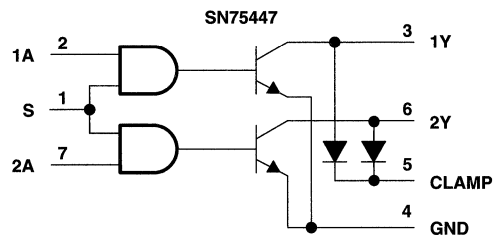


† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

## logic diagrams (positive logic)



Positive Logic:  $Y = \overline{AS}$  or  $\overline{A+S}$



Positive Logic:  $Y = \overline{AS}$  or  $\overline{A+S}$

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

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage, $V_I$	5.5 V
Output current, $I_O$ (see Note 2)	400 mA
Output clamp-diode current	400 mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°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. Voltage values are with respect to network GND.

2. Both halves of this dual circuit may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous dissipation ratings.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

# SN75446, SN75447 DUAL PERIPHERAL DRIVERS

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## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.75	5	5.25	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
Operating free-air temperature range, $T_A$	0		70	°C

## electrical characteristics over recommended operating free-air temperature range

PARAMETER		TEST CONDITIONS		MIN	TYP†	MAX	UNIT
$V_{IK}$	Input clamp voltage	$I_I = -12$ mA		-0.9	-1.5		V
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.75$ V, $V_{IH} = 2$ V, $V_{IL} = 0.8$ V	$I_{OL} = 100$ mA	0.1	0.3		V
			$I_{OL} = 200$ mA	0.22	0.45		
			$I_{OL} = 300$ mA	0.45	0.65		
			$I_{OL} = 350$ mA	0.55	0.75		
$V_{O(BR)}$	Output breakdown voltage	$V_{CC} = 4.75$ V,	$I_{OH} = 100$ $\mu$ A	70	100		V
$V_{R(K)}$	Output clamp-diode reverse voltage	$V_{CC} = 4.75$ V,	$I_R = 100$ $\mu$ A	70	100		V
$V_{F(K)}$	Output clamp-diode forward voltage	$V_{CC} = 4.75$ V,	$I_F = 350$ mA	0.6	1.2	1.6	V
$I_{OH}$	High-level output current	$V_{CC} = 4.75$ V, $V_{IL} = 0.8$ V,	$V_{IH} = 2$ V, $V_{OH} = 70$ V		1	100	$\mu$ A
$I_{IH}$	High-level input current	$V_{CC} = 5.25$ V,	$V_I = 5.25$ V	0.01	10		$\mu$ A
$I_{IL}$	Low-level input current	A input	$V_{CC} = 5.25$ V, $V_I = 0.8$ V	-0.5	-10		$\mu$ A
		S input		-1	-20		
$I_{CCH}$	Supply current, outputs high	SN75446	$V_{CC} = 5.25$ V	$V_I = 5$ V	11	18	mA
		SN75447		$V_I = 0$	11	18	
$I_{CCL}$	Supply current, outputs low	SN75446	$V_{CC} = 5.25$ V	$V_I = 0$	11	18	mA
		SN75447		$V_I = 5$ V	11	18	

† All typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ$ C.

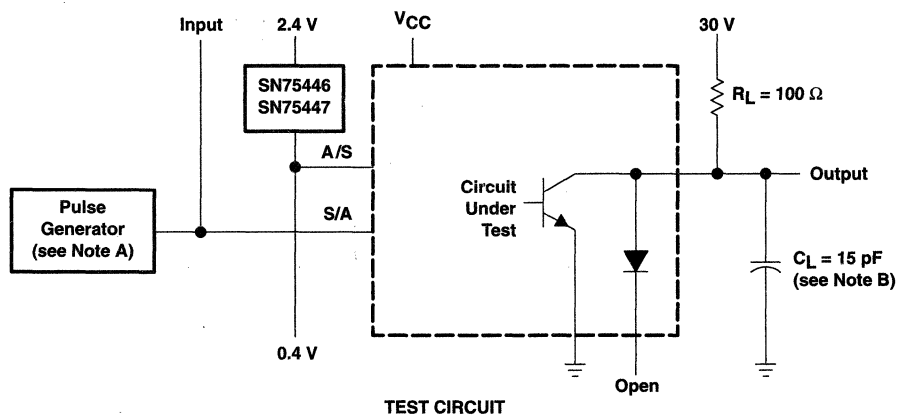
## switching characteristics, $V_{CC} = 5$ V, $T_A = 25^\circ$ C

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output	$C_L = 15$ pF, See Figure 1	$R_L = 100$ $\Omega$ ,		300	750	ns
$t_{PHL}$	Propagation delay time, high-to-low-level output				200	500	ns
$t_{TLH}$	Transition time, low-to-high-level output				50	100	ns
$t_{THL}$	Transition time, high-to-low-level output				50	100	ns
$V_{OH}$	High-level output voltage after switching	$V_S = 55$ V, See Figure 2	$I_O \approx 300$ mA,	$V_S - 0.018$			V

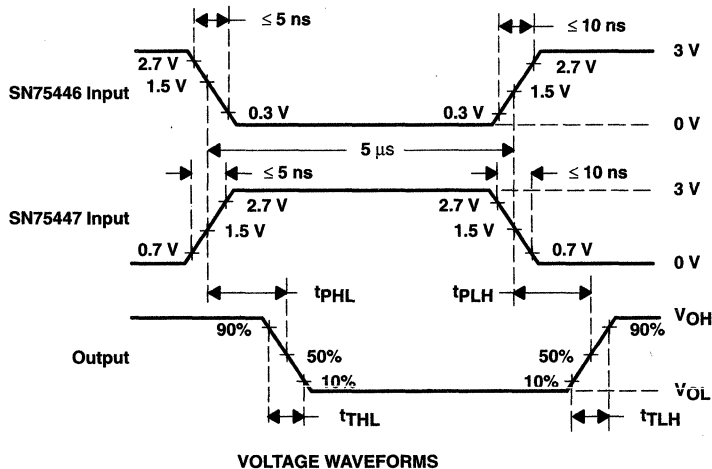
# SN75446, SN75447 DUAL PERIPHERAL DRIVERS

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

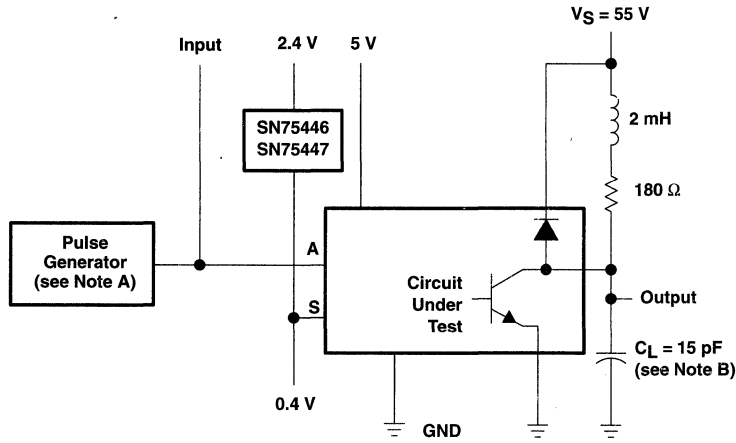


VOLTAGE WAVEFORMS

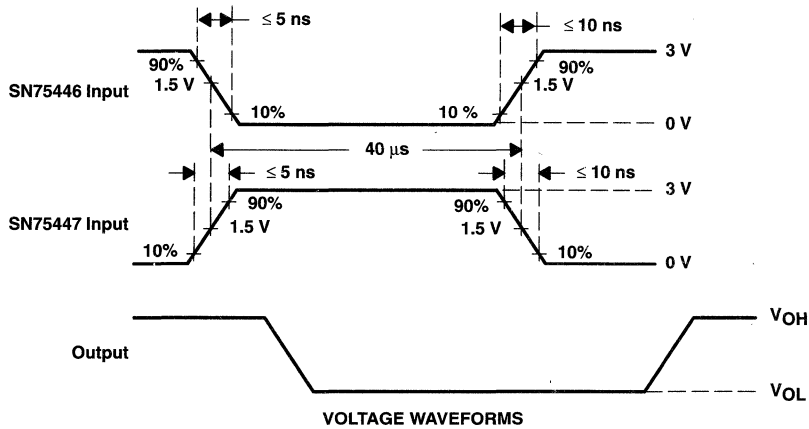
- NOTES: A. The pulse generator has the following characteristics: PRR = 100 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 1. Test Circuit and Voltage Waveforms, Switching Characteristics

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz, Z<sub>O</sub> = 50 Ω.  
 B. C<sub>L</sub> includes probe and jig capacitance.

Figure 2. Latch-Up Test Circuit and Voltage Waveforms



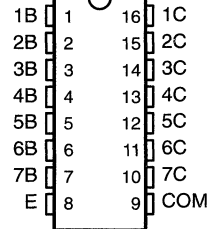
# SN75468, SN75469 DARLINGTON TRANSISTOR ARRAYS

SLRS023B – DECEMBER 1976 – REVISED SEPTEMBER 1995

## HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAYS

- 500-mA Rated Collector Current (Single Output)
- High-Voltage Outputs . . . 100 V
- Output Clamp Diodes
- Inputs Compatible With Various Types of Logic
- Relay Driver Applications
- Higher-Voltage Versions of ULN2003A and ULN2004A, for Commercial Temperature Range

D OR N PACKAGE  
(TOP VIEW)

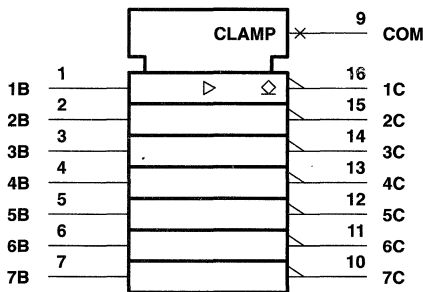


### description

The SN75468 and SN75469 are monolithic high-voltage, high-current Darlington transistor arrays. Each consists of seven npn Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of each Darlington pair is 500 mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers.

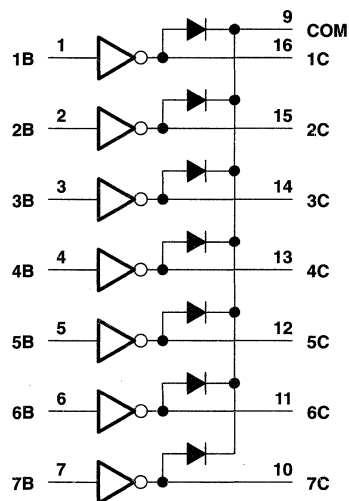
The SN75468 has a 2700- $\Omega$  series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS. The SN75469 has a 10.5-k $\Omega$  series base resistor to allow its operation directly with CMOS or PMOS that use supply voltages of 6 to 15 V. The required input current is below that of the SN75468.

### logic symbol†



† This symbol is in accordance with ANSI/IEEE Std91-1984 and IEC publication 617-12.

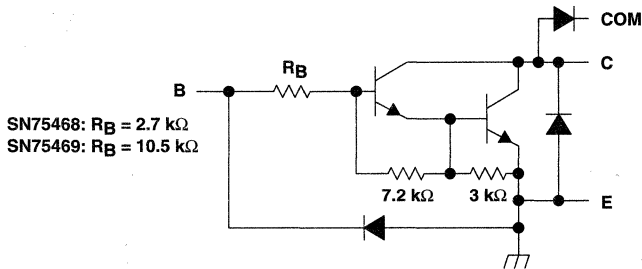
### logic diagram



# SN75468, SN75469 DARLINGTON TRANSISTOR ARRAYS

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## schematic (each Darlington pair)



All resistor values shown are nominal.

## absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-emitter voltage, $V_{CE}$ .....	100 V
Input voltage, $V_I$ (see Note 1) .....	30 V
Peak collector current (see Figures 14 and 15) .....	500 mA
Output clamp current, $I_{OK}$ .....	500 mA
Total emitter-terminal current .....	-2.5 A
Continuous total power dissipation .....	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ .....	0°C to 70°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

NOTE 1: All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	950 mW	7.6 mW/°C	608 mW
N	1150 mW	9.2 mW/°C	736 mW

**SN75468, SN75469**  
**DARLINGTON TRANSISTOR ARRAYS**

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**electrical characteristics,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST FIGURE	TEST CONDITIONS	SN75468			SN75469			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	5	$V_{CE} = 2\text{ V}$	$I_C = 125\text{ mA}$					5	V
			$I_C = 200\text{ mA}$			2.4		6	
			$I_C = 250\text{ mA}$			2.7			
			$I_C = 275\text{ mA}$					7	
			$I_C = 300\text{ mA}$			3			
$V_{CE(sat)}$ Collector-emitter saturation voltage	6	$I_I = 250\ \mu\text{A}, I_C = 100\text{ mA}$		0.9	1.1		0.9	1.1	V
		$I_I = 350\ \mu\text{A}, I_C = 200\text{ mA}$		1	1.3		1	1.3	
		$I_I = 500\ \mu\text{A}, I_C = 350\text{ mA}$		1.2	1.6		1.2	1.6	
$V_F$ Clamp-diode forward voltage	8	$I_F = 350\text{ mA}$		1.7	2		1.7	2	V
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 100\text{ V}, I_I = 0$			50			50	$\mu\text{A}$
	2	$V_{CE} = 100\text{ V}, T_A = 70^\circ\text{C}, V_I = 1\text{ V}$			100			100	
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50\text{ V}, T_A = 70^\circ\text{C}, I_C = 500\ \mu\text{A}$	50	65		50	65	$\mu\text{A}$	
$I_I$ Input current	4	$V_I = 3.85\text{ V}$		0.93	1.35				mA
		$V_I = 5\text{ V}$				0.35	0.5		
		$V_I = 12\text{ V}$				1	1.45		
$I_R$ Clamp-diode reverse current	7	$V_R = 100\text{ V}$			50			50	$\mu\text{A}$
		$V_R = 100\text{ V}, T_A = 70^\circ\text{C}$			100			100	
$C_i$ Input capacitance		$V_I = 0, f = 1\text{ MHz}$		15	25		15	25	pF

**switching characteristics,  $T_A = 25^\circ\text{C}$  free-air temperature**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	$V_S = 50\text{ V}, R_L = 163\ \Omega, C_L = 15\text{ pF},$ See Figure 9		0.25	1	$\mu\text{s}$
$t_{PHL}$ Propagation delay time, high-to-low-level output			0.25	1	$\mu\text{s}$
$V_{OH}$ High-level output voltage after switching	$V_S = 50\text{ V}, I_O = 300\text{ mA},$ See Figure 10	$V_S - 20$			mV



# SN75468, SN75469 DARLINGTON TRANSISTOR ARRAYS

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## PARAMETER MEASUREMENT INFORMATION

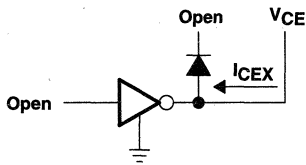


Figure 1.  $I_{C EX}$

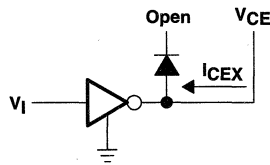


Figure 2.  $I_{C EX}$

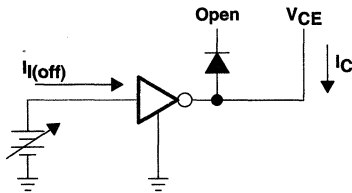


Figure 3.  $I_{I(off)}$

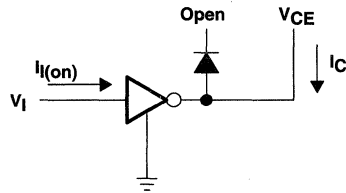


Figure 4.  $I_I$

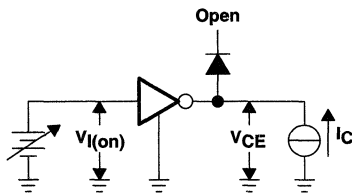
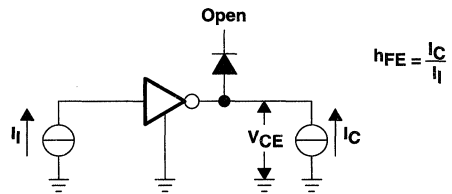


Figure 5.  $V_{I(on)}$



NOTE:  $I_I$  is fixed for measuring  $V_{CE(sat)}$ ,  
variable for measuring  $h_{FE}$ .

Figure 6.  $h_{FE}$ ,  $V_{CE(sat)}$

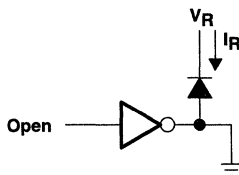


Figure 7.  $I_R$

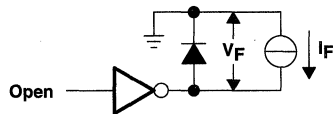


Figure 8.  $V_F$

PARAMETER MEASUREMENT INFORMATION

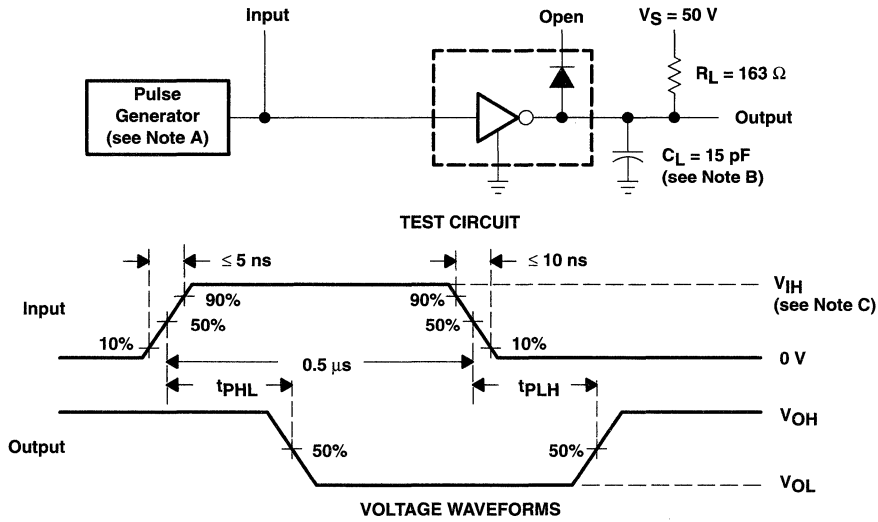


Figure 9. Test Circuit and Voltage Waveforms

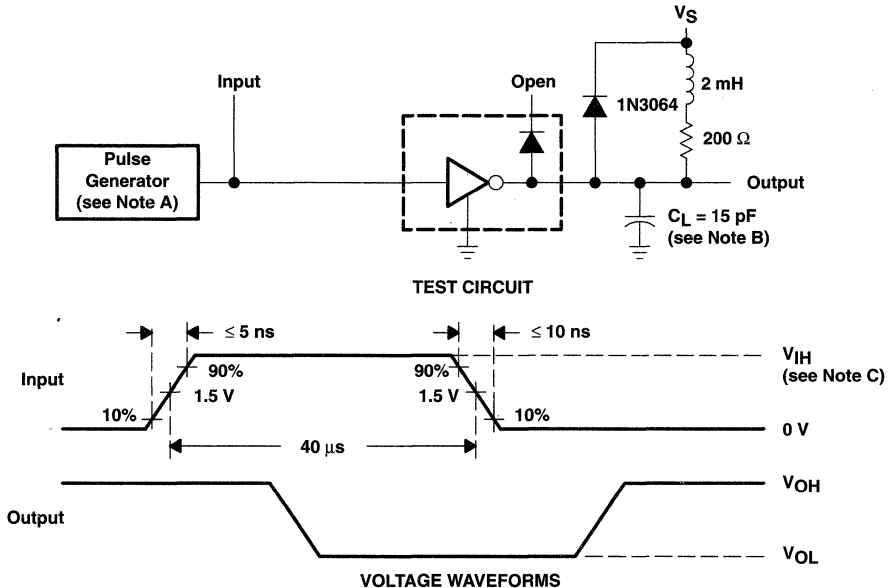


Figure 10. Latch-Up Test Circuit and Voltage Waveforms

- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.  
 C. For testing the '468,  $V_{IH} = 3 \text{ V}$ ; for the '469,  $V_{IH} = 8 \text{ V}$ .

# SN75468, SN75469 DARLINGTON TRANSISTOR ARRAYS

SLRS023B – DECEMBER 1976 – REVISED SEPTEMBER 1995

## TYPICAL CHARACTERISTICS

COLLECTOR-EMITTER  
SATURATION VOLTAGE  
vs  
COLLECTOR CURRENT  
(ONE DARLINGTON)

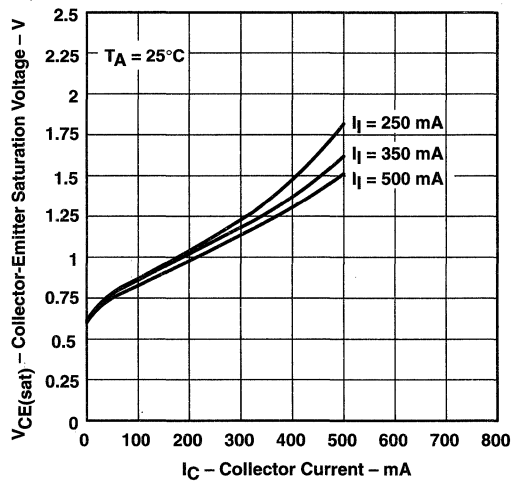


Figure 11

COLLECTOR-EMITTER  
SATURATION VOLTAGE  
vs  
COLLECTOR CURRENT  
(TWO DARLINGTONS PARALLELED)

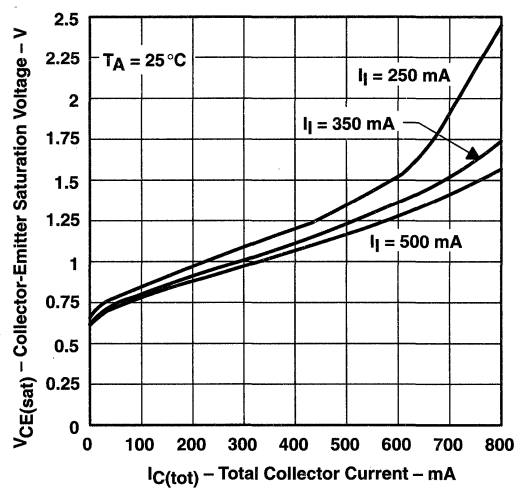


Figure 12

COLLECTOR CURRENT  
vs  
INPUT CURRENT

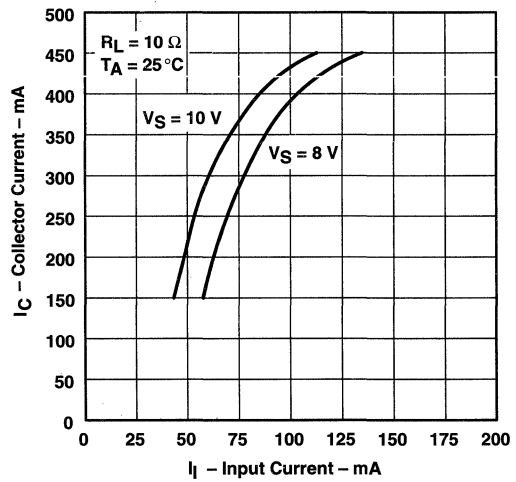


Figure 13

THERMAL INFORMATION

D PACKAGE  
 MAXIMUM COLLECTOR CURRENT  
 vs  
 DUTY CYCLE

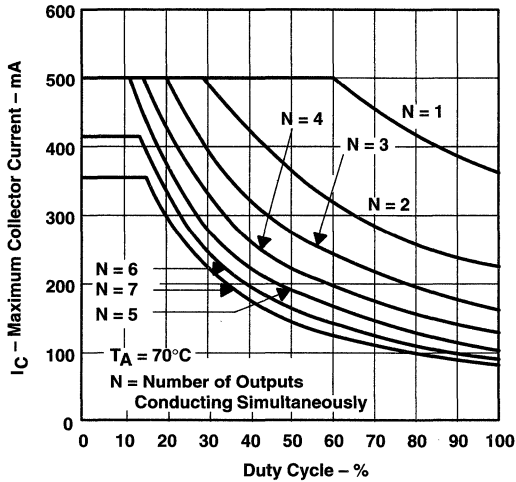


Figure 14

N PACKAGE  
 MAXIMUM COLLECTOR CURRENT  
 vs  
 DUTY CYCLE

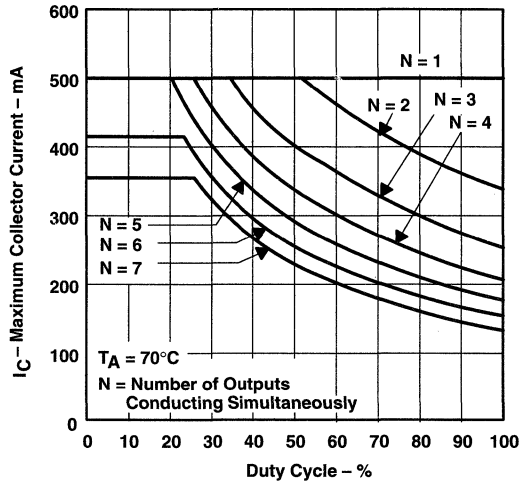


Figure 15

# SN75468, SN75469 DARLINGTON TRANSISTOR ARRAYS

SLRS023B – DECEMBER 1976 – REVISED SEPTEMBER 1995

## APPLICATION INFORMATION

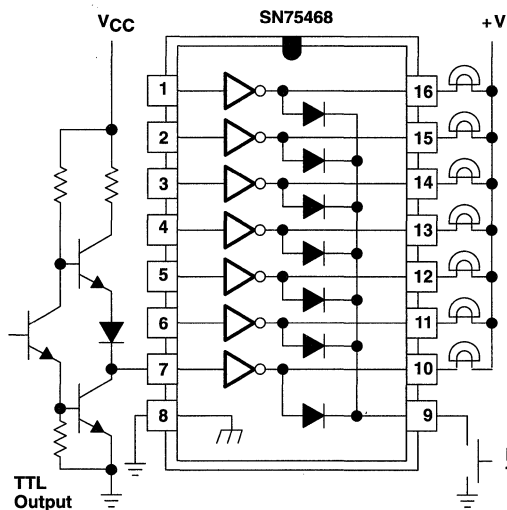


Figure 16. TTL to Load

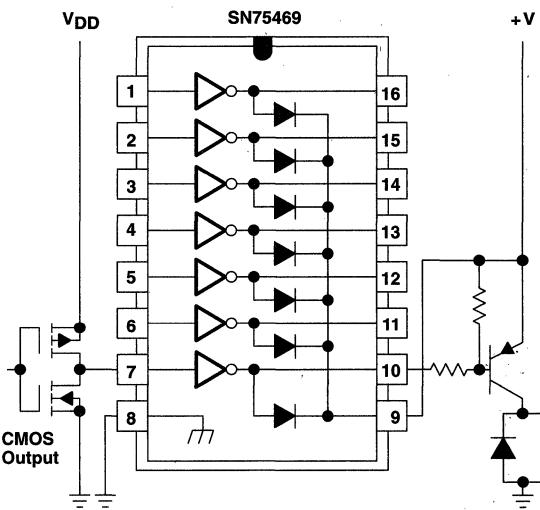


Figure 17. Buffer for Higher Current Loads

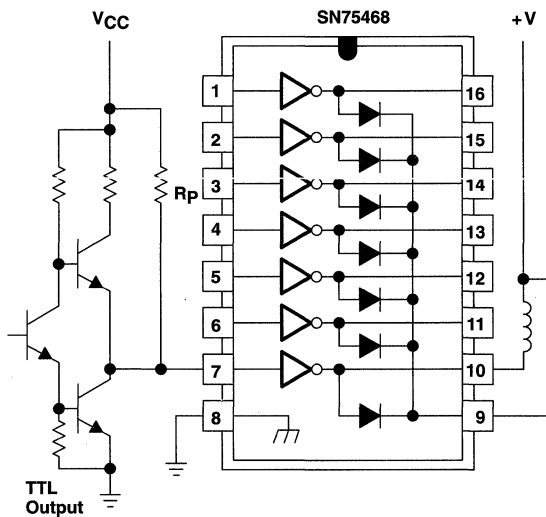


Figure 18. Use of Pullup Resistors to Increase Drive Current

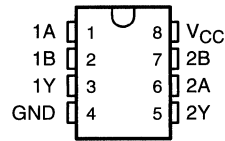
# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

SLRS024 – DECEMBER 1976 – REVISED MAY 1990

## PERIPHERAL DRIVERS FOR HIGH-VOLTAGE HIGH-CURRENT DRIVER APPLICATIONS

- Characterized for Use to 300 mA
- High-Voltage Outputs
- No Output Latch-Up at 55 V (After Conducting 300 mA)
- Medium-Speed Switching
- Circuit Flexibility for Varied Applications and Choice of Logic Function
- TTL-Compatible Diode-Clamped Inputs
- Standard Supply Voltages
- Plastic DIP (P) With Copper Lead Frame Provides Cooler Operation and Improved Reliability

D OR P PACKAGE  
(TOP VIEW)



SUMMARY OF SERIES SN75471

DEVICE	LOGIC OF COMPLETE CIRCUIT	PACKAGES
SN75471	AND	D, P
SN75472	NAND	D, P
SN75473	OR	D, P

### description

Series SN75471 dual peripheral drivers are functionally interchangeable with series SN75451B and series SN75461 peripheral drivers, but are designed for use in systems that require higher breakdown voltages than either of those series can provide at the expense of slightly slower switching speeds than series 75451B (limits are the same as series SN75461). Typical applications include high-speed logic buffers, power drivers, relay drivers, lamp drivers, MOS drivers, line drivers, and memory drivers.

The SN75471, SN75472, and SN75473 are dual peripheral AND, NAND, and OR drivers, respectively, (assuming positive logic), with the output of the logic gates internally connected to the bases of the npn output transistors.

Series SN75471 drivers are characterized for operation from 0°C to 70°C.

# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

SLRS024 – DECEMBER 1976 – REVISED MAY 1990

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

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage, $V_I$	5.5 V
Inter-emitter voltage (see Note 2)	5.5 V
Off-state output voltage, $V_O$	70 V
Continuous collector or output current (see Note 3)	400 mA
Peak collector or output current ( $t_w \leq 10$ ms, duty cycle $\leq 50\%$ , see Note 3)	500 mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°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

- NOTES: 1. Voltage values are with respect to the network GND, unless otherwise specified.  
 2. This is the voltage between two emitters, A and B.  
 3. Both halves of these dual circuits may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous dissipation rating.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$	DERATING FACTOR	$T_A = 70^\circ\text{C}$
	POWER RATING	ABOVE $T_A = 25^\circ\text{C}$	POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

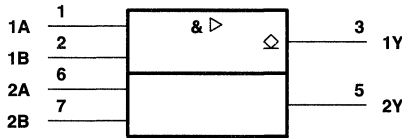
## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.75	5	5.25	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
Operating free-air temperature, $T_A$	0		70	°C

# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

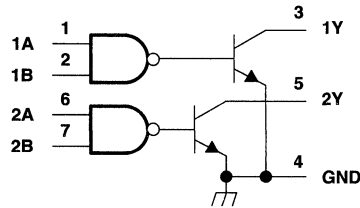
SLRS024 – DECEMBER 1976 – REVISED MAY 1990

## SN75471 logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## SN75471 logic diagram (positive logic)

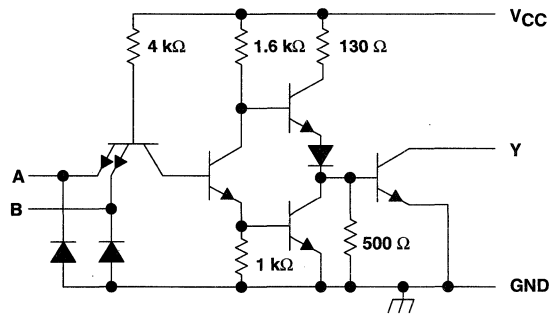


SN75471 FUNCTION TABLE  
(each driver)

A	B	Y
L	L	L (on state)
L	H	L (on state)
H	L	L (on state)
H	H	H (off state)

positive logic:  
 $Y = AB \text{ or } \bar{A} + \bar{B}$

## SN75471 schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS	SN75471			UNIT
		MIN	TYP‡	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = 4.75 \text{ V}$ , $I_I = -12 \text{ mA}$	-1.2	-1.5		V
$I_{OH}$ High-level output current	$V_{CC} = 4.75 \text{ V}$ , $V_{IH} = 2 \text{ V}$ , $V_{OH} = 70 \text{ V}$			100	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{CC} = 4.75 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 100 \text{ mA}$		0.25	0.4	V
	$V_{CC} = 4.75 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 300 \text{ mA}$		0.5	0.7	
$I_I$ Input current at maximum input voltage	$V_{CC} = 5.25 \text{ V}$ , $V_I = 5.5 \text{ V}$			1	mA
$I_{IH}$ High-level input current	$V_{CC} = 5.25 \text{ V}$ , $V_I = 2.4 \text{ V}$			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = 5.25 \text{ V}$ , $V_I = 0.4 \text{ V}$		-1	-1.6	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = 5.25 \text{ V}$ , $V_I = 5 \text{ V}$		7	11	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = 5.25 \text{ V}$ , $V_I = 0$		52	65	mA

‡ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

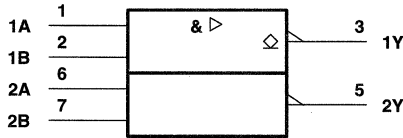
PARAMETER	TEST CONDITIONS	SN75471			UNIT
		MIN	TYP	MAX	
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200 \text{ mA}$ , $R_L = 50 \Omega$ , $C_L = 15 \text{ pF}$ , See Figure 1		30	55	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			25	40	
$t_{TLH}$ Transition time, low-to-high-level output			8	20	
$t_{THL}$ Transition time, high-to-low-level output			10	20	
$V_{OH}$ High-level output voltage after switching	$V_S = 55 \text{ V}$ , See Figure 2		$I_O \approx 300 \text{ mA}$ , $V_S - 18$		mV



# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

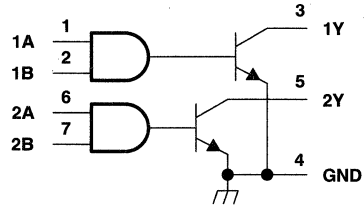
SLRS024 – DECEMBER 1976 – REVISED MAY 1990

## SN75472 logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## SN75472 logic diagram (positive logic)

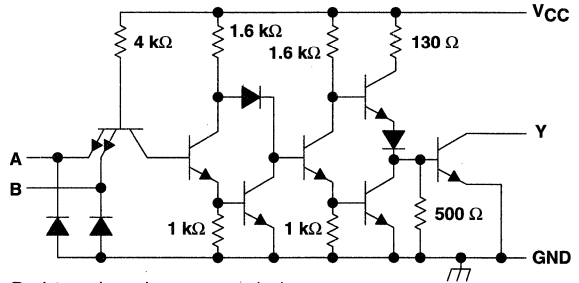


SN75472 FUNCTION TABLE (each driver)

A	B	Y
L	L	H (off state)
L	H	H (off state)
H	L	H (off state)
H	H	L (on state)

positive logic:  
 $Y = AB \text{ or } \bar{A} + \bar{B}$

## SN75472 schematic (each driver)



Resistor values shown are nominal.

## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS	SN75472			UNIT
		MIN	TYP‡	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = 4.75 \text{ V}$ , $I_I = -12 \text{ mA}$	-1.2	-1.5		V
$I_{OH}$ High-level output current	$V_{CC} = 4.75 \text{ V}$ , $V_{IH} = 2 \text{ V}$ , $V_{OH} = 70 \text{ V}$			100	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{CC} = 4.75 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 100 \text{ mA}$	0.25	0.4		V
	$V_{CC} = 4.75 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ , $I_{OL} = 300 \text{ mA}$	0.5	0.7		
$I_I$ Input current at maximum input voltage	$V_{CC} = 5.25 \text{ V}$ , $V_I = 5.5 \text{ V}$			1	mA
$I_{IH}$ High-level input current	$V_{CC} = 5.25 \text{ V}$ , $V_I = 2.4 \text{ V}$			40	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{CC} = 5.25 \text{ V}$ , $V_I = 0.4 \text{ V}$			-1	mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = 5.25 \text{ V}$ , $V_I = 5 \text{ V}$			13	mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = 5.25 \text{ V}$ , $V_I = 0$			61	mA

‡ All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

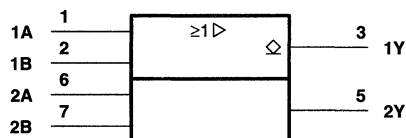
## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	SN75472			UNIT
		MIN	TYP	MAX	
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O = 200 \text{ mA}$ , $C_L = 15 \text{ pF}$ , $R_L = 50 \Omega$ , See Figure 1		45	65	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			30	50	
$t_{TLH}$ Transition time, low-to-high-level output			13	25	
$t_{THL}$ Transition time, high-to-low-level output			10	20	
$V_{OH}$ High-level output voltage after switching	$V_S = 55 \text{ V}$ , See Figure 2		$I_O = 300 \text{ mA}$ , $V_S - 18$		mV

# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

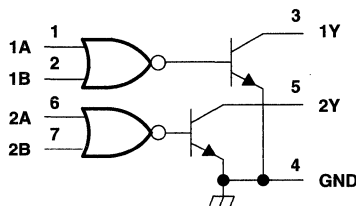
SLRS024 - DECEMBER 1976 - REVISED MAY 1990

## SN75473 logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## SN75473 logic diagram (positive logic)

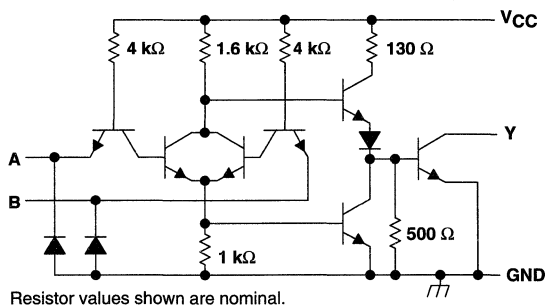


SN75473 FUNCTION TABLE  
(each driver)

A	B	Y
L	L	L (on state)
L	H	H (off state)
H	L	H (off state)
H	H	H (off state)

positive logic:  
 $Y = A + B$  or  $\bar{A}\bar{B}$

## SN75473 schematic (each driver)



## electrical characteristics over recommended operating free-air temperature range

PARAMETER	TEST CONDITIONS	SN75473			UNIT
		MIN	TYP‡	MAX	
$V_{IK}$ Input clamp voltage	$V_{CC} = 4.75$ V, $I_I = -12$ mA	-1.2	-1.5		V
$I_{OH}$ High-level output current	$V_{CC} = 4.75$ V, $V_{IH} = 2$ V, $V_{OH} = 70$ V			100	$\mu$ A
$V_{OL}$ Low-level output voltage	$V_{CC} = 4.75$ V, $V_{IL} = 0.8$ V, $I_{OL} = 100$ mA	0.25	0.4		V
	$V_{CC} = 4.75$ V, $V_{IL} = 0.8$ V, $I_{OL} = 300$ mA	0.5	0.7		
$I_I$ Input current at maximum input voltage	$V_{CC} = 5.25$ V, $V_I = 5.5$ V			1	mA
$I_{IH}$ High-level input current	$V_{CC} = 5.25$ V, $V_I = 2.4$ V			40	$\mu$ A
$I_{IL}$ Low-level input current	$V_{CC} = 5.25$ V, $V_I = 0.4$ V	-1	-1.6		mA
$I_{CCH}$ Supply current, outputs high	$V_{CC} = 5.25$ V, $V_I = 5$ V	8	11		mA
$I_{CCL}$ Supply current, outputs low	$V_{CC} = 5.25$ V, $V_I = 0$	58	76		mA

‡ All typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

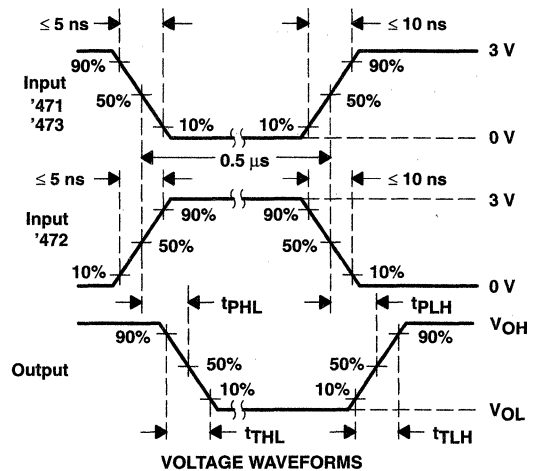
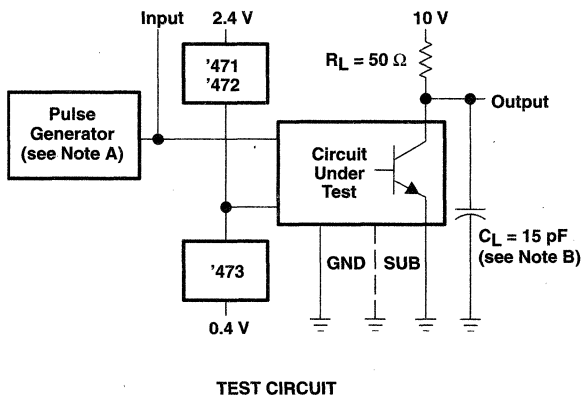
## switching characteristics, $V_{CC} = 5$ V, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	SN75473			UNIT
		MIN	TYP	MAX	
$t_{PLH}$ Propagation delay time, low-to-high-level output	$I_O \approx 200$ mA, $C_L = 15$ pF, $R_L = 50$ $\Omega$ , See Figure 1		30	55	ns
$t_{PHL}$ Propagation delay time, high-to-low-level output			25	40	
$t_{TLH}$ Transition time, low-to-high-level output			8	25	
$t_{THL}$ Transition time, high-to-low-level output			10	25	
$V_{OH}$ High-level output voltage after switching	$V_S = 55$ V, See Figure 2	$I_O \approx 300$ mA,	$V_S - 18$		mV

# SN75471 THRU SN75473 DUAL PERIPHERAL DRIVERS

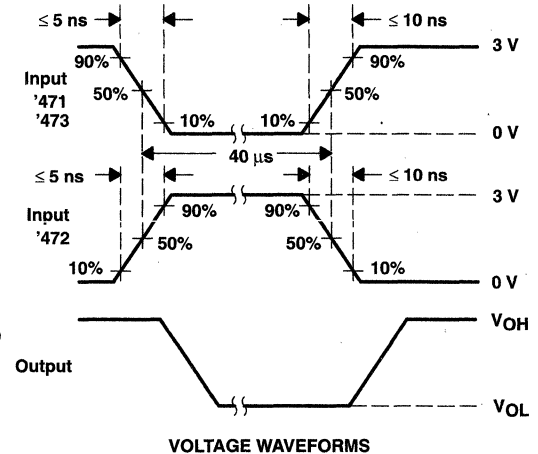
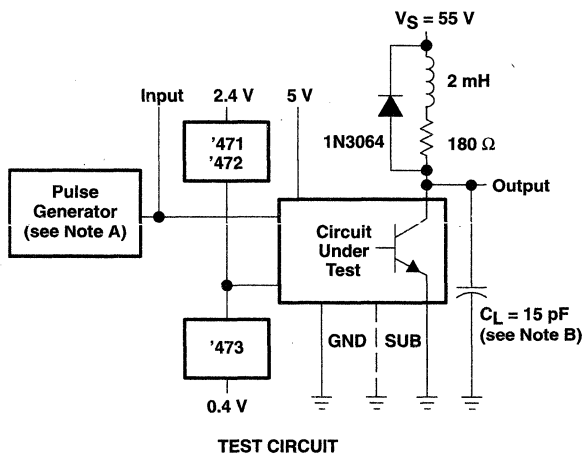
SLRS024 – DECEMBER 1976 – REVISED MAY 1990

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The pulse generator has the following characteristics:  $PRR \leq 1 \text{ MHz}$ ,  $Z_O \approx 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 1. Switching Times



- NOTES: A. The pulse generator has the following characteristics:  $PRR \leq 12.5 \text{ kHz}$ ,  $Z_O \approx 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

Figure 2. Latch-Up Test

# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

SLRS025A – DECEMBER 1976 – REVISED NOVEMBER 1995

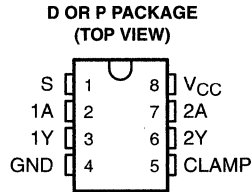
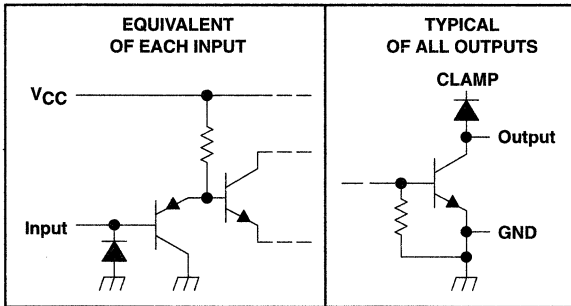
- Characterized for Use to 300 mA
- No Output Latch-Up at 55 V (After Conducting 300 mA)
- High-Voltage Outputs (100 V Typ)
- Output Clamp Diodes for Transient Suppression (300 mA, 70 V)
- TTL- or MOS-Compatible Diode-Clamped Inputs
- pnp Transistor Inputs Reduce Input Current
- Standard Supply Voltage
- Suitable for Hammer-Driver Applications
- Plastic DIP (P) With Copper-Lead Frame Provides Cooler Operation and Improved Reliability

## description

The SN75476 through SN75478 are dual peripheral drivers designed for use in systems that require high current, high voltage, and fast switching times. The SN75476, SN75477, and SN75478 provide AND, NAND, and OR drivers respectively. These devices have diode-clamped inputs as well as high-current, high-voltage clamp diodes on the outputs for inductive transient protection.

The SN75476, SN75477, and SN75478 drivers are characterized for operation from 0°C to 70°C.

## schematics of inputs and outputs



## Function Tables

SN75476  
(each AND driver)

INPUTS		OUTPUT
A	S	Y
H	H	H
L	X	L
X	L	L

SN75477  
(each NAND driver)

INPUTS		OUTPUT
A	S	Y
H	H	L
L	X	H
X	L	H

SN75478  
(each OR driver)

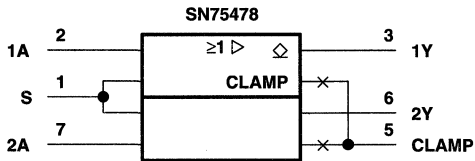
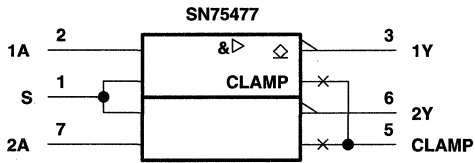
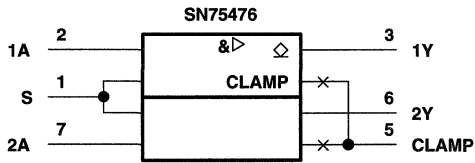
INPUTS		OUTPUT
A	S	Y
H	X	H
X	H	H
L	L	L

H = high level, L = low level  
X = irrelevant

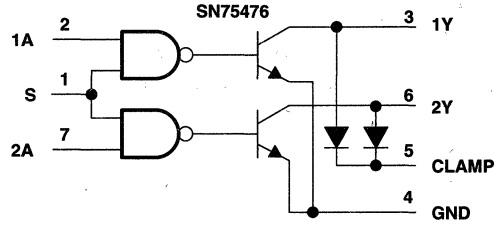
# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

SLRS025A – DECEMBER 1976 – REVISED NOVEMBER 1995

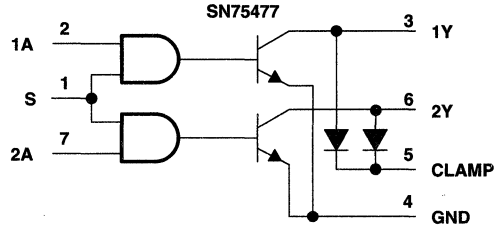
## logic symbols†



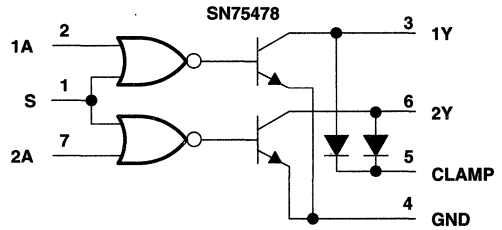
## logic diagrams (positive logic)



Positive Logic:  $Y = AS \text{ or } \overline{A+S}$



Positive Logic:  $Y = \overline{A}S \text{ or } \overline{A+S}$



Positive Logic:  $Y = A+S \text{ or } \overline{A} \overline{S}$

† These symbols are in accordance with ANSI/IEEE Std 91-1984 and IEC publication 617-12.

# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

SLRS025A—DECEMBER 1976—REVISED NOVEMBER 1995

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

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage, $V_I$	5.5 V
Continuous output current (see Note 2)	400 mA
Peak output current: $t_w \leq 10$ ms, duty cycle $\leq 50\%$	500 mA
$t_w \leq 30$ ns, duty cycle $\leq 0.002\%$	3 A
Output clamp current, $I_{OK}$	400 mA
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$	0°C to 70°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

NOTES: 1. Voltage values are with respect to network GND.

2. Both halves of this dual circuit may conduct rated current simultaneously; however, power dissipation averaged over a short time interval must fall within the continuous power dissipation ratings.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW
P	1000 mW	8.0 mW/°C	640 mW

## recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	5	5.5	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
Operating free-air temperature, $T_A$	0		70	°C

# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

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## electrical characteristics over recommended operating free-air temperature range

PARAMETER		TEST CONDITIONS		MIN	TYP†	MAX	UNIT	
$V_{IK}$	Input clamp voltage	$I_I = -12 \text{ mA}$		-0.95	-1.5		V	
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.5 \text{ V}$ , $V_{IH} = 2 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$	$I_{OL} = 100 \text{ mA}$	0.16	0.3		V	
			$I_{OL} = 175 \text{ mA}$	0.22	0.5			
			$I_{OL} = 300 \text{ mA}$	0.33	0.6			
$V_{O(BR)}$	Output breakdown voltage	$V_{CC} = 4.5 \text{ V}$ ,	$I_{OH} = 100 \mu\text{A}$	70	100		V	
$V_{R(K)}$	Output clamp reverse voltage	$V_{CC} = 4.5 \text{ V}$ ,	$I_R = 100 \mu\text{A}$	70	100		V	
$V_{F(K)}$	Output clamp forward voltage	$V_{CC} = 4.5 \text{ V}$ ,	$I_F = 300 \text{ mA}$	0.8	1.15	1.6	V	
$I_{OH}$	High-level output current	$V_{CC} = 4.5 \text{ V}$ , $V_{IL} = 0.8 \text{ V}$ ,	$V_{IH} = 2 \text{ V}$ , $V_{OH} = 70 \text{ V}$		1	100	$\mu\text{A}$	
$I_{IH}$	High-level input current	$V_{CC} = 5.5 \text{ V}$ ,	$V_I = 5.5 \text{ V}$		0.01	10	$\mu\text{A}$	
$I_{IL}$	Low-level input current	A input S input	$V_{CC} = 5.5 \text{ V}$ ,	$V_I = 0.8 \text{ V}$		-80	-110	$\mu\text{A}$
						-160	-220	
$I_{CCH}$	Supply current, outputs high	SN75476	$V_{CC} = 5.5 \text{ V}$	$V_I = 5 \text{ V}$	10	17	mA	
		SN75477		$V_I = 0$	10	17		
		SN75478		$V_I = 5 \text{ V}$	10	17		
$I_{CCL}$	Supply current, outputs low	SN75476	$V_{CC} = 5.5 \text{ V}$	$V_I = 0$	54	75	mA	
		SN75477		$V_I = 5 \text{ V}$	54	75		
		SN75478		$V_I = 0$	54	75		

† All typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

## switching characteristics, $V_{CC} = 5 \text{ V}$ , $T_A = 25^\circ\text{C}$

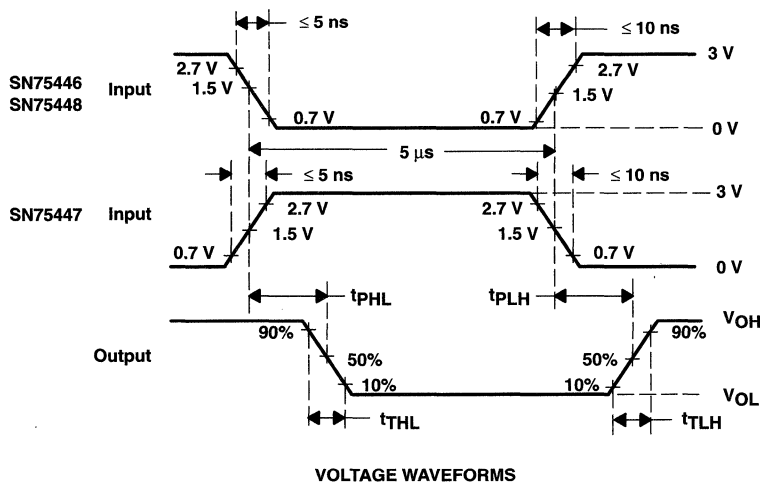
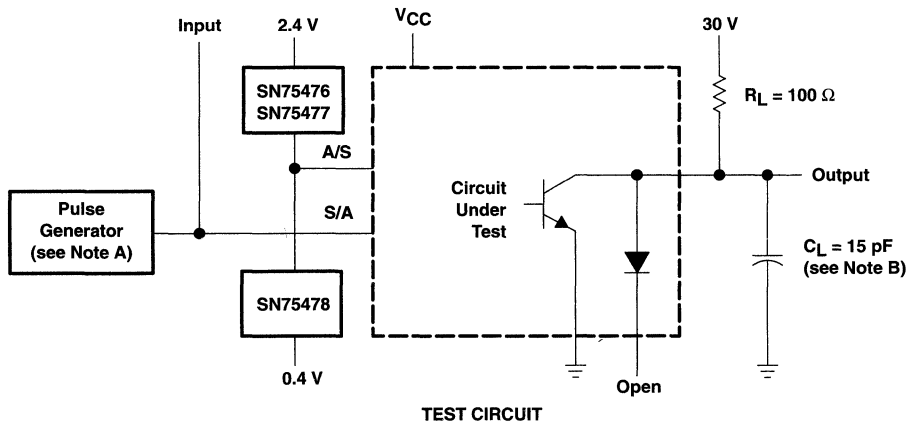
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output	$C_L = 15 \text{ pF}$ , See Figure 1	$R_L = 100 \Omega$		200	350	ns
$t_{PHL}$	Propagation delay time, high-to-low-level output				200	350	ns
$t_{TLH}$	Transition time, low-to-high-level output				50	125	ns
$t_{THL}$	Transition time, high-to-low-level output				90	125	ns
$V_{OH}$	High-level output voltage after switching	$V_S = 55 \text{ V}$ , See Figure 2	$I_O \approx 300 \text{ mA}$	$V_S - 18$			mV



# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The pulse generator has the following characteristics: PRR = 100 kHz,  $Z_O = 50 \Omega$ .  
B.  $C_L$  includes probe and jig capacitance.

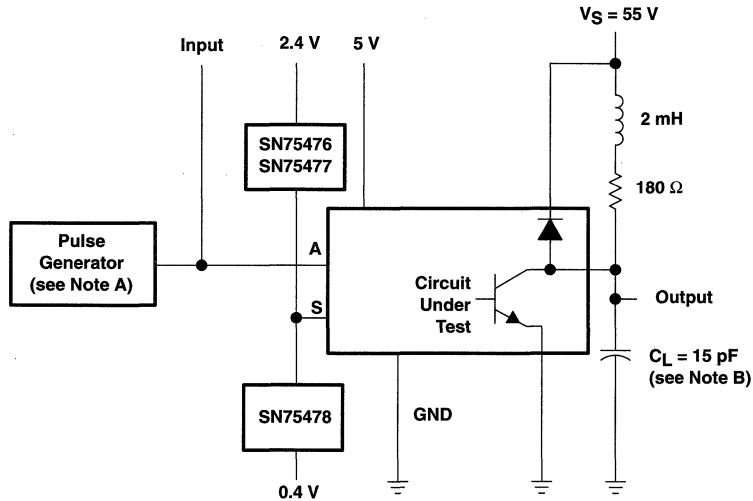
Figure 1. Test Circuit and Voltage Waveforms, Switching Characteristics



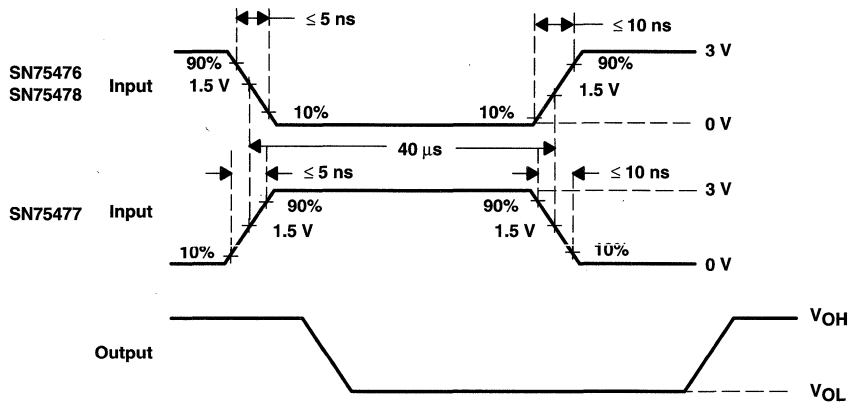
# SN75476 THRU SN75478 DUAL PERIPHERAL DRIVERS

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## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz, Z<sub>O</sub> = 50 Ω.  
B. C<sub>L</sub> includes probe and jig capacitance.

Figure 2. Latch-Up Test Circuit and Voltage Waveforms

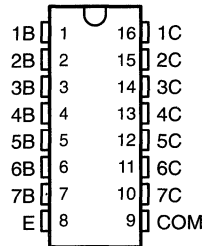
# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## HIGH-VOLTAGE HIGH-CURRENT DARLINGTON TRANSISTOR ARRAYS

- 500-mA Rated Collector Current (Single Output)
- High-Voltage Outputs . . . 50 V
- Output Clamp Diodes
- Inputs Compatible With Various Types of Logic
- Relay Driver Applications
- Designed to Be Interchangeable With Sprague ULN2001A Series

D OR N PACKAGE  
(TOP VIEW)

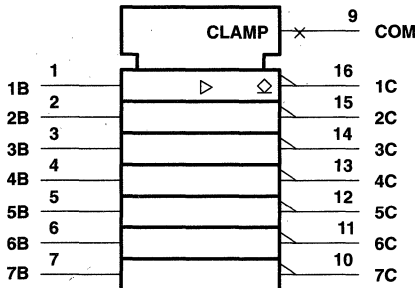


### description

The ULN2001A, ULN2002A, ULN2003A, and ULN2004A are monolithic high-voltage, high-current Darlington transistor arrays. Each consists of seven npn Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers.

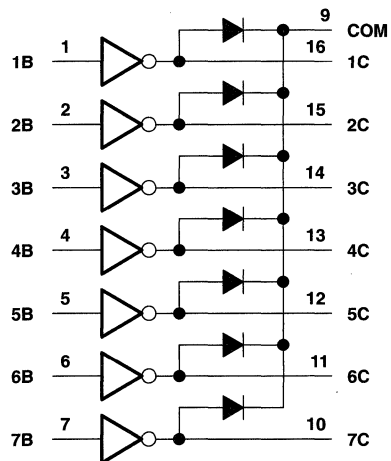
The ULN2001A is a general-purpose array and can be used with TTL and CMOS technologies. The ULN2002A is specifically designed for use with 14- to 25-V PMOS devices. Each input of this device has a zener diode and resistor in series to control the input current to a safe limit. The ULN2003A has a 2.7-k $\Omega$  series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices. The ULN2004A has a 10.5-k $\Omega$  series base resistor to allow its operation directly from CMOS devices that use supply voltages of 6 to 15 V. The required input current of the ULN2004A is below that of the ULN2003A, and the required voltage is less than that required by the ULN2002A.

### logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

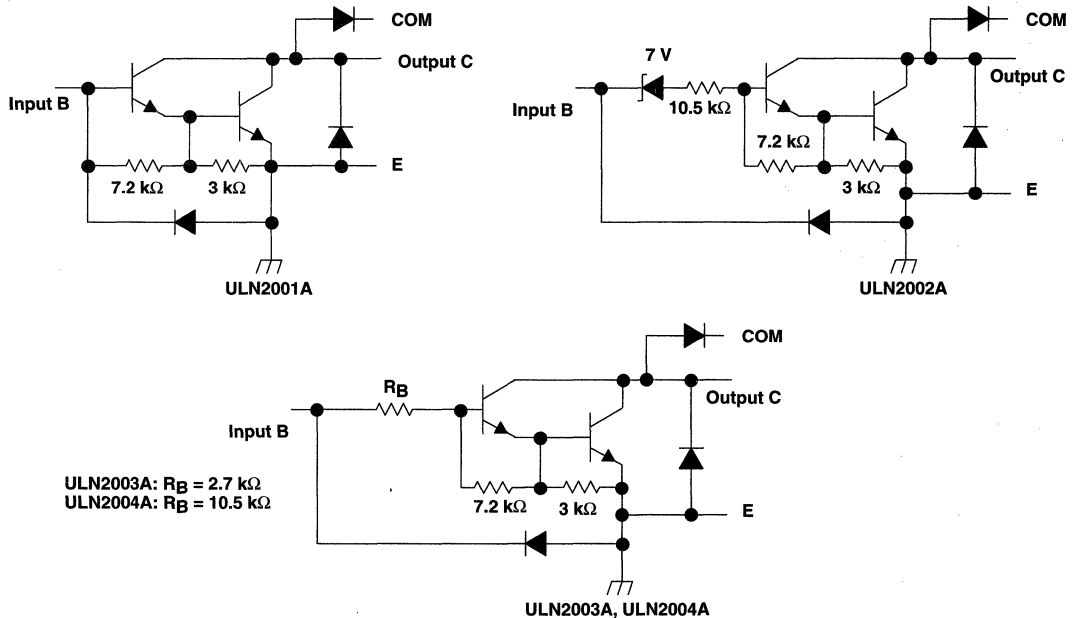
### logic diagram



# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## schematics (each Darlington pair)



All resistor values shown are nominal.

## absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-emitter voltage .....	50 V
Input voltage, $V_I$ (see Note 1) .....	30 V
Peak collector current (see Figures 14 and 15) .....	500 mA
Output clamp current, $I_{OK}$ .....	500 mA
Total emitter-terminal current .....	-2.5 A
Continuous total power dissipation .....	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ .....	-20°C to 85°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

NOTE 1: All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.

DISSIPATION RATING TABLE

PACKAGE	$T_A = 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 85^\circ\text{C}$ POWER RATING
D	950 mW	7.6 mW/°C	494 mW
N	1150 mW	9.2 mW/°C	598 mW

# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## electrical characteristics, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2001A			ULN2002A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{I(on)}$ On-state input voltage	6	$V_{CE} = 2\text{ V}$ , $I_C = 300\text{ mA}$						13	V
$V_{CE(sat)}$ Collector-emitter saturation voltage	5	$I_I = 250\ \mu\text{A}$ , $I_C = 100\text{ mA}$		0.9	1.1		0.9	1.1	V
		$I_I = 350\ \mu\text{A}$ , $I_C = 200\text{ mA}$		1	1.3		1	1.3	
		$I_I = 500\ \mu\text{A}$ , $I_C = 350\text{ mA}$		1.2	1.6		1.2	1.6	
$V_F$ Clamp forward voltage	8	$I_F = 350\text{ mA}$		1.7	2		1.7	2	V
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 50\text{ V}$ , $I_I = 0$			50			50	$\mu\text{A}$
	2	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $V_I = 6\text{ V}$			100			100	
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $I_C = 500\ \mu\text{A}$	50	65		50	65		$\mu\text{A}$
$I_I$ Input current	4	$V_I = 17\text{ V}$					0.82	1.25	$\text{mA}$
$I_R$ Clamp reverse current	7	$V_R = 50\text{ V}$ , $T_A = 70^\circ\text{C}$			100			100	$\mu\text{A}$
		$V_R = 50\text{ V}$			50			50	
$h_{FE}$ Static forward current transfer ratio	5	$V_{CE} = 2\text{ V}$ , $I_C = 350\text{ mA}$	1000						
$C_i$ Input capacitance		$V_I = 0$ , $f = 1\text{ MHz}$		15	25		15	25	$\text{pF}$

## electrical characteristics, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	ULN2003A			ULN2004A			UNIT		
			MIN	TYP	MAX	MIN	TYP	MAX			
$V_{I(on)}$ On-state input voltage	6	$V_{CE} = 2\text{ V}$	$I_C = 125\text{ mA}$						5	V	
			$I_C = 200\text{ mA}$			2.4			6		
			$I_C = 250\text{ mA}$			2.7					
			$I_C = 275\text{ mA}$						7		
			$I_C = 300\text{ mA}$					3			
			$I_C = 350\text{ mA}$								8
$V_{CE(sat)}$ Collector-emitter saturation voltage	5	$I_I = 250\ \mu\text{A}$ , $I_C = 100\text{ mA}$		0.9	1.1		0.9	1.1	V		
		$I_I = 350\ \mu\text{A}$ , $I_C = 200\text{ mA}$		1	1.3		1	1.3			
		$I_I = 500\ \mu\text{A}$ , $I_C = 350\text{ mA}$		1.2	1.6		1.2	1.6			
$I_{CEX}$ Collector cutoff current	1	$V_{CE} = 50\text{ V}$ , $I_I = 0$			50			50	$\mu\text{A}$		
	2	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $V_I = 1\text{ V}$			100			100			
$V_F$ Clamp forward voltage	8	$I_F = 350\text{ mA}$		1.7	2		1.7	2	V		
$I_{I(off)}$ Off-state input current	3	$V_{CE} = 50\text{ V}$ , $T_A = 70^\circ\text{C}$ , $I_C = 500\ \mu\text{A}$	50	65		50	65		$\mu\text{A}$		
$I_I$ Input current	4	$V_I = 3.85\text{ V}$		0.93	1.35				$\text{mA}$		
		$V_I = 5\text{ V}$					0.35	0.5			
		$V_I = 12\text{ V}$					1	1.45			
$I_R$ Clamp reverse current	7	$V_R = 50\text{ V}$			50			50	$\mu\text{A}$		
		$V_R = 50\text{ V}$ , $T_A = 70^\circ\text{C}$			100			100			
$C_i$ Input capacitance		$V_I = 0$ , $f = 1\text{ MHz}$		15	25		15	25	$\text{pF}$		

# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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switching characteristics,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low-to-high-level output	See Figure 9		0.25	1	$\mu\text{s}$
$t_{PHL}$ Propagation delay time, high-to-low-level output			0.25	1	$\mu\text{s}$
$V_{OH}$ High-level output voltage after switching	$V_S = 50\text{ V}$ , $I_O \approx 300\text{ mA}$ , See Figure 10	$V_S - 20$			mV

## PARAMETER MEASUREMENT INFORMATION

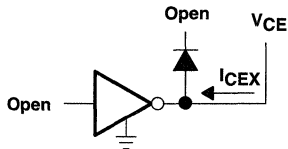


Figure 1.  $I_{CEX}$  Test Circuit

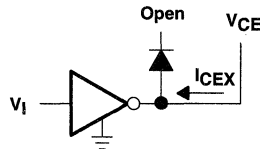


Figure 2.  $I_{CEX}$  Test Circuit

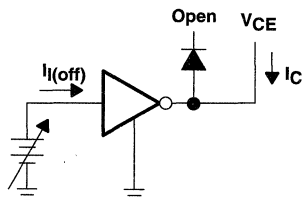


Figure 3.  $I_I(\text{off})$  Test Circuit

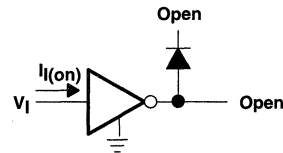
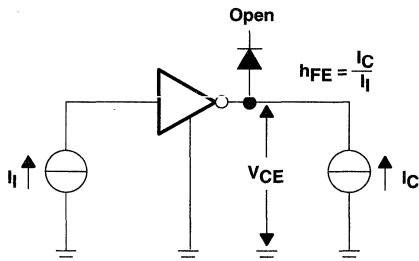


Figure 4.  $I_I$  Test Circuit



NOTE:  $I_I$  is fixed for measuring  $V_{CE(\text{sat})}$ , variable for measuring  $h_{FE}$ .

Figure 5.  $h_{FE}$ ,  $V_{CE(\text{sat})}$  Test Circuit

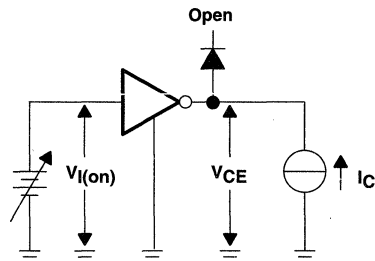


Figure 6.  $V_{I(\text{on})}$  Test Circuit

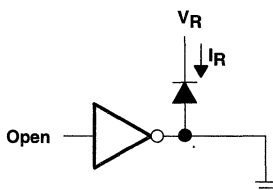


Figure 7.  $I_R$  Test Circuit

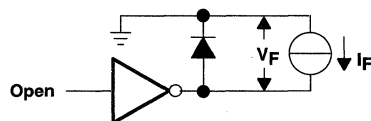


Figure 8.  $V_F$  Test Circuit

# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## PARAMETER MEASUREMENT INFORMATION

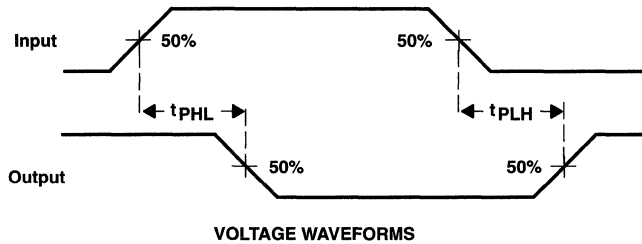
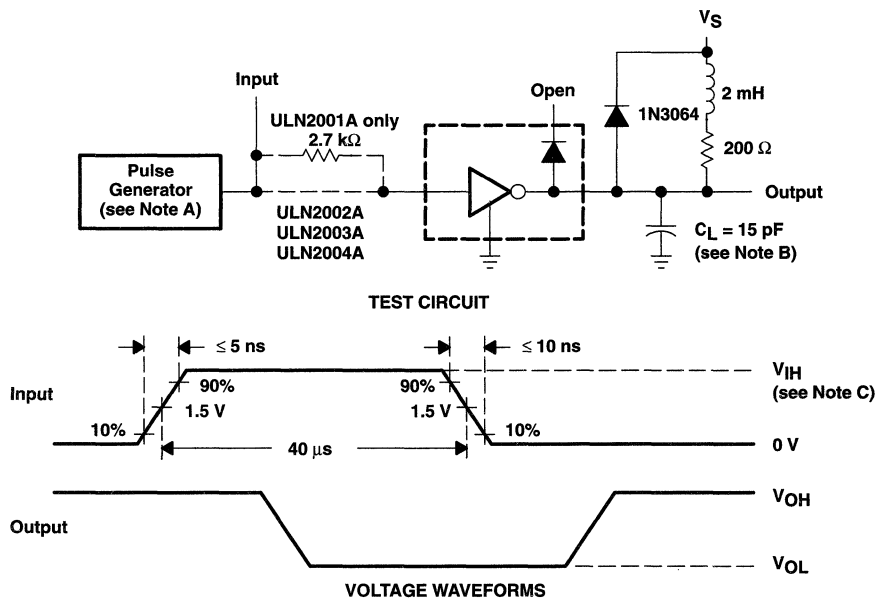


Figure 9. Propagation Delay Time Waveforms



- NOTES: A. The pulse generator has the following characteristics: PRR = 12.5 kHz,  $Z_O = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.  
 C. For testing the ULN2001A and the ULN2003A,  $V_{IH} = 3 \text{ V}$ ; for the ULN2002A,  $V_{IH} = 13 \text{ V}$ ; for the ULN2004A,  $V_{IH} = 8 \text{ V}$ .

Figure 10. Latch-Up Test Circuit and Voltage Waveforms

# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## TYPICAL CHARACTERISTICS

COLLECTOR-EMITTER  
SATURATION VOLTAGE  
vs  
COLLECTOR CURRENT  
(ONE DARLINGTON)

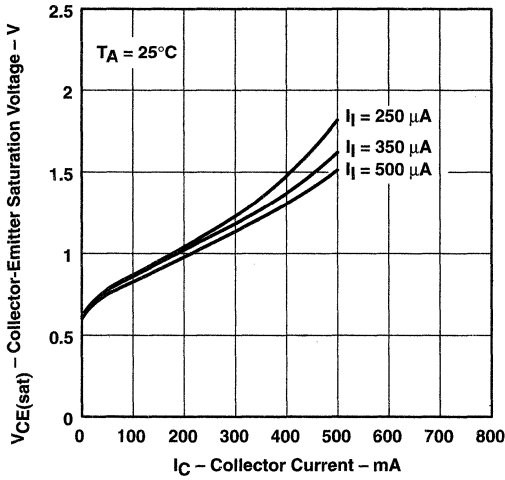


Figure 11

COLLECTOR-EMITTER  
SATURATION VOLTAGE  
vs  
TOTAL COLLECTOR CURRENT  
(TWO DARLINGTONS PARALLELED)

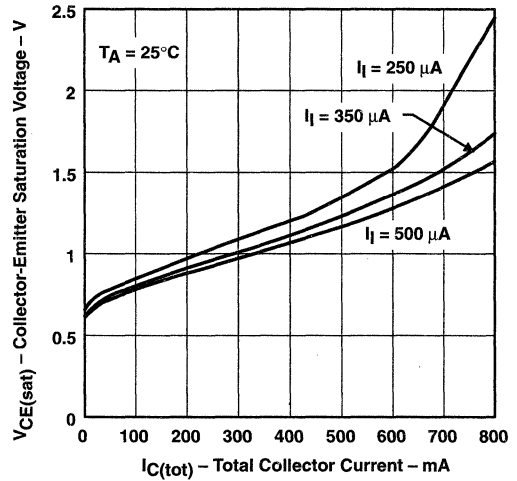


Figure 12

COLLECTOR CURRENT  
vs  
INPUT CURRENT

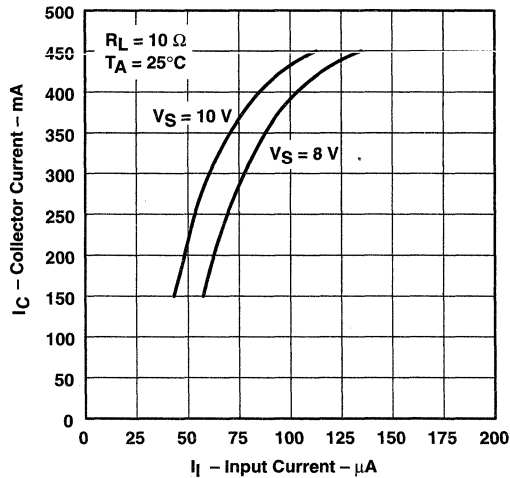


Figure 13

# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## THERMAL INFORMATION

**D PACKAGE  
MAXIMUM COLLECTOR CURRENT  
vs  
DUTY CYCLE**

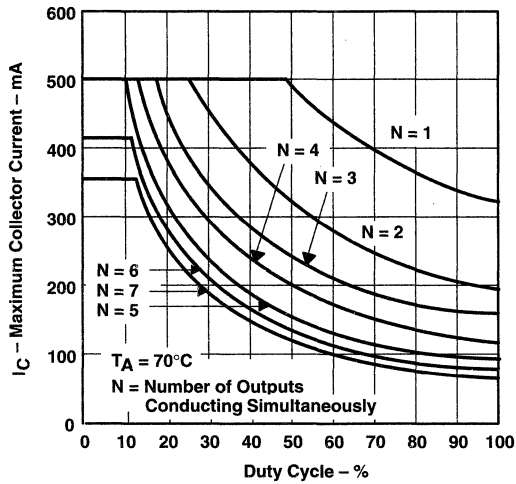


Figure 14

**N PACKAGE  
MAXIMUM COLLECTOR CURRENT  
vs  
DUTY CYCLE**

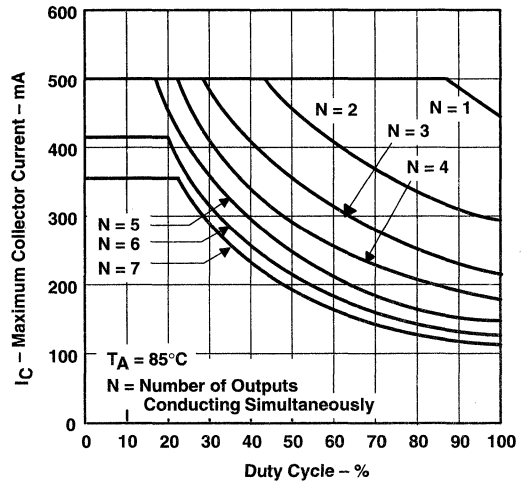


Figure 15



# ULN2001A THRU ULN2004A DARLINGTON TRANSISTOR ARRAYS

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## APPLICATION INFORMATION

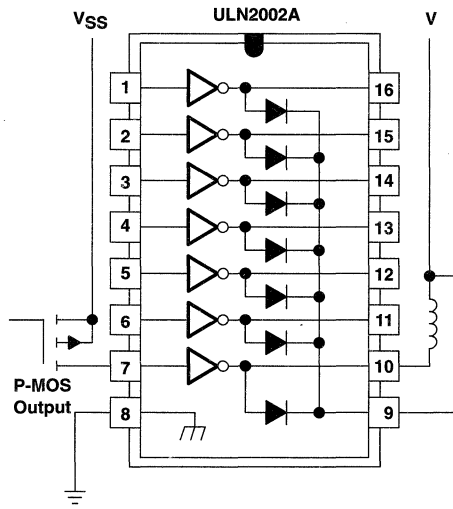


Figure 16. P-MOS to Load

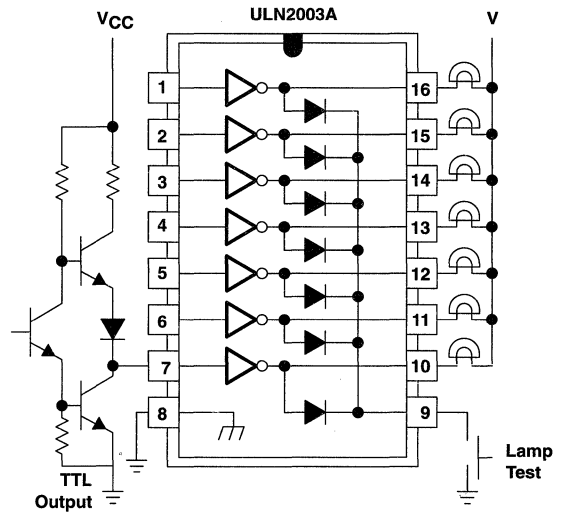


Figure 17. TTL to Load

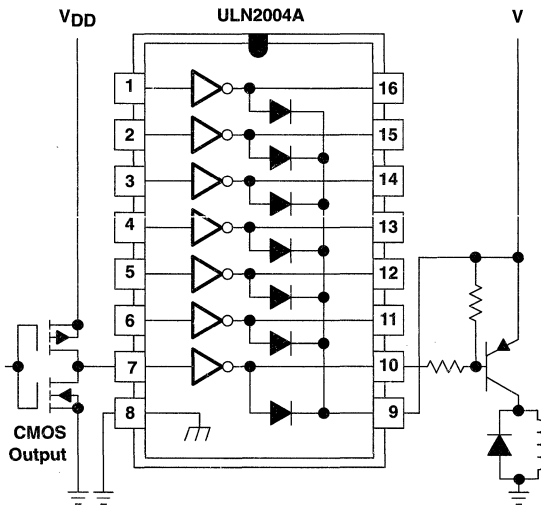


Figure 18. Buffer for Higher Current Loads

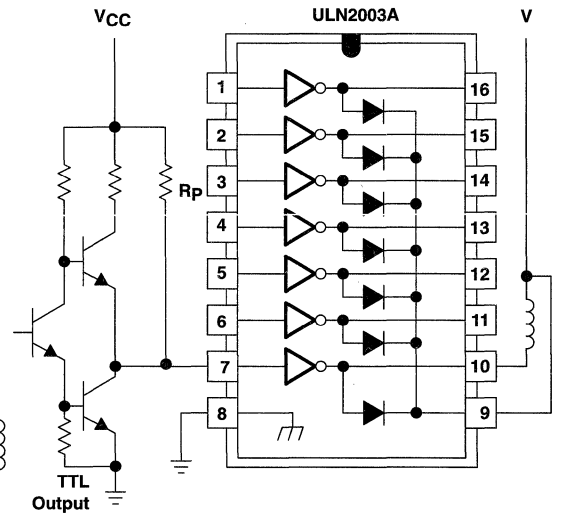


Figure 19. Use of Pullup Resistors to Increase Drive Current

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<b>Applications</b>	<b>4</b>
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# *Power System*



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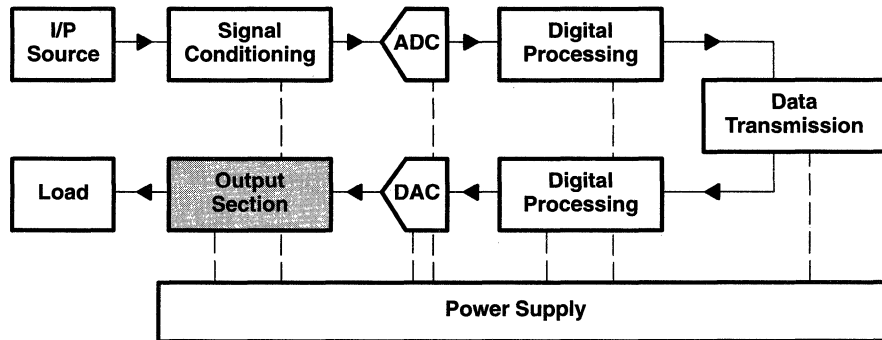
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## Introduction

The output section of a control system serves as the interface between electrical control signals and the real world. The end product of the output section is the control of a real-world function such as motion, light, sound, or any number of other physical actions. Control systems vary greatly in their complexity from controlling a simple single action to complex interactive systems with multiple feedback signals, fault isolation, and adaptive software. Regardless of the system complexity, an output system is normally employed to complete the interface between the control system and the real world (see Figure 1).



**Figure 1. Output Section**

Figure 2 represents a generalized output system consisting of a controller, an interface circuit, and a load. The design problem addressed is controlling the operation of a load with a small signal. Several typical loads such as motors, solenoids, speakers, and lamps are shown. For most of the loads, several signal paths exist from the controller through the interface circuits; each path represents a solution to one specific design problem. Although multiple solutions exist, they may not all be the best solution. The next section discusses the methodology for designing an output system that is well suited for a particular application.



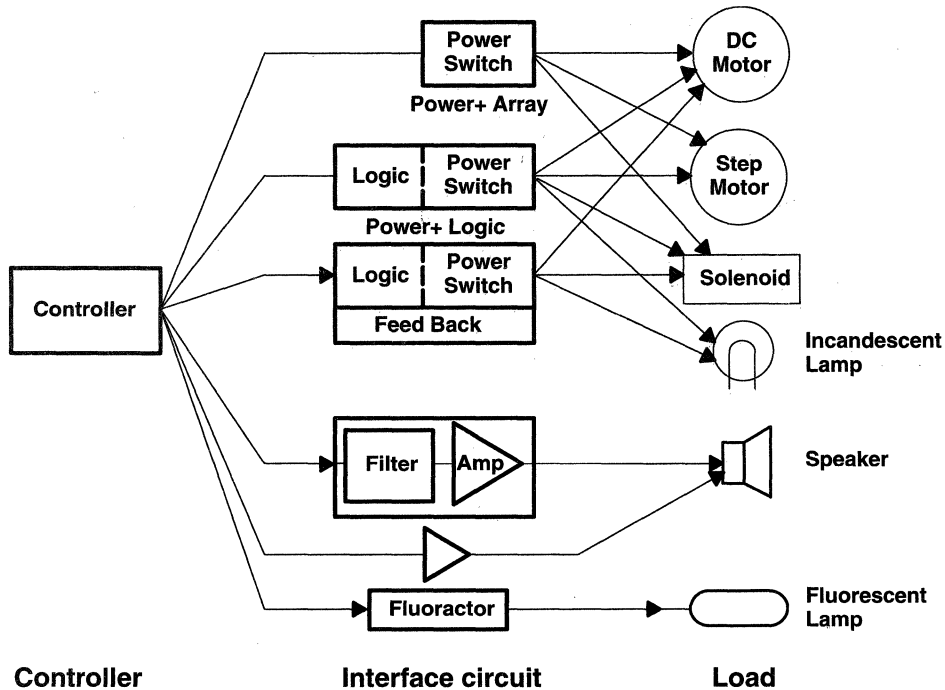


Figure 2. Generic Output Systems

## Output System Design

### Selection of a Load Device

The first step is to select a load. Selecting the load involves defining the type of output energy needed, selecting the proper class of load, and selecting the correct size load. Table 1 depicts some energy types with the corresponding load and output parameters. A dc motor, for example, usually has an output specification that is in terms of torque at a given speed. Matching the mechanical requirements for a particular application is outside the scope of this discussion. Assume a suitable load can be selected.

Table 1. Select a Load

ENERGY OUTPUT	LOAD	LOAD OUTPUT SPECIFICATIONS
Rotating Motion		
Continuous	DC Motor	HP – Torque – RPM
Incremental	Stepper Motor	Torque – Step Speed
Linear Motion	Solenoid	Ft-Lbs – Inches
Light	Incadescent Lamp	Watts – Lumens
	Fluorescent Lamp	Watts – Lumens
Sound	Loudspeaker	Watts – Hertz

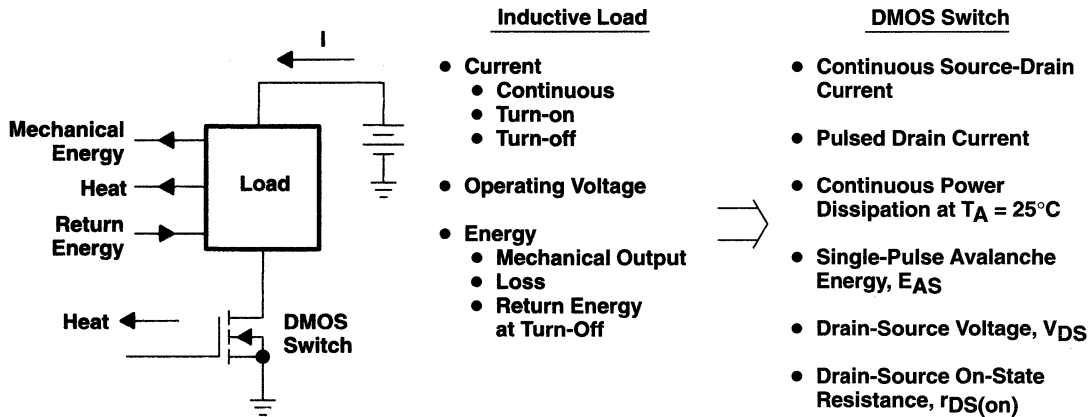
The second step is evaluation of the input requirements for a particular load. Load input specifications address the voltage and current requirements during normal operation. Normal operation includes load switching (turn on, turn off, and accompanying transients). Often the behavior of a load during switching is not adequately specified and must be characterized for the specific application. Understanding load input requirements leads to the interface circuit requirements.

### Interface Circuit Requirements

Assumed that the interface circuit is a switch, the following information can be used to select the correct switch.

Motors, solenoids, lamps, and other assorted loads are generally specified by operating voltage and current with a specified power output. The information provided is sufficient for operating at continuous duty cycle; however, in most applications, the load is switched on and off. When switching loads, the operating requirements, as well as transient conditions, must be considered. The power requirements are often further influenced by dynamic operating conditions.

Figure 3 shows an example of a load operating from a battery and controlled by a low-side switch. This helps to determine the need to design the switch and evaluate the system.



**Figure 3. Inductive Load Switch Requirements**

The system power supply and load choice determine:

- Current drawn from the battery, including transients when the switch is turned on and off
- Battery terminal voltage
- Energy output from the load (motion, sound, etc.)
- Energy dissipated from the load in the form of heat (IR loss, magnetic loss, friction)
- Energy returned to system (inductive, regeneration, cross coupling)

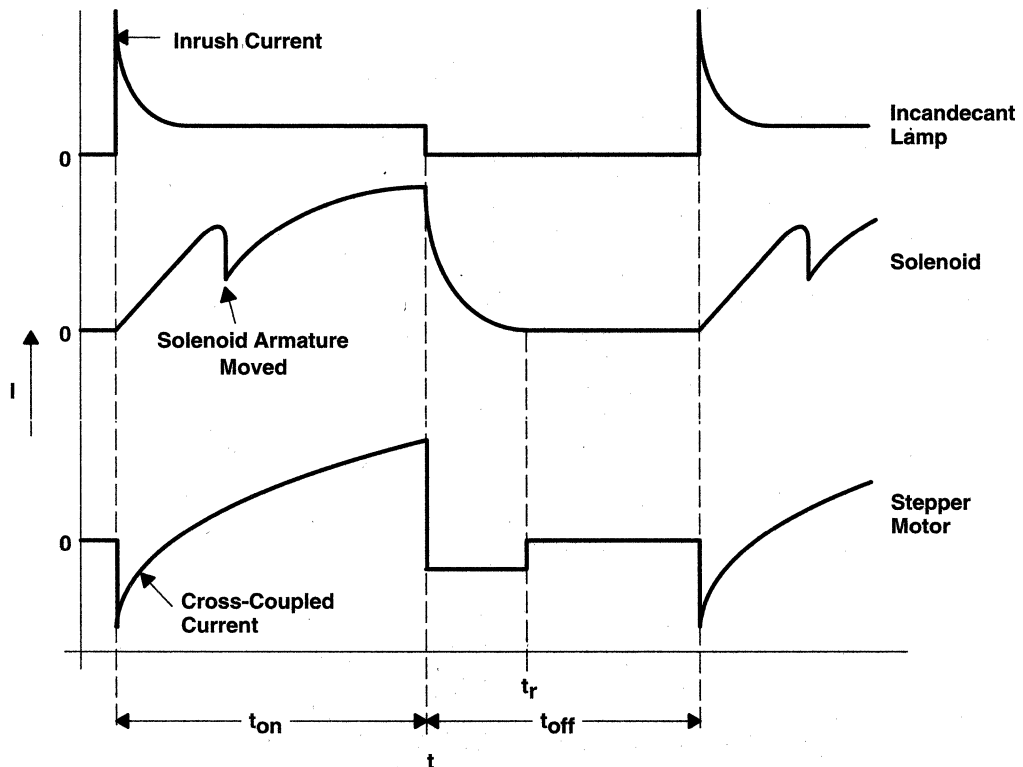
These system load requirements must then be used to determine the switch requirements:

- Continuous source-drain current
- Pulsed drain current
- Continuous power dissipation at  $T_A = 25^\circ\text{C}$
- Single-pulse avalanche energy,  $E_{AS}$  (energy returned to the device from back EMF)
- Drain-source voltage,  $V_{DS}$
- Drain-source on-state resistance,  $r_{DS(on)}$

Selecting or designing a switch is a three-step process; determine the total energy, current, and voltage required, select a switching device that accommodates the energy, and evaluate the system power dissipation to determine any heat-sinking requirements.

### Determine Total Energy

Determining the total energy begins with evaluating load current during operation and switching. Figure 4 shows the current waveforms for an incandescent lamp, a solenoid, and a stepper motor. This diagram depicts steady-state and switching conditions, which must be considered in controlling a load.



**Figure 4. Switching Load Currents**

The incandescent lamp current shows a high inrush value at turn on ( $t_{on}$ ), decreasing to a steady current value; the current remains at this value until turn off ( $t_{off}$ ). Upon  $t_{off}$ , the current drops to zero. The high inrush is due to the difference in filament resistance when cold and hot. A lamp control switch needs to withstand high peak currents or limit the current until the lamp filament warms up.

The solenoid current increases starting at  $t_{on}$  and continues to increase until  $t_{off}$ . Upon  $t_{off}$ , the current steadily drops until  $t_r$ . The change in current slope between  $t_{on}$  and  $t_{off}$  is caused by the solenoid armature moving closer to the coil and increasing the coil inductance. The current flow between  $t_{off}$  and  $t_r$  is a result of the magnetic field in the solenoid collapsing and returning energy to the system. A Solenoid switch must be capable of conducting the coil operating current and the system must provide a method for accommodating the energy returned to the system at turn off. Several methods are employed to deal with the returned energy. When this energy is dissipated in the switch, it is referred to as avalanche energy.

The stepper motor exhibits an exponential current increase characteristic of an inductive load. Return energy is a factor in stepper motor control. Additionally, stepper motor windings can produce currents as a result of cross coupling from adjacent motor windings. A control circuit for a stepper motor, such as one depicted in Figure 4, must accommodate for the transient energy at turn on and the returned energy at turn off.

Once the load characteristics are determined, energy calculations can follow.

### Energy and Power Calculations for an Inductive Load

Power-on time MOSFET dissipation

$$P_{on} = \frac{1}{3} (I_P^2) r_{DS(on)} d$$

For

$$\frac{L}{R_L} > t_{on}$$

Back EMF energy

$$E_T = \frac{3 L I_P^2 V_{CL}}{6(V_{CL} - V_{SS}) + 4R_L I_P}$$

Power off dissipation

$$P_{off} = E_T f$$

Total average switch power dissipation

$$P_T = (P_{on} + P_{off})n + P_{(quies)}$$

- L = Load inductance
- $I_P$  = Peak drain current
- $V_{CL}$  = Max output clamp voltage
- $V_{SS}$  = Load supply voltage
- $R_L$  = Inductor resistance
- f = Switching frequency
- d = Duty cycle (ratio)
- $r_{DS(on)}$  = Drain-to-source on-resistance
- n = Total number of switches operating
- $P_{(quies)}$  = Quiescent power dissipation of switch circuit
- $t_{on}$  = Switch on time

The intent is to calculate the total power dissipated in the transistor switch.

During the power-on time, the inductor current approximates to a linear ramp assuming the inductor  $L/R_L$  time constant is greater than the turn-on time ( $t_{on}$ ). This results in a mean square drain current of  $1/3 I_P^2$  with  $I_P$  equal to the peak drain current. Therefore, the average power dissipated in the output MOSFET ( $P_{on}$ ) is equal to:

$$P_{on(av)} = \frac{1}{3} \cdot (I_P^2) \cdot r_{DS(on)} \cdot d$$

This assumption is applicable to the stepper motor waveform in Figure 4, but does not work for the solenoid. The solenoid time constant ( $L/R_L$ ) is less than  $t_{on}$ ; therefore,  $P_{on}$  is greater than that calculated above.

When the output MOSFET is turned off, the back EMF generated by the inductor raises the drain voltage, which must be clamped either externally or internally. External clamping is normally accomplished with a snubber diode; internal clamping is also accomplished with a zener diode. The clamp voltage ( $V_{CL}$ ) is also called avalanche voltage.

The equation to define avalanche energy is:

$$E_T = (3 \cdot L \cdot I_P^2 \cdot V_{CL}) / [6 \cdot (V_{CL} - V_{SS}) + 4 \cdot R_L \cdot I_P] \text{ JEDEC Standard No. 10}$$

This equation assumes a linear decay of the current in the inductor. A more accurate  $E_T$  calculation can be accomplished by integrating the inductor current and clamp voltage in the load. The integration is taken from turn off ( $t_1$ ) until the inductor current decays to zero. The calculation is as follows:

$$E_T = \int_0^{t_1} V_{CL} \cdot I_L \cdot dt$$

$$I_L = \left[ I_P + \frac{(V_{CL} - V_{SS})}{R_L} \right] \cdot e^{-\frac{R_L}{L}t} - \frac{(V_{CL} - V_{SS})}{R_L}$$

$$I_P = \frac{V_{SS}}{R_L} \cdot \left[ 1 - e^{-\left(\frac{R_L}{L} \cdot \frac{d}{f}\right)} \right]$$

$$t_1 = \frac{L}{R_L} \cdot \ln \left[ 1 + \frac{I_P \cdot R_L}{(V_{CL} - V_{SS})} \right]$$

$$E_T = V_{CL} \cdot \frac{L}{R_L} \cdot \left[ I_P - \frac{(V_{CL} - V_{SS})}{R_L} \cdot \ln \left[ 1 + \frac{I_P \cdot R_L}{(V_{CL} - V_{SS})} \right] \right]$$

The power dissipated during the turn-off period ( $P_{\text{off}}$ ) can be equated to the product of  $E_T$  and the frequency of switching.

$$P_{\text{off}} = E_T \cdot f$$

Hence, the total power ( $P_T$ ) dissipated in an integrated switch with multiple output sections is:

$$P_{T(\text{av})} = (P_{\text{off}} + P_{\text{on}}) \cdot n + P_{(\text{quies})}$$

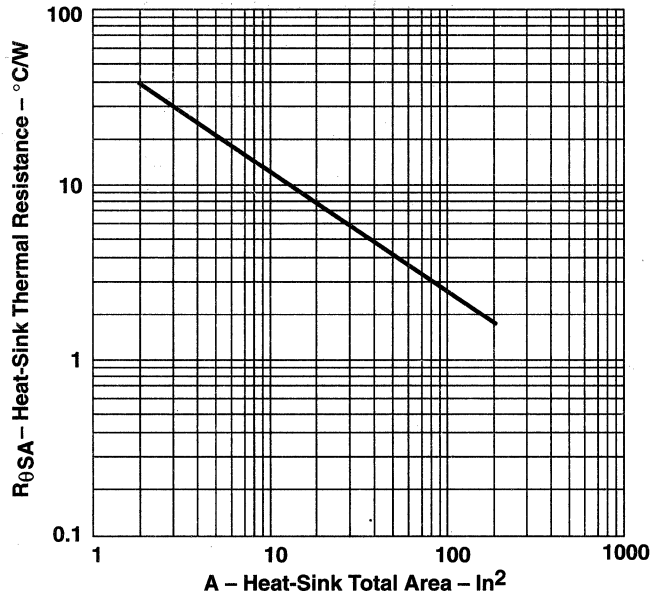
This is the average power dissipation for multiple sections whose duty cycles have a fixed time relationship to each other. For multiple outputs with variable duty cycles, the power calculation becomes more difficult.

Where:

- $E_T$  = Total turn-off transient energy absorbed
- $f$  = Switching frequency
- $d$  = Duty cycle
- $L$  = Load inductance
- $I_p$  = Peak output load current
- $n$  = Number of output switches operating
- $P_{\text{off}}$  = Turn-off power dissipation in each switch
- $P_{\text{on}}$  = On-state power dissipation in each switch
- $P_{(\text{quies})}$  = Interface device bias power dissipation
- $P_{T(\text{av})}$  = Average total power dissipation
- $R_L$  = Resistance of inductor
- $V_{\text{CL}}$  = Clamp voltage
- $V_{\text{SS}}$  = Load supply voltage

## Thermal Considerations

When the total power dissipation for the device is calculated, thermal evaluation can proceed. The objective is to determine if external heat sinking is required. Figure 5 shows a standard heat sink curve.



Max Power Dissipation

$$P_{MAX} = \frac{(T_{J(max)} - T_A)}{R_{\theta JA}}$$

Thermal Resistance

$$R_{\theta SA} = \frac{T_J - T_A}{P_{T(av)}} = |R_{\theta JC} + R_{\theta CS}|$$

Where:

$R_{\theta SA}$  = Heat sink-to-ambient thermal resistance, °C/W

$R_{\theta JC}$  = Device junction-to-case thermal resistance,  
= 3°C/W

$R_{\theta CS}$  = Case-to-heat sink thermal resistance, °C/W  
= 0.5°C/W typical with thermal joint compound

$P_{T(av)}$  = Total average power dissipation, W

$T_J$  = Junction operating temperature, °C

$T_A$  = Operating ambient temperature, °C

Figure 5. Thermal Considerations for Power Switches

The requirement for external heat sinking is calculated based on the device's total average power dissipation, maximum junction temperature, and ambient operating temperature. The maximum power that can be dissipated in a device ( $P_D$ ) can be determined as follows:

$$P_D = \frac{T_J - T_A}{R_{\theta JA}}$$

Where:

- $T_J$  = Maximum device junction operating temperature, °C
- $T_A$  = Maximum ambient operating temperature, °C
- $R_{\theta JA}$  = Junction-to-ambient thermal resistance, °C/W

$T_J$  and  $R_{\theta JA}$  are taken from the device specification and  $T_A$  is determined by the application environment.

### Heat Sink Requirement

If the total power dissipated in the device ( $P_T$ ) exceeds the maximum power dissipation ( $P_D$ ), then a heat sink must be used or a different device must be selected.

A heat sink size can be determined by first calculating the required heat sink-to-ambient thermal resistance ( $R_{\theta SA}$ ) as follows:

$$R_{\theta SA} = \frac{T_J - T_A}{P_{T(av)}} - |R_{\theta JC} + R_{\theta CS}|$$

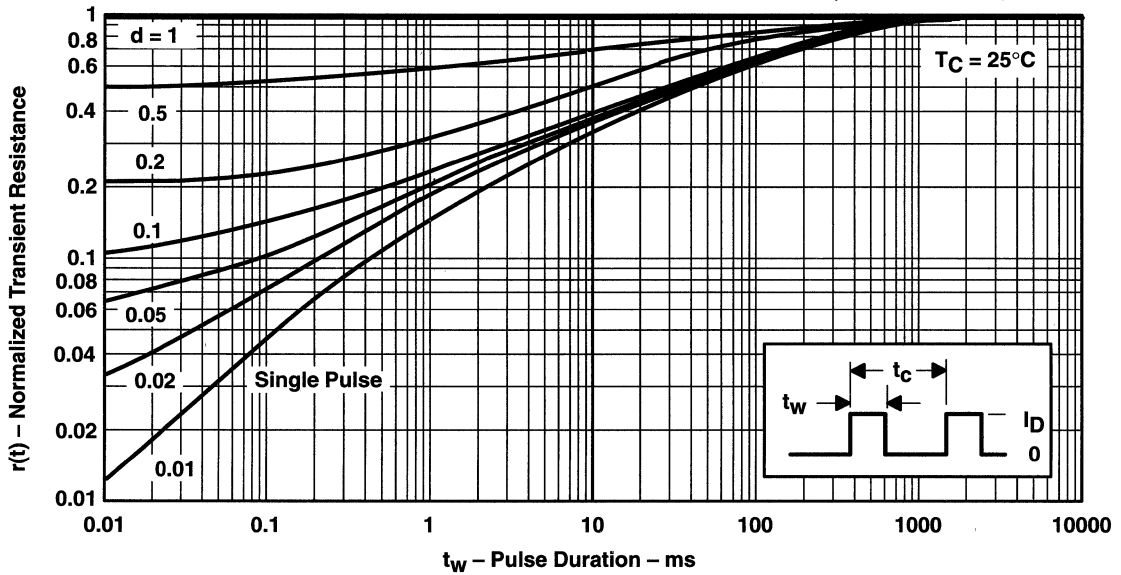
Where:

- $R_{\theta JC}$  = Device junction-to-case thermal resistance, °C/W
- $R_{\theta CS}$  = Case to-heat sink thermal resistance, °C/W  
= 0.5°C/W typical with thermal joint compound
- $P_{T(av)}$  = Total average power dissipation, W
- $T_J$  = Junction operating temperature, °C
- $T_A$  = Operating ambient temperature, °C

The  $R_{\theta SA}$  required can now be compared to heat sink design specifications to determine the design type and size required.

The preceding thermal calculations are based on the assumption that the device average power is duty cycle dependent. This is true if the pulse widths are short in relation to the device thermal time constant. In the example of a switch that is on for one hour in every twenty four hours, the actual duty cycle is low but the system must be designed to accommodate 100% on time for the switch. The graph in Figure 6 gives the times associated with the Power+ Arrays.





NOTES:  $Z_{\theta JC}(t) = r(t) R_{\theta JC}$   
 $t_w$  = pulse duration  
 $t_c$  = period  
 $d$  = duty cycle =  $t_w/t_c$

**Figure 6. Power+ Arrays Thermal Impedance Characteristics**

### Conclusion

To summarize the process, begin with selection of a load based on the load output specifications. System energy can then be calculated based on the load characteristics and load input specifications. A switching device can then be selected based on power and energy calculations. A thermal analysis based on the selected device thermal specifications determine if additional heat sinking and external circuitry for back EMF energy dissipation is required.

The design of the switch section is complete when actual measurements from the system are used to verify the design. This design flow is summarized in Figure 7.

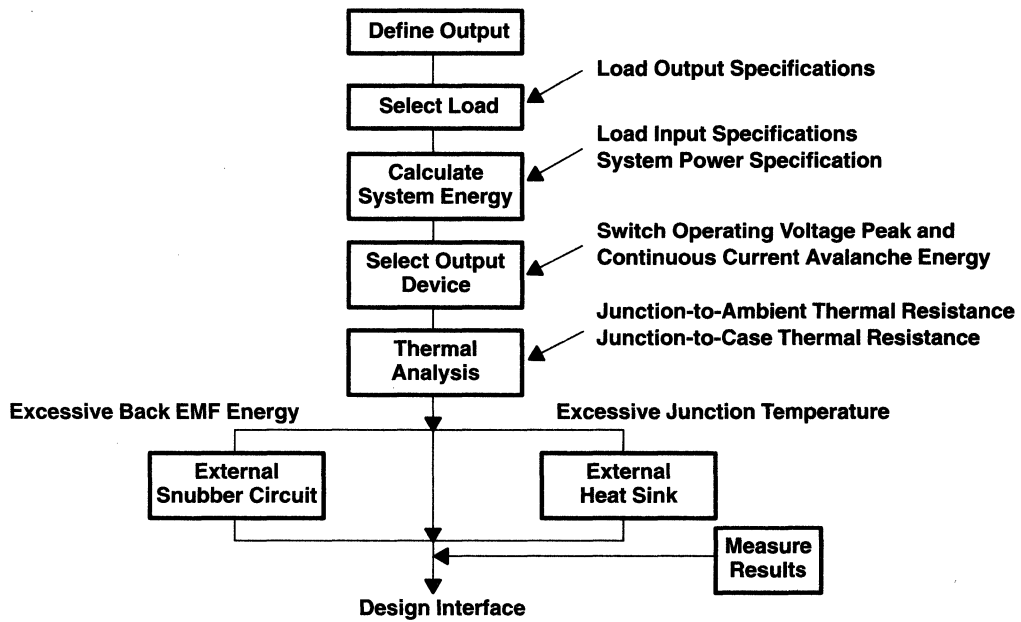


Figure 7. Output Switch Design Flow

## Stepper Motor Application

Stepper motors are often chosen to provide incremental rotating motion. Some typical applications are printers, copiers, and industrial robots. Stepper motors present a multiple phase inductive load to the output circuit.

Figure 8 shows a block diagram of the application. The motor chosen has unipolar windings, which require a peak current of 1 A.

- Control Signal Interface
  - Serial Bus From ASIC
  - CMOS Logic Levels
- Load Definition
  - Stepper Motor
  - Permanent Magnet Rotor
  - Unipolar Windings
  - Current 1-A Peak/Winding
- Design Considerations for Interface
  - Peak Current (1 A)
  - Recirculating Current
  - Power Dissipation

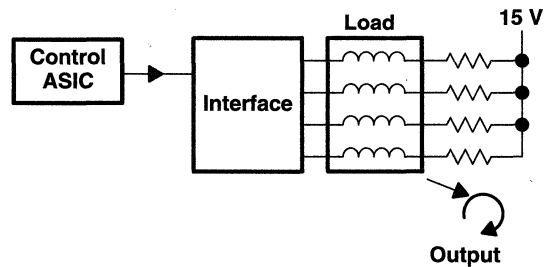


Figure 8. Stepper Motor Application

### Load Description

The first consideration in designing this application is to consider the load, which in this case is a Superior Electric stepper motor. The permanent magnet rotor stepper motor has two forms of stator winding. The bipolar stepper motor has a single winding on each stator pole and uses a full bridge to drive each phase winding. In the unipolar stepper motor, the flux reversal is accomplished by individually driving a bifilar winding on each pole. The windings are phased such that when current is passed through one winding, a given flux direction is generated. By passing current through the other winding, the opposite flux polarity is produced. Thus, the overall magnetic effect is the same as the bipolar motor, but the phase windings can be more economically driven by interface devices with open-drain outputs. The motor chosen for this application has unipolar windings. Due to the manner in which the windings are constructed when one winding is turned off, a back EMF voltage is induced both in the winding that was turned off and in the other bifilar winding.

### Energy Calculations

Figure 9 shows a timing waveform of the stepper motor. The table in the lower right section shows the winding switching sequence. Additionally, at any step, two windings are energized. With the knowledge that the windings are driven two at a time and by observation of the current waveform, energy can be calculated. The value of back EMF energy remains the same as if it is all returned to one winding.

Observation of the timing diagram indicates  $t_{on} = 5$  ms and that the winding current approximates a linear ramp ( $L/R > t_{on}$ ). This indicates that the simplified formula is a good approximation.

Therefore:

$$P_{on} = \frac{1}{3} \cdot (I_P^2) \cdot r_{DS(on)} \cdot d$$

Where:

$$d = 0.5 \text{ (each winding conducts twice in the four-step cycle)}$$

In this example, if the motor is stopped, the current through each winding is a steady 1 A. The power calculations are based on an assumed operating frequency. If the motor is stopped, the individual drive currents may exceed the maximum continuous current rating of the switches. When calculating energy and power, worst-case assumptions must be considered.

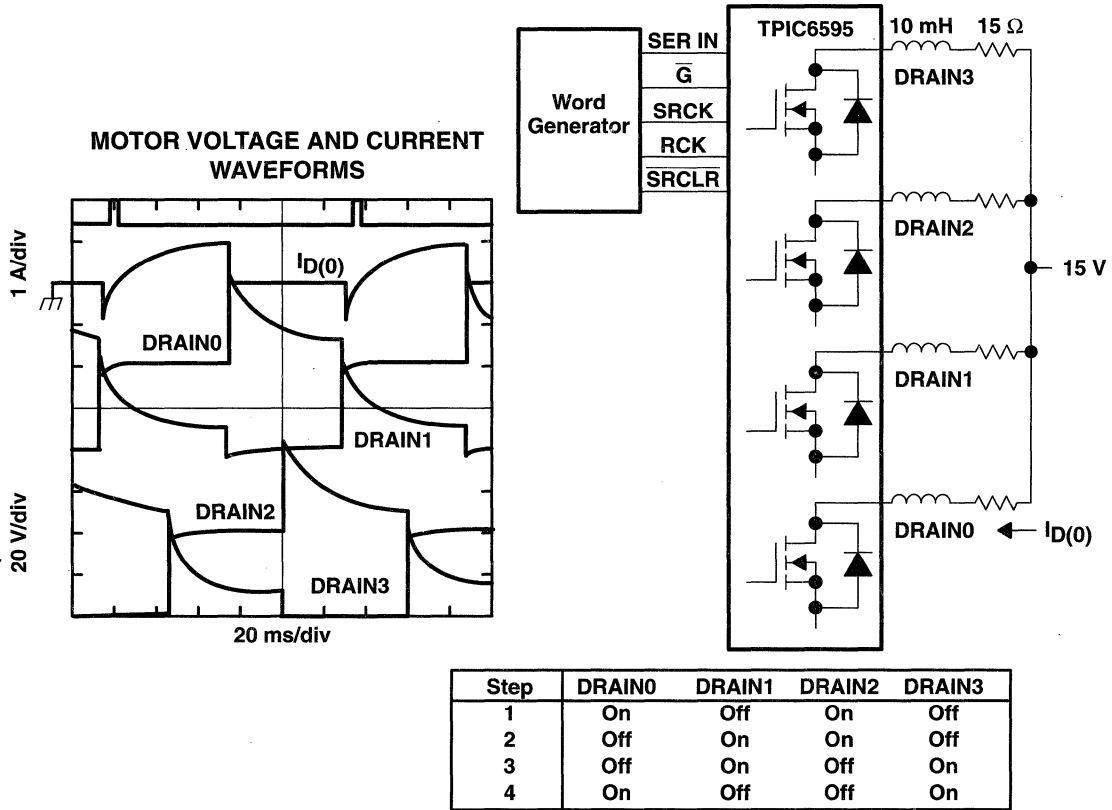


Figure 9. Stepper Motor Timing Waveforms

### Choosing an Interface Circuit

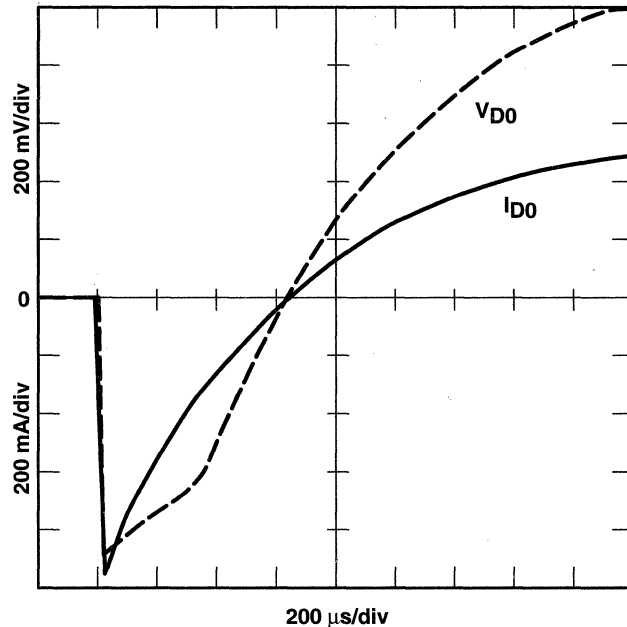
For the application in Figure 9, the TPIC6595 has been chosen. This device was chosen because it can meet the power requirements, can drive all four windings from a single integrated circuit, and includes interface logic.

Figure 9 shows the TPIC6595 driving the stepper motor. The motor is driven at its rated 1 A by operating two output DMOS transistors in parallel. In Figure 9, DRAIN0 is representative of output transistors 1 and 5 in parallel. Similarly, DRAIN1 is representative of output transistors 2 and 6, etc. Anti-parallel

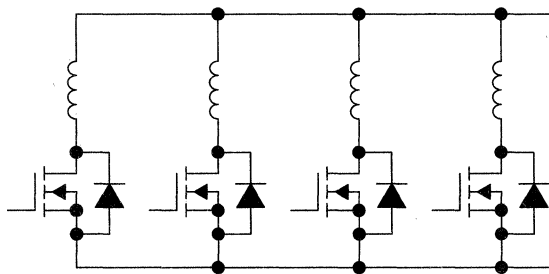
source-drain diodes are included for clarity. In this example, the input logic that would normally be provided by the system's microprocessor, is provided by a Hewlett Packard HP8180 A data generator.

The anti-parallel diodes are used to recirculate the current that is induced in the winding when the current through the previously activated winding on the pole is terminated. Hence, during each motor revolution, both positive and negative current flows through the power switches that control the winding.

Figure 10 shows an expansion of the waveforms of the negative current region of the winding pulse from the stepper motor application.



Current and Voltage Waveforms at Instant of Winding Turn on  
(a) SUPERIOR ELECTRIC UNIPOLAR STEPPING MOTOR



- Reverse current flows through windings at turn-on.
- DMOS power transistor conducts in reverse mode, reducing power dissipation.
- High peak reverse currents are possible.

(b) STEPPER MOTOR WINDINGS AND DMOS DRIVERS

Figure 10. TPIC6595 Synchronous Rectification Characteristics

As previously mentioned, the anti-parallel diodes of the DMOS output allow the recirculation of current at winding turn on. It is the anti-parallel diode that allows the DMOS output to withstand high peak reverse currents. In contrast, a power bipolar structure does not benefit from an inherent anti-parallel diode; one must be physically added, either to the integrated circuit design or externally at the board level. If negative currents are required of a bipolar power switch that does not include such a diode, parasitic isolation diodes in the bipolar structure will conduct currents which may cause system malfunction. It is for this reason that a DMOS solution is often the most practical and economical for motor drive applications.

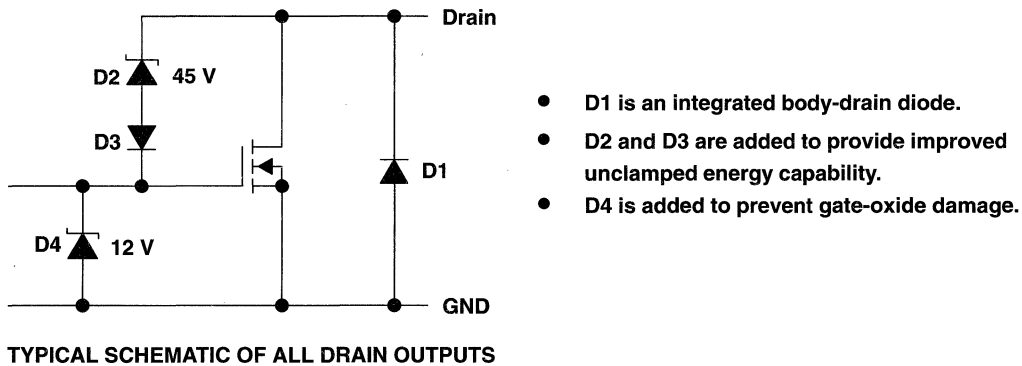
In the stepper motor example, as the winding turns on, the voltage drop across the output decreases. Once the voltage drop across the output ceases to be at least 0.7 V, the body-drain diode no longer conducts. At this point, the DMOS power transistor turns on in the reverse direction, allowing continued negative current flow to the inductor.

Once reverse conduction through the DMOS becomes the vehicle for negative current flow to the inductor, the power dissipation is given by the product of  $r_{DS(on)}$  and the square of the drain current. Reverse conduction continues through the DMOS transistor until the current reaches zero.

### Benefits of Choosing Power+ Logic

- The DMOS output structure is power efficient.
- The output structure can withstand high avalanche energy.
- System design is simpler than with discrete DMOS or bipolar transistors.

The TPIC6595 device has 8 power DMOS outputs with built-in 45-V clamps for enhanced inductive energy switching capability. Figure 11 shows the typical schematic of each output. When switching inductive loads, high voltage transients are seen at the device output when the output is placed in the high impedance state. The voltage generated by the inductive transient is limited by the breakdown mechanism of the output structure.



**Figure 11. Power+ Logic Output Structure**

For the Power+ Logic devices, the internal dynamic 45-V clamp circuit eventually conducts during switching of an unclamped inductive load, allowing current to charge up the gate of the transistor. Once the DMOS gate voltage exceeds the threshold voltage of the device, the DMOS turns back on, completely dissipating the energy from the inductor.

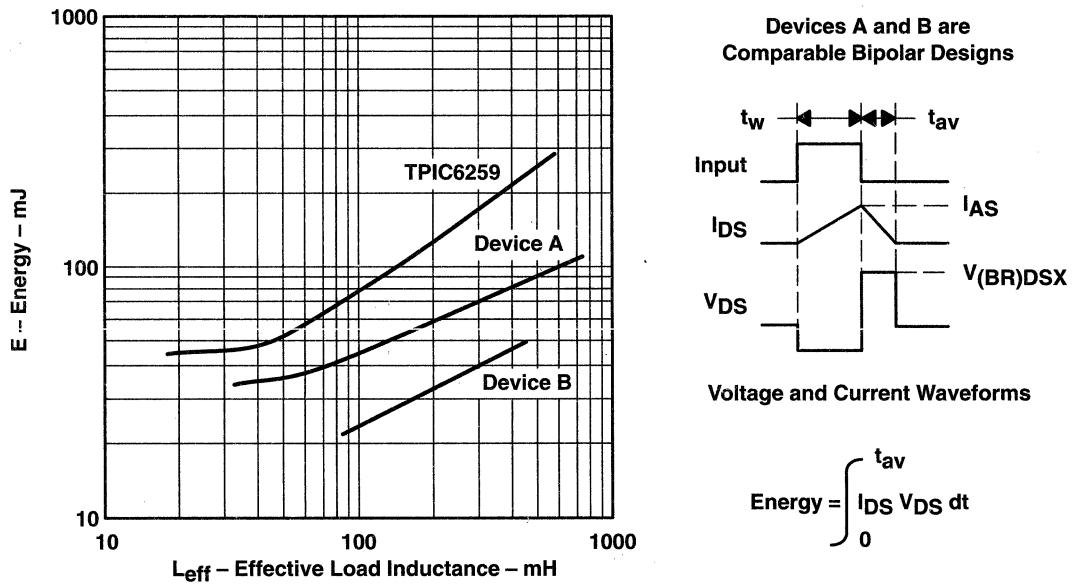
Thus, the entire active area of the DMOS transistor is used in the forward-bias mode to absorb energy from the inductive load. Without the internal clamp circuitry, the device output would be driven into avalanche breakdown and would operate in a much lower energy capability reverse-bias mode. The built-in voltage

clamps of the Power+ Logic devices allow the user to switch up to 75 mJ of avalanche energy without the use of external snubber circuitry.

Each DMOS output of the TPIC6259 can provide 250 mA of continuous current with all outputs turned on. Individually, the outputs can be pulsed to provide up to 1.5 A of current. Multiple outputs can be paralleled for increased current drive of up to 6 A of pulsed total load current. This rating is sufficient to drive the stepper motor when operating at the described duty cycle.

In describing the ruggedness of any power output, a key parameter is the avalanche energy capability. While the maximum energy capability is determined by thermal limitations of the silicon, the energy that can be dissipated during avalanche is not a constant, but varies with peak switching current and load inductance. Some power structures, however, may be prematurely limited by secondary breakdown and will have a constant energy rating. For an inductive switching pulse within the energy capability of the device, the energy dissipated in the output is proportional to the product of the current and voltage waveforms.

Figure 12 benchmarks the ruggedness of the Power+ Logic device against two low-side bipolar devices having comparable voltage capability. Device A has a breakdown voltage of 37 V, while Device B has a breakdown voltage of 50 V. Each bipolar device has approximately twice the output active area as the Power+ Logic device. The data in Figure 12 reflects the last point of output survival just prior to its destruction.



**Figure 12. Power+ Logic Versus Bipolar Output Energy**

It is evident that the Power+ Logic DMOS device is much more rugged than either of the bipolar structures. While switching a 350-mH inductor, the TPIC6259 dissipates 200 mJ prior to destruction, more than twice the energy of the bipolar devices. While the energy capability of the Power+ Logic device decreases to 45 mJ while switching a 30-mH load, this is still significantly more than comparable bipolar devices.

The following terms and definitions apply to Table 2:

- $I_{AS}$  = Peak current reached during device avalanche
- $t_{av}$  = Time duration of device in avalanche
- $L$  = Load inductance
- $L_{eff}$  = Effective load inductance; accounts for supply voltage
- $E$  = Energy absorbed by device under test ( $L_{eff} \times I_{AS}^2/2$ )
- $V_{DD}$  = Output supply voltage
- $V_{DSX}$  = Effective device avalanche voltage
- $T_c$  = Case temperature
- $T_m$  = Maximum junction rise that occurs in inductive switching
- $P_o$  = Power =  $I_{AS} \times V_{DSX}$
- $K$  =  $139.5 = A$  thermal constant where the area of active silicon = 1k mils square.  
=  $2/(A (p kc)^{1/2})$

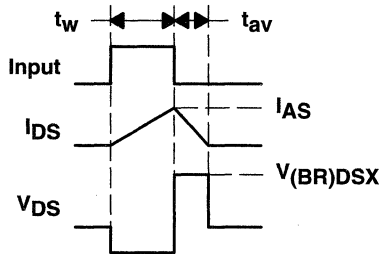
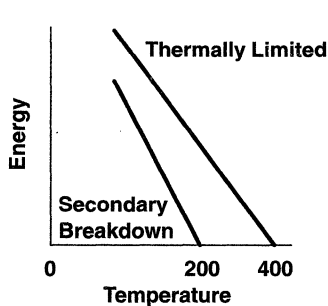
Where:

- $A$  = Area of power generation silicon
- $p$  = density of silicon
- $k$  = thermal conductivity of silicon
- $c$  = thermal capacity of silicon
- $T_m = (2^{0.5})/3 P_o k(t_{av})^{0.5}$
- $T_{j(pk)} = \text{Peak junction temperature at point of destruction} = T_m + T_c$

**Table 2. Unclamped Inductive Switching Test Data†**

DEVICE TYPE	$I_{AS}$ (A)	$t_{av}$ (ms)	$V_{DSX}$ (V)	$V_{DD}$ (V)	$L_{eff}$ (mH)	$L$ (mH)	$E$ (mJ)	$P_o$ (W)	$K$	$T_m$ (°C)	$T_{j(pk)}$ (°C)
DMOS TPIC6259	2.1	0.8	50	15.1	19	13.2	42.2	105.5	269.0	378	403
	1.7	1.4	50	15.1	42	29.4	58.1	83.0	269.0	394	419
Bipolar Device A	1.3	1.5	37	9.0	41	30.7	35.4	48.8	139.5	122	147
	0.9	2.6	37	12.8	101	66.3	43.9	34.4	139.5	114	139
	0.8	5.0	37	19.0	247	120.0	69.4	27.8	139.5	129	154
Bipolar Device B	0.8	1.3	50	11.6	80	61.4	25.6	40.0	139.5	94	119
	0.7	1.8	50	9.5	125	101.0	30.6	35.0	139.5	96	121
	0.5	3.4	50	15.0	335	335.0	41.9	25.0	139.5	95	120

† Maximum energy capability prior to device destruction,  $T_j$  = starting junction temperature = 25°C.



$$\text{Energy} = \int_0^{t_{av}} I_{DS} V_{DS} dt$$

Voltage and Current Waveforms



In addition to peak switching current and load inductance, the energy capability of a power device varies with temperature. As the junction temperature of the device increases, energy capability decreases. This temperature-energy relationship has been exploited to further understand the avalanche energy capabilities of the Power+ Logic device.

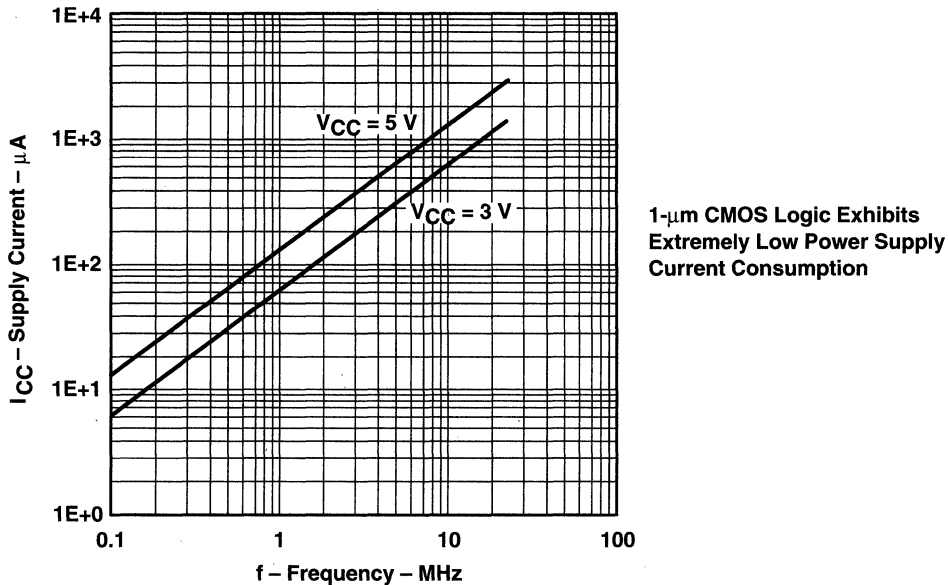
Unclamped inductive switching tests have been performed on the Power+ Logic device in which the junction temperature of the DMOS output was gradually raised by forcing the device to dissipate increasingly large amounts of energy. The virtual junction temperature of the device immediately prior to destruction was calculated. For the purposes of these tests, the 150°C maximum junction temperature specification of the Power+ Logic device was violated; these tests do not reflect recommended operation of the Power+ Logic device.

Assuming the mechanical limitations of the package are disregarded, the maximum avalanche energy capability of a power device operating in the forward-bias mode is limited by the thermal capabilities of the silicon. However, the actual avalanche energy dissipated by a given power structure may be prematurely limited by a secondary breakdown mechanism. In the case of the Power+ Logic outputs, the absence of forward secondary breakdown can be shown. The calculated virtual junction temperature of the Power+ Logic output structure at the point of device destruction is greater than 400°C. Since silicon is thermally limited at approximately 400°C, silicon thermal limitations are the probable cause of device destruction.

For comparison, similar tests have been performed on bipolar devices A and B. Bipolar device B (50-V clamp) had a calculated maximum virtual temperature of approximately 120°C immediately prior to destruction, clearly illustrating a secondary breakdown limitation. Bipolar device A (37-V clamp) had improved characteristics, but still clearly experienced secondary breakdown limitations with destruction temperatures ranging from approximately 140°C to 150°C.

The Power+ Logic devices integrate performance power output structures with high density sub-micron CMOS logic. Figure 13 shows  $I_{CC}$  versus SRCK frequency for the TPIC6595 with the outputs static and an alternating bit pattern on the SER IN pin. This example demonstrates the high logic frequency capability of the Power+ Logic devices, as well as the low  $V_{CC}$  power consumption. High logic speed capability allows the information to be transferred from the micro-processor interface very quickly even though the switch and load operation occur at a much slower repetition rate. This is especially important when cascading several devices for a large number of outputs all controlled by a single serial interface.

The power described in this graph is the term  $P_{quies}$  and is used in calculating the total average power dissipated in a device.

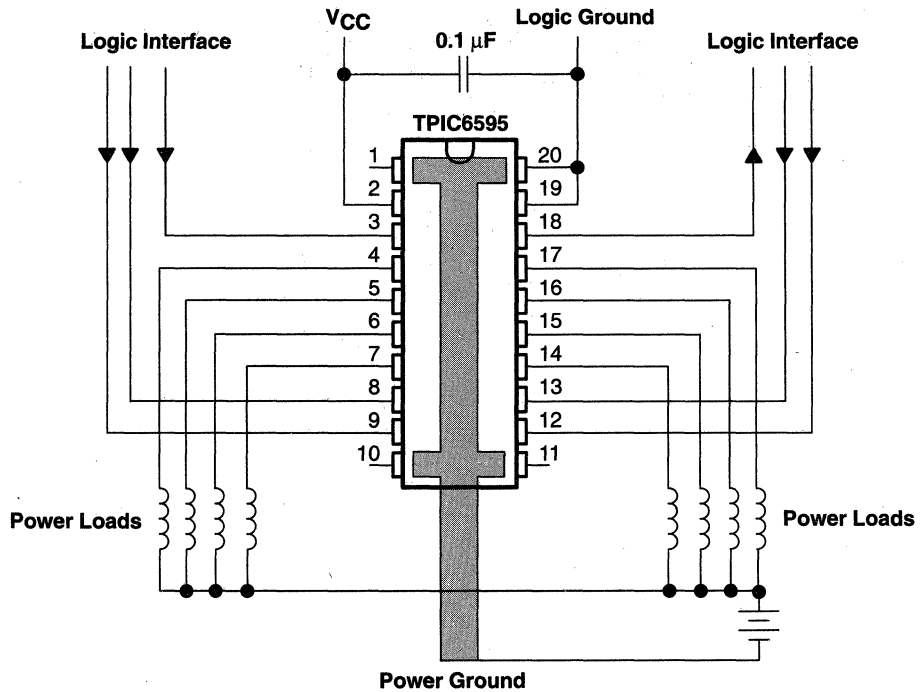


**Figure 13. Power+ Logic Features Low Quiescent Current**

When using the TPIC6595 or any of the Power+ Logic devices, there are several printed-circuit board (PCB) layout considerations that should be kept in mind. High frequency layout rules should be used when designing power switching systems. This is because mutual inductance (i.e. capacitance between the drive circuit and load circuit) can cause coupling of erroneous signals resulting in false operation. The following precautions are offered:

- Use of a power ground bus on the PCB to eliminate crosstalk between the power loads and input logic.
- Addition of a 0.1- $\mu$ F bypass capacitor between  $V_{CC}$  and the logic ground line, placed close to the device to dampen any stray signals experienced by the drive circuit.
- Separate power and logic ground circuits.

Figure 14 shows the implementation on these board layout considerations using the TPIC6595.



- Creation of a power ground bus on the board which eliminates crosstalk between logic and power loads
- Bypass capacitor of  $0.1 \mu\text{F}$  placed close to the device
- Separate logic ground circuit

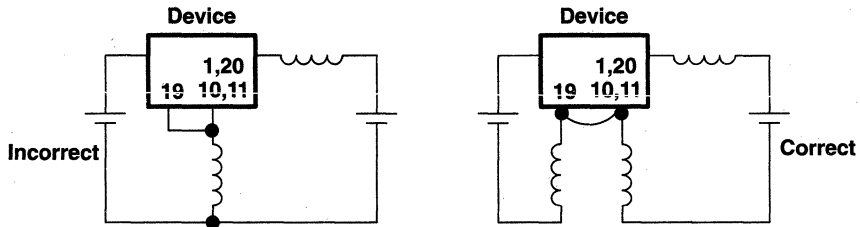


Figure 14. Layout Precautions for the TPIC6595

## Bidirectional Motor Drive Application

DC motors play an important role in a wide variety of electronic systems. Efficient control of motor speed and torque is an important issue for many system designers.

Figure 15 shows a bidirectional dc motor being driven from a 14.5-V supply by two dual DMOS switch devices arranged in a full H-bridge configuration. This circuit uses 20-kHz PWM input signals that are 180 degrees out of phase. In most systems, these signals are supplied by a micro-controller. A 50% duty cycle on both input signals produces a net zero voltage across the motor, creating a stall condition. Control of the motor's speed and direction of rotation is achieved by varying the duty cycle of one of the input signals while keeping the other fixed at 50% duty cycle. This variation between the input signals results in a net dc voltage across the motor providing the drive current needed to meet the torque requirements of the motor.

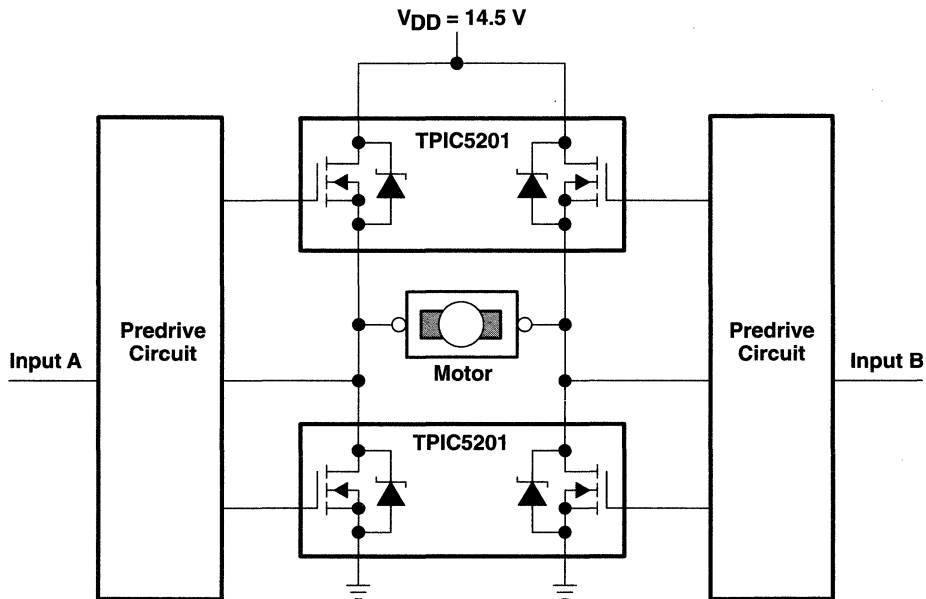
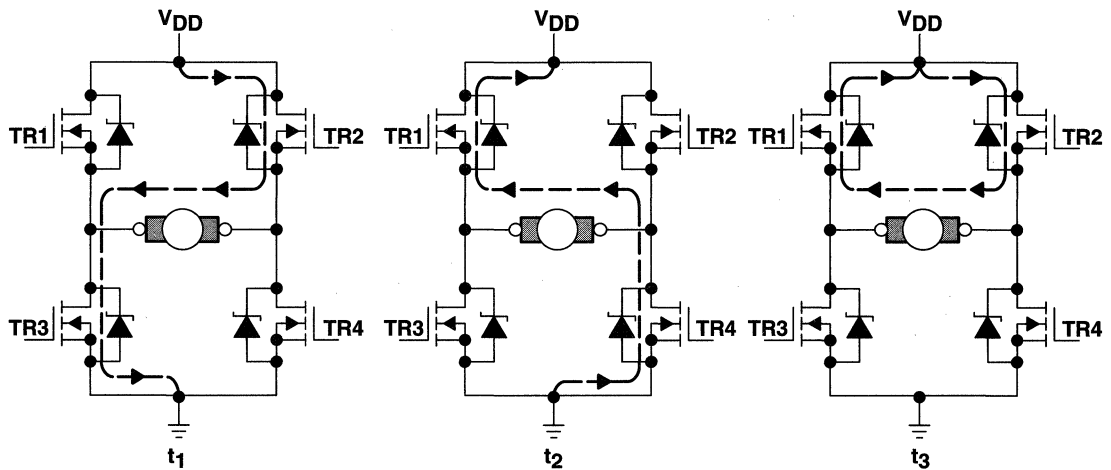


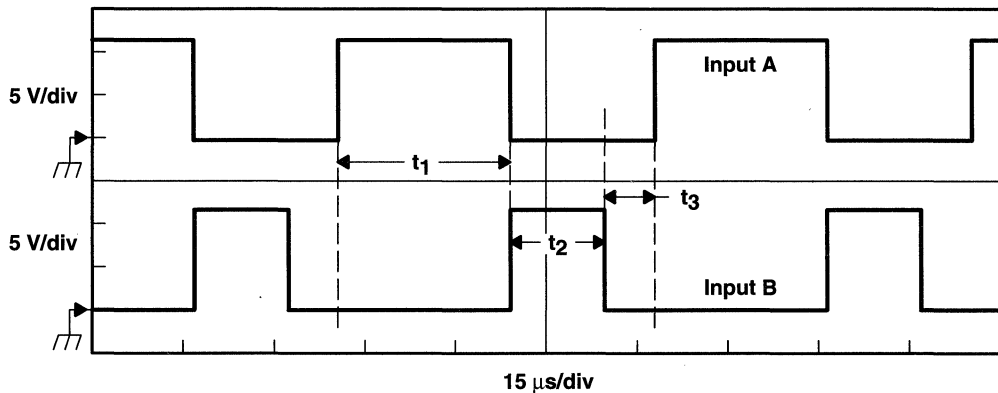
Figure 15. Bidirectional DC Motor Application

### Motor Operation

Motor operation is shown in Figure 16. In this example, the motor is driven in the forward direction. The motor speed is controlled by varying the duty cycle of input signal B. While input signal A is high and input signal B is low, there is a net negative voltage across the terminals of the motor and current through the motor ramps up. Once input A goes low, a net positive voltage appears across the motor terminals and the motor current ramps down. When both input signals are low, there is no net voltage across the motor terminals and the H-bridge recirculates a relatively constant current through its upper stages. To drive the motor in the reverse direction, input signal B is held to a 50% duty cycle while the duty cycle of input A is varied.



(a) MOTOR DRIVE CURRENT PATHS



(b) INPUT VOLTAGE WAVEFORMS

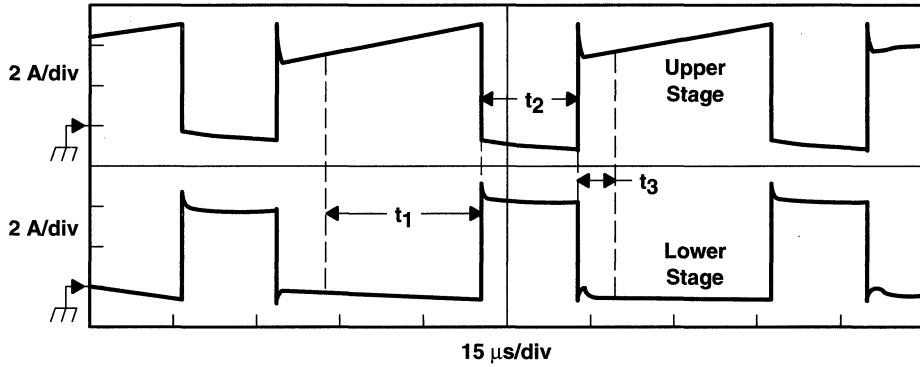
Figure 16. DC Motor Operation

Figure 17(a) shows the current through the transistors on one side of the H-bridge during time periods  $t_1$ ,  $t_2$ , and  $t_3$ . Operation of the other side of the H-Bridge is similar. Figure 17(b) shows the motor voltage and currents during the same time periods.

In this example, the pulse width of the input signal is approximately  $25 \mu\text{s}$  at a 50% duty cycle. It is important to note that when switching both the upper and lower transistors on the same side of the H-bridge, a brief delay must occur to allow the conducting transistor to turn off before the non-conducting transistor is allowed to turn on. Without this delay, excessive cross-conduction current may result. Cross conduction is a condition in which the upper and lower FETs on one side of the H-bridge are on simultaneously, providing a low impedance path between the source voltage and ground. While small cross-conductance currents can actually be used to enhance system performance, uncontrolled cross conduction can result in excessive heat dissipation and degradation of the device.

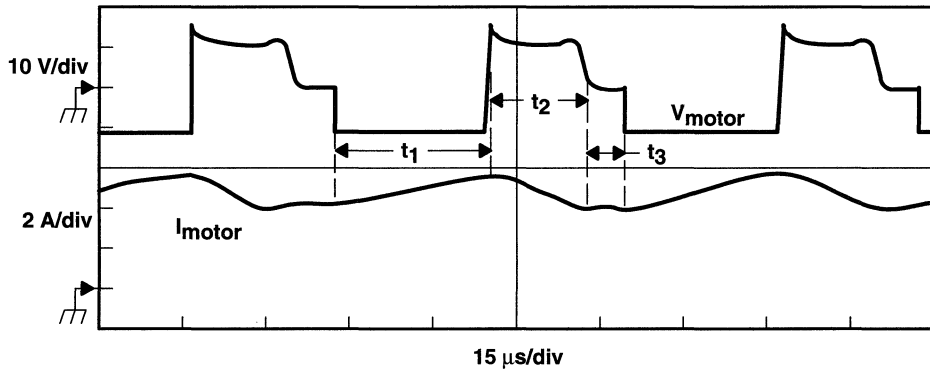
### System Power Considerations

The motor drive current shown in Figure 17(b) has a peak value of slightly less than 6 A with a minimum value of 4 A. Energy calculations must be based on the condition when one of the input signals is at the minimum duty cycle. The motor current during time  $t_3$  is due to back EMF and must be included in power dissipation calculations.



Current through the upper and lower stages of the H-Bridge, transistors TR2 and TR4

(a) H-BRIDGE CURRENT WAVEFORMS



Differential motor voltage and current waveforms

(b) MOTOR WAVEFORMS

Figure 17. DC Motor and H-Bridge Currents

## Choosing an Output Switch

The device required for this application must be capable of conducting at least 5 A continuously, and as shown in the previous diagrams, must be configured as an H-bridge.

The device chosen for this application is a TPIC5201 Power+ Array as shown in Figure 18. This device contains two totally independent high performance DMOS transistors in a single power package. The independent transistors allow for an H-bridge configuration. The low  $r_{DS(on)}$  minimizes the power dissipation.

- Two independent N-channel enhancement-mode DMOS transistors
- 7.5-A Continuous current per channel
- Low  $r_{DS(on)}$  . . . 90 m $\Omega$  typ
- 60-V Maximum output voltage
- 15-A Pulsed current per channel
- High avalanche energy rating . . . 120 mJ

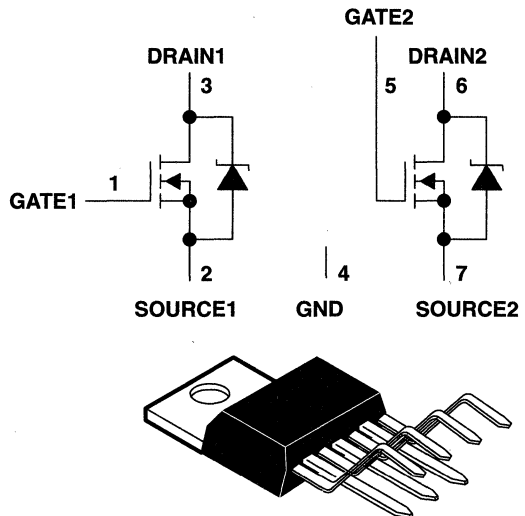


Figure 18. TPIC5201 Power+ Array

## Predrive Circuit

In this application, two symmetrical predrive circuits are used to drive the gates of the upper and lower FETs. The predrive circuit schematic is shown in Figure 19. Drive to the upper transistors is achieved through the use of an HCPL2531 optocoupler followed by an emitter-follower stage. The high speed optocoupler isolates and level shifts the upper stage FETs from the input while providing a reference to ground. The emitter-follower provides low impedance drive for fast charging of the intrinsic gate-source capacitor to enhance switching times.

A 0.1- $\mu$ F bootstrap capacitor is used to allow the gates of the upper FETs to rise above the supply voltage rail. The bootstrap must be at least 10 times larger than the parasitic gate capacitance of the TPIC5201, typically 18 nF. Inclusion of the emitter-follower and the bootstrap capacitors allow the upper transistors to be turned on hard when the input signal transitions high.

The low gate capacitance of the TPIC5201 allows for improved efficiency in the motor control circuit. In a power switching application, as the switching frequency increases, switching losses due to the continuous charge and discharge of the gate capacitor become the dominating component of the power loss. By minimizing typical gate capacitance, the TPIC5201 reduces switching losses, which results in reduced system power consumption and improved system efficiency.

The predrive circuit includes a delay RC network to ensure that cross conduction does not occur. The time constant of this RC network must be greater than the 0.8- $\mu$ s propagation delay time associated with the switching times of the HCPL2531 optocoupler. By delaying the turn-on drive to the gates of the power MOSFETs, cross-conduction currents are eliminated.

External under-voltage-lockout protection is added to the circuit to keep the lower-stage FETs turned off until a predefined threshold voltage is obtained. This threshold voltage is determined by the threshold of the zener diode coupled with the threshold of the TP4050 buffer. In this circuit, the lower FETs remain off between 2 V and 6.2 V.

### **Advantages Over Discrete Transistors**

Since the two power MOSFETs of each TPIC5201 are fabricated monolithically, the FETs within each device are inherently well matched. As a result, there is little variation in the switching times and transconductance of the upper-stage transistors. This device matching aids in system design by significantly reducing the need for feedback circuitry to compensate for potential switching time mismatches. As a result, the necessary predrive circuitry is greatly simplified.

Each power transistor in the TPIC5201 features a low on-state resistance of 90 m $\Omega$ . By minimizing on-state resistance, the power consumption of the H-bridge is reduced increasing the power available to the motor. Motor control systems built with low on-state resistance power switches allow more efficient motor performance.

The energy capabilities of the TPIC5201 have been characterized over its entire range of operation. The specifications for the TPIC5201 include peak avalanche current versus avalanche time-rating curves. Unlike the single-point energy specifications typical of discrete MOSFETs, designers using the TPIC5201 can accurately monitor compliance with active safe-operating-area design constraints.



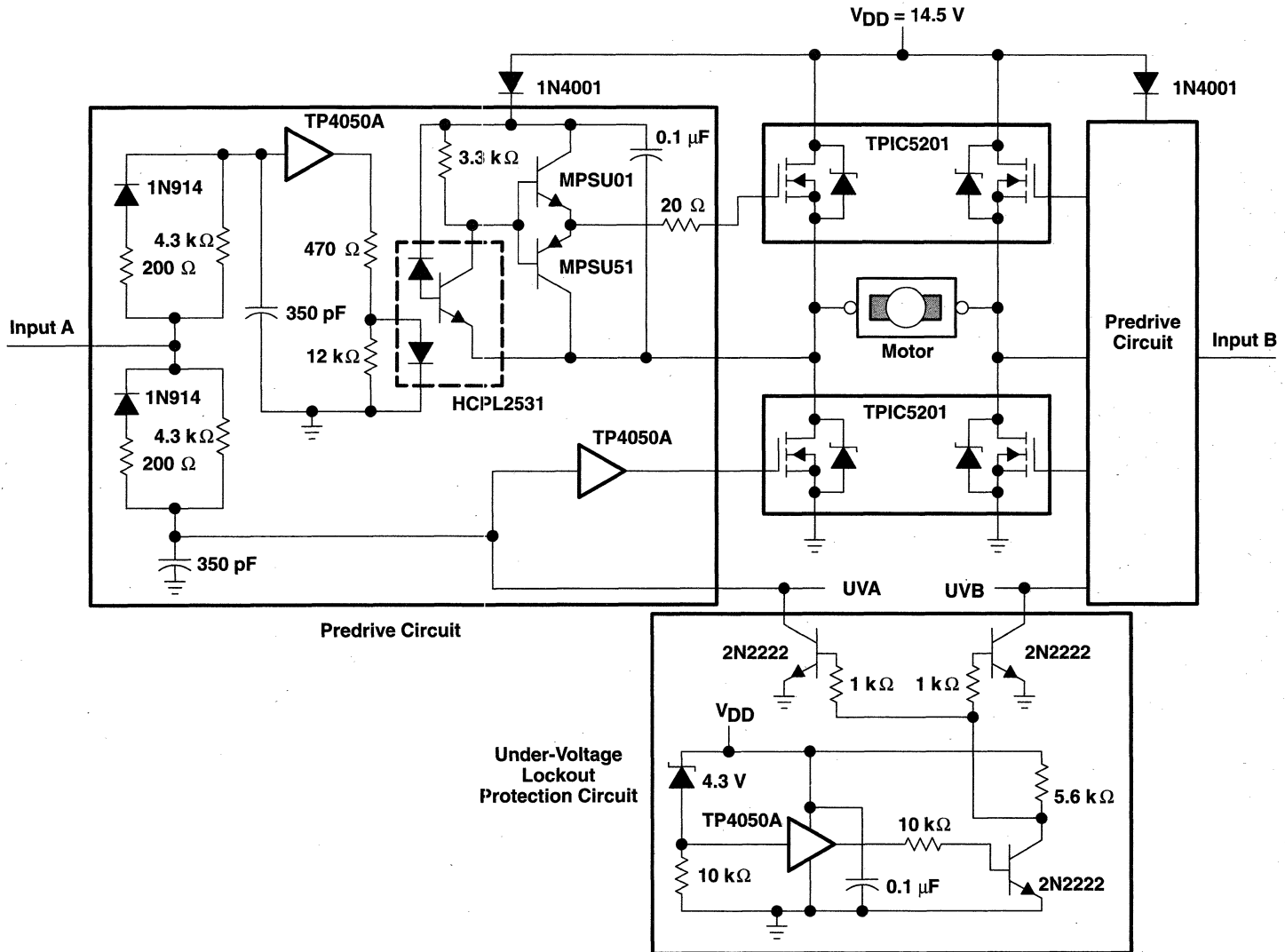
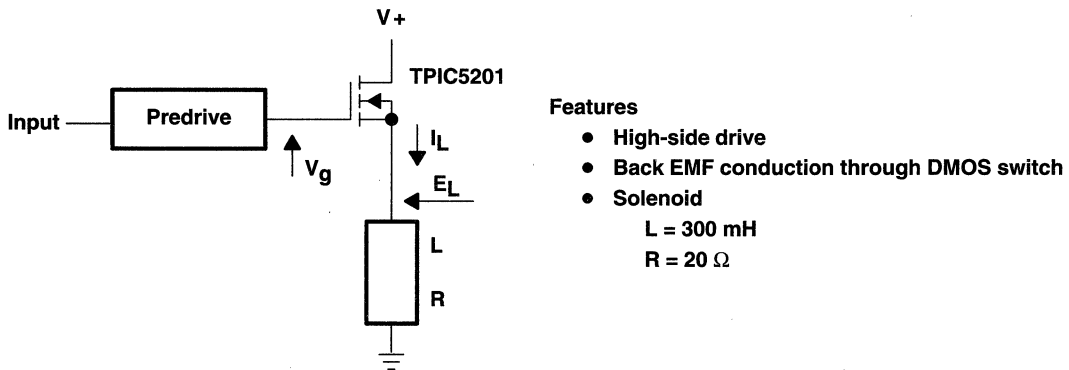


Figure 19. Predrive Circuit Detail

## Solenoid Application

Solenoids are used to provide linear motion. Solenoid applications include electric locks on automobiles, mechanism actuators in tape recorders, and air-control valves.

Figure 20 shows a solenoid with a high-side driver. The high-side drive places the control switch between  $V_{CC}$  and the load. Selection of a switch device for this application must include an energy evaluation and a device that can operate as a high-side switch. The solenoid load is inductive like the stepper motor; however, instead of having cross-coupled signals, the solenoid has a dynamically changing impedance.



**Figure 20. Solenoid High-Side Application**

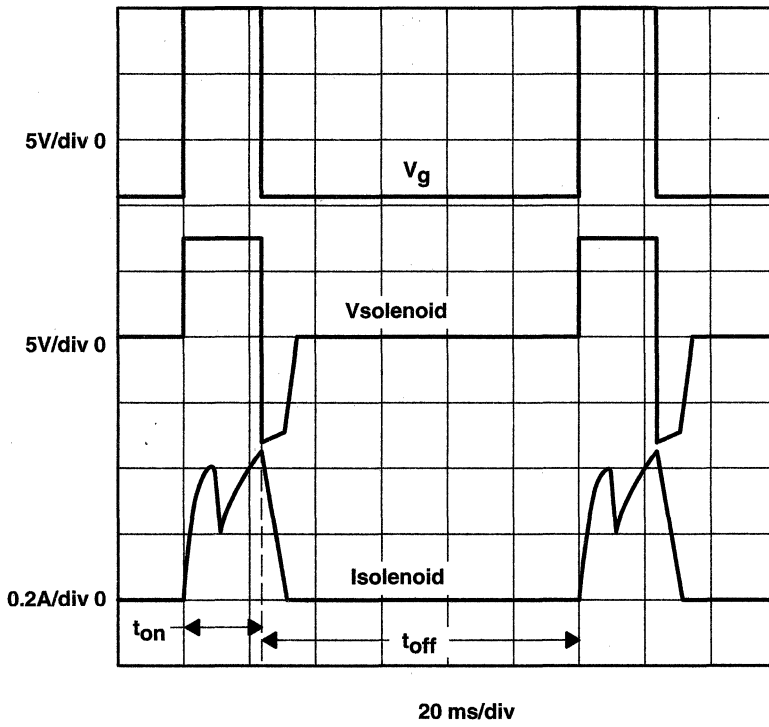
When the current reaches a level sufficient to cause the solenoid to operate, the armature begins to move. When the armature moves relative to the coil, the coil inductance changes. The amount of change is a function of the solenoid design. Conventional relays also exhibit this change in inductance since they are solenoids that operate switches.

Energy and power considerations are similar to the stepper motor. The interface circuit must drive an inductive load with a peak current. The solenoid winding inductance and resistance must be considered when evaluating the avalanche energy. Just as with any inductive load, the total avalanche energy must be considered as well as the peak avalanche current.

### Choosing an Interface Device

The voltage and current waveforms for the solenoid are shown in Figure 21. This particular solenoid is chosen because of the drastic inductance change during operation. The inductance change causes the discontinuity seen in the inductor current during  $t_{on}$ .

The output from the predrive circuit,  $V_g$ , is at  $-5 \text{ V}$  during  $t_{off}$ . The circuit as shown relies on the DMOS transistor to provide the conduction path for the back EMF current from the inductor when the drive is turned off ( $t_{off}$ ), as described in the stepper motor application. When the switch is turned off, the solenoid voltage goes negative. When the solenoid voltage reaches approximately  $-7.5 \text{ V}$  ( $V_g - 2.5 \text{ V}$ ), the DMOS transistor is turned on, effectively clamping the inductor voltage. If  $V_g = 0 \text{ V}$  at  $t_{off}$ , then the solenoid voltage is clamped at  $-2.5 \text{ V}$  and the time required for the solenoid current to reach zero is longer.



**Figure 21. Solenoid Voltage and Current**

## Power and Energy Calculation

Switching:

$$E_T = 113 \text{ mJ}$$

$$P_{\text{off}} = 940 \text{ mW}$$

$$P_{\text{on}} = 2 \text{ mW}$$

$$P_T = 942 \text{ mW}$$

$$E_T = \frac{3L I_P^2 V_{\text{CL}}}{6 (V_{\text{CL}} - V_{\text{SS}}) + 4 R_L I_P}$$

$$P_{\text{off}} = E_T f$$

$$P_{\text{on}} = \frac{1}{3} (I_P^2) r_{\text{DS(on)}} d$$

$$P_T = P_{\text{off}} + P_{\text{on}} + P_{\text{quies}}$$

Continuous:

$$P_{\text{on}} = 32.4 \text{ mW}$$

$$P_{\text{on}} = I_P^2 r_{\text{DS(on)}}$$

Where:

$$t_{\text{on}} = 25 \text{ ms}$$

$$L = 300 \text{ mH}$$

$$t_{\text{off}} = 95 \text{ ms}$$

$$I_P = 0.5 \text{ A}$$

$$V_{\text{SS}} = 12 \text{ V}$$

$$r_{\text{DS(on)}} = 90 \text{ m}\Omega$$

$$V_{\text{CL}} = 8 \text{ V}$$

$$P_{\text{quies}} = 0$$

Using the current waveforms from Figure 21, the energy dissipated in the switch can be calculated. The TPIC5201 Power+ Array has been chosen as the switch for this application.

Using the calculations presented in the Output System Design section:

$$E_T = \frac{3 (L \cdot I_P^2 \cdot V_{\text{CL}})}{6 (V_{\text{CL}} - V_{\text{SS}}) + 4 (R \cdot I_P)} = 113 \text{ mJ}$$

$$P_{\text{off}} = E_T \cdot f = 0.94 \text{ W}$$

$$P_{\text{on}} = \frac{1}{3} \cdot I_P^2 \cdot r_{\text{DS(on)}} \cdot d = 7.5 \text{ mW}$$

$$P_{T(\text{av})} = P_{\text{off}} + P_{\text{on}} + P_{\text{quies}} = 0.94 \text{ W}$$

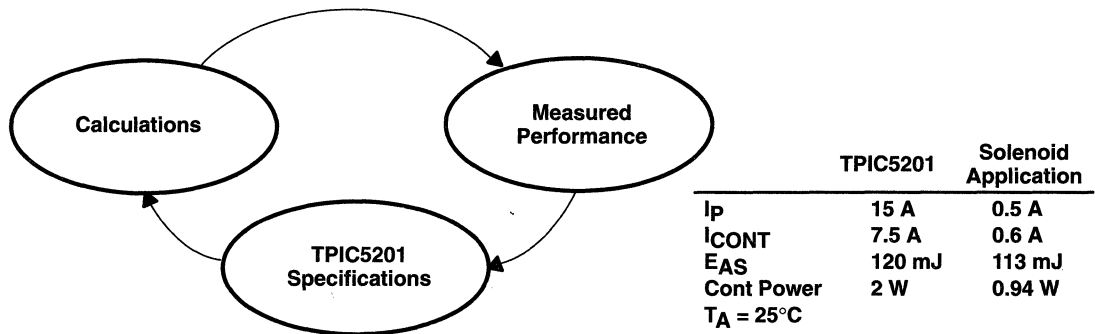
Assuming that the solenoid could be turned on for an extended period of time, the power dissipated in the switch would be:

$$P_T = I^2 \cdot r_{DS(on)}$$

$$I = \frac{V_{CC}}{R} = 0.6 \text{ A}$$

$$P_T = 0.6^2 \cdot 0.09 = 32.4 \text{ mW}$$

Closing the design loop and comparing calculations, results and specifications verify the design and indicate changes when necessary, as shown in Figure 22.



**Figure 22. Closing the Loop**

The results of this comparison are not what might be expected. The avalanche energy is high (113 mJ), while the power dissipation is quite low (0.9 W). This indicates that no heat sinking is required and that a device with a lower power and current rating could be used in this application. It also illustrates the importance of doing thorough energy calculations. In this case, a quick look at current handling alone might suggest the device chosen is overkill; but when avalanche energy is considered, it can be seen that the TPIC5201 is a good match for the application. A similar device rated at a lower peak current value would probably be unable to handle the avalanche energy, possibly resulting in repeated mysterious device failures.

## Power+ Product Summary

Power+ products are available in many configurations. Tables 3 through 5 show the key comparisons of Power+ Arrays, Power+ Logic, and Power+ Control, respectively. These tables can serve as a starting point in choosing the product that functionally fits an application.

**Table 3. Power+ Array Key Comparisons**

Devices	TPIC: 2202 2301 2701 5201	TPIC: 2302 3302 5302 5404 5601	TPIC: 2322L 3322L 5322L 5424L 5621L	TPIC: 1301 5203 5303 5401 5403	TPIC: 1321L 5223L 5323L 5421L 5423L
V <sub>DSmax</sub> : 60 V I <sub>cont</sub> : 0.5 A – 7.5 A r <sub>DS(on)</sub> : 0.09 Ω – 0.6 Ω					
5 V Logic-level interface			X		X
4000 V ESD protection				X	X
Configured for motor drive		X	X	X	X
Solenoids, motors, relays	X				
Surface-mount packaging		X	X	X	X

**Table 4. Power+ Logic Key Comparisons**

Devices	TPIC6259 TPIC6273 TPIC6595	TPIC62A259 TPIC62A595	TPIC6B259 TPIC6B273 TPIC6B595	TPIC6E175† TPIC6E261† TPIC6E585†
Typical r <sub>DS(on)</sub> (Ω)	1.3	1	5	1
Output clamp voltage (V)	45	50	50	40
Avalanche energy (mJ)	75	75	30	100
Transistor outputs	8	8	8	4
Continuous current (mA)	250	350	150	§
Pulsed current per output (A)	1.5	1.1†	0.5‡	1
Quiescent current, typical (μA)	15	500	20	1600
Packaging	DIP/SO	DIP/SO	DIP/SO	DIP

† Current-limiting capability and short-circuit protection

‡ Current-limiting capability

§ User-programmable PWM from 300 mA–1 A

†† Preliminary data only

**Table 5. Power+ Control Key Comparisons**

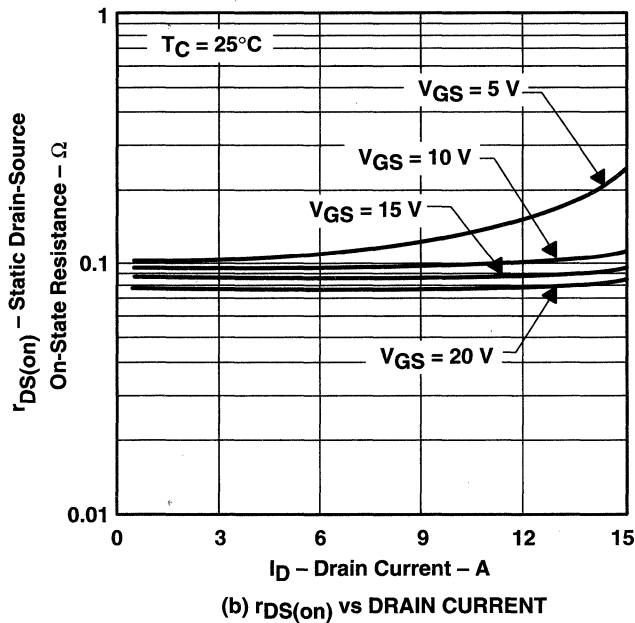
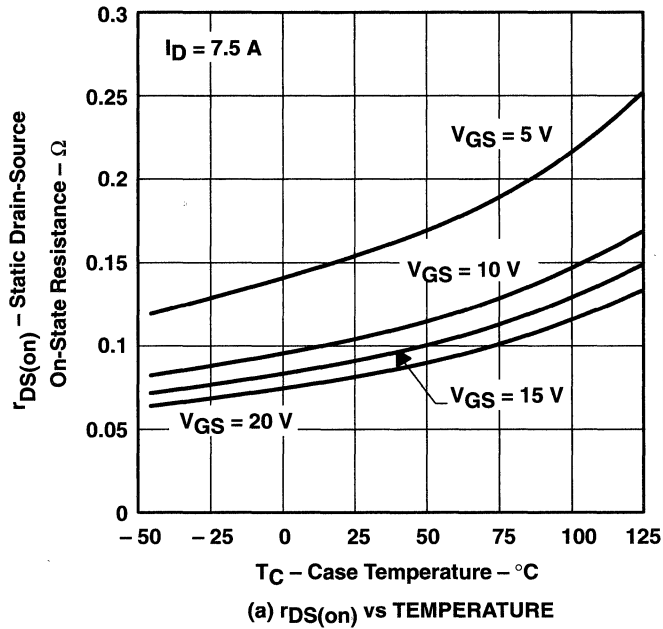
<b>Devices</b>	<b>TPIC2101</b>	<b>TPIC2603†</b>
Number of channel	1	6
Internet FET	No	Yes
Diagnostics	No	Yes
Fault protection	Yes	Yes
Battery supply voltage (V)	8 – 16	5.5 – 25
Frequency, typical (kHz)	20	4000
Quiescent current, max (μA)	200	50
Packaging	DIP/SO	DIP/SO

† Preliminary data only

Selecting a Power+ product includes choosing a product that meets the application performance requirements. These tables compare some of the key specifications from both product families. These are the parameters most often used for an initial product selection.

The applications and design information presented in the previous sections have relied on some assumptions about device parameters in order to simplify the analysis while still arriving at a meaningful evaluation.

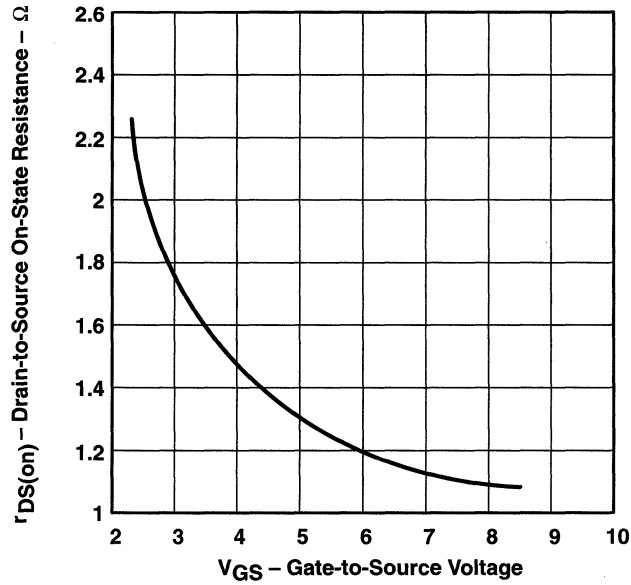
Figure 23 shows the excellent on-state resistance stability for the Power+ Array DMOS transistors. This also shows the type of device information available in the data sheets; complete device characterization is provided in the data sheets for Texas Instruments Power+ products.



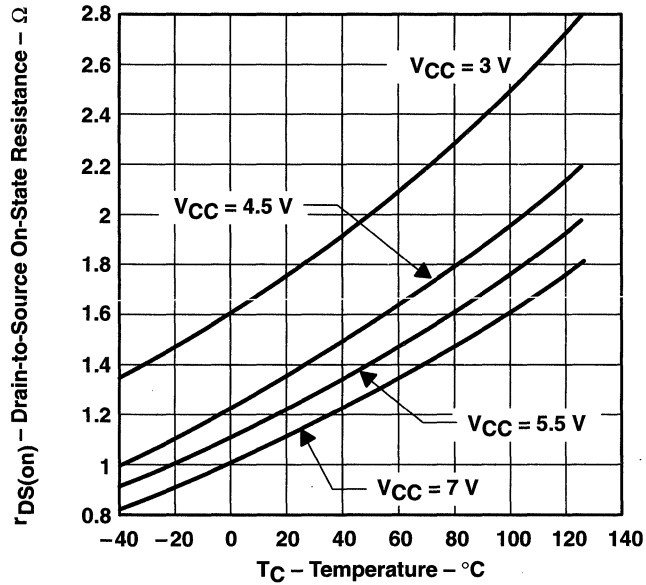
**Figure 23. Power+ Arrays On-Resistance Characteristics**

Figure 24 shows device on-state resistance performance for the Power+ Logic family of devices. While the  $r_{DS(on)}$  is higher than that of the Power+ Arrays, the power handling for these outputs is still substantial as shown in Table 4.





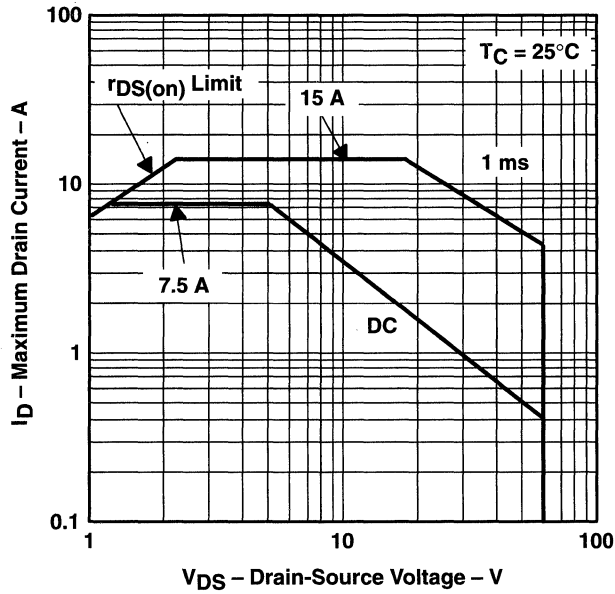
(a)  $r_{DS(on)}$  vs GATE-TO-SOURCE VOLTAGE



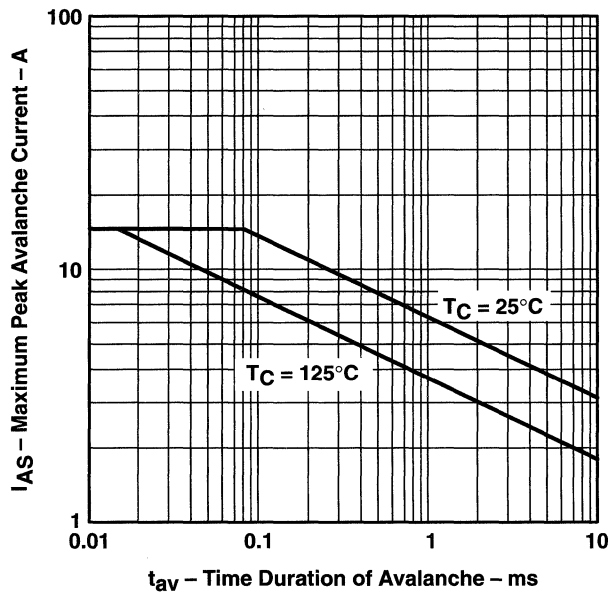
(b)  $r_{DS(on)}$  vs TEMPERATURE

**Figure 24. Power+ Logic Output Characteristics**

The safe-operating-area (SOA) characteristics are presented in graphical form to include peak currents and absolute times. Avalanche energy capability depends on many factors and cannot be adequately described by a single number. Figure 25 indicates the relationship between safe avalanche operating conditions and time, temperature, and current for Power+ Arrays. Similar information is included in the data sheets for Power+ Logic products.



(a) MAXIMUM DRAIN CURRENT vs DRAIN-SOURCE VOLTAGE



(b) MAXIMUM AVALANCHE CURRENT vs TIME DURATION

Figure 25. Power+ Arrays SOA Characteristics



***TPIC6595 Power+ Logic™  
Eight-Bit Shift Register With  
Low-Side Power DMOS Switches***



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## Introduction

The TPIC6595 is a monolithic Power+ Logic™ device that contains eight 1.5-A peak/45-V low-side DMOS power switches packaged in a 20-pin dual-in-line plastic package. The logic functions of the TPIC6595 consist of the logic functions existing in the high-speed CMOS (HCMOS) SN74HC595 catalog parts except the outputs are inverted relative to the HCMOS version. The eight DMOS switches are controlled from a single input, SER IN (serial input), and by an 8-bit serial word. Data is transferred through an 8-bit shift register on the rising edge of SRCK. SER OUT is provided at the last bit of the shift register to allow cascading in applications requiring more than eight DMOS switches.

Each of the eight DMOS switches are equipped with an internal 45-V drain-to-gate zener clamp that greatly enhances their capability to switch unclamped inductive loads. Since the zener clamp causes the DMOS switch to be forward biased instead of being avalanche during inductive-load turn off, a power switch avalanche energy rating of 75 mJ maximum is achieved.

This device provides a cost-effective single-chip solution for direct control of motors, relays, solenoids, and other high-energy, high-electrical stress loads including lamps. Since the device implements a direct control link between the microcontroller and the system electrical loads, use of multiple logic integrated circuits and discrete power devices are eliminated. The reduction of discrete devices not only reduces cost, but saves circuit space and improves system reliability by the reduction of active components.

## Functional Description

The TPIC6595 is an 8-bit serial-in-to-parallel-out power driver having separate power and logic ground pins. A functional block diagram is shown in Figure 1. Data is transferred through an 8-bit shift register on rising edges on SRCK. The data in the shift register is latched to the outputs by the rising edge on RCK. All outputs are placed in a high-impedance mode with a high level on  $\overline{G}$ , but the data is not cleared from the storage register latches.  $\overline{SRCLR}$  clears all data in the shift register only. SER OUT is provided at the last bit of the shift register to allow for cascading in applications requiring more than eight output bits.

The logic used is specified within the data sheet to operate from 4.5 V to 5.5 V, but it is capable of operation down to 3 V and up to an absolute maximum voltage of 7 V. The CMOS transistors used in the digital logic have small feature sizes and short channel lengths as well as tightly controlled, low threshold voltages. Due to these characteristics, the CMOS gains are high, and the parasitic capacitance is minimized. Because of this, the logic is able to function at greater than 25-MHz operation over the full  $V_{CC}$  range of 3 V to 7 V and over the temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Another result of using primarily CMOS-type transistors in the design of the power logic is a low quiescent current ( $I_{CC}$ ).

The predrive circuitry is a CMOS buffer stage that provides adequate sink/source drive to the gate of the output power DMOS. A series resistor has been added between the buffer stage and the gate of the DMOS in order to provide a more controlled gate-drain capacitor charging current than could be achieved with a CMOS buffer alone. The current-limit resistor serves two purposes: first, it limits power dissipation in the drain-to-gate zener clamp structure under inductive transient conditions, and second, it controls the voltage rise and fall of the DMOS gate. This reduces radio frequency interference (RFI) during output switching. The rise and fall times at the gate are controlled by the effective RC time constant, which consists of the series resistor and the  $C_{iss}$  of the DMOS.

The DMOS outputs are designed to have a typical static drain-source on-state resistance of  $1.3\ \Omega$  with a continuous output current of 250 mA at  $25^{\circ}\text{C}$  and  $V_{CC}$  of 5 V. The DMOS transistors are designed to have



a low threshold voltage. The low threshold voltage along with the high gain of the devices allow the gates to be driven without the aid of any additional supply voltage above  $V_{CC}$ . Thus a charge pump or additional level shifting voltage supply is not necessary. The elimination of a charge-pump circuit reduces turn-on times, thereby minimizing power dissipation in the outputs during switching. The use of a charge pump also increases the susceptibility of generating RFI due to the need for an internal oscillator. An oscillator provides little interference due to its low power, but the DMOS may serve as a transconductance amplifier for the oscillator circuit, especially when switching small resistive loads.

Variation of the output characteristics is primarily a function of temperature and  $V_{CC}$ . With the CMOS predrive buffer used, the  $V_{GS}$  of the output DMOS varies directly with  $V_{CC}$ . A typical  $r_{DS(on)}$  of  $1.8 \Omega$  at  $25^\circ\text{C}$  can be achieved with a  $V_{CC}$  of 3 V. This low static drain-source on-state resistance is directly attributable to the low DMOS threshold voltage in the process. Output  $r_{DS(on)}$  primarily consists of the intrinsic DMOS resistance, the series resistance of the source and drain lead busing, bonding resistance, and lead frame resistance. All of these resistances have a positive temperature coefficient.

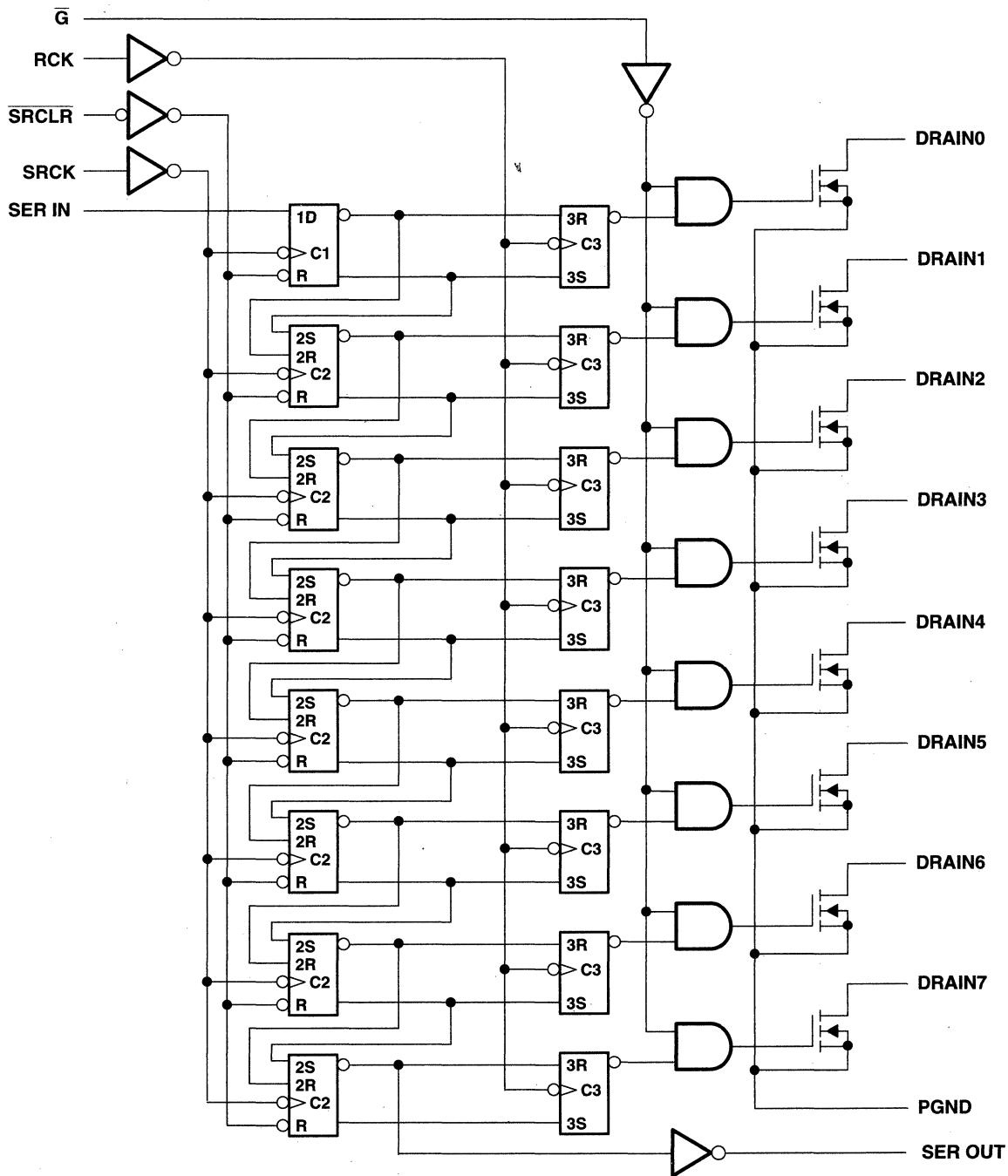


Figure 1. Functional Block Diagram

## Application Design Considerations

### Power and Thermal Considerations

Three important application considerations for a power device are the power, thermal, and inductive energy ratings with respect to the operational load demands. The following illustrate analytical approaches that ensure that the device is operating within these maximum ratings.

To calculate the current  $I_D$  for a single output with  $n$  outputs conducting equal current, use equation (1)

$$I_D = \sqrt{\frac{T_J - T_A}{R_{\theta JA} \times r_{DS(on)} \times 8}} K_n \quad (1)$$

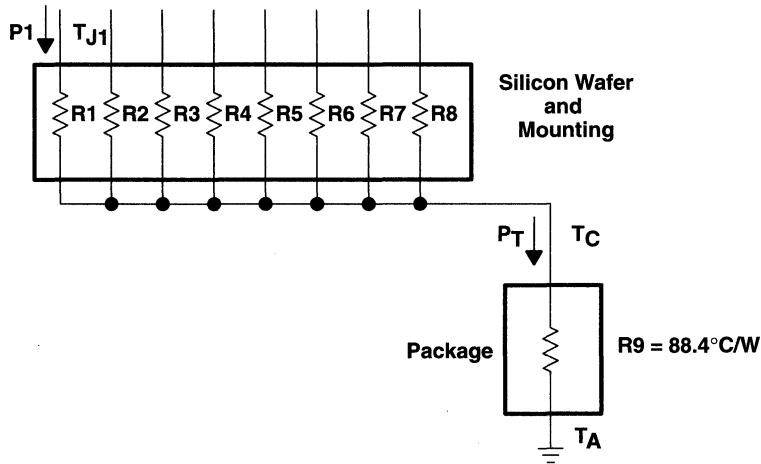
Where:

- $K_n$  = current coefficient for the current of a single output with  $n$  outputs simultaneously conducting equal current
- $R_{\theta JA}$  = thermal resistance or junction-to-ambient,  $90^\circ\text{C}/\text{W}$
- $r_{DS(on)}$  = static drain-source on-state resistance at  $150^\circ\text{C}$  (worst case)  $3.5 \Omega$
- $T_J$  = junction operating temperature,  $^\circ\text{C}$
- $T_A$  = operating ambient temperature,  $^\circ\text{C}$

**Table 1. Values for the Current Coefficient  $K_n$**

Total Outputs On $n$	Current Coefficient $K_n$
1	2.67
2	1.95
3	1.61
4	1.40
5	1.26
6	1.50
7	1.07
8	1.00

The current coefficient values,  $K_n$ , shown in Table 1 are derived from the thermal model shown in Figure 2 and the TPIC6595 data sheet thermal resistance values.



**Figure 2. Thermal Model-Thermal Equilibrium, No Heat Sink**

The following equations apply for the thermal model in Figure 2:

$$R1 \parallel R2 \parallel R3 \parallel R4 \parallel R5 \parallel R6 \parallel R7 \parallel R8 + R9 = 90^{\circ}\text{C/W}$$

$$R1 \parallel R2 \parallel R3 \parallel R4 \parallel R5 \parallel R6 \parallel R7 \parallel R8 = 1.6^{\circ}\text{C/W}$$

$$R_n, n = 1-8 = 12.8^{\circ}\text{C/W}$$

$$R9 = 88.4^{\circ}\text{C/W}$$

$T_{J(n)}$  = junction temperature of an individual output with n outputs conducting equal current

$$P1 = P2 = P3 = P4 = P5 = P6 = P7 = P8$$

Therefore:

$$T_{J(n)} = P1R1 + nP1R9 + T_A$$

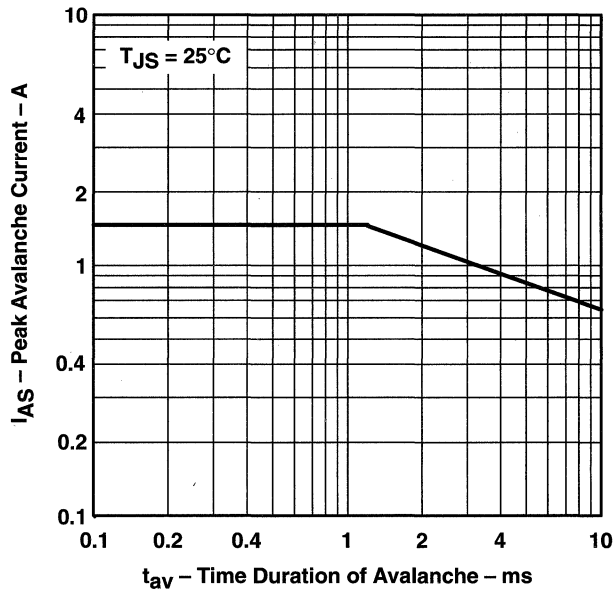
From the thermal model in Figure 2, P1 can be calculated using equation 1.

$$P_1 = \frac{T_{J(n)} - T_A}{R1 + nR9} = I_D^2 r_{DS(on)} = I_D^2 3.5 \Omega \quad (2)$$

### Switching Unclamped Inductive Loads and Turn-Off Power Dissipation, $P_{OFF}$

The data sheet shows an energy rating of 75 mJ. This energy rating is a specific point on the curve shown in Figure 5 on the data sheet, which is repeated here as Figure 3 for clarity.

The energy capability of the device in Figure 3 is not described in a traditional manner but as a graph of peak-switching current versus avalanche time for a starting junction temperature of 25°C.



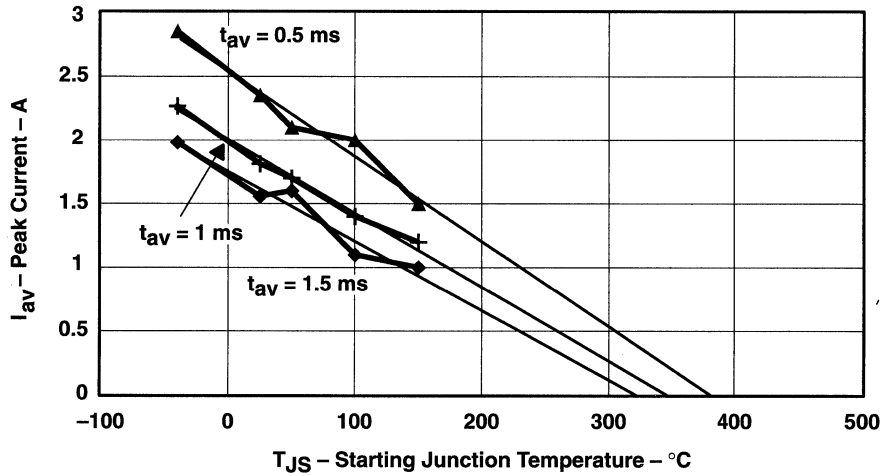
**Figure 3. Peak Avalanche Current Versus Time Duration of Avalanche**

It has been established that the energy limitations of these devices during inductive switching is due to the self heating of the silicon structure. Figure 4(a) shows the measurements of the peak-switching current versus starting junction temperature and idealized inductive switching waveforms. The power absorbed by the device during switching is proportional to the peak switched current,  $I_{av}$ . If the failure mechanism is thermal, the power capability of the device is related to the transient thermal impedance, starting temperature of the device, and maximum physical temperature that the silicon can withstand. It is well known<sup>1</sup> that for the typical resistivities used in the manufacture of these devices, the maximum temperature that silicon can operate at is in the range of 400°C. Therefore, if the peak switching temperature is plotted as a function of starting temperature, the relationship should be linear and intercept the temperature axis at 400°C. Study of Figure 4(a) shows that the 0.5-ms line has an intercept with the starting temperature is directly attributable to the zener diode that has been integrated between the drain and the gate of the device. The zener diode forces the whole DMOS structure to be active during voltage clamping and therefore gives the maximum possible energy absorption capability.

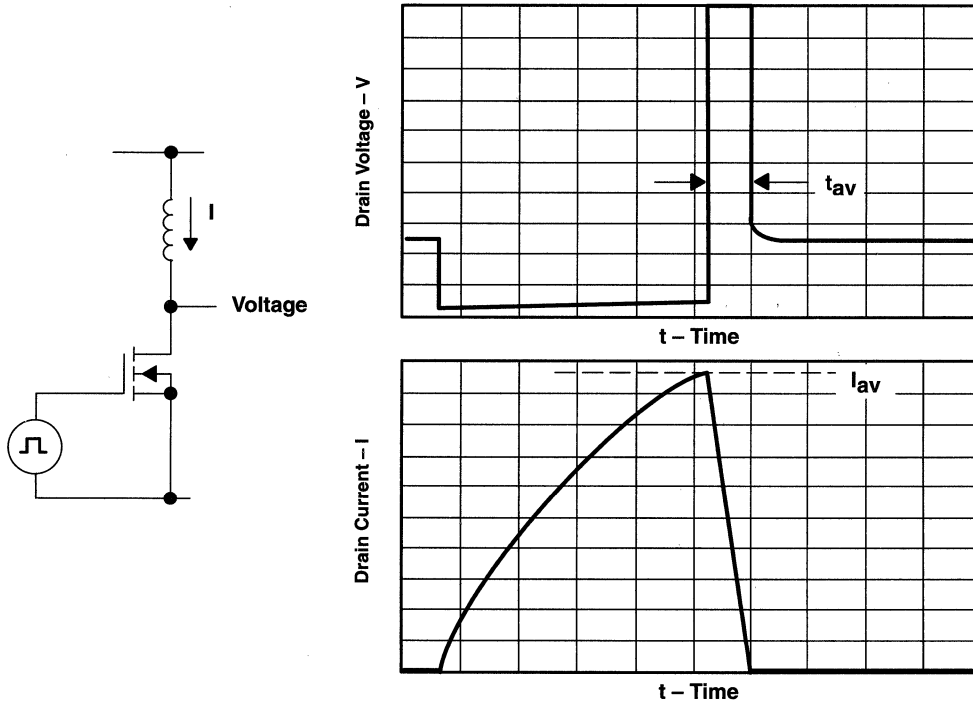
As a consequence of a thermally-limited failure mechanism, the concept of a single energy rating for the device does not fully characterize its capabilities, since the maximum energy capability is related to the time duration over which the energy is absorbed. Consequently, the inductive switching energy characterization of the TPIC6595 has been expanded to show peak switching current,  $I_{as}$ , versus avalanche time for the device,  $t_{av}$ .

The equation,  $|V| = L di/dt$ , can be used to relate this curve to a practical application circuit. Given a supply voltage,  $V_{DD}$ , and an internal clamp voltage of  $V_{BR(DSX)}$  the avalanche time,  $t_{av}$ , is given by  $(V_{BR(DSX)} - V_{DD})/L$ , and the peak switching current  $I_{av}$  is simply the maximum current at switch off.

<sup>1</sup>Physics of Semiconductor Devices, Second Edition. Sze. John Wiley & Sons, pp. 19–26.



(a) PEAK SWITCHING CURRENT VERSUS JUNCTION TEMPERATURE



(b) IDEALIZED INDUCTIVE SWITCHING WAVEFORMS

Figure 4. Peak Switching Current Versus Starting Junction Temperature

If the maximum power dissipation of the device is not exceeded, it is possible to drive an inductive load by operating a number of the devices in parallel. This is due to the close matching of the gate-drain zener diodes.

Figure 5(a) shows four switches operating in parallel while driving a 105-mH/11.5-Ω load at 1 A. The power absorbed during switching is often greater than the power dissipated during the on period.

$$E_{\text{off}} = \frac{3L_{\text{H}}I_{\text{DM}}^2BV_{(\text{BR})\text{DSX}}}{\left[6(V_{(\text{BR})\text{DSX}} - V_{\text{DD}}) + 4R_{\text{L}}I_{\text{DM}}\right]} \quad (3)$$

Where:

$E_{\text{off}}$	Total energy absorbed by TPIC6595 during turn-off transient	59.6 mJ
$f$	Switching frequency	25 Hz
$L_{\text{H}}$	Load inductance	105 mH
$I_{\text{DM}}$	Peak output load current	1 A
$P_{\text{off}}$	Turn-off power dissipation	1.26 W
$R_{\text{L}}$	Inductor resistance	11.5 Ω
$V_{(\text{BR})\text{DSX}}$	Clamp voltage	45 V
$V_{\text{DD}}$	Load supply voltage	13 V

$$P_{\text{off}} = E_{\text{off}}f = 1.49 \text{ W} \quad (4)$$

In the above example, switching frequency of only 25 Hz can result in a power dissipation that is greater than the package rating device. If it is assumed that  $T_{\text{A}} = 25^{\circ}\text{C}$  and  $T_{\text{J}} = 150^{\circ}\text{C}$ , the maximum power dissipation,  $P_{\text{max}}$ , is given by

$$P_{\text{max}} = (T_{\text{Jmax}} - T_{\text{A}})/R_{\theta\text{JA}}$$

Where:

$T_{\text{Jmax}}$  is the maximum junction temperature,

$T_{\text{A}}$  is the ambient temperature, and

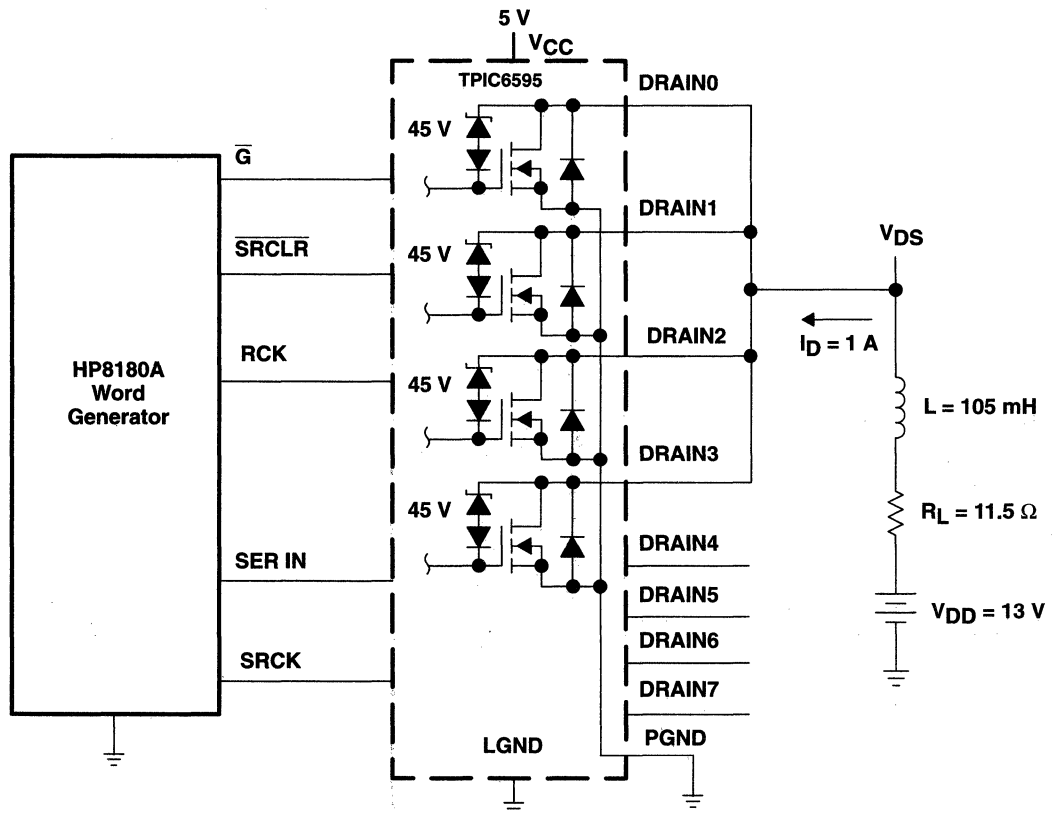
$R_{\theta\text{JA}}$  is the thermal resistance.

Thus,

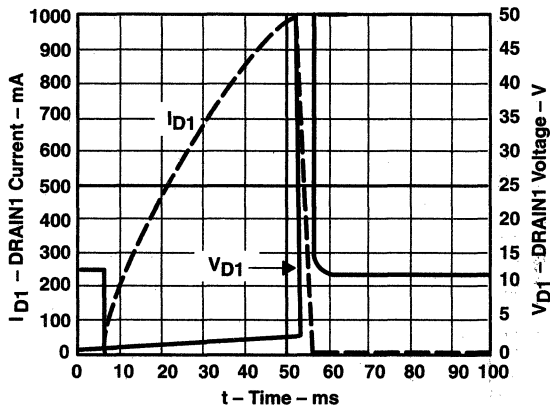
$$P_{\text{max}} = (150 - 25)/90 = 1.39 \text{ W and at a switching speed of 25 Hz,}$$

$$P_{\text{off}} = 59.6 \text{ mJ} \times 25 \text{ Hz} = 1.49 \text{ W}$$

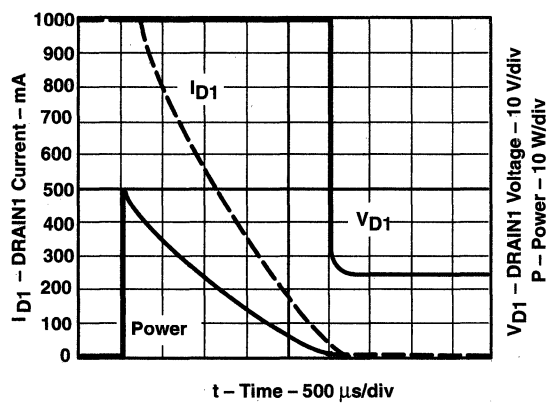
The above example demonstrates that the power dissipation associated with load turn off is often significantly greater than during the on period.



(a) POWER SWITCHES CONNECTED IN PARALLEL



(b) FULL CYCLE INDUCTIVE LOAD SWITCHING



(c) TURN-OFF INDUCTIVE LOAD SWITCHING

Figure 5. Power Switches Connected in Parallel



### Parallel Operation of Output Switches for Extended Current Capability

If all eight output switches are not needed for an application and a continuous output load current greater than 0.25 A is required, the switches can be connected in parallel for extended current capability. The current-sharing capability of the switches is demonstrated in a circuit while operating at  $T_A = 40^\circ\text{C}$  (see Figure 6). The individual switch current,  $I_D$ , is determined by equation (5).

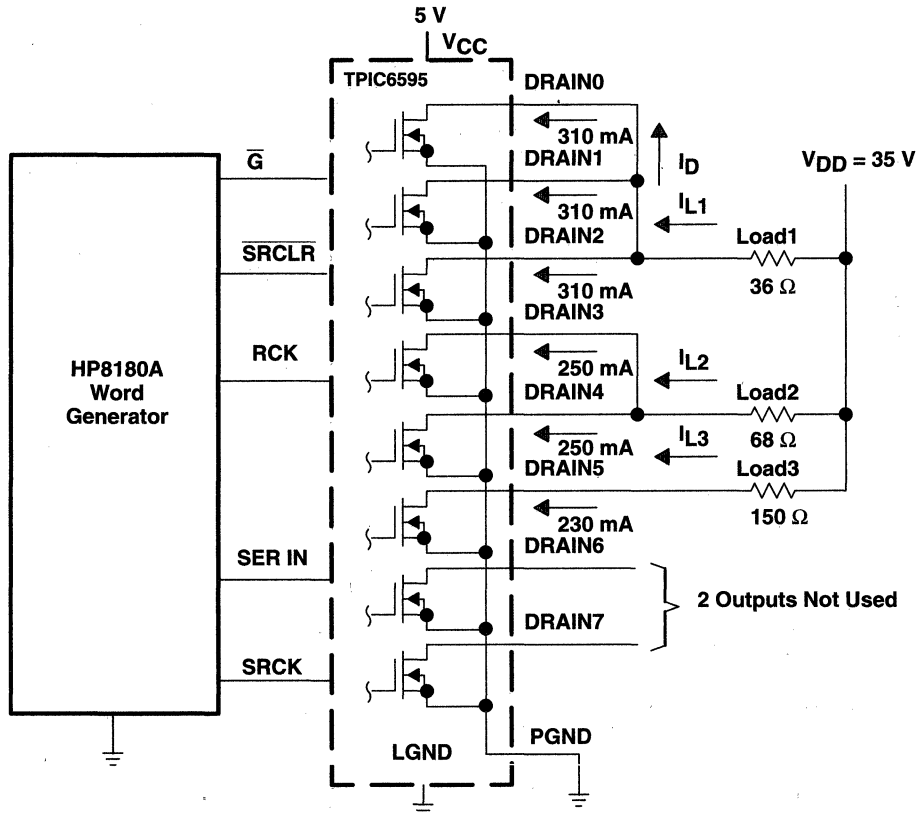


Figure 6. Parallel Operation of Output Switches for Extended Current Capability

$$I_D = \sqrt{\frac{T_J - T_A}{R_{\theta JA} \times r_{DS(on)} \times 8}} K_n \quad (5)$$

$K_n$  = current coefficient = 1.5, 6 outputs on

Where:

$$I_D = \sqrt{\frac{150^\circ\text{C} - 40^\circ\text{C}}{90^\circ\text{C} \times 3.5 \Omega \times 8}} K_n$$

$$I_D = 0.209 \text{ A} \times 1.5 = 0.313 \text{ A each switch}$$

$$I_{L1} = 3 \times I_D = 0.940 \text{ A max current for Load1}$$

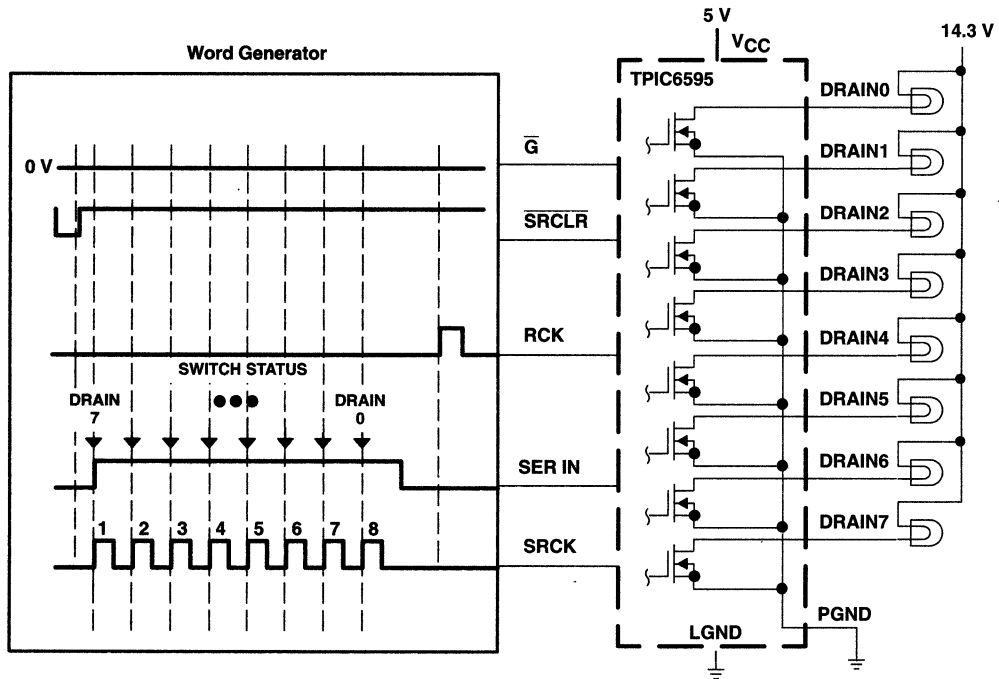
$$I_{L2} = 2 \times I_D = 0.627 \text{ A max current for Load2}$$

$$I_{L3} = 1 \times I_D = 0.313 \text{ A max current for Load3}$$

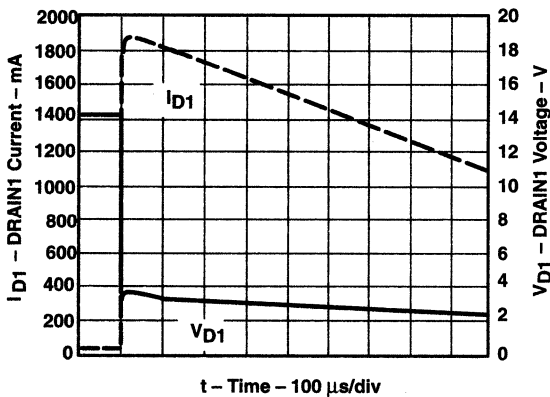
## Application Design Examples

### Direct Drive of Eight Lamps

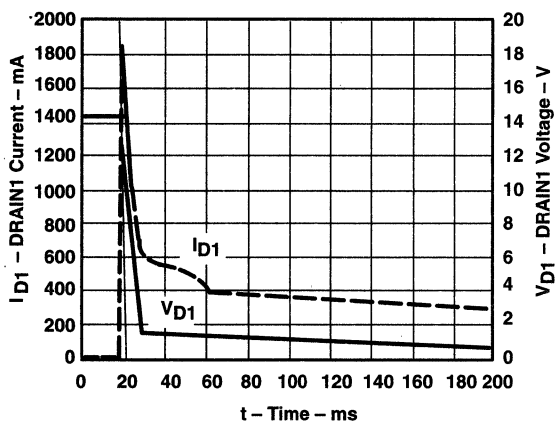
Figure 7 shows the TPIC6595 circuit simultaneously switching eight No. 194 automotive lamps from a 14.3-V source and various waveforms, which demonstrate the internal current limiting at approximately 1.8 A.



(a) LAMP SWITCHING TEST CIRCUIT



(b) INITIAL LAMP IN-RUSH CURRENT



(c) HOT FILAMENT LAMP CURRENT

Figure 7. Simultaneous Switching of Eight Lamps

The nature of an incandescent lamp is capacitive during turn on and represents an instantaneous short circuit. Previous measurements have indicated that the in-rush current (peak switching current) of the incandescent bulbs shown in Figure 7 is typically 2.6 A. As shown on the previous page, the TPIC6595 limits this current to approximately 1.8 A.

### Direct Drive of Eight Relays

The worst-case power dissipation for continuous operation of all outputs is calculated as 0.438 W based on the device measurements.

$$\begin{aligned} \text{Maximum } r_{DS(on)} &= 3.5 \Omega \quad (T_J = 150^\circ\text{C}): \\ I_{\text{rms}} &\approx 0.125 \text{ A} \quad (\text{see Figure 9}) \\ P &= I_{\text{rms}}^2 \times r_{DS(on)} \times 8 \text{ outputs on} \\ P &= (0.125 \text{ A})^2 \times 3.5 \Omega \times 8 = 0.438 \text{ W} \end{aligned}$$

The power dissipation created by inductive energy is insignificant in this case because the resistance component of the load is large compared to the inductance. Based on  $R_{\theta JA} = 90^\circ\text{C} / \text{W}$  and  $T_J = 150^\circ\text{C}$ , the maximum permissible ambient operating temperature ( $T_A$ ) for driving the eight relays at continuous operation is  $110^\circ\text{C}$ .

$$\begin{aligned} T_A = T_J - PR_{\theta JA} &= 150^\circ\text{C} - 0.438 \times 90^\circ\text{C} \\ &= 110^\circ\text{C} \end{aligned}$$

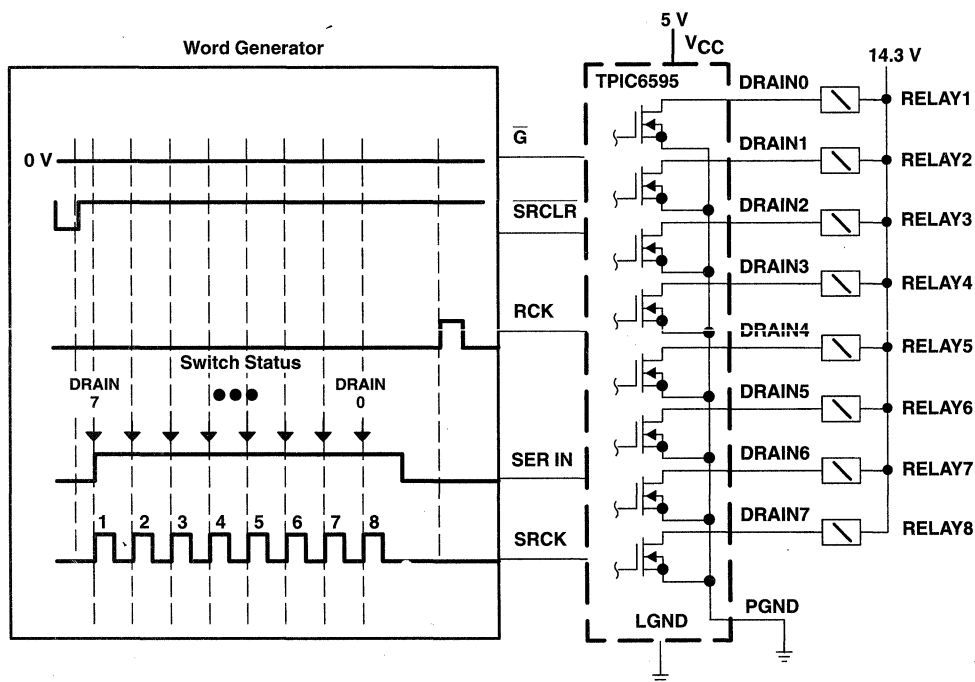
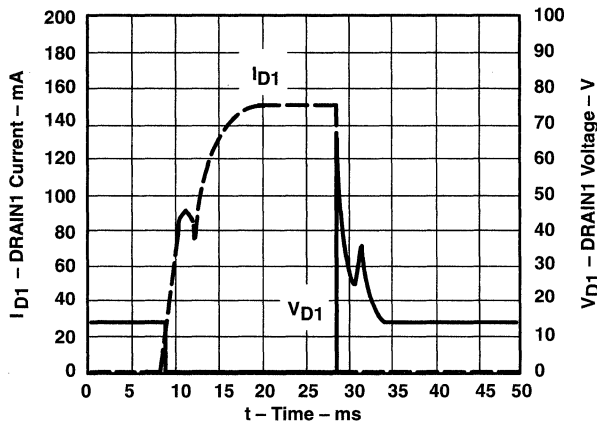


Figure 8. Simultaneous Switching of Eight 12-V, 10/20-A Relays



**Figure 9. DRAIN1 Voltage and Current Waveforms of Figure 8 Application Circuit**

### Unipolar Stepper Motor Drive

Stepping motors, due to their digital drive requirements, are natural motion providers for microprocessors or ASIC-based systems. The TPIC6595 provides a simple solution to the problem of translating logic-level timing to high-voltage and current requirements of stepping motors.

The permanent magnet stepping motor has two types of stator winding. The bipolar type has a single winding on each stator pole and uses a full bridge to drive each phase winding. In the unipolar type, the flux reversal is accomplished by individually driving a bifilar winding on each pole. The windings are phased such that when current is passed through one winding, a given flux polarity is generated. By passing current through the other winding, the opposite flux polarity is produced. The overall magnetic effect is the same as the bipolar motor, but the phase windings can be more economically driven by devices with open-drain outputs such as the TPIC6595.

Printers are one major application of stepping motors because the stepping motor is ideally matched to the needs of paper feeding. In this application, the paper is required to move in well-defined increments, which through gearing equate to fixed numbers of motor steps. Since the paper position is initialized by the user or at paper loading, there is no need for positional feedback. Therefore, the motion system is an open loop, and the paper is advanced by stepping the motor's rotor a given amount.

The system clock is set for a frequency of 4 kHz. This is based on time per motor step of 2.5 ms and a total of ten clock pulses required per each motor step. This is seen in equation (6), i.e., eight clock pulses for the data word plus one additional clock pulse before and after the data word.

$$t_{\text{CLK}} = \frac{2.5 \text{ ms/step}}{10 \text{ clock pulses step}} = 0.25 \text{ ms or } f_{\text{CLK}} = 4 \text{ kHz} \quad (6)$$

Figures 10, 11, and 12 illustrate two different techniques for driving a unipolar stepping motor with the TPIC6595. The motor is driven at its rated 1-A peak by operating two output DMOS transistors in parallel. In these examples the input logic, which would normally be provided by the system's microprocessor, is generated by a Hewlett Packard HP8180A Data Generator; the logic steps are shown in Table 2 and illustrated in Figure 10.

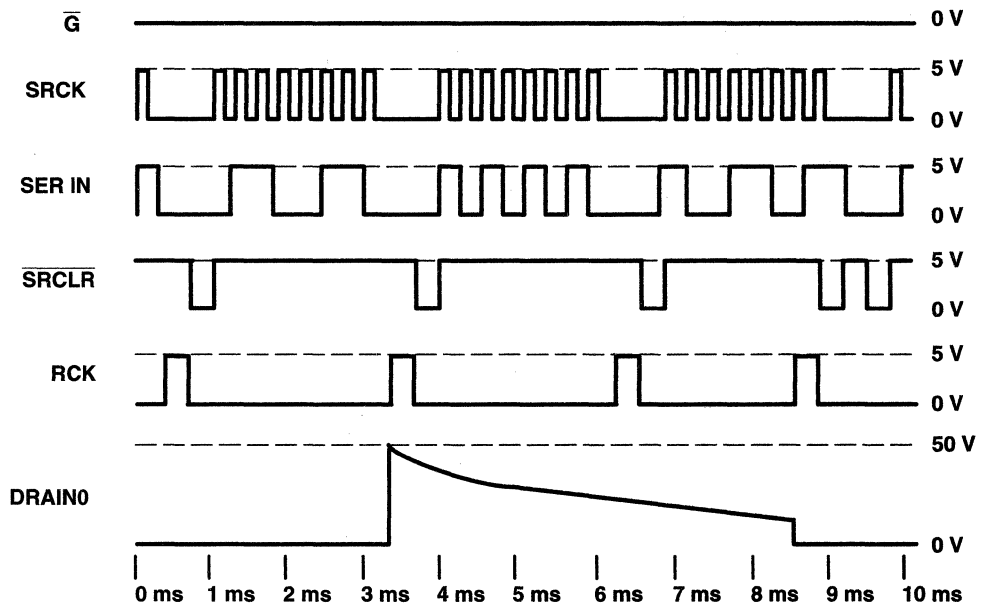


Figure 10. Logic and DRAIN0 Output Waveforms

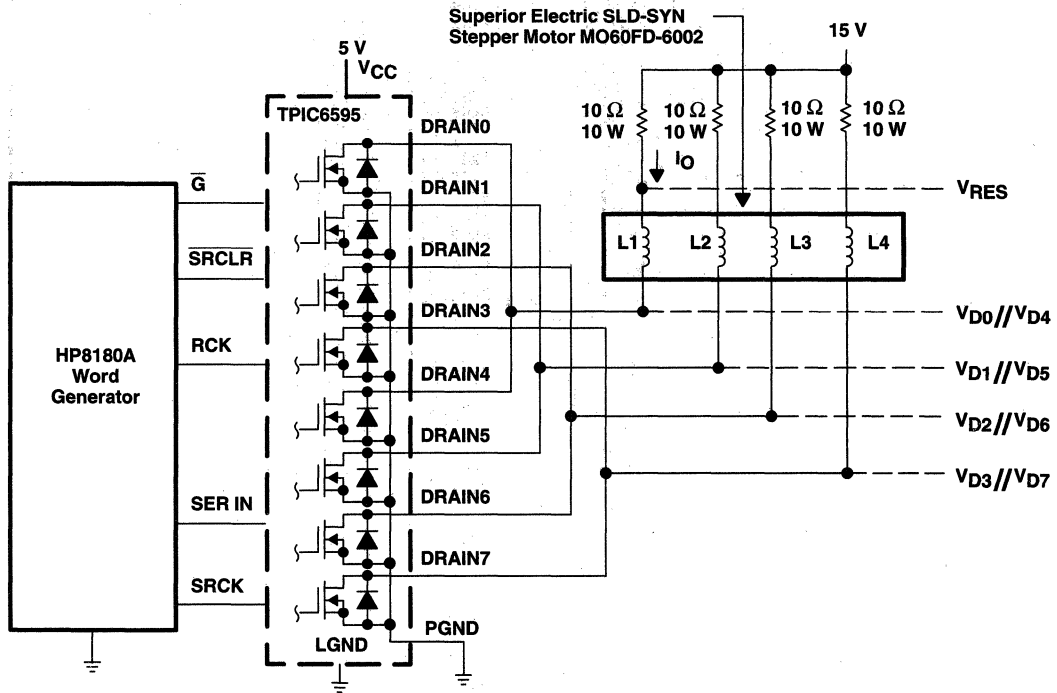
**Table 2. Word Generator Program (Four-Step Sequence)**

CW STEP†	SER IN INPUT DATA WORD	TPIC6595 SWITCHES ON
1	01010101	DRAIN0    DRAIN4, DRAIN2    DRAIN6
2	01100110	DRAIN1    DRAIN5, DRAIN2    DRAIN6
3	10101010	DRAIN1    DRAIN5, DRAIN3    DRAIN7
4	10011001	DRAIN0    DRAIN4, DRAIN3    DRAIN7
1	01010101	DRAIN0    DRAIN4, DRAIN2    DRAIN6

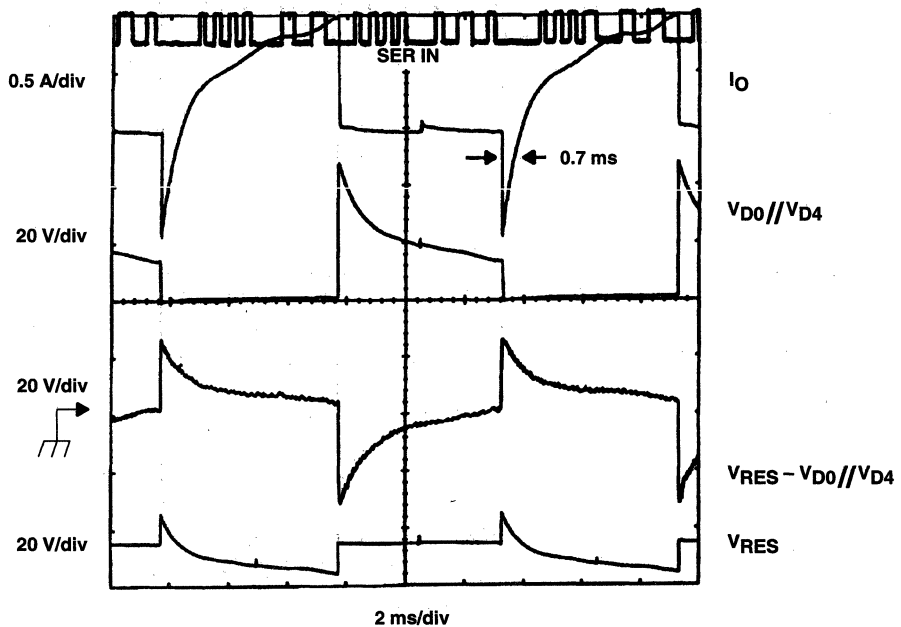
† For CCW rotation, read step sequence up from bottom.

In Figure 11(a), the construction of a stepper motor results in strong magnetic coupling between the stator windings. Consequently, a change in magnetic flux that occurs when the current in winding L1 is interrupted results in an induced current within winding L2. The timing of this motor is such that when D1 parallel with D5 are switched off, D0 parallel with D4 are switched on. The current that is induced in winding L1 is in the negative direction and first flows through the body-drain diode of the DMOS transistors, decays to zero, and then increases in a positive manner. The voltage and current waveforms are shown in Figure 11(b), where it can be seen that the decay time for the negative current is approximately 700  $\mu$ s. Consequently, the nature of a stepper-motor load causes both positive and negative current to flow through the DMOS power transistor.

It is possible to block the recirculating negative current by placing a diode in series with each pole winding. This is shown in Figure 12(a). In this circuit, the drain is allowed to fly to its clamp voltage, since no current is induced in another motor pole winding. The decay time of the current is now reduced to approximately 310  $\mu$ s, which is considerably faster than in the previous example. However, since the energy of the pole winding is not transferred to another pole, it must be absorbed by the DMOS transistor. The device then runs considerably warmer than in the previous case. This technique can only be used in an application that does not result in the device's thermal rating being exceeded.

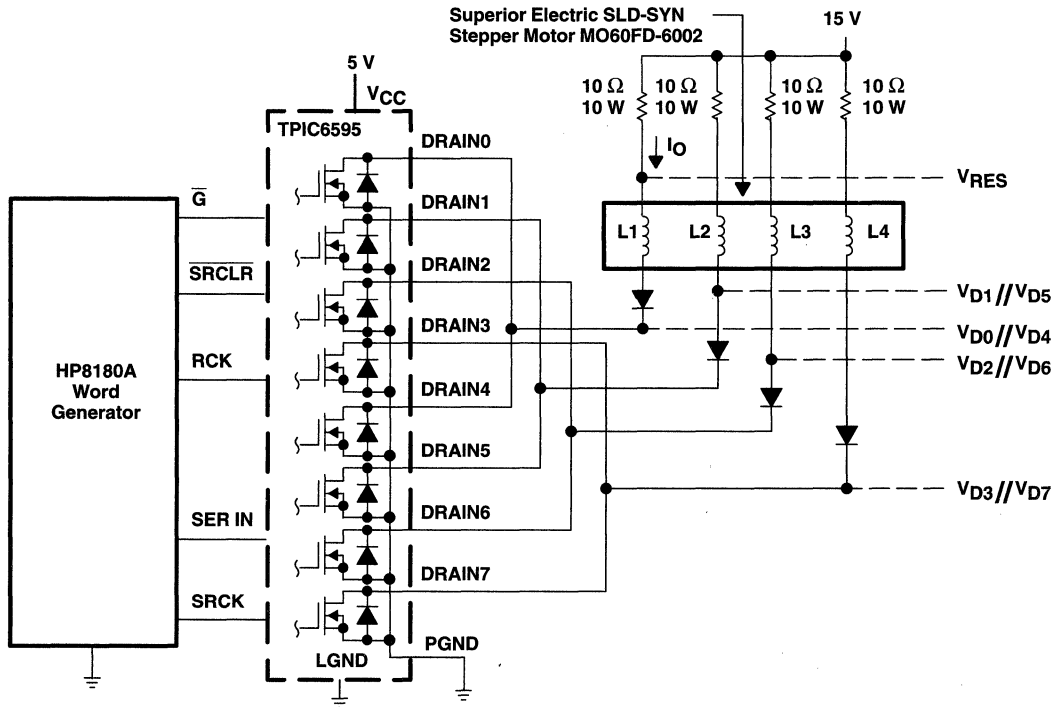


(a) MOTOR DRIVE CIRCUIT

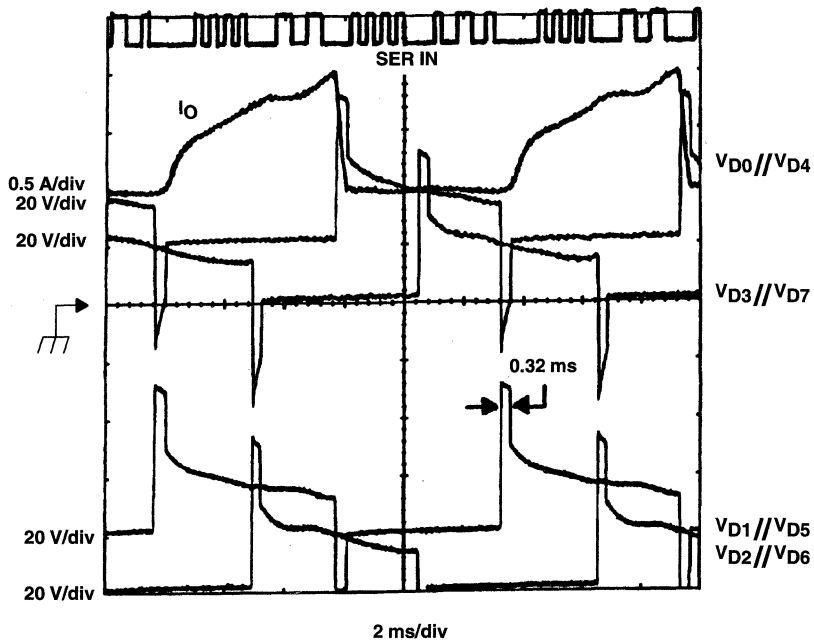


(b) VOLTAGE AND CURRENT WAVEFORMS AT NODES SHOWN IN FIGURE 11(a)

Figure 11. Unipolar Stepper Motor Drive Circuit



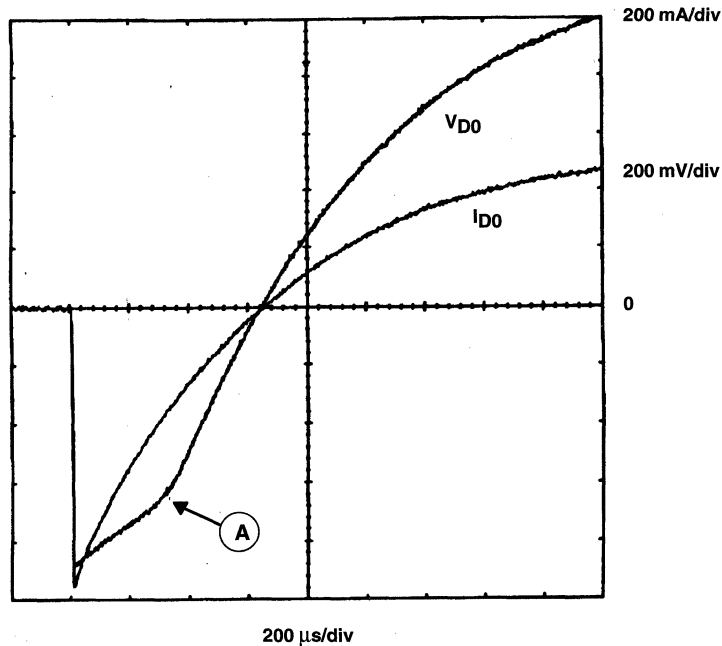
(a) MOTOR DRIVE CIRCUIT



(b) VOLTAGE AND CURRENT WAVEFORM AT NODES SHOWN IN FIGURE 12(a)

Figure 12. Current and Voltage Waveforms That Occur in the Winding L1





**Figure 13. Expansion of Body Diode Reverse-Current Waveform From Figure 10(b)**

The current waveform shown within Figure 11 shows that during each winding pulse, both negative and positive current flows through the power switch. A time expansion of the negative current flow region is given in Figure 13.

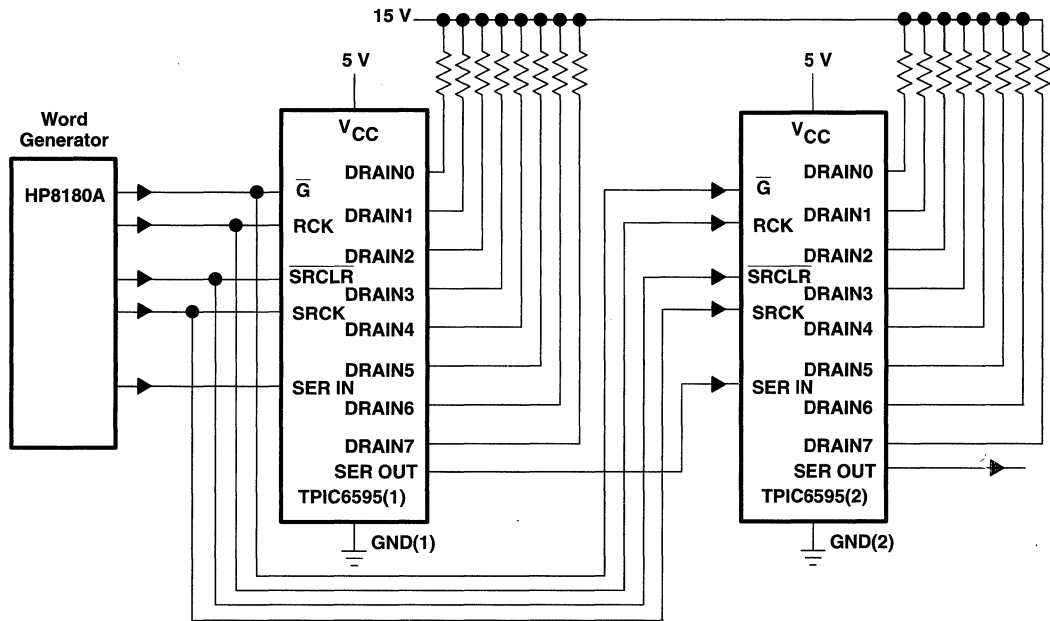
Figure 13 reveals an inflection point (denoted as point A) in the voltage waveform at approximately  $-700$  mV. When the voltage across the device is less than  $700$  mV, the DMOS transistor is conducting in the reverse direction, and the power dissipation is given by the product of  $R_{DS(on)}$  and the square of the drain current. When the voltage across the device is greater than  $700$  mV, the current flow is split between the source-drain diode and the power DMOS transistor.

A feature of power integrated circuits that is often neglected is their ability to conduct current in the reverse direction. When driving inductive loads, the body drain diode is forced to conduct in the reverse direction and the resulting current flow through this device can have effects on the integrated drive logic, causing functional problems within the device. Special consideration to these problems has been given during the design phase of the TPIC6595, and no susceptibility to this type of problem has been found to exist.

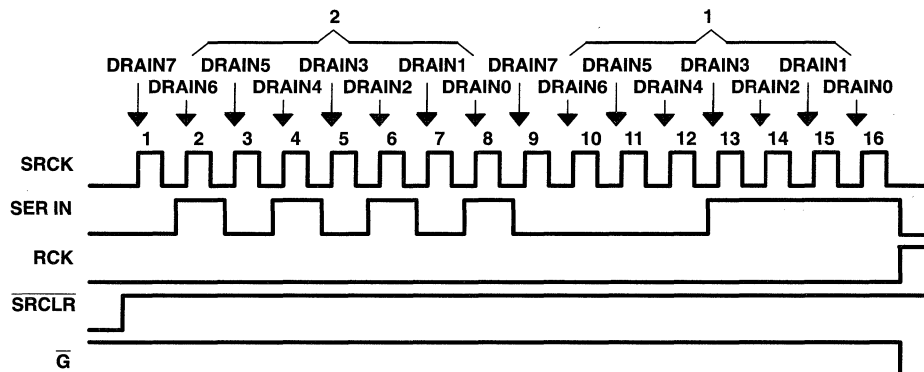
### Cascade Operation of Multiple TPIC6595s

By shifting data into SER IN and out SER OUT, TPIC6595s can be connected in cascade. Figure 14 shows two TPIC6595s connected in cascade including an example SER IN timing diagram of the 16-bit data word for turning on the device number 2's output switches DRAIN6(2), DRAIN4(2), DRAIN2(2), and DRAIN0(2) and the device number 1's output switches DRAIN3(1), DRAIN2(1), DRAIN1(1), and DRAIN0(1). Also, Figure 14(b) is an oscilloscope waveform of device number 1's operation per the conditions described.

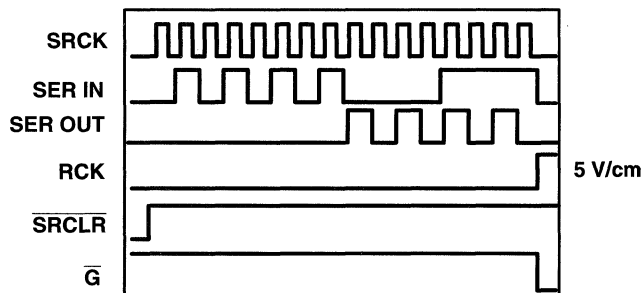
The HP8180A data generator data page for generating the example 16-bit timing diagram explained above is listed in Table 3.



(a) TWO TPIC6595s CONNECTED IN CASCADE



(b) SER IN TIMING DIAGRAM OF 16-BIT DATA WORDS



Horizontal = 20 μs/cm

(c) WAVEFORMS OF FIGURE 14(a) AND SER OUT

Figure 14. Cascade Operation of Multiple TPIC6595s

**Table 3. HP8180A Data Generator Data**

ADDRESS	STR	DATA (for generator outputs)				
		1-0 Out NRZ RCK	0-3 Out NRZ SRCLR	0-2 Out RZ SRCK	0-1 Out NRZ G	0-0 Out NRZ SER IN
0000	1	0	0	0	1	0
0001	0	0	1	0	1	0
0002	0	0	1	1	1	0
0003	0	0	1	1	1	1
0004	0	0	1	1	1	0
0005	0	0	1	1	1	1
0006	0	0	1	1	1	0
0007	0	0	1	1	1	1
0008	0	0	1	1	1	0
0009	0	0	1	1	1	1
0010	0	0	1	1	1	0
0011	0	0	1	1	1	0
0012	0	0	1	1	1	0
0013	0	0	1	1	1	0
0014	0	0	1	1	1	1
0015	0	0	1	1	1	1
0016	0	0	1	1	1	1
0017	0	0	1	1	1	1
0018	0	1	1	0	0	0

† The width is equal to 50 μs, delay 0.20 μs.

NOTE: The frequency is equal to 20 kHz.

### Simultaneous Turn-on/Turn-off of Eight Inductors That Simulate Driving Solenoids Under Worst-Case Conditions

Figure 15 shows the test circuit and oscilloscope waveforms switching eight high-inductance inductors ( $R = 60 \Omega$  and  $L = 250 \text{ mH}$ ) from a 15.6-V source. The device provides 0.25-A current to each inductor and dissipates 1.12 W as seen in equation (10), which is a safe-operating condition based on the 1.39-W continuous dissipation rating.

$$E_T = E_L + E_s - E_R = \frac{3L_H I_{DM}^2 V_{(BR)DSX}}{6 \left[ V_{(BR)DSX} - V_{DD} \right] + 4R_L I_{DM}} = 9 \text{ mJ} \quad (7)$$

The calculated power dissipation  $P_{OFF}$  is 1.58 W as seen in equation (5).

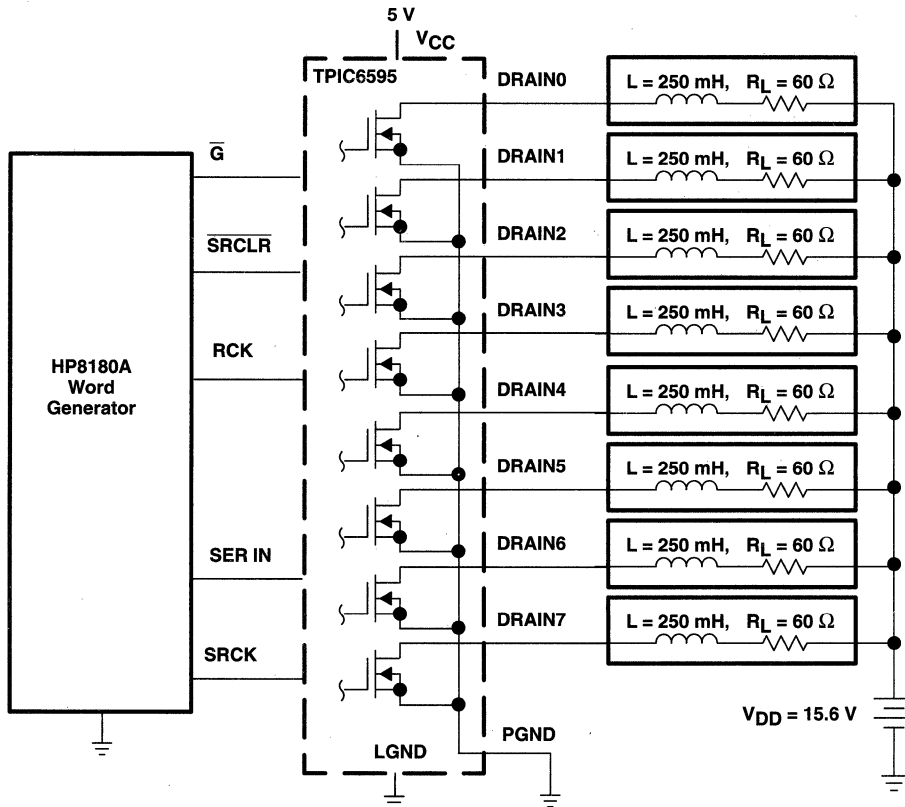
$$P_{OFF} = E_T \times f = 0.009 \text{ J} \times 10 \text{ Hz} = 0.087 \text{ W} \quad (8)$$

$$P_{ON} = I_{DM}^2 \times r_{DS(on)} = (0.25 \text{ A})^2 3.5 \Omega = 0.219 \text{ W} \quad (9)$$

$$\begin{aligned} P_{T(AV)} &= P_{OFF} \times n + P(\text{QUIES}) + P_{ON} \times d \times n \\ &= 0.087 \times 8 + 0.0001 \times 5 + 0.219 \times 0.24 \times 8 \\ &= 1.12 \text{ W} \end{aligned} \quad (10)$$

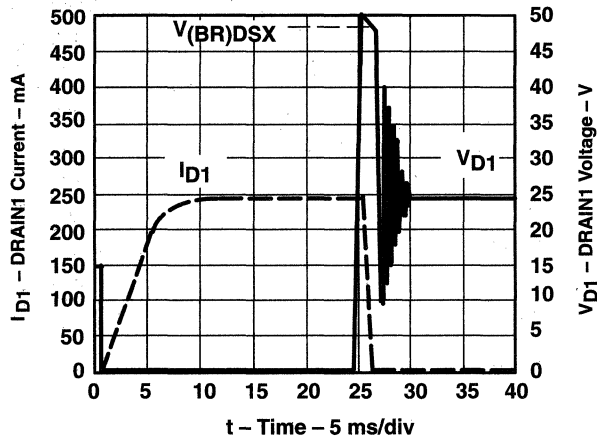
Where:

$E_L$	Inductive energy stored in inductor	7.7 mJ
$E_R$	Energy absorbed by resistance during turn-off transient	1.7 mJ
$E_S$	Energy from power supply during turn-off transient	2.7 mJ
$E_T$	Total energy absorbed by each switch during turn-off transient	8.7 mJ
$f$	Switching frequency	10 Hz
$d$	Duty cycle	0.24
$L_H$	Load inductance	250 mH
$I_{DM}$	Peak output load current	0.25 A
$N$	Number of switches operating	8
$P_{OFF}$	Turn-off power dissipation each switch	0.087 W
$P_{ON}$	On-state power dissipation each switch (see Equation 9)	0.219 W
$P(QUIES)$	Bias power dissipation	0 W
$P_{T(AV)}$	Average total power dissipation	1.12 W
$R_L$	Inductor resistance	60 $\Omega$
$V_{(BR)DSX}$	Clamp voltage [measured, see Figure 15(b)]	50 V
$V_{DD}$	Load supply voltage	15.6 V
$r_{DS(on)}$	Static drain-source on-state resistance, $T_J = 150^\circ\text{C}$	3.5 $\Omega$



(a) SIMULTANEOUS TURN-ON/TURN-OFF CIRCUIT

Figure 15. Driving Solenoid Under Worst-Case Conditions



(b) SWITCHING EIGHT HIGH INDUCTIVE LOADS

Figure 15. Driving Solenoid Under Worst-Case Conditions (continued)

### Circuit Mechanical Layout Considerations

As in any application where power is being controlled by digital and/or analog signals, it is recommended that special attention be given to the circuit layout. There are a few standard layout techniques that eliminate false triggering of the logic inputs due to noise coupling from the power components. A suggested layout is given in Figure 16.

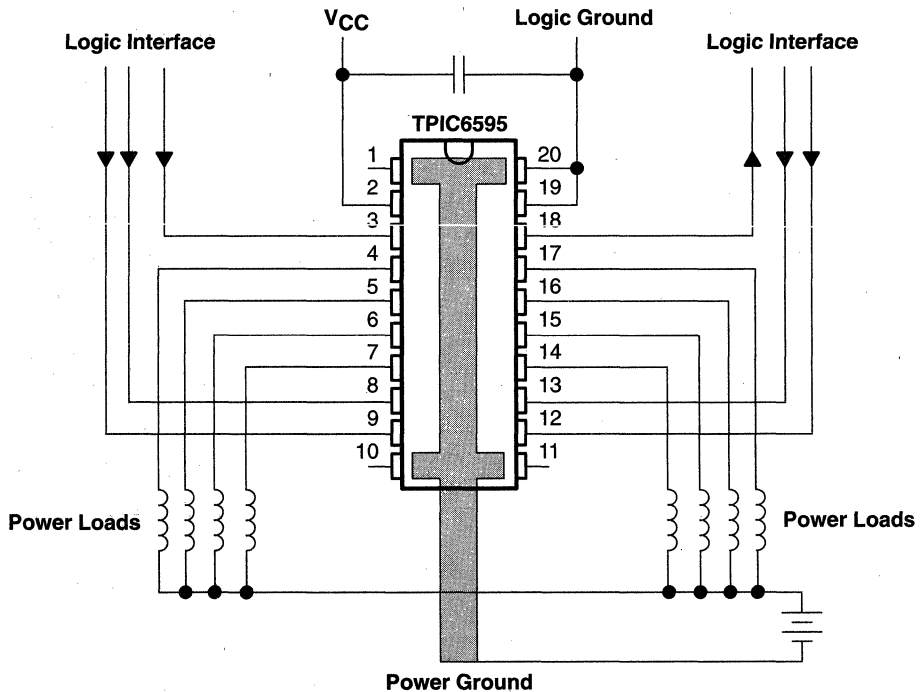


Figure 16. Mechanical Layout

A 0.1- $\mu$ F ceramic bypass capacitor should be connected across  $V_{CC}$  and LGND and placed physically close to the TPIC6595.

A power ground bus should be created on the circuit board that is the return ground for the power loads. The PGNDs connect to the power ground bus.

The ground for the logic interface circuits should be routed separately from the power ground bus. The logic ground and power ground runs should tie in common at only one point; this one connection pin should be placed close to LGND.

The logic components that drive the TPIC6595 should be placed close to the IC.

## **Conclusion**

The TPIC6595 is a monolithic power logic device that contains eight 1.5-A peak/45-V low-side DMOS power switches packaged in a 20-pin dual-in-line plastic package (DIP) and wide-body surface-mount package (DW). Control of the eight power switches is accomplished from a single input by an 8-bit serial word that independently controls each of the eight power switches. All inputs accept standard TTL- and CMOS-logic levels.

The TPIC6595 is a cost-effective single-chip solution for direct control of motors, relays, solenoids, and other high energy, high electrical stress loads. Since the device implements a direct control link between the microcontroller and the system electrical loads, use of multiple logic ICs and discrete power devices are eliminated. The reduction of discrete devices not only reduces cost but saves circuit space and improves system reliability by the reduction of active components.

## **Acknowledgment**

The authors Joe Mings and Dave Cotton wish to acknowledge the contribution of Ross Tegatz and Joe Devore for the report section Functional Description, to Dale Skelton for the section Circuit Mechanical Layout Considerations, and to Ken Echelberger for building the application circuits described and preparing report artwork.



# ***DC Brush Motor Control Using the TPIC2101***







In many applications, a key design goal is to minimize variations in power delivered to a load as the supply voltage varies. This application brief describes a simple DC brush motor control circuit using the Texas Instruments TPIC2101 to maintain a constant effective voltage across the motor.

The TPIC2101 is a pulse-width-modulated (PWM) power FET predriver used for speed control of DC brush motors. It can also be used for other applications requiring PWM. The device has three states: Sleep state, Run state, and Fault state.

The Sleep state is the power conserving state. The Run state is the normal operating state of the device. Fault state is entered when the device detects an over voltage or over current condition. The device features two input modes (Manual and Auto), soft start, over/under voltage protection, and the ability to limit the power dissipation of an externally driven device.

### Theory of Operation

Figure 1 illustrates a fan motor circuit used in an automobile application. The TPIC2101 generates a pulse width drive to an external power NMOS transistor which is proportional to the input signal while also compensating for supply voltage changes. For a detailed description of each pin, refer to the TPIC2101 data sheet.

### Operation Modes

#### Auto Mode

To assert the Auto mode, an open collector PWM signal is used to pull the AUTO pin low while the MAN (Manual) pin is open. The input PWM frequency required is approximately 100 Hz. This signal is conditioned by the internal circuitry and becomes an output at the SPEED pin. An external RC integrates this signal, which then becomes the input for the INT (integrator) pin. At the INT pin a DC voltage of 0.72 V to 4 V corresponds to an input pulse width from 100% to 0% as seen at pin 3, and will generate

### SYSTEM BENEFITS

- ▼ Constant Load Voltage
- ▼ Over Voltage/Current Protection
- ▼ Low Power Consumption During Sleep State
- ▼ Built-In Soft Start

an output PWM drive signal at the GD (gate drive) pin varying from 18% to 100% depending on the supply voltage, ( $V_{bat}$ ). The output gate drive frequency is approximately 20 kHz. The output pulse width in Auto mode is determined by the formula,  $PWM_{out} = ((2.88 + 13.12(1 - \text{input duty cycle}))/V_{bat}) * 100\%$ . Figures 2 and 2A demonstrate the Auto mode operation.

Figure 2 shows the input configuration for Auto mode. Figure 2A shows the relationship between PWM in (input

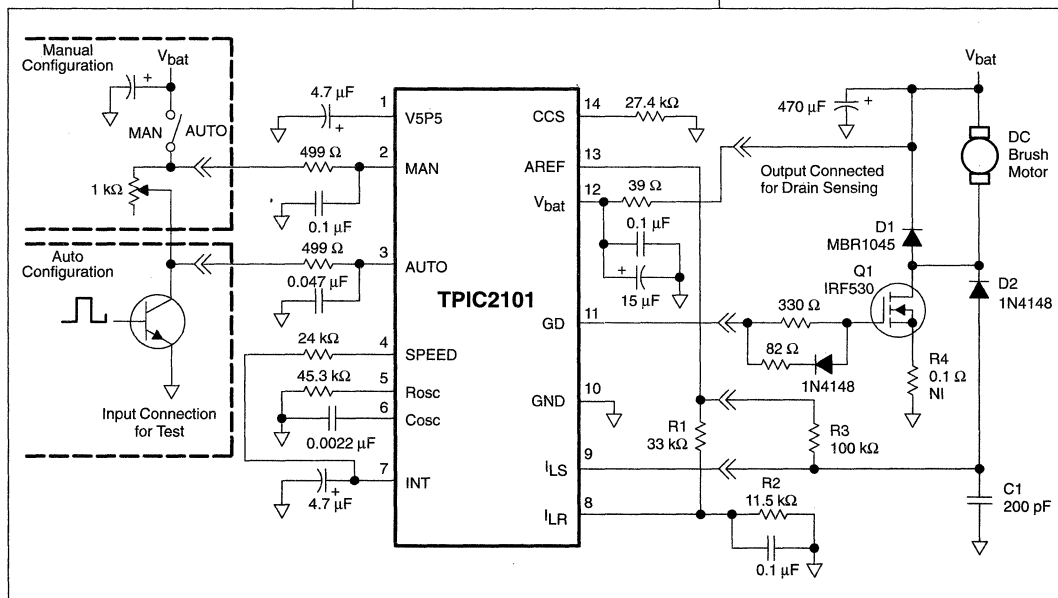


Figure 1. Fan Motor Schematic with PWM Speed Control

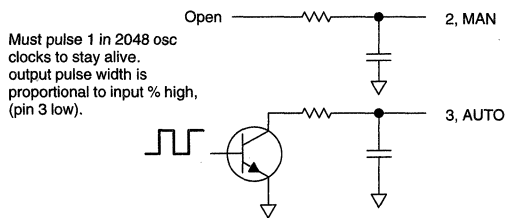


Figure 2. Auto Mode Input

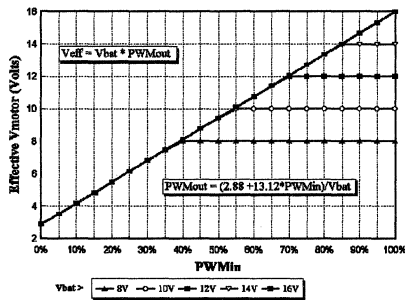


Figure 2A. Auto Mode Effective Voltage

Voltage difference between pin 2 and pin 3 is the input signal. 0 V to 2.2 V controls output pulse width from 18% to 100%

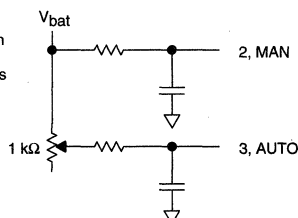


Figure 3. Manual Mode Input

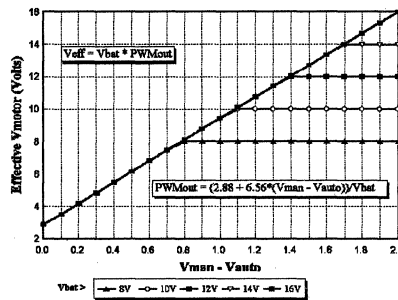


Figure 3A. Manual Mode Effective Voltage

PWM at the base of the NPN transistor) and  $V_{eff}$  (effective motor voltage).

### Manual Mode

To assert Manual mode, the MAN pin is pulled high, and the voltage difference between the MAN and AUTO pins, 0 V to 2.2 V, determines the IC's output PWM drive signal of approximately 18% to 100% depending on  $V_{bat}$ . Just as in Auto mode, the input signal is conditioned by the internal circuitry, output at the SPEED pin, and via an external RC becomes an input of 0.72 V to 4 V DC at the INT pin. Both the MAN and AUTO pins sink 2 mA in the Manual mode. Therefore, simply placing a resistor between the two pins will generate the required input signal. For example, a 1 kΩ potentiometer can be used to generate the 0 V to 2.2 V required for a full range output. The output pulse width in Manual mode is determined by the formula,  $PWMout = ((2.88 + 6.56) (V_{man} - V_{auto}) / V_{bat}) * 100\%$ .

Figure 3 shows the input configuration for the Manual mode of operation. Figure 3A illustrates the relationship between the differential voltage ( $V_{man} - V_{auto}$ ) and the effective motor voltage.

Note: In both Auto and Manual modes, the INT pin actually controls the output pulse width by comparing  $V_{COSC}$  and  $V_{INT}$ . When  $V_{COSC}$  is greater than  $V_{INT}$ , the GD output is turned off. These waveforms are illustrated in Figure 5. The INT pin could be used as an input for some special applications not requiring the input signal conditioning by floating the SPEED pin and applying the input signal directly to the INT pin as shown in Figure 4.

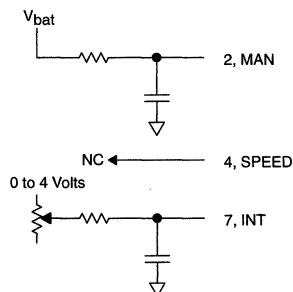


Figure 4. Aux Mode Method

### Sleep State

When the integrated circuit is not in Run state, it is in Sleep state. In this condition, the supply current for the IC is reduced from a maximum of 10 mA to less than 200 μA. The purpose of Sleep state is to preserve battery life when applicable.

### Soft Start

In order to prevent abrupt application of power to the motor, the TPIC2101 includes a soft start feature that gradually ramps the output signal. When Run state is asserted, the output GD is increased in width from 0 to the commanded percent width over approximately 1 second. As previously discussed, the SPEED pin outputs the conditioned input signal, and the INT pin controls the IC's output pulse width. The resistor between the SPEED and INT pins has a minimum value of 20 kΩ, and the capacitor is selected for the start up time desired, usually 4.7 μF for approximately 1 second to full on.

Figure 5 demonstrates the soft start feature for Manual mode. For this illustration a, 1 k $\Omega$  resistor was placed between the MAN pin and the AUTO pin to command a 100% output pulse width. The INT capacitor was reduced to 680 pF for a start up time of approximately 350  $\mu$ s (this short time is used to make the waveform more visible). On the top trace, the rising edge shows when Manual mode is asserted.

The second trace shows the oscillator which generates the output PWM frequency. The third trace is an overlay of trace two, and illustrates the rise time of the INT pin. The bottom trace shows the GD pulse width increasing from 0% to 100% as the INT pin voltage rises.

#### Under Voltage

Under voltage occurs when  $V_{bat}$  falls below 8 V. Under voltage conditions will cause the device to enter Sleep state with the gate drive held low. Recovery is automatic when  $V_{bat}$  increases approximately 1 V above the under voltage threshold. Hysteresis prevents the device from toggling in and out of Sleep state.

### Fault States

#### Over Voltage

Over voltage is sensed by the  $V_{bat}$  pin internally and is not user adjustable. Over voltage occurs when  $V_{bat}$  rises between 17 V and 20 V. During over voltage condition, GD will be turned off and the device will enter Fault state. Recovery is automatic when  $V_{bat}$  decreases 0.5 V to 1 V below the over voltage threshold. Hysteresis will ensure that the condition does not toggle off and on near the threshold.

#### Over Current (limit)

If while the GD pin is high,  $I_{LS}$  (current limit sense) pin is higher than  $I_{LR}$  (current limit reference) pin, the internal circuitry will pull the INT pin low, thereby reducing the commanded output GD pulse width. This is on a

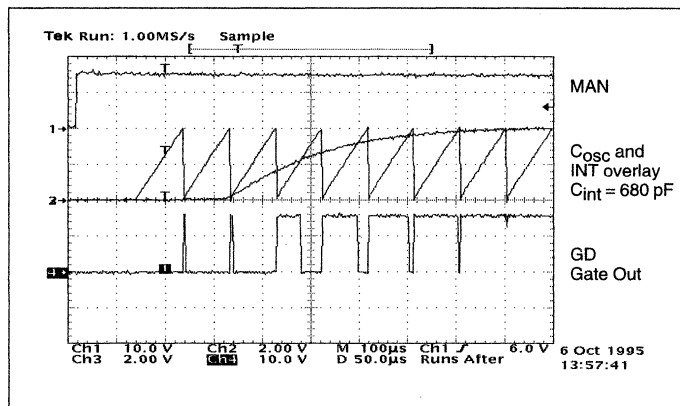


Figure 5. Soft Start

pulse by pulse basis. This limits the power dissipation of the output device in the short term.

#### Over Current (fault)

If the above condition persists during the next 64,000 pulses, the IC will enter Fault state with the GD held low for 64,000 pulses. At that time, one automatic restart will be attempted. If the over current condition occurs a second consecutive time, the IC will remain in Fault state until the device is cycled through a Sleep state to a Run state. This is accomplished when the input command is removed and re-established. Note that 64,000 pulses at 20 kHz is approximately three seconds. The actual time will be proportional to the PWM frequency in use. For a more detailed description of the internal circuit, refer to the TPIC2101 data sheet.

Figures 6–8 illustrate the device's response to overload conditions using a drain sense configuration. Refer to Figure 1 for the detailed schematic. Figure 6 demonstrates normal operation without overload. The top trace shows the current in the lead to the INT capacitor. The second trace shows the voltage at the  $I_{LS}$  pin. The voltage at the  $I_{LS}$  pin rises from zero at the beginning of each pulse at a rate determined by R3 and C1 until it

reaches one diode drop above the drain voltage of the external transistor. This is compared by the internal circuitry to the voltage set at the  $I_{LR}$  pin. This reference voltage is set by the voltage divider R1/R2 from  $V_{AREF}$ . The third trace shows the drain current of the external transistor well under the threshold setting determined by the reference voltage. The bottom trace shows the GD voltage.

In Figure 7, the load has been increased to the threshold setting. The top trace shows that the internal circuit is pulling current out of the INT capacitor which lowers the demand voltage at the INT pin. The second trace is reaching the threshold set by the  $I_{LR}$  pin. The third trace shows the drain current at the higher level, and the bottom trace reflects the narrower drive signal, as compared to Figure 6.

Figure 8 illustrates the effect of an additional load increase. As the load continues to increase, the pulse width is substantially reduced. If the load continues to increase until the pulse width is less than the rise time of the sensing voltage at the  $I_{LS}$  pin (determined by R3 and C1), overload detect is no longer functioning, and a minimum pulse width has been reached. Therefore, the components should be selected to obtain the minimum width required for starting the motor, within the 64,000 pulses

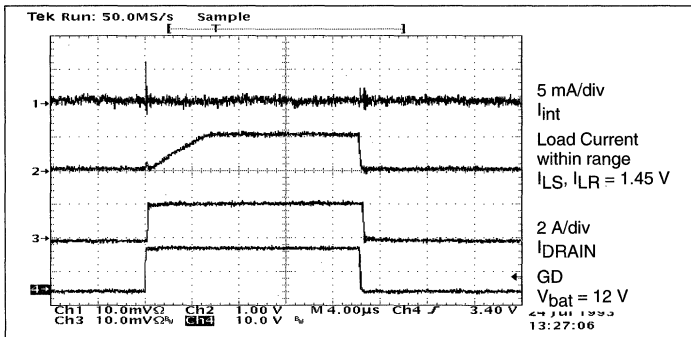


Figure 6. Normal Run State

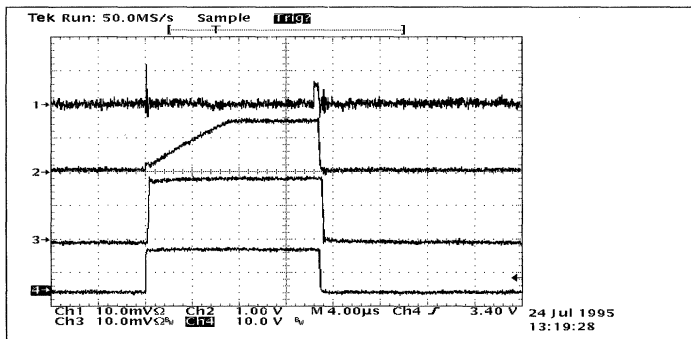


Figure 7. Run State at Threshold

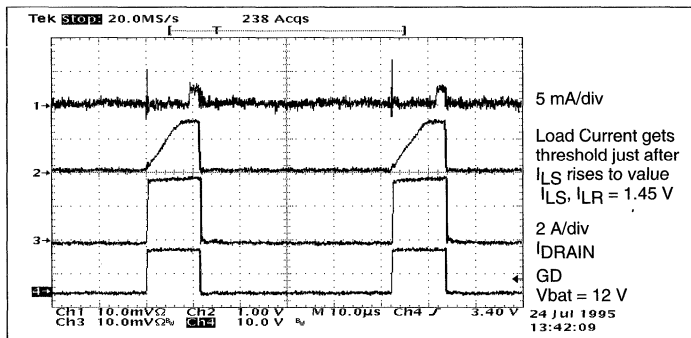


Figure 8. Run State Over Threshold

(approximately 3 seconds), or a fault will be sensed. On the other hand, the pulse cannot be so wide that it allows the external transistor to exceed its power rating.

### Run State

Although other output methods can be used, this brief summarizes Run state

using the drain voltage sensing method. Referring to the overall schematic Figure 1, the GD pin goes high turning the external transistor full on for a time equal to the commanded pulse width. During that time, current flows through the motor and transistor. When GD goes low, the transistor turns off, but the current in the motor continues to flow by way of

the recirculation diode, D1, using the energy stored in the motor inductance.

When GD is low, the  $I_{LS}$  pin is held low internally. When GD goes high, capacitor C1 starts charging through R3 from AREF, and the voltage at  $I_{LS}$  rises until it is clamped by forward biasing diode D2 to the drain of the external transistor Q1. Therefore, during the on time, the voltage at the  $I_{LS}$  pin becomes:

$$V_{ILS} = I_D * (R5 + R_{DS(on)}) + V_{FD1},$$

$I_D$  = drain current = 3.6 A (at desired trip point),

$R4 = 0.1 \Omega$  (This non-inductive resistor is used for monitoring the current. It is not required for this connection, but must be considered if there),

$R_{DS(on)} = 0.1 \Omega$  (On-resistance at 3.6 A from IRF530 data sheet),

$V_{FD1} = 0.7 \text{ V}$  (Diode forward voltage).

Using these component values,  $V_{ILS} = 1.42 \text{ V}$ .

Also, if the bias at the  $I_{LR}$  pin is set by divider R1, R2 from AREF to a value of 1.45 V, overload will trip at 1.45 V +/- 10 mV.

The advantage of drain sensing is that the output device is power dissipation limited. As power dissipation increases, the temperature of the external FET also increases. This rise in temperature results in a higher  $R_{DS(on)}$ . Therefore, since  $V_{DRAIN} = I_{DRAIN} * R_{DS(on)}$ ,  $V_{DRAIN}$ , which is being sensed, responds to that increase. The disadvantage of this method is that the characteristics of the external transistor, such as  $V_{SAT}$  drain-to-source, must be considered when selecting the FET.

### Conclusions

The TPIC2101 provides a cost effective means of maintaining a constant effective voltage in DC motor applications.

# ***Bidirectional Motor Drive Using the TPIC5201***



Since motors play an important role in a wide variety of electronic systems, efficient control of motor speed and torque is an important issue for many system designers. Discrete power MOSFETs, with their low on-state voltages and intrinsic anti-parallel diodes, are a natural choice over bipolar transistors for many motor control circuits. Texas Instrument's new family of Power+ Arrays™ integrates multiple high-performance power MOSFETs on a single chip. These cost-effective devices provide several additional advantages over discrete MOSFETs which make them very well-suited for motor control applications which require pulsed currents of 15 A or less.

Figure 1 shows a bidirectional dc motor being driven from a 14.5 V supply by two TPIC5201 devices arranged in a full H-bridge configuration. This circuit uses two 20 kHz PWM input signals that are 180 degrees out of phase. In most systems, these signals would be supplied by a microcontroller. A 50% duty cycle on both input signals produces a net zero voltage across the motor. Control of the motor's

speed and direction of rotation is achieved by varying the duty cycle of one of the input signals while keeping the other fixed at 50% duty cycle. This variation between the input signals results in a net dc voltage across the motor, providing the drive current needed to meet the torque requirements of the motor.

### Motor Operation

Typical motor operation is shown in Figure 1 and Figure 2. In this example, the motor is driven in the forward direction, and the motor speed is controlled by varying the duty cycle of input signal B. While input signal A is high and input signal B is low, there is a net negative voltage across the terminals of the motor and current through the motor ramps up. Once input A goes low, a net positive voltage appears across the motor terminals, and the motor current ramps down. When both input signals are low, there is no net voltage across the motor terminals, and the H-bridge recirculates a relatively constant current through its upper stages. To drive the motor in the reverse direction, input signal

B is held to a 50% duty cycle, while the duty cycle of input A is varied.

In this example, the pulse width of the input signal is approximately 25  $\mu$ s at a 50% duty cycle. It is important to note that when switching both the upper and lower transistors on the same side of the H-bridge, a brief delay must occur to allow the conducting transistor to turn off before the nonconducting transistor is allowed to turn on. Without this delay, excessive cross conduction current may result. Cross conduction is a condition in which the upper and lower FETs on

### System Benefits

- ▼ Improved power efficiency
- ▼ Reduced pre-drive requirements
- ▼ Improved switching performance
- ▼ Reduced system cost

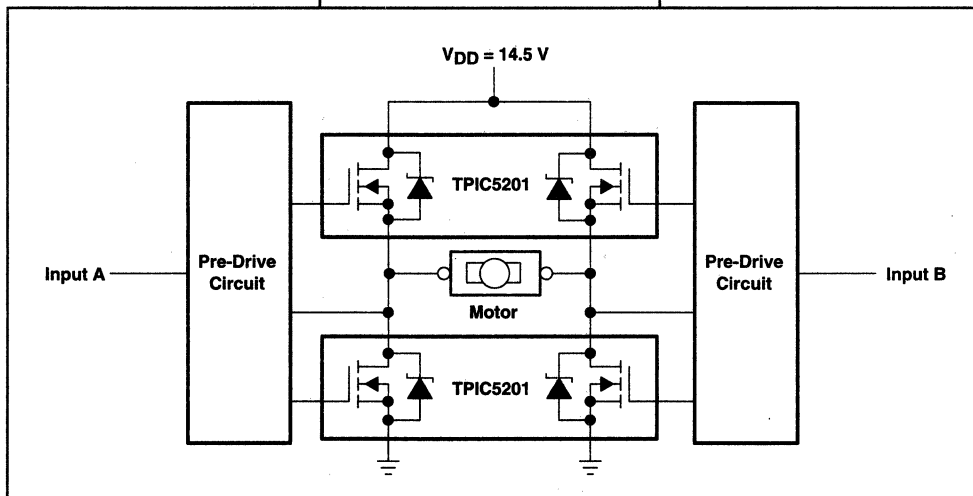
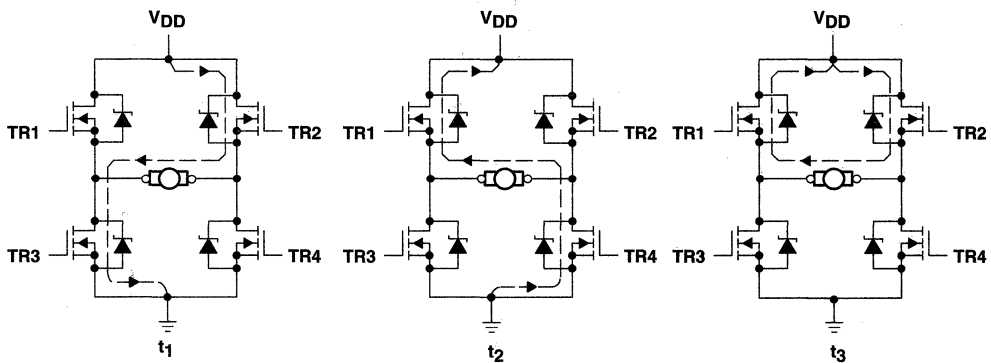
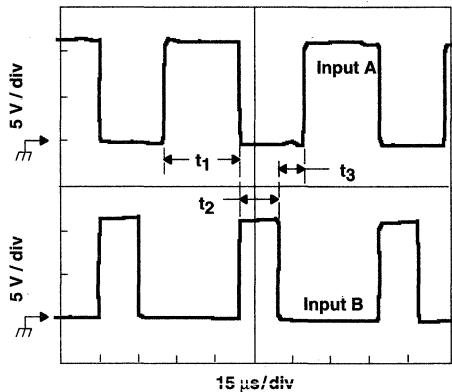


Figure 1. Basic Architecture of the Bidirectional Motor Drive

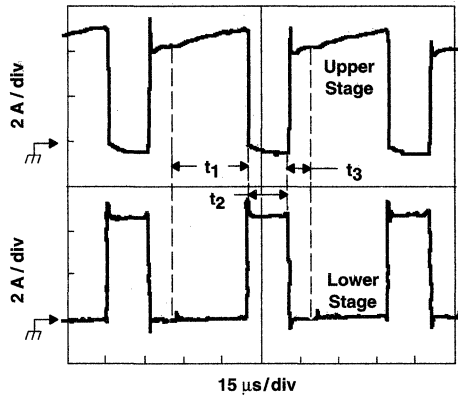




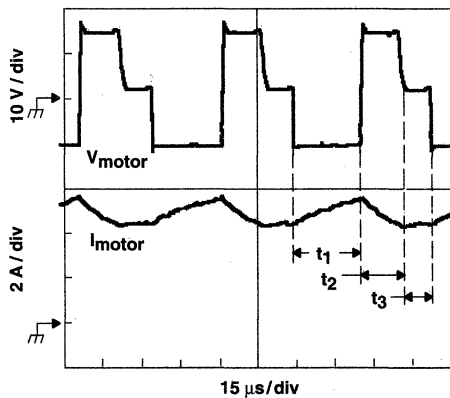
(a) CURRENT PATH THROUGH THE MOTOR AND H-BRIDGE DURING TIME PERIODS  $t_1$ ,  $t_2$ ,  $t_3$



(b) INPUT VOLTAGE WAVEFORMS



(c) CURRENT THROUGH THE UPPER AND LOWER STAGE OF THE H-BRIDGE, TRANSISTORS TR2 AND TR4



(d) DIFFERENTIAL MOTOR VOLTAGE AND CURRENT WAVEFORMS

Figure 2. Typical Motor Operation Characteristics

one side of the H-bridge are on simultaneously, providing a low impedance path between the source voltage and ground. While small cross conduction currents can actually be used to enhance system performance, uncontrolled cross conduction can result in excessive heat dissipation and degradation of the device.

### Pre-Drive Circuit

In this application, two symmetrical pre-drive circuits are used to drive the gates of the upper and lower FETs. The pre-drive circuit schematic is shown in Figure 3. Drive to the upper transistors is achieved through the use of an HCPL2531 optocoupler followed by an emitter-follower stage. The

high-speed optocoupler isolates and level-shifts the upper stage FETs from the input, while providing a reference to ground. The emitter-follower provides low impedance drive for fast charging of the intrinsic gate-source capacitor to enhance switching times.

A 0.1  $\mu\text{F}$  bootstrap capacitor is used to allow the gates of the upper FETs to rise above the supply voltage rail. The bootstrap must be at least 10 times larger than the parasitic gate charge of the TPIC5201, typically 18 nC. Inclusion of the emitter-follower and the bootstrap capacitor allow the upper transistors to be turned on hard when the input signal transitions high.

The low gate capacitance of the TPIC5201 allows for improved efficiency in the motor control circuit. In a power switching application, as the switching frequency increases, switching losses due to the continuous charge and discharge of the gate-source capacitor become the dominant component of the power loss. By minimizing typical gate capacitance, the TPIC5201 reduces switching losses, which results in reduced system power consumption, and improved system efficiency.

The pre-drive circuit includes a delay RC network to insure that cross conduction does not occur. The time constant of this RC

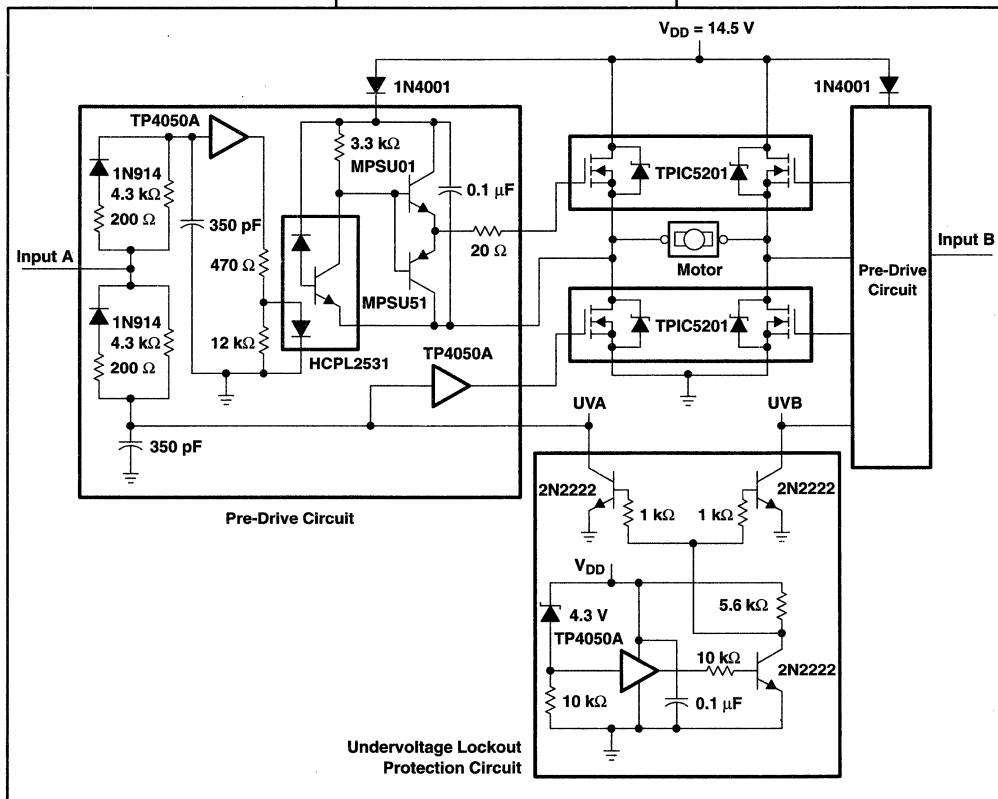


Figure 3. Pre-Drive Circuit Detail

network must be greater than the 0.8  $\mu$ s propagation delay associated with the switching times of the HCPL2531 optocoupler. By delaying the turn-on drive to the gates of the power MOSFETs, cross conduction currents are eliminated.

External undervoltage lockout protection is added to the circuit to keep the lower stage FETs turned off until a predefined threshold voltage is obtained. This threshold voltage is determined by the threshold of the zener diode coupled with the threshold of the TP4050 buffer. In this circuit, the lower FETs remain off between 2 V and 6.2 V.

#### **Advantages Over Discretes**

Since the two power MOSFETs of each TPIC5201 are fabricated monolithically, the FETs within each device are inherently well-matched. As a result, there is little variation in the switching times and

transconductance of the upper stage transistors. This device-matching aids in system design by significantly reducing the need for feedback circuitry to compensate for potential switching time mismatches. As a result, the necessary pre-drive circuitry is greatly simplified.

Each power transistor in the TPIC5201 features a low on-resistance of 90 m $\Omega$  nominal. By minimizing on-resistance, the power consumption of the H-bridge is reduced, increasing the power available to the motor. Motor control systems built with low on-resistance power switches allow more efficient motor performance. While discrete MOSFETs can offer equivalent on-resistance performance, the integrated TPIC5201 provides low on-resistance more cost-effectively and in less board space than discretes.

The energy capabilities of the TPIC5201 have been characterized over its entire range of operation. The specifications for the TPIC5201 include peak avalanche current versus avalanche time rating curves. Unlike the single point energy specifications typical of discrete MOSFETs, designers using the TPIC5201 can accurately monitor compliance with active safe operating area design constraints.

The TPIC5201 Power+ Array is one of the first devices to provide true integration of discrete power MOSFETs. TI's Power+ Array family of products offer the advantages of integrated circuits with the robustness of traditional discrete power MOSFETs. Excellent device performance, transistor matching, and savings in component cost, board, and heat rail space combine to give the system designer new options for highly-efficient motor control.

# ***Bidirectional DC Brush Motor Control Using the TPIC5404***





Motors are pervasive in a variety of electronic systems covering a broad scope of both function and complexity. As trends toward increased automation expand across commercial, industrial, and consumer equipments, the efficient control of motor speed and torque is an increasingly important concern for many system designers.

Developing a motor control system often begins with creating a simple circuit to perform the basic motor drive functions; such a circuit allows the system designer to quickly evaluate the suitability of the selected interface FET's for the motor being driven. This initial evaluation circuit can then be expanded to include additional functionality to fine-tune the control of the motor for the system requirements at hand. This application brief describes a simple, effective circuit using Texas Instrument's TPIC5404 Power+ Array™ to drive a fractional horsepower dc brush motor.

DC brush motors are one of the most frequently selected motor types in use today. Their ease of control and cost-effectiveness account for their popularity. Figure 1 shows a bidirectional dc brush

motor being driven from a 10 V supply by a TPIC5404 which has been configured as a full bridge. The specific motor used draws 1 A of current when unloaded, which is within the continuous current rating of the TPIC5404 when two channels are in conduction. The motor drive circuit includes pre-FET drivers to condition the gates of the motor driver FET's. As the transistors array in the TPIC5404 are N-channel structures, a simple charge pump is featured to provide the necessary upper stage gate voltage. A variable duty cycle square wave generator is also included to allow speed control of the motor. The resulting circuit, which can be built from five standard IC's, provides a self-contained, bidirectional, variable-speed motor controller.

### Circuit Details

Figure 2 shows the complete schematic for the bidirectional motor controller. The TPIC5404, configured as an H-bridge, creates an effective, single-chip, motor driver. The low on-resistance of the TPIC5404, coupled with its SOIC footprint, results in increased motor operating efficiency and in board space savings.

The FET predrive is accomplished by two SN75372 dual MOSFET

drivers. Using integrated FET drivers with an integrated transistor array provides excellent performance matching with minimum skew. The dead time needed between PWM transitions to prevent cross-conduction can be minimized. As a result, the system can be operated at higher frequencies without additional feedback circuitry. Resistors are included between the outputs of the SN75372 devices and the gates of the TPIC5404 motor driver FET's. These resistors, in this example 100  $\Omega$ , are sized to control the  $dV/dt$  of the motor drive. This slew rate limiting helps reduce potential RF interference.

A charge pump is developed using a TLC555 timer to provide the gate voltage for the upper stage motor drive FET's. Since the charge pump produces a voltage greater than the positive rail, care must be taken to ensure that the maximum transistor gate voltages are not exceeded. In this example, the charge pump generates a voltage approximately  $2 \times$  the  $V_{DD}$  supply voltage. By limiting the  $V_{DD}$  supply to a maximum of 10 V, the charge pump provides a  $V_{GS}$  of approximately 10 V to the high side transistors when they are in conduction.

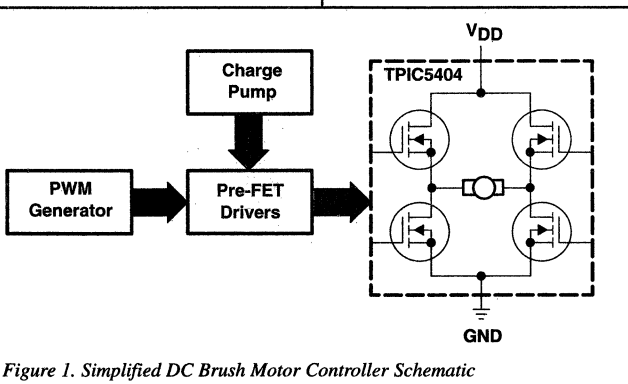


Figure 1. Simplified DC Brush Motor Controller Schematic

### System Benefits

- ▼ Simple, cost-effective motor control scheme
- ▼ Enhanced motor operating efficiency
- ▼ Improved switching performance

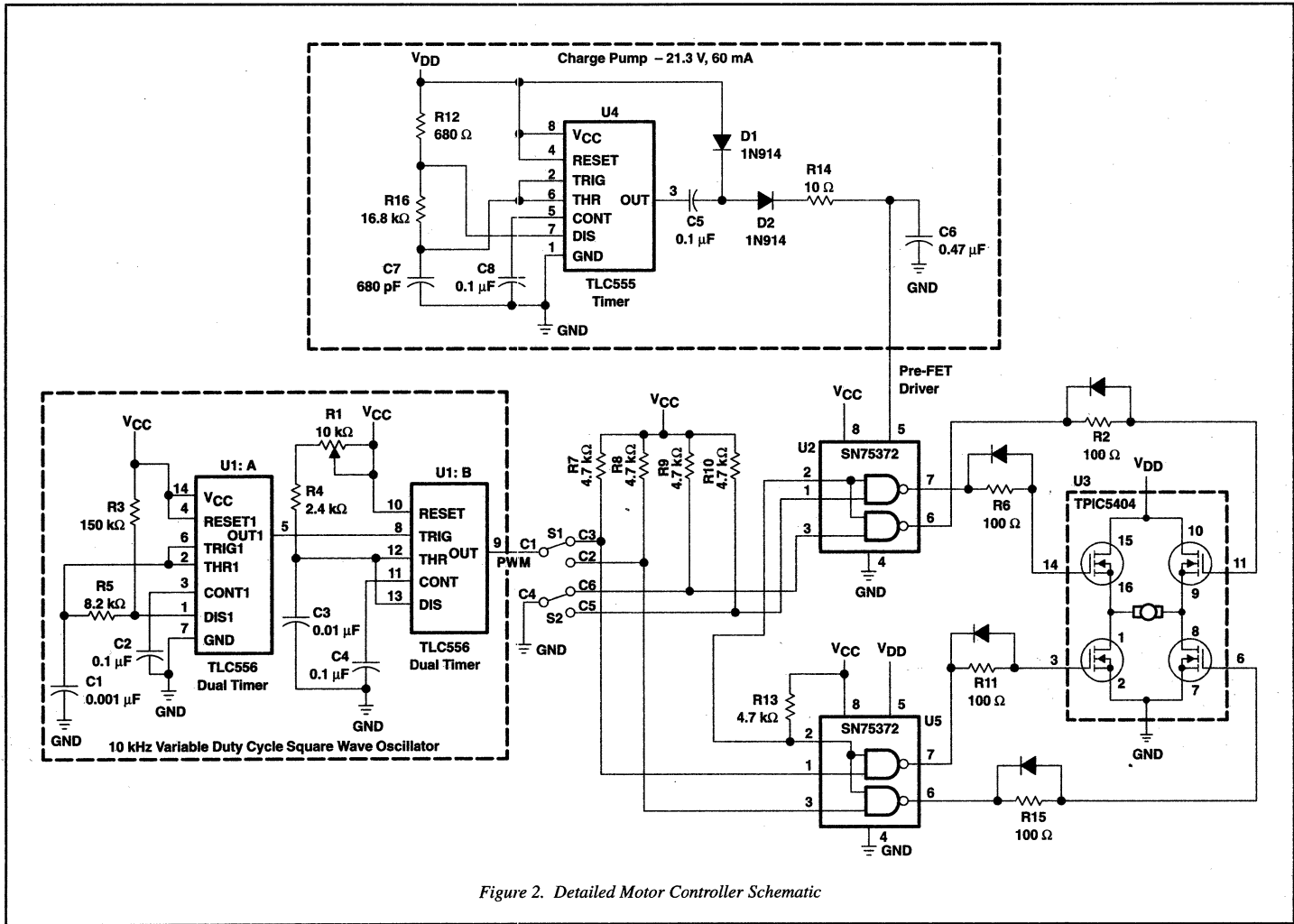


Figure 2. Detailed Motor Controller Schematic

## PWM Control

A 10 kHz variable duty cycle square wave oscillator is designed using a TLC555 dual timer. This oscillator generates a pulse width modulated (PWM) output which is used to vary the motor speed. This technique relies on the inertia of the motor averaging the PWM pulses.

This circuit uses a simple scheme in which the PWM pulses are delivered via switch S1 to the lower stage of the H-bridge, while the upper stage of the H-bridge is connected to a direction switch S2 which controls whether the motor operates in forward or reverse. This scheme has the advantage that at 0% and 100% PWM, the motor sees the full supply voltage (less the on-state transistor voltage drops). A disadvantage of this scheme is that the PWM pattern must be inverted when the motor direction is changed, otherwise the control sense will be reversed – maximum speed becomes 0% rather than 100% duty cycle.

A major concern when using a PWM control technique is that the rapid, repeated switching of the motor driver FET's does not allow a condition in which the right or left pair of transistors is turned-on simultaneously for a significant time. Were this cross-conduction or shoot-through condition to occur, the supply rails would be connected via the transistor bridge, resulting in either severe stress to the H-bridge or unwanted power supply current surges. It is

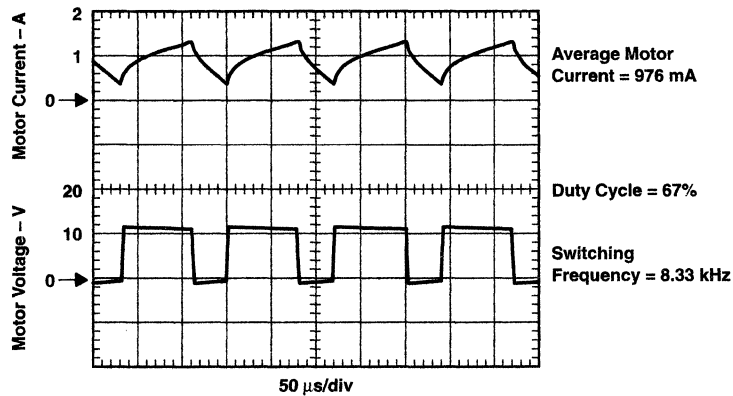


Figure 3 Typical Motor Operating Waveforms

important, therefore, that either the turn-off time of the driver FET's is faster than the turn-on time, or that a dead-time be built into the control circuitry. To help facilitate the design of the turn-on/turn-off dead-time circuitry, detailed gate charge characteristics are included in the Power+ Array data sheets which allow easy calculation of the intrinsic delay time. Nevertheless, including provisions for dead-time adds complexity to the circuit design and slows the system response.

### Shoot-Through Elimination

Conventionally, when seeking to push the limits of PWM design, feedback circuitry is used to determine the state of the outputs and control the switching of the motor driver transistor gates. This implementation can be complex, but when using discrete MOSFET's, it is a workable solution which enables a system to switch faster than would otherwise be possible. When using an

integrated Power+ Array, such as the TPIC5404, the transistor gate characteristics are closely matched. As a result, a much simpler scheme for eliminating shoot-through may be used.

The example circuit uses a resistor and diode at each gate to control shoot-through. The resistor reduces the turn-on time of the motor drive FET's by limiting current to the gate. The diode provides a bypass for the resistor when turning-off, thereby giving a faster transistor turn-off than turn-on. This means that near-simultaneous transitions can be generated by the control logic, without risk of destroying the FET's through simultaneous conduction. Combining this simple scheme for preventing shoot-through with the simplified control logic previously discussed, a worthwhile reduction in system size and cost can be realized when combined with the up-integration benefits of the TPIC5404 Power+ Array.





***Four-Wire 16-Lamp Remote Power and  
Brightness Control With Power+ Logic™***





The two devices, TPIC6A595 and TPIC6595, are Power+ Logic™ shift registers. They can be loaded remotely by means of clock and data signals and cascaded in long chains suitable for (e.g.) video display systems. The input logic function follows the SN74HCxxx numbering convention so that SN74HC595 and TPIC6595 are both shift registers.

The eight outputs are well-specified lateral double-diffused MOSFETs (LDMOS FETs) with excellent avalanche energy characteristics. These ensure that it is possible to

predict their performance in inductive circuits which return energy to the switch. This can prevent the mysterious field failures often encountered with unsnubbed bipolar devices in similar applications. At the time of writing, other members of the family of Power+ Logic devices include the TPIC6273, TPIC6259, and TPIC6A259.

### The Demonstrator

The demonstrator described here provides two cascaded devices and

the schematic shows them driving incandescent lamps (and/or LEDs), Figure 1. The principal features of the two devices are shown in the Power+ Logic block. Figure 2 shows the common device diagram. The input format is a data clock and data signal with a transfer clock pulse to load the holding registers. Figure 3 illustrates the output structure which integrates a substantial protection network. This enhances the avalanche energy capability which in turn helps dissipate the energy returned by (e.g.) inductive loads.

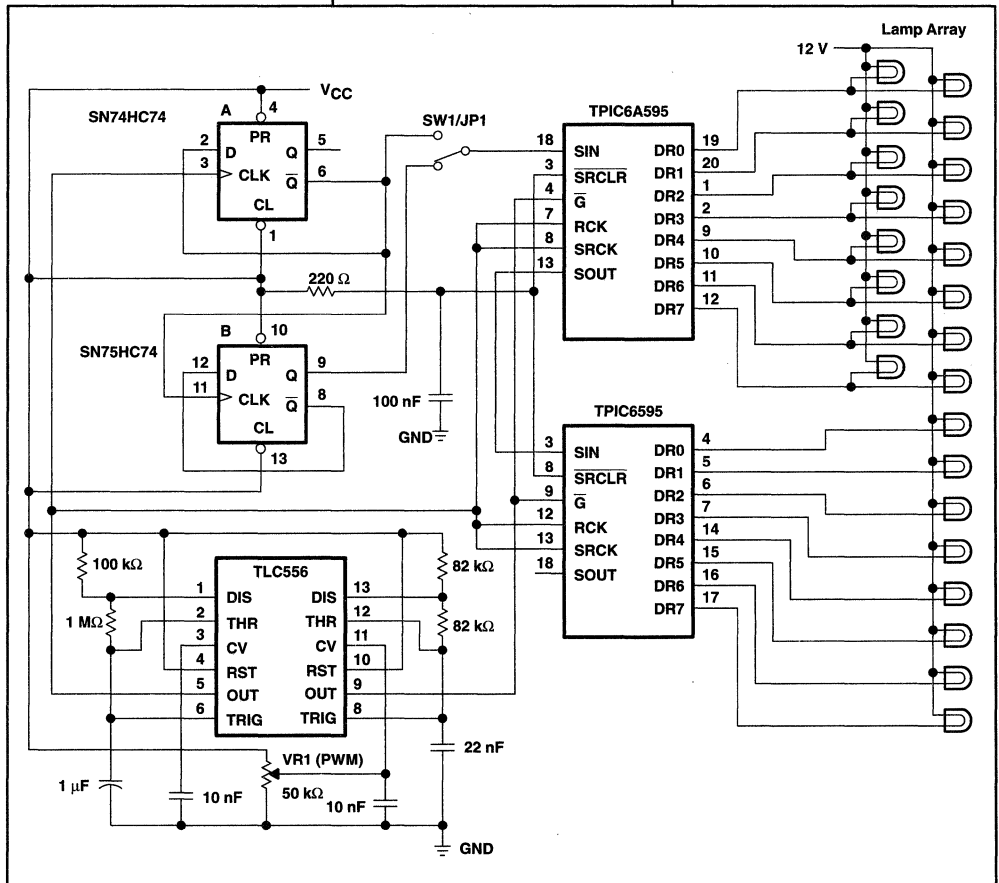


Figure 1. Circuit Schematic

## Power+ Logic

- TPIC6xxx series – 0.25 A, 1.5 A pk, 45 V, 1.3  $\Omega$ , 75 mJ, 20-pin DIP or 20-pin SO package
  - TPIC6259 – 8-Bit addressable latch
  - TPIC6273 – Octal D-type latch
  - TPIC6595 – 8-Bit SIPO (shift register)
- TPIC6Axxx series – 0.35 A, 1.1 A limit, 50 V, 1  $\Omega$ , 75 mJ, 20-pin DIP or 24-pin SO package
  - TPIC6A259 – 8-Bit addressable latch
  - TPIC6A595 – 8-Bit SIPO (shift register)

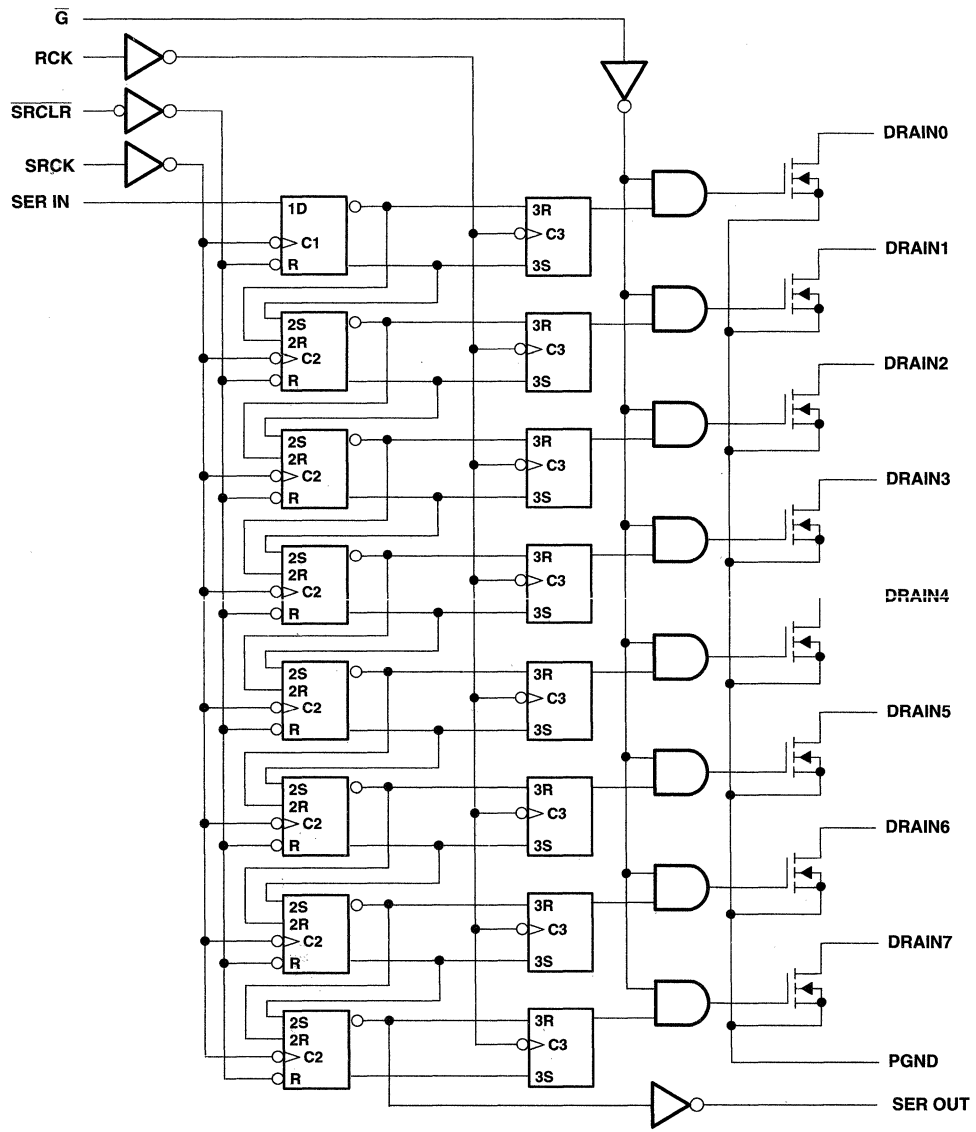


Figure 2. Common Block Diagram of TPIC6595 and TPIC6A595

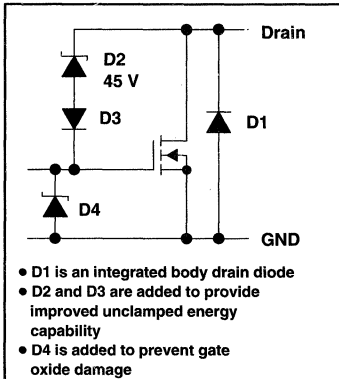


Figure 3. Power+ Logic Output Structure (Typical Schematic - All Drain Outputs)

### PWM and Incandescent Lamps

The pulse-width-modulated (PWM) output current limit on the TPIC6A595 is particularly useful when driving incandescent lamps. These lamps exhibit current surges many times greater than the continuously rated figure when first turned on.

These current surges are due to the considerable change in temperature of the incandescent filament and a corresponding change in its resistance. Figure 4 illustrates a typical current characteristic where a nominally 190 mA lamp takes an initial current of over 2 A from a 15 V supply.

Other advantages to the current limit include immunity from failures due to short circuits at the output and the ability to start larger motors than an unlimited part. It can also be of use when driving stepper motors whose resonance problems are greatly reduced when the motor is current controlled.

The TPIC6595 has been configured to drive either eight incandescent lamps or four lamps and four LEDs. The TPIC6A595 has sixteen lamp positions arranged as eight parallel

pairs to reflect its greater current capability (and PWM current limit). When only eight lamps are to be used, the parallel positions are convenient for evaluating the short-circuit capability or attaching test probes.

The TPIC6A595 has built-in short-circuit protection. The TPIC6595 does not and care should be taken to avoid shorting unprotected outputs.

output holding registers. In a more conventional system, the data would be loaded into all the shift registers using SRCK, then a single pulse of RCK would transfer the data to the holding registers.

The clear input  $\overline{\text{SRCLR}}$  is held high at all times and does not affect the data in either register bank. In another system, it might be used to clear the shift registers before reloading.

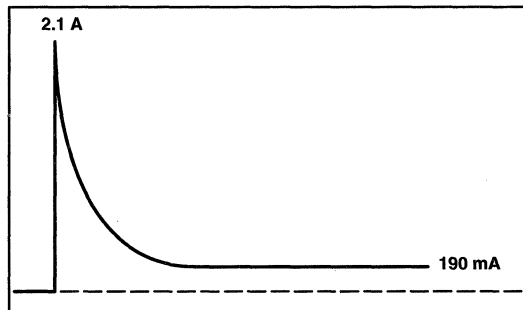


Figure 4. Lamp Inrush Characteristic

### System Logic

The clock and data generator logic is reduced to a minimum; half of the TLC556 dual timer is used to generate a slow clock signal (around 1 Hz). This is used to drive both shift-register (SRCK) and holding register (RCK) clocks, as shown in the block diagram, Figure 5.

Data is therefore clocked into the shift register on the rising edge and is also transferred from there to the

### PWM Brightness Control

The output enable  $\overline{\text{G}}$  is used in conjunction with the other half of the TLC556 to provide a common brightness control for both TPIC devices. This works with the TLC556 configured as an astable PWM generator whose pulse width is altered by VR1. As this is altered, the duty cycle of the TPIC's output enable  $\overline{\text{G}}$  changes. This provides a range of brightness control from very dim to full on.

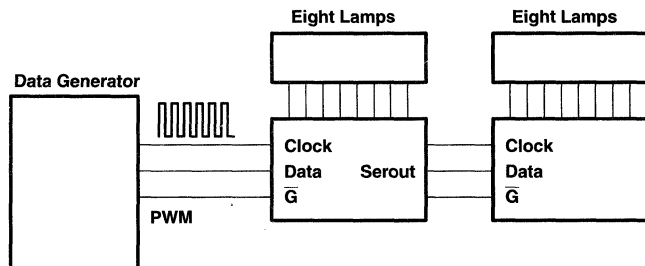


Figure 5. Block Diagram

### Data Generator

Serial data for the TPIC devices is generated by dividing the clock by 2 or by 4 using an SN74HC74. A moving pattern will travel down the two shift registers. The serial data output of the TPIC6A595 is connected to the data input of the TPIC6595. This can be extended to suit the application and is particularly useful with large video LEDs or lamp arrays.

A switch (or jumper) is used to select the data division ratio which causes a change in the pattern of lamp illumination. Should all 1s or all 0s be needed for test purposes, a jumper is recommended rather than a switch. A connection to  $V_{CC}$  or GND can then be made to the center pin.

### Three-Wire, Four-Wire, or Five-Wire Interface

The total connection between the TPIC devices and their control logic is therefore four wires, combined clock (SRCK and RCK), data, output enable ( $\bar{G}$ ), and ground. In a system requiring transparency in the loading of the data, a separate RCK line would be justified. In a minimal system lacking a brightness control, the  $\bar{G}$  wire could be omitted, reducing it to a three-wire interface.

### PCB Layout

The printed circuit board layout is intended to minimize noise problems due to switching high currents adjacent to high-impedance logic inputs and care is taken to decouple  $V_{CC}$  locally on both devices. The short, wide tracking from logic and power grounds to the supply point minimizes the inductive and resistive EMFs generated when switching high currents, as shown in Figure 6. The PCB overlay is shown in Figure 7.

Although the clock in this system is slow, extensive use is made of ground and supply planes. Since the Power+ Logic parts are high speed CMOS logic devices, they can be clocked at over 20 MHz.

This speed is invaluable when driving large arrays such as emulating a video screen with an array of LEDs or even incandescent lamps, see Figure 8.

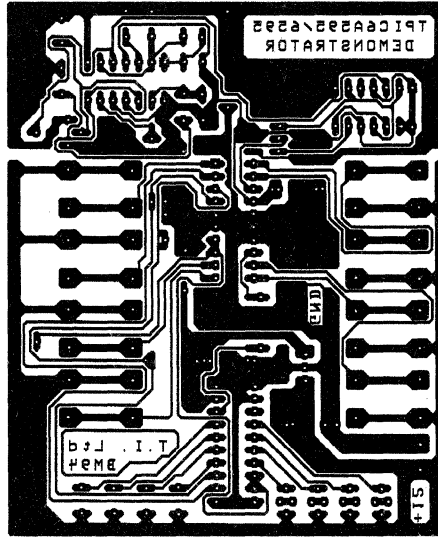


Figure 6. PCB Track Layout (Single-Sided)

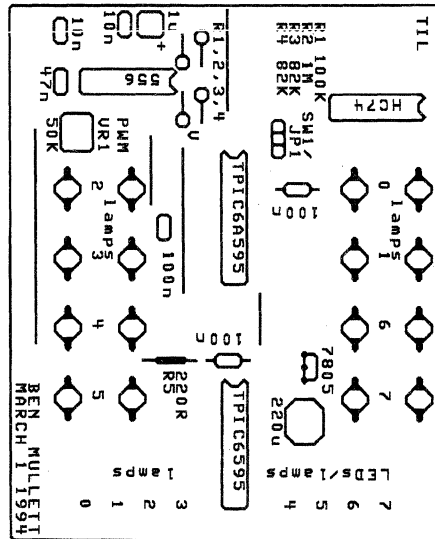


Figure 7. PCB Component Overlay

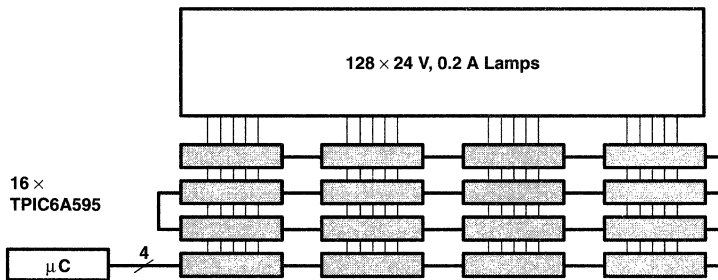


Figure 8. Driving Large Lamp Arrays

### Load Problems

Matching a device to a load can cause problems when the load is as variable as an incandescent lamp. There are limitations even to PWM current limit schemes. For example, the TPIC6A595 PWM current limit is specified in the data sheet to deliver an approximate 2% duty cycle current limited to a peak value of typically 0.8 A.

Should a lamp (or lamps) require more than this to move up the resistance/temperature curve, the output PWM will remain in 2% duty cycle mode indefinitely as in a partial short circuit. It is wise to check what a given type of lamp requires as a start-up current and to remember that this is also temperature dependent. It should be remembered that if the earlier example (the 190 mA lamp) were used with a 250 mA switch, the initial current surge of over 2 A would in all probability destroy a bipolar switch.

To estimate this surge without recourse to dynamic testing of each device, the value of the cold resistance will indicate the size of the initial surge on a given supply voltage. It can be revealing to do this on an existing piece of equipment. Since cold resistance has not always been taken sufficiently into consideration, this may be the underlying cause behind sporadic field failures.

### Summary

In conclusion, the demonstrator shows the ease of driving lamps and LEDs with these Power+ Logic products over a minimal 3-wire interface with improved benefits

when additional signal wires are added. Remote control of lamp brightness is one of these benefits, such as using a PWM control signal on the  $\bar{G}$  enable line.

### Parts List

#### Integrated Circuits

uA7805C	Voltage regulator -5 V, TO-220
TLC556N	Timer IC
SN74HC74N	Dual D-type
TPIC6595N	8-Bit shift register with 250 mA output
TPIC6A595NE	8-Bit shift register with 350 mA output and PWM current limit

#### Passives

1 M $\Omega$	Resistor, 1/8 Watt
100 k $\Omega$	Resistor, 1/8 Watt
82 k $\Omega$ (2)	Resistor, 1/8 Watt
220 $\Omega$	Resistor, 1/8 Watt
50 k $\Omega$	Resistor, variable
220 $\mu$ F	Electrolytic capacitor, 16 V or better
1 $\mu$ F	Electrolytic capacitor, 16 V or better
100 nF	Non-polarized capacitor, 6 V or better
47 nF	Non-polarized capacitor, 6 V or better
10 nF (2)	Non-polarized capacitor, 6 V or better

SPDT switch or jumper as preferred (see text).

#### Lamps

TPIC6595:	8-14 V, 55 mA, sub-miniature lamps or similar, or 4 lamps and 4 LEDs with 4 current-limiting resistors to suit.
TPIC6A595:	8-14 V, 190 mA, 10 mm lamps or similar.





<b>General Information</b>	<b>1</b>
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<b>Peripheral Drivers/Actuators</b>	<b>3</b>
<b>Applications</b>	<b>4</b>
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Mechanical Data

**ORDERING INSTRUCTIONS**

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 three-part type number as shown in the following example.

**Example: TPIC 1301 DW**

**Prefix**

MUST CONTAIN ONE TO FOUR LETTERS

SN ..... TI Special Functions or Interface Products  
 TPIC ..... TI Power IC Products

STANDARD SECOND-SOURCE PREFIXES

DS ..... National  
 L ..... SGS  
 ULN ..... Sprague

**Unique Circuit Description**

MUST CONTAIN THREE OR MORE CHARACTERS  
 (From Individual Data Sheets)

Examples: 293            6B595  
           2701            754410  
           2322L          75437A

**Package**

MUST CONTAIN ONE OR TWO LETTERS

D, DW, FK, JG, KC, KV, N, NE, P  
 (From Pin-Connection Diagram(s) on Individual Data Sheets)

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 (JG, N, NE, P)  
 – A-Channel Antistatic or  
   Conductive Plastic Tubing

Small Outline (D, DW)  
 – Tape and Reel  
 – Antistatic or Conductive  
   Plastic Tubing

Chip Carriers (FK)  
 – Antistatic or Conductive  
   Plastic Tubing

Power Tab (KC, KV)  
 – A-Channel Antistatic or  
   Conductive Plastic Tubing





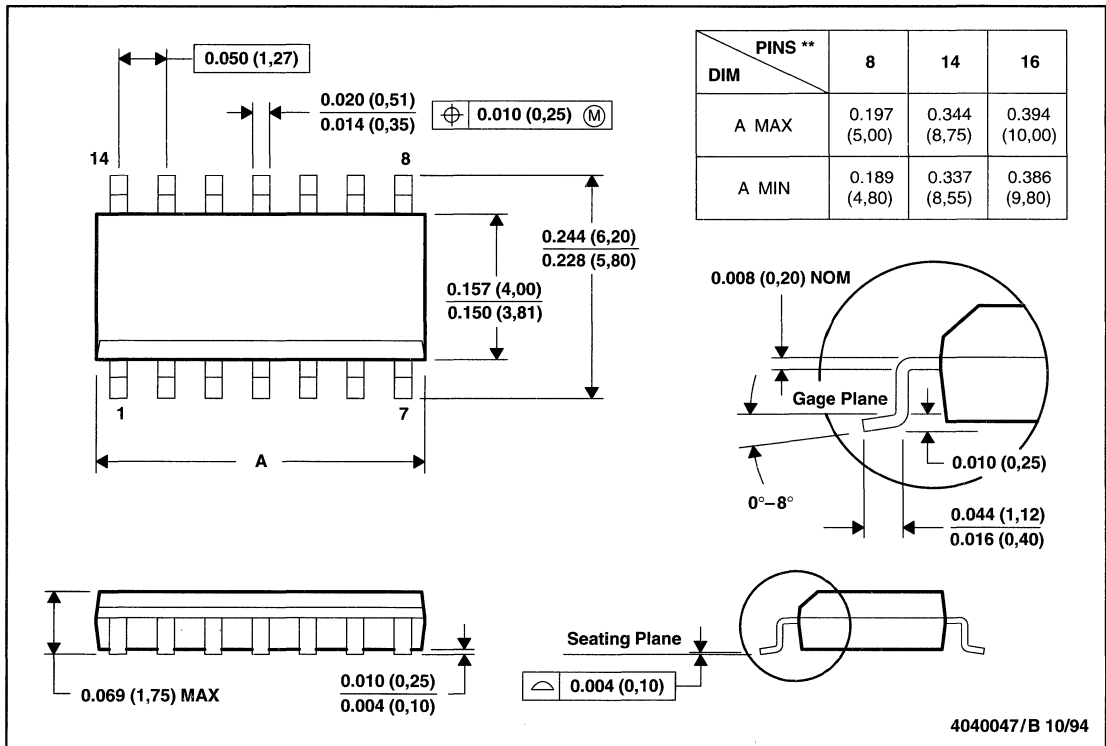
# MECHANICAL DATA

JANUARY 1996

D (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



- 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. Four center pins are connected to die mount pad.  
 E. Falls within JEDEC MS-012

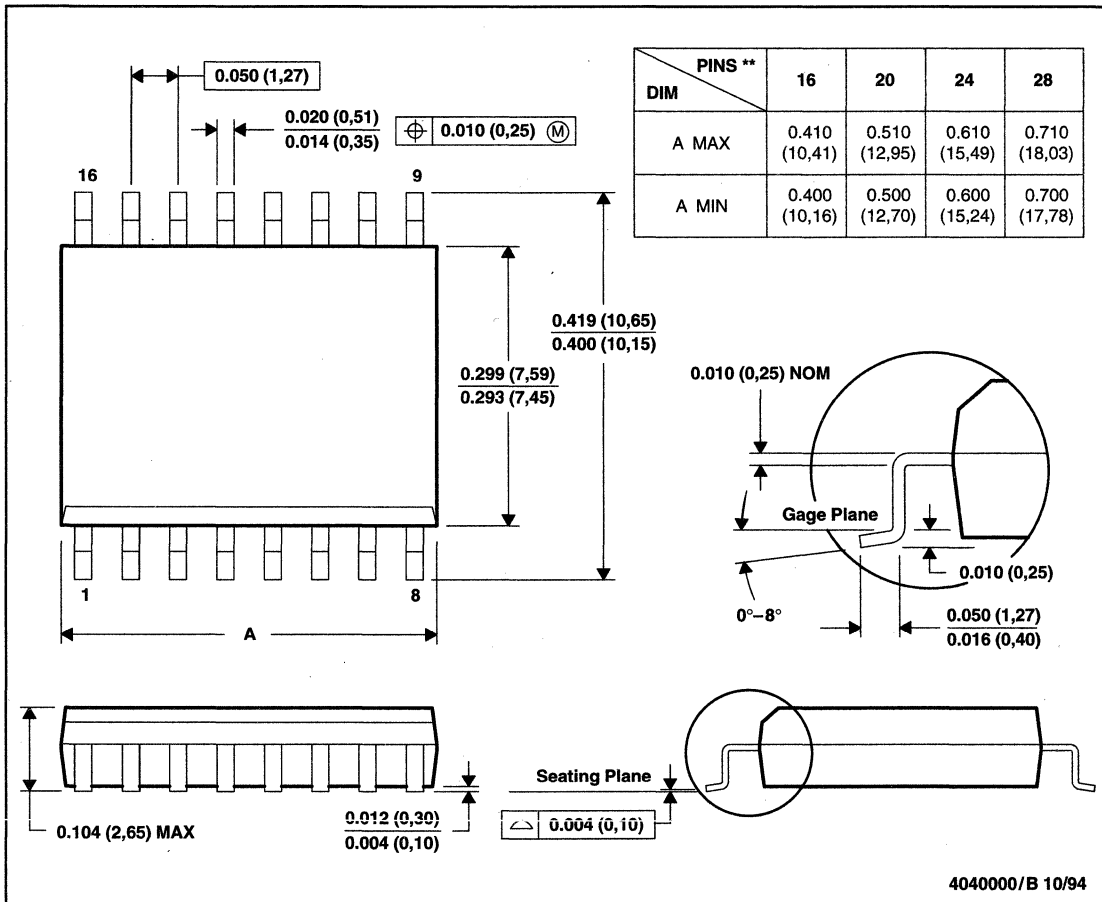
# MECHANICAL DATA

JANUARY 1996

DW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

16 PIN SHOWN



- 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-013

4040000/B 10/94

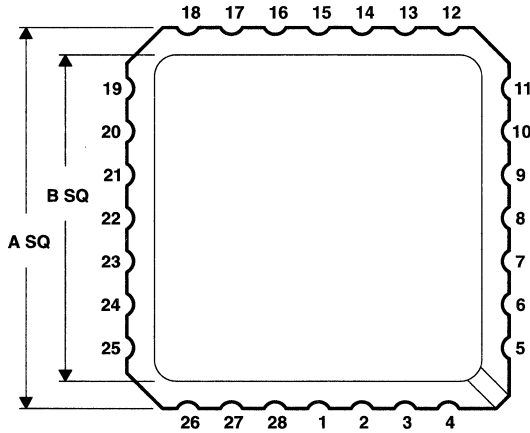
# MECHANICAL DATA

JANUARY 1996

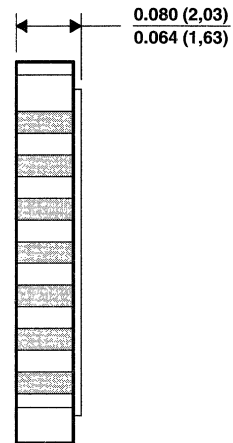
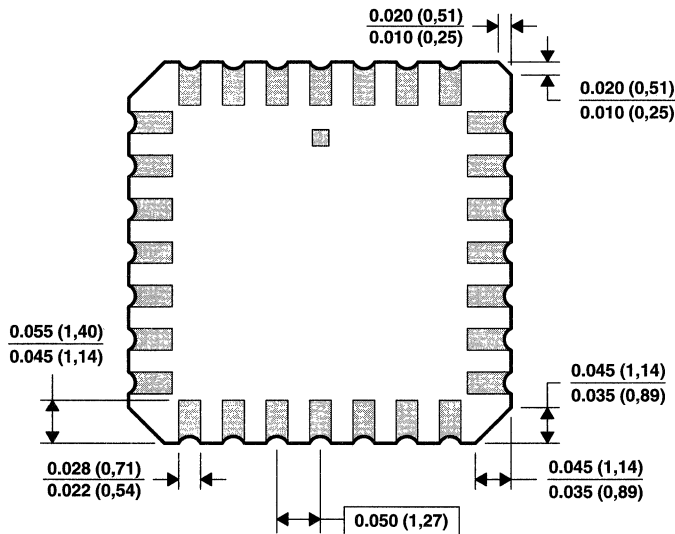
FK (S-CQCC-N\*\*)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



4040140/C 11/95

- 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

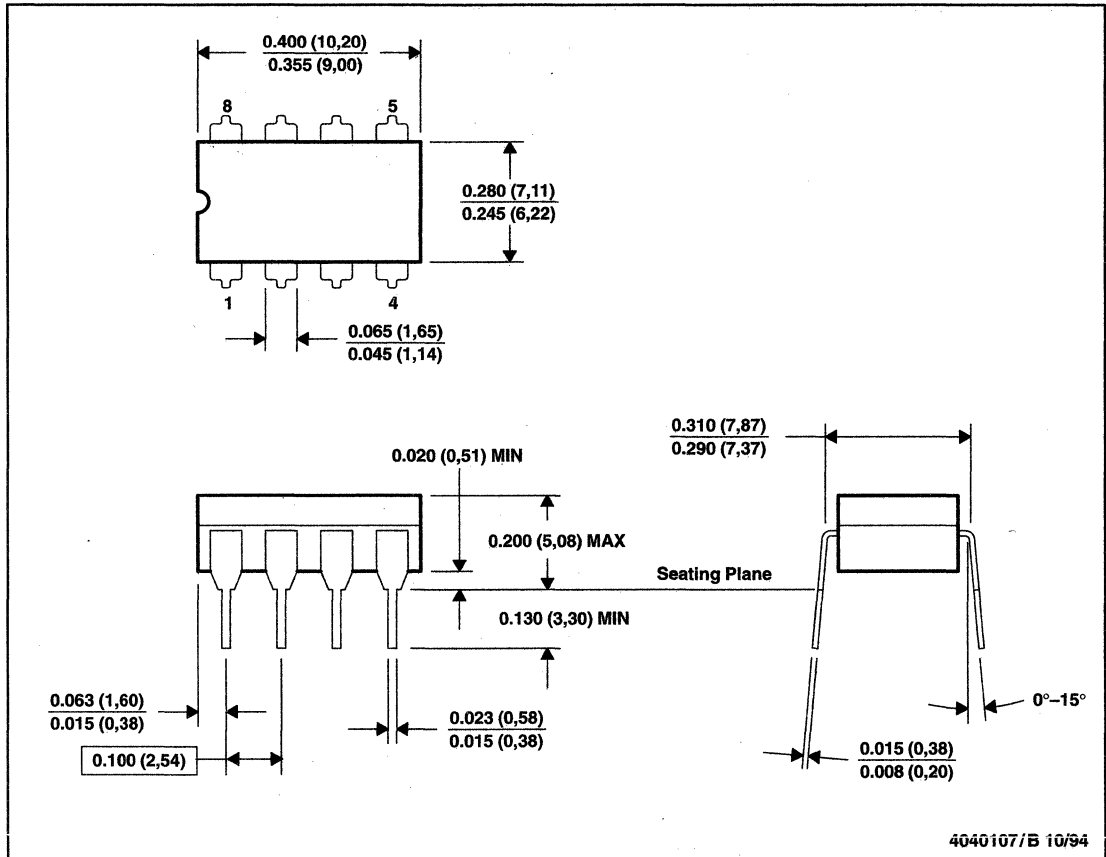


# MECHANICAL DATA

JANUARY 1996

JG (R-GDIP-T8)

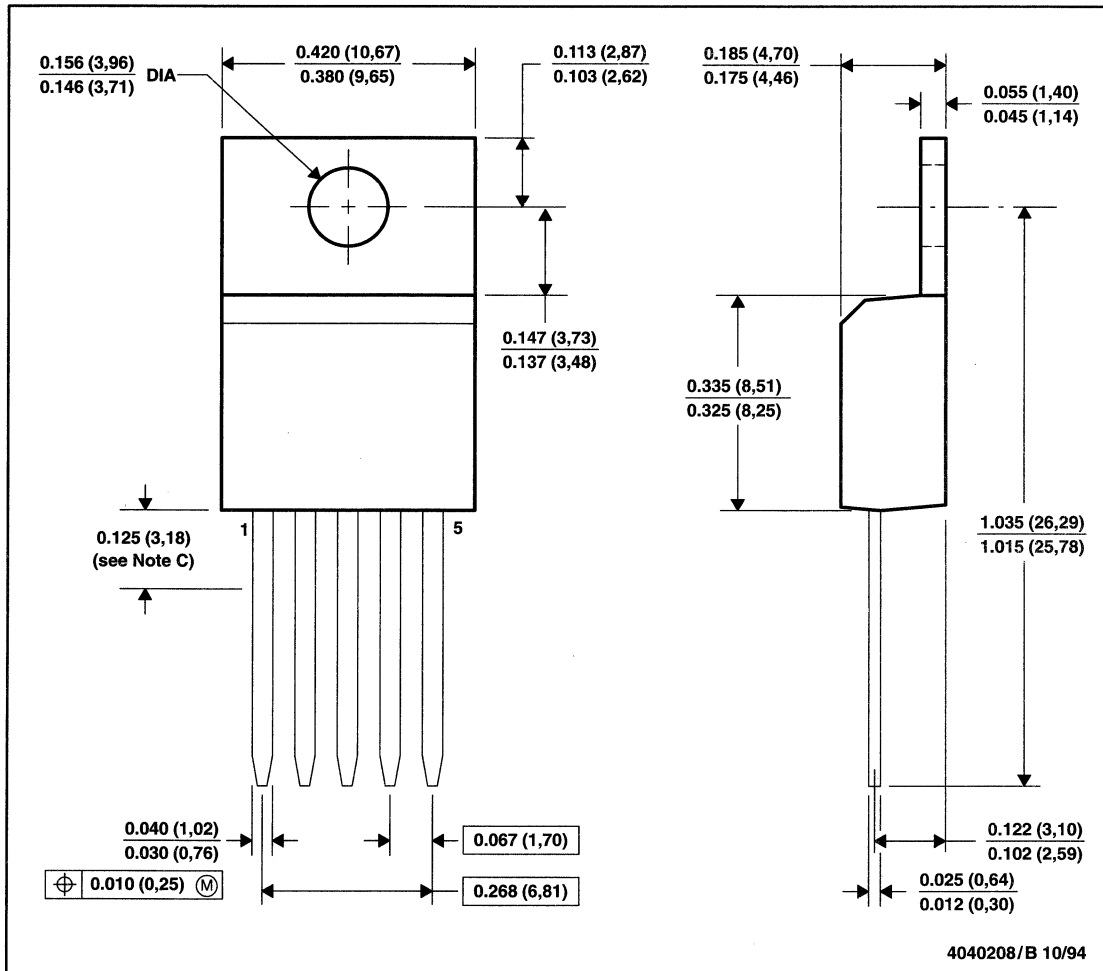
CERAMIC DUAL-IN-LINE PACKAGE



- 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

KC (R-PSFM-T5)

PLASTIC FLANGE-MOUNT PACKAGE



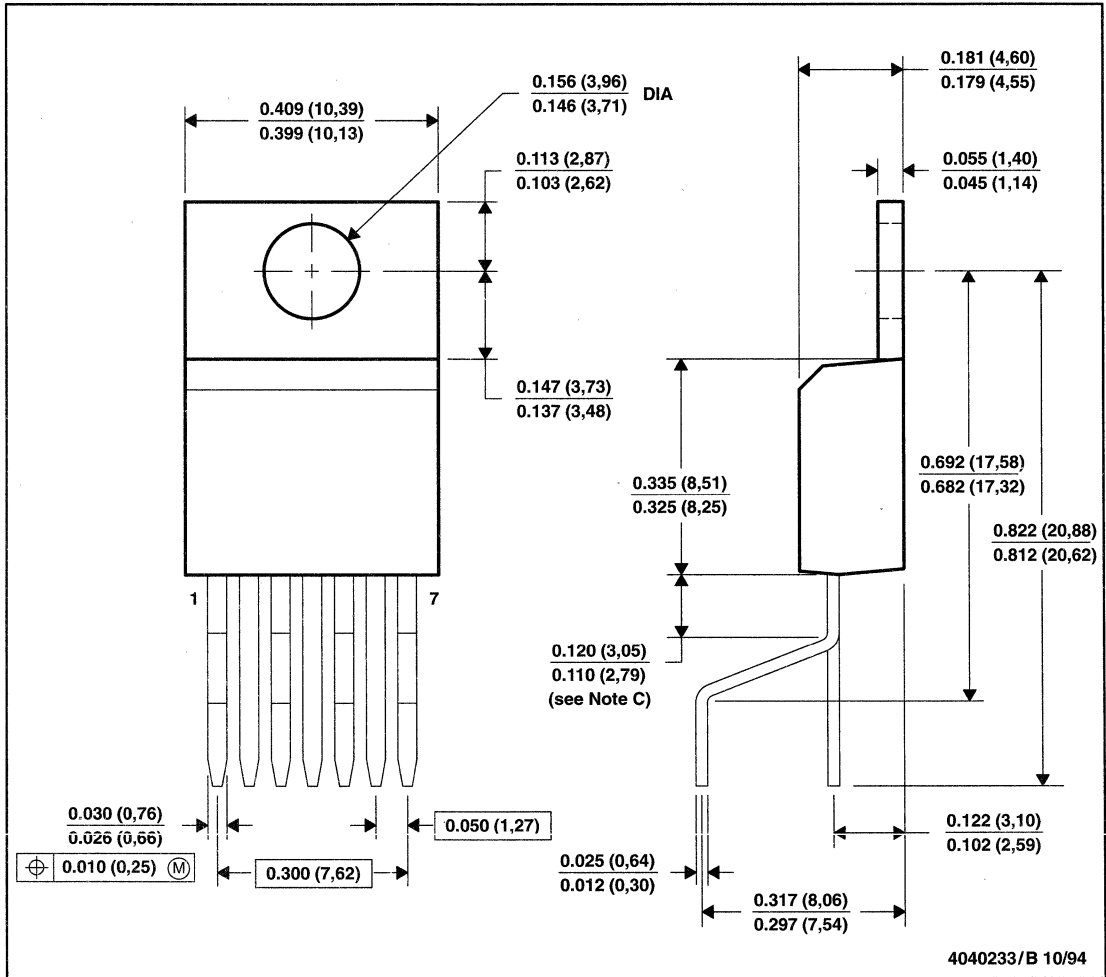
- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Lead dimensions are not controlled within this area.  
 D. All lead dimensions apply before solder dip.  
 E. The center lead is in electrical contact with the mounting tab.

# MECHANICAL DATA

JANUARY 1996

KV (R-PZFM-T7)

PLASTIC FLANGE-MOUNT PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Lead dimensions are not controlled within this area.  
 D. All lead dimensions apply before solder dip.

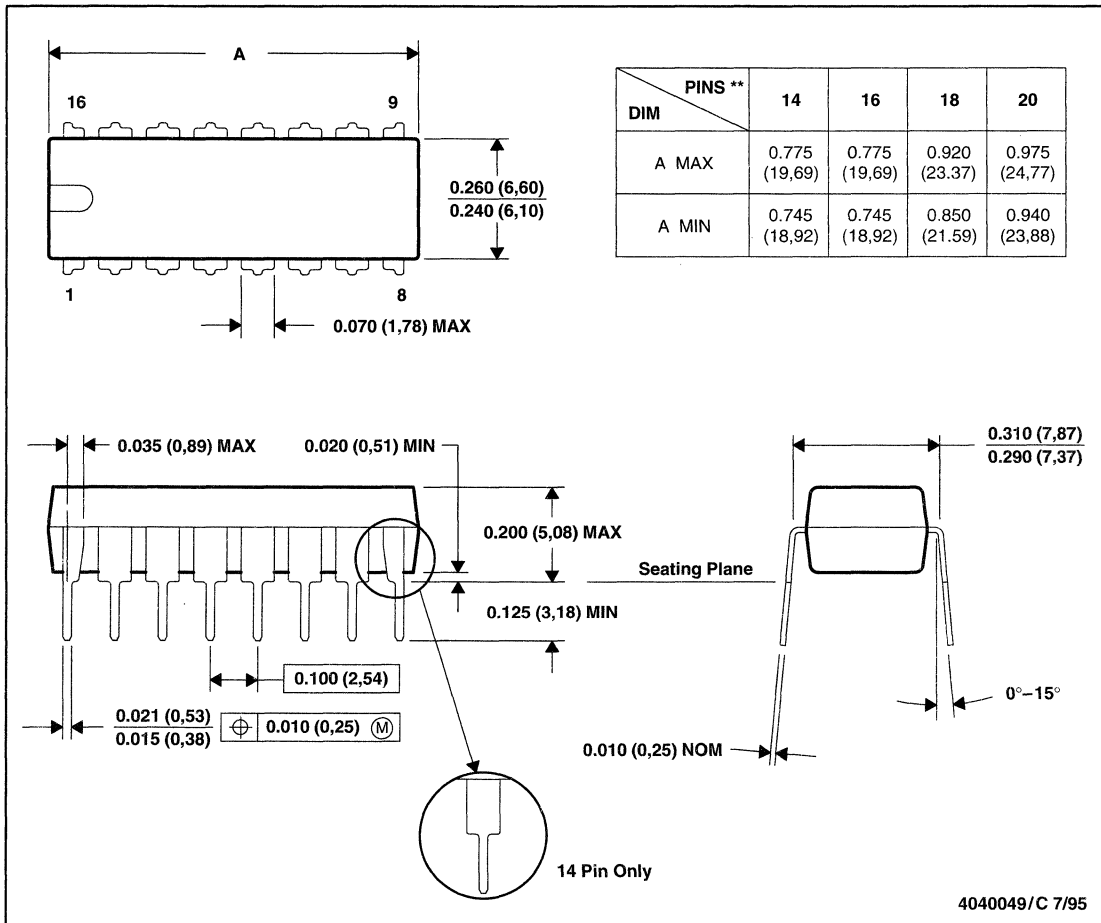
# MECHANICAL DATA

JANUARY 1996

**N (R-PDIP-T\*\*)**

**PLASTIC DUAL-IN-LINE PACKAGE**

16 PIN SHOWN



- 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 than MS-001)

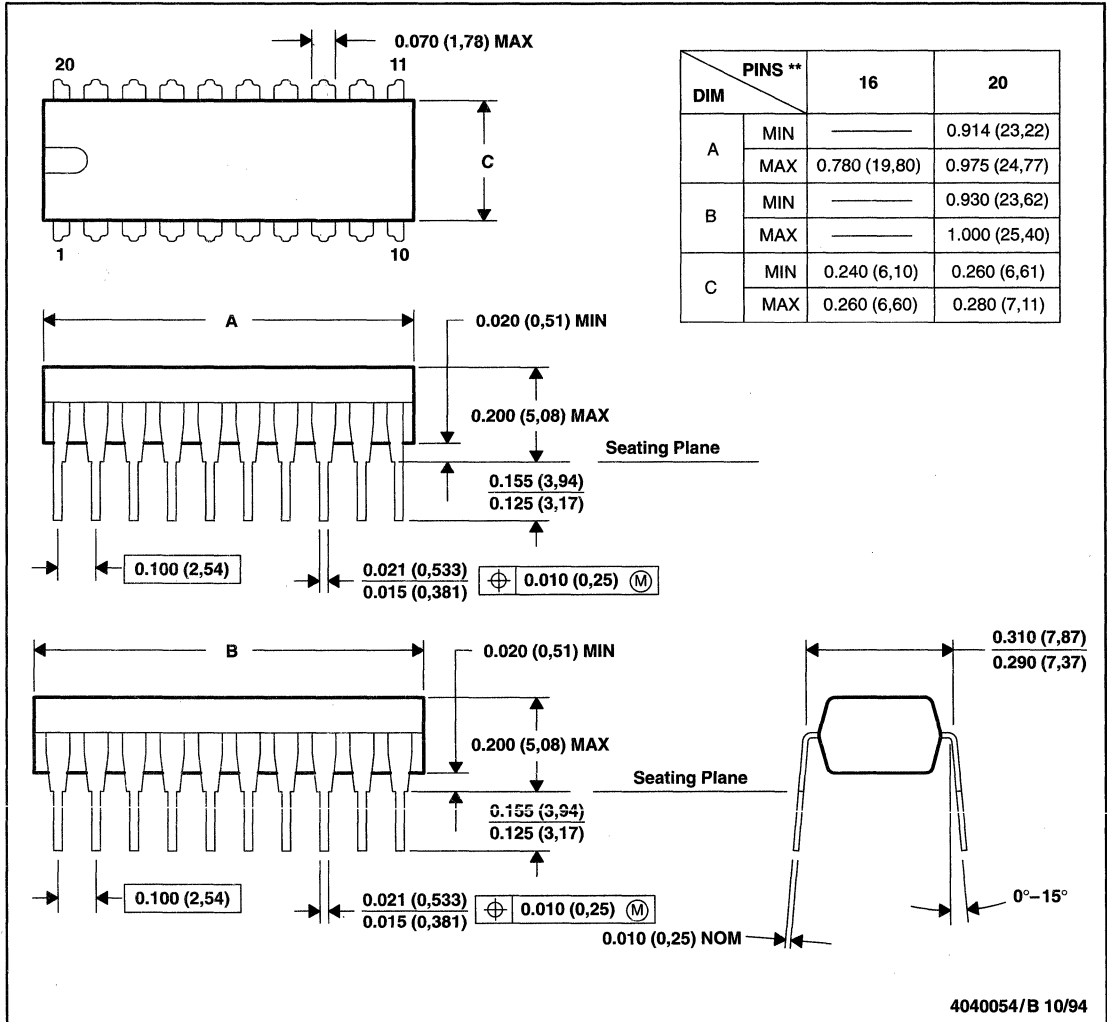
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JANUARY 1996

NE (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

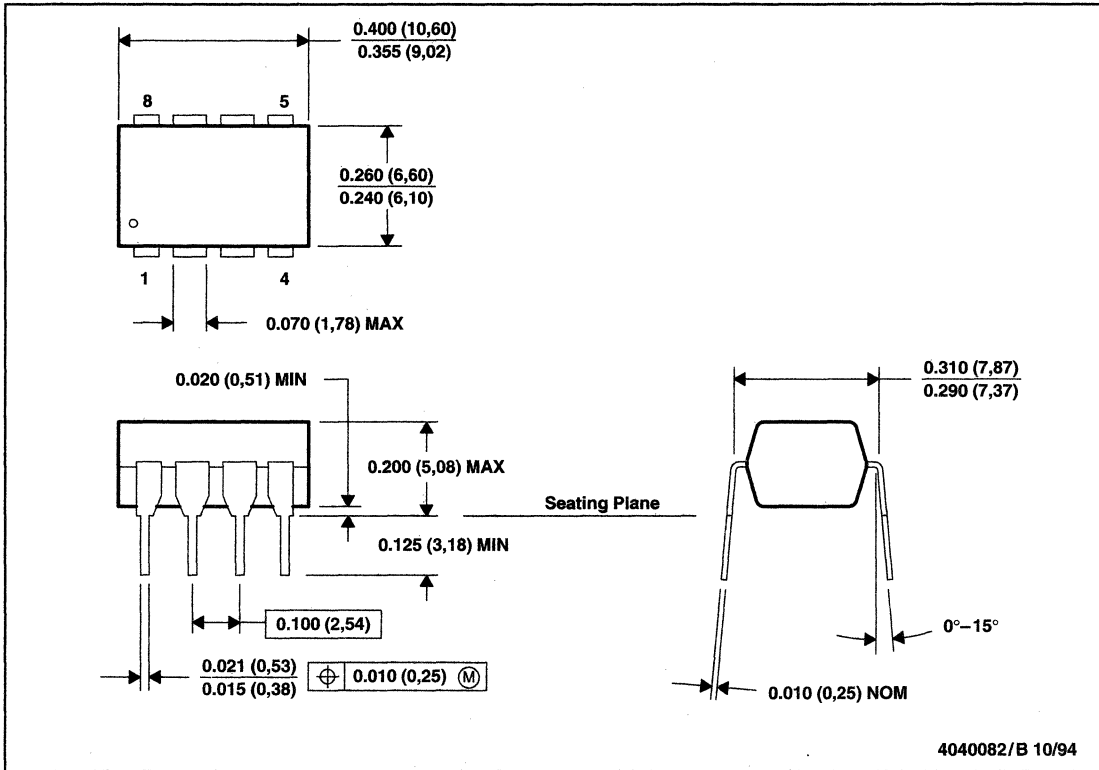
20 PIN SHOWN



- 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)

P (R-PDIP-T8)

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



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**NOTES**



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