UNITRODE SEMICONDUCTOR DATABOOK 1982-1983

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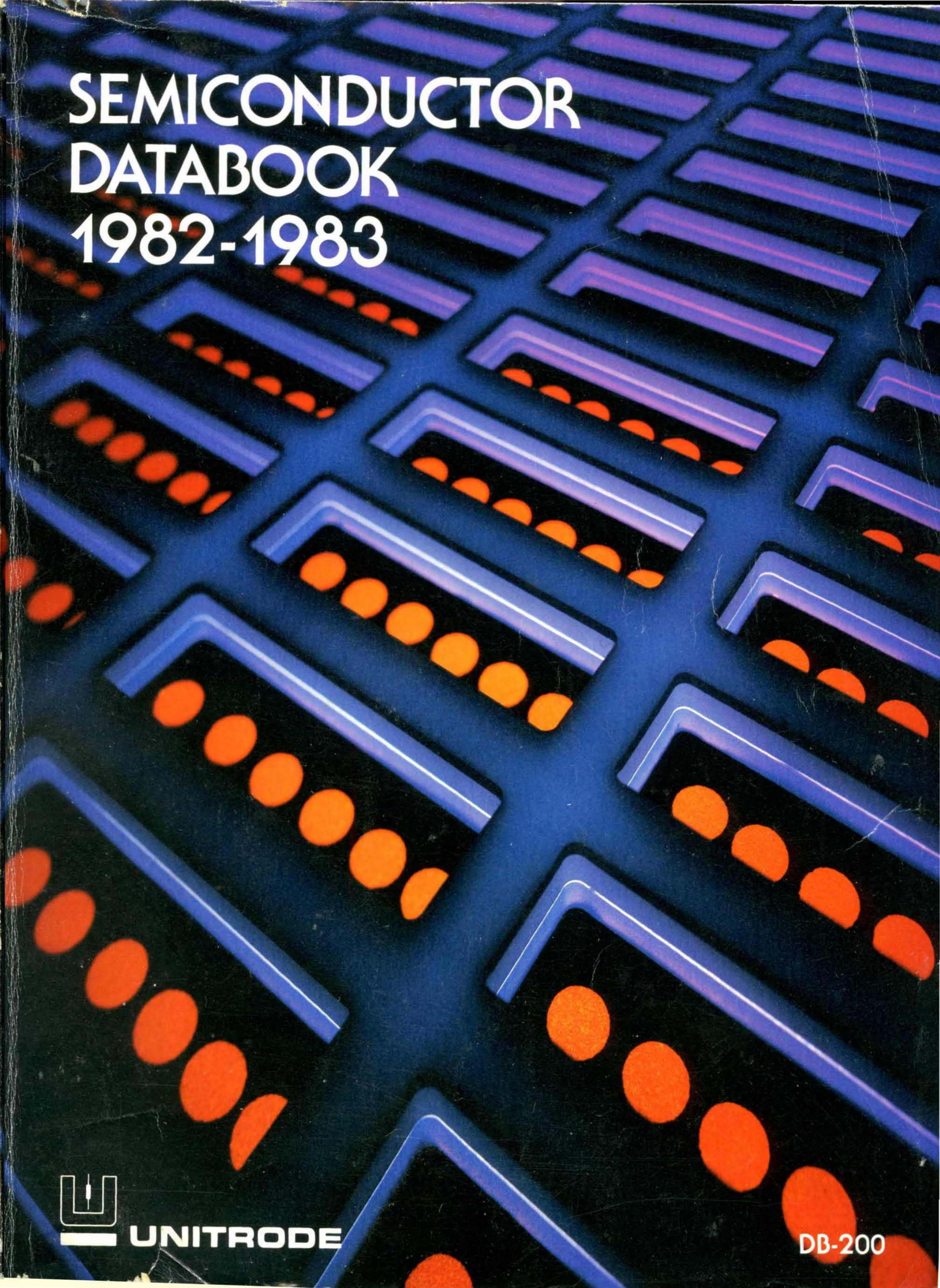

UNITRODE

DB-200

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INTRODUCTION

Unitrode is recognized today as a world-wide leader in the design, manufacture and marketing of discrete semiconductor components. From its inception more than twenty-two years ago, Unitrode has earned and maintained a reputation of setting the highest standards of reliability and performance. Excellence was first established with a unique packaging concept for axial-leaded rectifiers and zeners for the military market. This fused-in-glass product is still unsurpassed in its reliability and performance. This year, Unitrode has entered a major, new semiconductor market and is now offering Linear Integrated Circuits.

Unitrode offers a broad line of other semiconductor products including:

1) Power Transistors and Darlingtons
2) Power Hybrid Circuits
3) Rectifiers
4) High Voltage Rectifiers, Rectifier Modules and Multipliers
5) Rectifier Bridge Assemblies
6) Power Zeners and Transient Voltage Suppressors
7) SCRs and Triacs
8) Switching and General Purpose Diodes
9) PIN Diodes

We are also the world's leading manufacturer of glass-encapsulated axial-leaded monolithic ceramic capacitors and, now of Sensistors®. We offer data acquisition and conversion products through our Micro Networks Division in Worcester, Massachusetts and miniaturized power supply modules through our Powercube subsidiary in Billerica, Massachusetts.

Unitrode's products are designed to meet the demands of many markets including:

Data Processing

Telecommunications

Instrumentation

Military

Industrial Controls

Nine component manufacturing plants in three countries, thirteen sales offices and a world-wide network of sales representatives and distributors help us to serve you better. We take pride in our products, and know they will add more value to your company's products.

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*	1N458A	100mA; 150V
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PAGE	PART NUMBER	DESCRIPTION
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724	1N4447	200mA; 75V; DO-35
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*	1N5180	4.0A; 100V
478	1N5181 (HVE40)	4.0kV
478	1N5182 (HVE50)	5.0kV
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478	1N5184 (HVE100)	10.0kV
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*	1N5207	4.0A; 400V
*	1N5320	1.0A; 120V
*	1N5330	0.5A; 1500V
315	1N5415, J, JTX, JTXV	3.0A; 50V
315	1N5416, J, JTX, JTXV	3.0A; 100V
315	1N5417, J, JTX, JTXV	3.0A; 200V

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PAGE	PART NUMBER	DESCRIPTION
		RECTIFIER
315	1N5418, J, JTX, JTXV	3.0A; 400V
315	1N5419, J, JTX, JTXV	3.0A; 500V
315	1N5420, J, JTX, JTXV	3.0A; 600V
*	1N5433	2.0A; 700V
*	1N5434	2.0A; 700V
*	1N5435	12.0A; 700V
		RECTIFIER
317	1N5550, J, JTX, JTXV	5.0A; 200V
317	1N5551, J, JTX, JTXV	5.0A; 400V
317	1N5552, J, JTX, JTXV	5.0A; 600V
317	1N5553, J, JTX, JTXV	5.0A; 800V
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471	1N5600, J	5.0kV
471	1N5603, J	5.0kV
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592	1N5610, J, JTX	33V
592	1N5611, J, JTX	43.7V
592	1N5612, J, JTX	54V
592	1N5613, J, JTX	191V
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319	1N5614, J, JTX, JTXV	1.0A; 200V
321	1N5615, J, JTX, JTXV	1.0A; 200V
319	1N5616, J, JTX, JTXV	1.0A; 400V
321	1N5617, J, JTX, JTXV	1.0A; 400V
319	1N5618, J, JTX, JTXV	1.0A; 600V
321	1N5619, J, JTX, JTXV	1.0A; 600V
319	1N5620, J, JTX, JTXV	1.0A; 800V
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741	1N5767	General Purpose, PIN
		RECTIFIER
323	1N5802	2.5A; 50V
327	1N5802, J, JTX, JTXV	2.5A; 50V
323	1N5803	2.5A; 75V
323	1N5804	2.5A; 100V
327	1N5804, J, JTX, JTXV	2.5A; 100V
323	1N5805	2.5A; 125V
323	1N5806	2.5A; 150V
327	1N5806, J, JTX, JTXV	2.5A; 150V
323	1N5807	6.0A; 50V
327	1N5807, J, JTX, JTXV	6.0A; 50V
323	1N5808	6.0A; 75V
323	1N5809	6.0A; 100V
327	1N5809, J, JTX, JTXV	6.0A; 100V
323	1N5810	6.0A; 125V
323	1N5811	6.0A; 150V
327	1N5811, J, JTX, JTXV	6.0A; 150V
323	1N5812	20.0A; 50V; DO-4
330	1N5812, J, JTX, JTXV	20.0A; 50V; DO-4
323	1N5813	20.0A; 75V; DO-4
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330	1N5814, J, JTX, JTXV	20.0A; 100V; DO-4
323	1N5815	20.0A; 125V; DO-4
323	1N5816	20.0A; 150V; DO-4
330	1N5816, J, JTX, JTXV	20.0A; 150V; DO-4
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332	1N5818	1.0A; 30V; ASA
332	1N5819	1.0A; 40V; ASA
334	1N5820	3.0A; 20V; ASB
334	1N5821	3.0A; 30V; ASB
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PAGE	PART NUMBER	DESCRIPTION
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590	1N5968	5.0W; 5%
590	1N5969	5.0W; 5%
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336	1N6096	25A; 40V; DO-4
338	1N6097	50A; 30V; DO-5
338	1N6098	50A; 40V; DO-5
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340	1N6304, J, JTX, JTXV	70A; 50V; DO-5
340	1N6305, J, JTX, JTXV	70A; 100V; DO-5
340	1N6306, J, JTX, JTXV	70A;150V; DO-5
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594	1N6462, J, JTX, JTXV	6.0V
594	1N6463, J, JTX, JTXV	12.0V
594	1N6464, J, JTX, JTXV	15.0V
594	1N6465, J, JTX, JTXV	24.0V
594	1N6466, J, JTX, JTXV	30.5V
594	1N6467, J, JTX, JTXV	40.3V
594	1N6468, J, JTX, JTXV	51.6V
		SCR
*	2N876	.35A@100°C 15V; TO-18
*	2N877	.35A@100°C 30V; TO-18
*	2N878	.35A@100°C 60V; TO-18
*	2N879	.35A@100°C 100V; TO-18
*	2N880	.35A@100°C 150V; TO-18
*	2N881	.35A@100°C 200V; TO-18
*	2N882	.35A@100°C 300V; TO-18
*	2N883	.35A@100°C 400V; TO-18
*	2N884	.35A@100°C 15V; TO-18
*	2N885	.35A@100°C 30V; TO-18
*	2N886	.35A@100°C 60V; TO-18
*	2N887	.35A@100°C 100V; TO-18
*	2N888	.35A@100°C 150V; TO-18
*	2N889	.35A@100°C 200V; TO-18
*	2N890	.35A@100°C 300V; TO-18
*	2N891	.35A@100°C 400V; TO-18
*	2N948	.26A@125°C 30V; TO-18
*	2N949	.26A@125°C 60V; TO-18
*	2N950	.26A@125°C 100V; TO-18
*	2N951	.26A@125°C 200V; TO-18
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*	2N1596	1.0A@80°C 100V; TO-39
*	2N1597	1.0A@80°C 200V; TO-39
*	2N1598	1.0A@80°C 300V; TO-39
*	2N1599	1.0A@80°C 400V; TO-39
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*	2N1648	NPN; 3.0A; 80V; TO-59
*	2N1649	NPN; 3.0A; 60V; TO-59
*	2N1650	NPN; 3.0A; 80V; TO-59
*	2N1714	NPN; 0.75A; 60V; TO-5
*	2N1715	NPN; 0.75A; 100V; TO-5
*	2N1716	NPN; 0.75A; 60V; TO-5
*	2N1717	NPN; 0.75A; 100V; TO-5
*	2N1718	NPN; 0.75A; 60V; TO-5; Stud Mount
*	2N1719	NPN; 0.75A; 100V; TO-5; Stud Mount
*	2N1720	NPN; 0.75A; 60V; TO-5; Stud Mount
*	2N1721	NPN; 0.75A; 100V; TO-5; Stud Mount

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PAGE	PART NUMBER	DESCRIPTION
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*	2N6580	NPN; 10A; 400V; TO-3
*	2N6581	NPN; 10A; 450V; TO-3
*	2N6582	NPN; 10A; 350V; TO-3
*	2N6583	NPN; 10A; 400V; TO-3
*	2N6584	NPN; 10A; 450V; TO-3
196	2N6671	NPN; 8A; 450V; TO-3
196	2N6672	NPN; 8A; 550V; TO-3
196	2N6673	NPN; 8A; 650V; TO-3
200	2N6674	NPN; 10A; 450V; TO-3
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204	2N6678	NPN; 15A; 650V; TO-3
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	2N6682 (IP202)	1A; 200V; TO-92
	2N6683 (IP204)	1A; 400V; TO-92
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	2N6685 (IP208)	1A; 800V; TO-92
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535	469-2, J, JTX	1 ph; 10A; 400V
535	469-3, J, JTX	1 ph; 10A; 600V
537	483-1, JTX	3 ph; 25.0A; 200V
537	483-2, JTX	3 ph; 25.0A; 400V
537	483-3, JTX	3 ph; 25.0A; 600V
539	673-1	1 ph; 1.5A; 100V
539	673-2	1 ph; 1.5A; 200V
539	673-3	1 ph; 1.5A; 300V
539	673-4	1 ph; 1.5A; 400V
539	673-5	1 ph; 1.5A; 500V
539	673-6	1 ph; 1.5A; 600V
541	673-7	1 ph; 0.6A; 1200V
541	673-7.5	1 ph; 0.5A; 1800V
541	673-8	1 ph; 0.4A; 2400V
541	673-8.5	1 ph; 0.3A; 3000V
541	673-9	1 ph; 0.2A; 3600V
541	673-10	1 ph; .18A; 4200V
541	673-11	1 ph; .16A; 4800V
541	673-12	1 ph; .16A; 5000V
539	676-1	1 ph; 1.0A; 100V
539	676-2	1 ph; 1.0A; 200V
539	676-3	1 ph; 1.0A; 300V
539	676-4	1 ph; 1.0A; 400V
539	676-5	1 ph; 1.0A; 500V
539	676-6	1 ph; 1.0A; 600V
541	676-12	1 ph; 0.4A; 1200V
541	676-18	1 ph; .35A; 1800V
541	676-24	1 ph; .325A; 2400V
541	676-30	1 ph; .25A; 3000V
541	676-36	1 ph; .175A; 3600V
541	676-42	1 ph; .15A; 4200V
541	676-48	1 ph; .135A; 4800V
541	676-50	1 ph; .125A; 5000V
544	678-1	3 ph; 25A; 100V
544	678-2	3 ph; 25A; 200V
544	678-3	3 ph; 25A; 300V
544	678-4	3 ph; 25A; 400V
544	678-5	3 ph; 25A; 500V
544	678-6	3 ph; 25A; 600V
547	679-1	1 ph; 25A; 100V
547	679-2	1 ph; 25A; 200V
547	679-3	1 ph; 25A; 300V
547	679-4	1 ph; 25A; 400V
547	679-5	1 ph; 25A; 500V

PAGE	PART NUMBER	DESCRIPTION
		FULL WAVE BRIDGE
547	679-6	1 ph; 25A; 600V
547	680-1	1 ph; 10A; 100V
547	680-2	1 ph; 10A; 200V
547	680-3	1 ph; 10A; 300V
547	680-4	1 ph; 10A; 400V
547	680-5	1 ph; 10A; 500V
547	680-6	1 ph; 10A; 600V
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550	681-1	15A; 100V
550	681-2	15A; 200V
550	681-3	15A; 300V
550	681-4	15A; 400V
550	681-5	15A; 500V
550	681-6	15A; 600V
		FULL WAVE BRIDGE
544	682-1	3 ph; 20A; 100V
544	682-2	3 ph; 20A; 200V
544	682-3	3 ph; 20A; 300V
544	682-4	3 ph; 20A; 400V
544	682-5	3 ph; 20A; 500V
544	682-6	3 ph; 20A; 600V
547	683-1	1 ph; 20A; 100V
547	683-2	1 ph; 20A; 200V
547	683-3	1 ph; 20A; 300V
547	683-4	1 ph; 20A; 400V
547	683-5	1 ph; 20A; 500V
547	683-6	1 ph; 20A; 600V
547	684-1	1 ph; 10A; 100V
547	684-2	1 ph; 10A; 200V
547	684-3	1 ph; 10A; 300V
547	684-4	1 ph; 10A; 400V
547	684-5	1 ph; 10A; 500V
547	684-6	1 ph; 10A; 600V
		RECTIFIER MODULE
474	688-10	10kV
474	688-12	12kV
474	688-15	15kV
474	688-18	18kV
474	688-20	20kV
474	688-25	25kV
		DOUBLER OR CENTER-TAP
550	689-1	15A; 100V
550	689-2	15A; 200V
550	689-3	15A; 300V
550	689-4	15A; 400V
550	689-5	15A; 500V
550	689-6	15A; 600V
		FULL WAVE BRIDGE
544	695-1	3 ph; 15A; 100V
544	695-2	3 ph; 15A; 200V
544	695-3	3 ph; 15A; 300V
544	695-4	3 ph; 15A; 400V
544	695-5	3 ph; 15A; 500V
544	695-6	3 ph; 15A; 600V
544	696-1	3 ph; 15A; 100V
544	696-2	3 ph; 15A; 200V
544	696-3	3 ph; 15A; 300V
544	696-4	3 ph; 15A; 400V
544	696-5	3 ph; 15A; 500V
544	696-6	3 ph; 15A; 600V
552	697-1	1 ph; 2.5A; 100V
552	697-2	1 ph; 2.5A; 200V
552	697-3	1 ph; 2.5A; 300V

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PAGE	PART NUMBER	DESCRIPTION
		LINEAR INTEGRATED CIRCUITS
*	UC340-15T	1A; +15V; TO-220; Precision Fixed Reg.
61	UC350K	3A; TO-3; Pos. Adj. Reg.
		FULL WAVE BRIDGE
*	UC3BA1	3 ph; 25A; 100V
*	UC3BA2	3 ph; 25A; 200V
*	UC3BA4	3 ph; 25A; 400V
*	UC3BA6	3 ph; 25A; 600V
*	UC3BA1F	3 ph; 20A; 100V
*	UC3BA2F	3 ph; 20A; 200V
*	UC3BA4F	3 ph; 20A; 400V
*	UC3BA6F	3 ph; 20A; 600V
		LINEAR INTEGRATED CIRCUITS
65	UC493AJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC493AN	40V; 200mA; Precision PWM; Plastic Dip
65	UC494AJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC494AN	40V; 200mA; Precision PWM; Plastic Dip
65	UC495AJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC495AN	40V; 200mA; Precision PWM; Plastic Dip
65	UC493ACJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC493ACN	40V; 200mA; Precision PWM; Plastic Dip
65	UC494ACJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC494ACN	40V; 200mA; Precision PWM; Plastic Dip
65	UC495ACJ	40V; 200mA; Precision PWM; Ceramic Dip
65	UC495ACN	40V; 200mA; Precision PWM; Plastic Dip
74	UC1524AJ	60V; 200mA; Precision PWM; Ceramic Dip
74	UC1524AN	60V; 200mA; Precision PWM; Plastic Dip
69	UC1524J	40V; 100mA; PWM; Ceramic Dip
69	UC1524N	40V; 100mA; PWM; Plastic Dip
78	UC1525AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC1525AN	40V; 500mA; Precision PWM; Plastic Dip
78	UC1527AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC1527AN	40V; 500mA; Precision PWM; Plastic Dip
*	UC1840J	40V; 200mA; PWM Controller; Ceramic Dip
*	UC1840N	40V; 200mA; PWM Controller; Plastic Dip
74	UC2524AJ	60V; 200mA; Precision PWM; Ceramic Dip
74	UC2524AN	60V; 200mA; Precision PWM; Plastic Dip
69	UC2524J	40V; 100mA; PWM; Ceramic Dip

PAGE	PART NUMBER	DESCRIPTION
		LINEAR INTEGRATED CIRCUITS
69	UC2524N	40V; 100mA; PWM; Plastic Dip
78	UC2525AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC2525AN	40V; 500mA; Precision PWM; Plastic Dip
78	UC2527AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC2527AN	40V; 500mA; Precision PWM; Plastic Dip
*	UC2840J	40V; 200mA; PWM Controller; Plastic Dip
*	UC2840N	40V; 200mA; PWM Controller; Ceramic Dip
74	UC3524AJ	50V; 200mA; Precision PWM; Ceramic Dip
74	UC3524AN	50V; 200mA; Precision PWM; Plastic Dip
69	UC3524J	40V; 100mA; PWM; Ceramic Dip
69	UC3524N	40V; 100mA; PWM; Plastic Dip
78	UC3525AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC3525AN	40V; 500mA; Precision PWM; Plastic Dip
78	UC3527AJ	40V; 500mA; Precision PWM; Ceramic Dip
78	UC3527AN	40V; 500mA; Precision PWM; Plastic Dip
*	UC3840J	40V; 200mA; PWM Controller; Plastic Dip
*	UC3840N	40V; 200mA; PWM Controller; Ceramic Dip
91	UC7805ACK	1A; +5V; TO-3; Precision Fixed Reg.
91	UC7805ACT	1A; +5V; TO-220; Precision Fixed Reg.
91	UC7805AK	1A; +5V; TO-3; Precision Fixed Reg.
85	UC7805CK	1A; +5V; TO-3; Fixed Reg.
85	UC7805CT	1A; +5V; TO-220; Fixed Reg.
85	UC7805K	1A; +5V; TO-3; Fixed Reg.
91	UC7812ACK	1A; +12V; TO-3; Precision Fixed Reg.
91	UC7812ACT	1A; +12V; TO-220; Precision Fixed Reg.
91	UC7812AK	1A; +12V; TO-3; Precision Fixed Reg.
85	UC7812CK	1A; +12V; TO-3; Fixed Reg.
85	UC7812C	1A;+12V;TO-220; Fixed Reg.
85	UC7812K	1A; +12V; TO-3; Fixed Reg.
91	UC7815ACK	1A; +15V; TO-3; Precision Fixed Reg.
91	UC7815ACT	1A; +15V; TO-220; Precision Fixed Reg.
91	UC7815AK	1A; +15V; TO-3; Precision Fixed Reg.
85	UC7815CK	1A; +15V; TO-3; Fixed Reg.
85	UC7815CT	1A; +15V;TO-220;Fixed Reg.
85	UC7815K	1A; +15V; TO-3; Fixed Reg.
103	UC7905ACK	1A; −5V; TO-3; Precision Fixed Reg.
103	UC7905ACT	1A; −5V; TO-220; Precision Fixed Reg.

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PAGE	PART NUMBER	DESCRIPTION
		LINEAR INTEGRATED CIRCUITS
103	UC7905AK	1A; -5V; TO-3; Precision Fixed Reg.
97	UC7905CK	1A; -5V; TO-3; Fixed Reg.
97	UC7905CT	1A; -5V; TO-220;Fixed Reg.
97	UC7905K	1A; -5V; TO-3; Fixed Reg.
103	UC7912ACK	1A; -12V; TO-3; Precision Fixed Reg.
103	UC7912ACT	1A; -12V; TO-220; Precision Fixed Reg.
103	UC7912AK	1A; -12V; TO-3; Precision Fixed Reg.
97	UC7912CK	1A; -12V; TO-3; Fixed Reg.
97	UC7912CT	1A;-12V;TO-220;Fixed Reg.
97	UC7912K	1A; -12V; TO-3; Fixed Reg.
103	UC7915ACK	1A; -15V; TO-3; Precision Fixed Reg.
103	UC7915ACT	1A; -15V; TO-220; Precision Fixed Reg.
103	UC7915AK	1A; -15V; TO-3; Precision Fixed Reg.
97	UC7915CK	1A; -15V; TO-3; Fixed Reg.
97	UC7915CT	1A; -15V;TO-220;Fixed Reg.
97	UC7915K	1A; -15V; TO-3; Fixed Reg.
		FULL WAVE BRIDGE
*	UCBA1	1 ph; 25A; 100V
*	UCBA2	1 ph; 25A; 200V
*	UCBA4	1 ph; 25A; 400V
*	UCBA6	1 ph; 25A; 600V
*	UCBA1F	1 ph; 20A; 100V
*	UCBA2F	1 ph; 20A; 200V
*	UCBA4F	1 ph; 20A; 400V
*	UCBA6F	1 ph; 20A; 600V
*	UCBHM1	1 ph; 10A; 100V
*	UCBHM2	1 ph; 10A; 200V
*	UCBHM4	1 ph; 10A; 400V
*	UCBHM6	1 ph; 10A; 600V
*	UCBHM1F	1 ph; 10A; 100V
*	UCBHM2F	1 ph; 10A; 200V
*	UCBHM4F	1 ph; 10A; 400V
*	UCBHM6F	1 ph; 10A; 600V
		DOUBLER OR CENTER-TAP
*	UCDA1	15A; 100V
*	UCDA2	15A; 200V
*	UCDA4	15A; 400V
*	UCDA6	15A; 600V
*	UCDA1F	15A; 100V
*	UCDA2F	15A; 200V
*	UCDA4F	15A; 400V
*	UCDA6F	15A; 600V
*	UCNA1	15A; 100V
*	UCNA2	15A; 200V
*	UCNA4	15A; 400V
*	UCNA6	15A; 600V
*	UCNA1F	15A; 100V
*	UCNA2F	15A; 200V
*	UCNA4F	15A; 400V
*	UCNA6F	15A; 600V
*	UCPA1	15A; 100V
*	UCPA2	15A; 200V
*	UCPA4	15A; 400V
*	UCPA6	15A; 600V
*	UCPA1F	15A; 100V
*	UCPA2F	15A; 200V

PAGE	PART NUMBER	DESCRIPTION
		DOUBLER OR CENTER-TAP
*	UCPA4F	15A; 400V
*	UCPA6F	15A; 600V
		RECTIFIER MODULE
510	UDA5	5.0kV
510	UDA7.5	7.5kV
510	UDA10	10kV
510	UDA15	15kV
510	UDB2.5	2.5kV
510	UDB5	5.0kV
510	UDB7.5	7.5kV
510	UDC5	5.0kV
510	UDC7.5	7.5kV
510	UDC10	10kV
510	UDC15	15kV
510	UDD2.5	2.5kV
510	UDD5	5.0kV
510	UDD7.5	7.5kV
510	UDE2.5	2.5kV
510	UDE5	5.0kV
510	UDF2.5	2.5kV
510	UDF5	5.0kV
		ZENER
602	UDZ707-UDZ790	Bidirectional; 3W; 5%
602	UDZ807-UDZ890	Bidirectional; 3W; 10%
602	UDZ5707-UDZ5790	Bidirectional; 5W; 5%
602	UDZ5807-UDZ5890	Bidirectional; 5W; 10%
602	UDZ8707-UDZ8791	Bidirectional; 1W; 5%
602	UDZ8807-UDZ8891	Bidirectional; 1W; 10%
		RECTIFIER
323	UES101 (1N5802)	2.5A; 50V
323	UES102 (1N5803)	2.5A; 75V
323	UES103 (1N5804)	2.5A; 100V
323	UES104 (1N5805)	2.5A; 125V
323	UES201 (1N5807)	6.0A; 50V
323	UES202 (1N5808)	6.0A; 75V
323	UES203 (1N5809)	6.0A; 100V
323	UES204 (1N5810)	6.0A; 125V
*	UES301	20.0A; 50V
*	UES302	20.0A; 75V
*	UES303	20.0A; 100V
*	UES304	20.0A; 125V
363	UES501	50.0A; 50V; DO-5
363	UES502	50.0A; 75V; DO-5
363	UES503	50.0A; 100V; DO-5
363	UES504	50.0A; 125V; DO-5
363	UES505	50.0A; 150V; DO-5
366	UES701	25.0A; 50V; DO-4
366	UES702	25.0A; 100V; DO-4
366	UES703	25.0A; 150V; DO-4
368	UES704	20.0A; 200V; DO-4
368	UES705	20.0A; 300V; DO-4
368	UES706	20.0A; 400V; DO-4
371	UES801	70.0A; 50V; DO-5
371	UES802	70.0A; 100V; DO-5
371	UES803	70.0A; 150V; DO-5
374	UES804	50.0A; 200V; DO-5
374	UES805	50.0A; 300V; DO-5
374	UES806	50.0A; 400V; DO-5
377	UES1001	1A; 50V
377	UES1002	1A; 100V
377	UES1003	1A; 150V
379	UES1101	2.5A; 50V
379	UES1102	2.5A; 100V
379	UES1103	2.5A; 150V

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PAGE	PART NUMBER	DESCRIPTION
		RECTIFIER MODULE
521	US12	1.2kV
521	US15	1.5kV
521	US18	1.8kV
521	US20	2.0kV
521	US25	2.5kV
521	US30	3.0kV
521	US35	3.5kV
521	US40	4.0kV
521	US45A	4.5kV
521	US50A	5.0kV
521	US60A	6.0kV
521	US70A	7.0kV
521	US80A	8.0kV
521	US100A	10kV
521	US120A	12kV
521	US150A	15kV
521	US180A	18kV
521	US200A	20kV
514	USB2.5	2.5kV
514	USB5	5.0kV
514	USB7.5	7.5kV
514	USB10	10kV
		TRIAC
696	USC1420-2	8.0A; 200V; TO-220AB; Isolated Tab
696	USC1420-4	8.0A; 400V; TO-220AB; Isolated Tab
696	USC1420-6	8.0A; 600V; TO-220AB; Isolated Tab
696	USC1420-8	8.0A; 800V; TO-220AB; Isolated Tab
696	USC1440-2	10A; 200V; TO-220AB; Isolated Tab
696	USC1440-4	10A; 400V; TO-220AB; Isolated Tab
696	USC1440-6	10A; 600V; TO-220AB; Isolated Tab
696	USC1440-8	10A; 800V; TO-220AB; Isolated Tab
696	USC1470-2	8.0A; 200V; TO-220AB; Non-Isolated Tab
696	USC1470-4	8.0A; 400V; TO-220AB; Non-Isolated Tab
696	USC1470-6	8.0A; 600V; TO-220AB; Non-Isolated Tab
696	USC1470-8	8.0A; 800V; TO-220AB; Non-Isolated Tab
696	USC1490-2	10A; 200V; TO-220AB; Non-Isolated Tab
696	USC1490-4	10A; 400V; TO-220AB; Non-Isolated Tab
696	USC1490-6	10A; 600V; TO-220AB; Non-Isolated Tab
696	USC1490-8	10A; 800V; TO-220AB; Non-Isolated Tab
698	USC2120-2	15A; 200V; TO-220AB; Isolated Tab
698	USC2120-4	15A; 400V; TO-220AB; Isolated Tab
698	USC2120-6	15A; 600V; TO-220AB; Isolated Tab
698	USC2120-8	15A; 800V; TO-220AB; Isolated Tab
698	USC2140-2	20A; 200V; TO-220AB; Isolated Tab
698	USC2140-4	20A; 400V; TO-220AB; Isolated Tab

PAGE	PART NUMBER	DESCRIPTION
		TRIAC
698	USC2140-6	20A; 600V; TO-220AB; Isolated Tab
698	USC2140-8	20A; 800V; TO-220AB; Isolated Tab
698	USC2250-2	15A; 200V; TO-220AB; Non-Isolated Tab
698	USC2250-4	15A; 400V; TO-220AB; Non-Isolated Tab
698	USC2250-6	15A; 600V; TO-220AB; Non-Isolated Tab
698	USC2250-8	15A; 800V; TO-220AB; Non-Isolated Tab
698	USC2270-2	20A; 200V; TO-220AB; Non-Isolated Tab
698	USC2270-4	20A; 400V; TO-220AB; Non-Isolated Tab
698	USC2270-6	20A; 600V; TO-220AB; Non-Isolated Tab
698	USC2270-8	20A; 800V; TO-220AB; Non-Isolated Tab
		SCHOTTKY RECTIFIER
406	USD320C	30A; 20V; TO-3
406	USD335C	30A; 35V; TO-3
406	USD345C	30A; 45V; TO-3
408	USD420	40A; 20V; DO-4
408	USD435	40A; 35V; DO-4
408	USD445	40A; 45V; DO-4
410	USD520	75A; 20V; DO-5
410	USD535	75A; 35V; DO-5
410	USD545	75A; 45V; DO-5
413	USD545HR2	75A; 45V; DO-5
416	USD620	12A; 20V; sim to TO-220
416	USD635	12A; 35V; sim to TO-220
416	USD640	12A; 40V; sim to TO-220
416	USD645	12A; 45V; sim to TO-220
418	USD620C	12A; 20V; TO-220AB
418	USD635C	12A; 35V; TO-220AB
418	USD640C	12A; 40V; TO-220AB
418	USD645C	12A; 45V; TO-220AB
420	USD720	16A; 20V; sim to TO-220
420	USD735	16A; 35V; sim to TO-220
420	USD740	16A; 40V; sim to TO-220
420	USD745	16A; 45V; sim to TO-220
422	USD720C	16A; 20V; TO-220AB
422	USD735C	16A; 35V; TO-220AB
422	USD740C	16A; 40V; TO-220AB
422	USD745C	16A; 45V; TO-220AB
424	USD820	12A; 20V; sim to TO-220
424	USD835	12A; 35V; sim to TO-220
424	USD840	12A; 40V; sim to TO-220
424	USD845	12A; 45V; sim to TO-220
426	USD920	16A; 20V; sim to TO-220
426	USD935	16A; 35V; sim to TO-220
426	USD940	16A; 40V; sim to TO-220
426	USD945	16A; 45V; sim to TO-220
		RECTIFIER MODULE
521	USR12	1.2kV
521	USR15	1.5kV
521	USR18	1.8kV
521	USR20	2.0kV
521	USR25	2.5kV
521	USR30	3.0kV
521	USR35	3.5kV
521	USR40A	4.0kV
521	USR45A	4.5kV

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PAGE	PART NUMBER	DESCRIPTION
		RECTIFIER MODULE
521	USR50A	5.0kV
521	USR60A	6.0kV
521	USR70A	7.0kV
521	USR80A	8.0kV
521	USR100A	10kV
521	USR120A	12kV
521	USR150A	15kV
521	USR180A	18kV
514	USS5	5.0kV
514	USS7.5	7.5kV
514	USS10	10kV
514	USS15	15kV
		RECTIFIER
*	UT111 (1N536)	0.75A; 50V
*	UT112 (1N537)	0.75A; 100V
*	UT113 (1N3656)	0.75A; 200V
*	UT114 (1N539)	0.75A; 300V
*	UT115 (1N3657)	0.75A; 400V
*	UT117 (1N547)	0.75A; 500V
*	UT118 (1N3658)	0.75A; 600V
*	UT119	0.75A; 800V
*	UT120	0.75A; 1000V
*	UT211 (1N645)	0.75A; 225V
*	UT212 (1N646)	0.75A; 300V
*	UT213 (1N647)	0.75A; 400V
*	UT214 (1N648)	0.75A; 500V
*	UT215 (1N649)	0.75A; 600V
*	UT221 (1N676)	0.5A; 100V
*	UT222 (1N677)	0.75A; 100V
*	UT223 (1N678)	0.5A; 200V
*	UT224 (1N679)	0.75A; 200V
*	UT225 (1N681)	0.5A; 300V
*	UT226 (1N682)	0.75A; 300V
*	UT227 (1N683)	0.5A; 400V
*	UT228 (1N684)	0.75A; 400V
*	UT229 (1N685)	0.5A; 500V
*	UT231 (1N686)	0.75A; 500V
*	UT232 (1N687)	0.5A; 600V
*	UT233 (1N689)	0.75A; 600V
428	UT234	1.0A; 200V
428	UT235	1.0A; 400V
428	UT236	1.0A; 100V
428	UT237	1.0A; 500V
428	UT238	1.0A; 600V
428	UT242	1.25A; 200V
428	UT244	1.25A; 400V
428	UT245	1.25A; 500V
428	UT247	1.25A; 600V
428	UT249	1.25A; 100V
428	UT251	1.5A; 100V
428	UT252	1.5A; 200V
428	UT254	1.5A; 400V
428	UT255	1.5A; 500V
428	UT257	1.5A; 600V
428	UT258	1.5A; 800V
428	UT261	2.0A; 100V
428	UT262 (1N3981)	2.0A; 200V
428	UT264 (1N3982)	2.0A; 400V
428	UT265	2.0A; 500V
428	UT267 (1N3983)	2.0A; 600V
428	UT268	2.0A; 800V
428	UT347	1.0A; 1000V
428	UT361	1.0A; 800V
428	UT362	1.2A; 800V
428	UT363	1.2A; 1000V
428	UT364	1.5A; 1000V
432	UT2005	2.0A; 50V

PAGE	PART NUMBER	DESCRIPTION
		RECTIFIER
432	UT2010	2.0A; 100V
432	UT2020	2.0A; 200V
432	UT2040	2.0A; 400V
432	UT2060	2.0A; 600V
*	UT2080	2.0A; 800V
432	UT3005	3.0A; 50V
432	UT3010	3.0A; 100V
432	UT3020	3.0A; 200V
432	UT3040	3.0A; 400V
432	UT3060	3.0A; 600V
*	UT3080	3.0A; 800V
432	UT4005	4.0A; 50V
432	UT4010 (1N5180)	4.0A; 100V
432	UT4020	4.0A; 200V
432	UT4040 (1N5207)	4.0A; 400V
432	UT4060	4.0A; 600V
*	UT4080	4.0A; 800V
*	UT4100	4.0A; 1000V
436	UT5105	7.5A; 50V
436	UT5110	7.5A; 100V
436	UT5120	7.5A; 200V
436	UT5130	7.5A; 300V
436	UT5140	7.5A; 400V
436	UT5150	7.5A; 500V
436	UT5160	7.5A; 600V
436	UT6105	9.0A; 50V
436	UT6110	9.0A; 100V
436	UT6120	9.0A; 200V
436	UT6130	9.0A; 300V
436	UT6140	9.0A; 400V
436	UT6160	9.0A; 600V
436	UT8105	12.0A; 50V
436	UT8110	12.0A; 100V
436	UT8120	12.0A; 200V
436	UT8130	12.0A; 300V
436	UT8140	12.0A; 400V
436	UT8160	12.0A; 600V
439	UTR01	1.0A; 50V
439	UTR02	2.0A; 50V
439	UTR10	0.5A; 100V
439	UTR11	1.0A; 100V
439	UTR12	2.0A; 100V
439	UTR20	0.5A; 200V
439	UTR21	1.0A; 200V
439	UTR22	2.0A; 200V
439	UTR30	0.5A; 300V
439	UTR31	1.0A; 300V
439	UTR32	2.0A; 300V
439	UTR40	0.5A; 400V
439	UTR41	1.0A; 400V
439	UTR42 (1N5206)	2.0A; 400V
439	UTR50	0.5A; 500V
439	UTR51	1.0A; 500V
439	UTR52	2.0A; 500V
439	UTR60	0.5A; 600V
439	UTR61	1.0A; 600V
439	UTR62	2.0A; 600V
*	UTR70	0.5A; 700V
*	UTR71	1.0A; 700V
443	UTR2305	2.0A; 50V
443	UTR2310	2.0A; 100V
443	UTR2320	2.0A; 200V
443	UTR2340	2.0A; 400V
443	UTR2350	2.0A; 500V
443	UTR2360	2.0A; 600V
443	UTR3305	3.0A; 50V
443	UTR3310	3.0A; 100V

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DESIGNERS' GUIDES II

POWER SUPPLY DESIGNERS' GUIDE

POWER HYBRID CIRCUITS

Switching Regulator Power Output Circuits

The PIC600 through PIC672 series of devices consist of a driver transistor, a fast switching output transistor, a suitably matched fast recovery catch diode and thick film resistors in a hybrid circuit, designed, constructed and specified for use in high current switching regulator applications. Specific ratings for each type is summarized in this table.

Type	Output Current, Pk.	Input/Output Voltage	Polarity	Fall Time Volt. (ns)	Fall Time Cur. (ns)	On-State Voltage (V) @ (A)	Pkg.
PIC600		60	Pos.				
PIC601		80	Pos.				
PIC602	5A	100	Pos.	75	150	1.5 @ 2	**4 PIN TO-66 (Isolated)**
PIC610		60	Neg.				
PIC611		80	Neg.				
PIC612		100	Neg.				
PIC660		60	Pos.				
PIC661		80	Pos.	150	250		
PIC662	10A	100	Pos.			1.5 @ 5	**4 PIN TO-66 (Isolated)**
PIC670		60	Neg.				
PIC671		80	Neg.	250	250		
PIC672		100	Neg.				
PIC625		60	Pos.				
PIC626		80	Pos.	175	300		
PIC627	15A	100	Pos.				**4 PIN TO-66 (Isolated)**
PIC635		60	Neg.			1.5 @ 7	
PIC636		80	Neg.	300	300		
PIC637		100	Neg.				
PIC645		60	Pos.				
PIC646		80	Pos.	150	300		
PIC647	20A	100	Pos.			1.5 @ 7	**3 PIN TO-3**
PIC655		60	Neg.				
PIC656		80	Neg.	300	300		
PIC657		100	Neg.				

The PIC730 and 740 series offer a Schottky diode in place of the fast recovery PN catch diode, to permit higher operating efficiencies in switching regulator designs.

PIC730 PIC740	30A	30 40	Pos. Pos.	350	300	1 @ 20	**3 PIN TO-3**

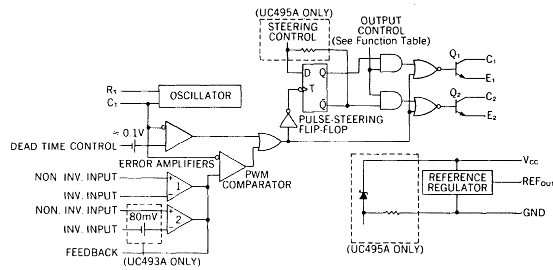
The PIC800 through 811 series are high voltage (up to 400V) versions of the PIC600 series. Applications include high voltage buck or flyback regulators, and, in combination, half bridge or full bridges, as well as deflection circuits and DC motor drives.

PIC800 PIC801	8A	350 400	Pos.	200	200	1.5 @ 5	**4 PIN TO-66 (Isolated)**
PIC810 PIC811	8A	350 400	Neg.	200	200	1.5 @ 5	**4 PIN TO-66 (Isolated)**

Regulating Pulse Width Modulators

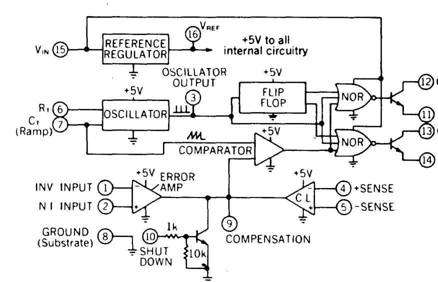
UC493A/UC494A/UC495A
UC493AC/UC494AC/UC495AC

- Fully Interchangeable, Advanced Version of 494 family.
- Uncommitted Outputs for Single-ended or Push-pull Applications
- Supply Voltage, V_{CC} .... 7V to 40V
- Reference Voltage, V_{REF} .... 5V to ±1%
- Dual Error Amplifiers
- Wide Range, Variable Deadtime
- Under-Voltage Lockout
- Double-pulse Protection
- Sawtooth Oscillator Operation to 300kHz
- High Performance Current Limit on UC493A
- Internal 39V Zener for Operation above 40V on UC495A
- Buffered Output Steering Control on UC495A



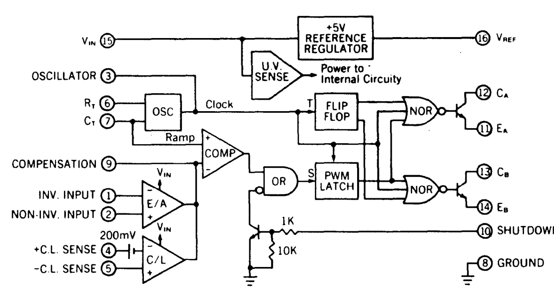
UC1524/UC2524/UC3524

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for Single-ended or Push-pull Applications 100mA
- Output Voltage 40V
- Supply Voltage, V_{CC} .... 8V to 40V
- Low Standby Current ....8mA Typical
- Reference Voltage, V_{REF} ....5V ± 4%
- Sawtooth Oscillator Operation to 300kHz
- Analog External Shutdown
- Analog Current Limiting
- 16 Pin Dual-in-line Package



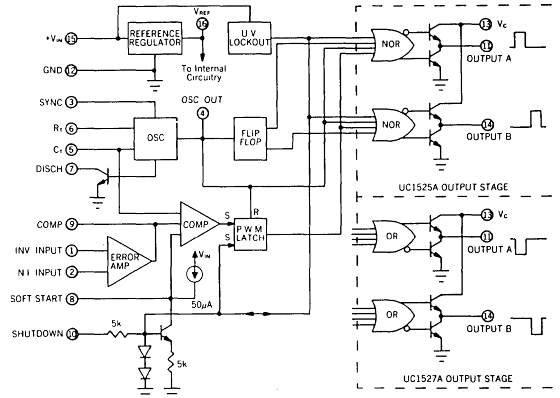
UC1524A/UC2524A/UC3524A

- Fully Interchangeable, Advanced Version of UC1524 family
- Output Current 200mA
- Output Voltage 60V
- High-Performance Current Limit
- Under-Voltage Lockout
- Low Standby Current ....5mA Typical
- Reference Voltage, V_{REF} ....5V ± 1%
- Wide Common-Mode Input Range for Both Error and Current Limit Amplifiers
- PWM Latch Insures Single Pulse per Period
- 100ns Shutdown
- Guaranteed Frequency Accuracy
- Sawtooth Oscillator Operation to 500kHz
- 16 Pin Dual-in-line Package



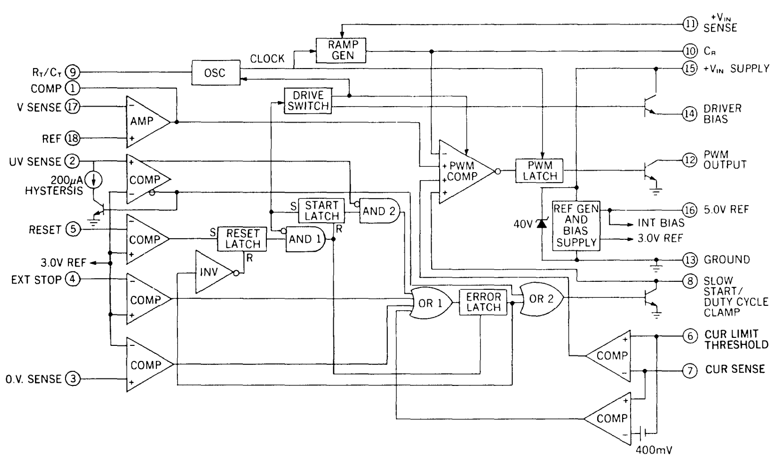
UC1525A/UC2525A/UC3525A
UC1527A/UC2527A/UC3527A

- 8V to 35V Operation
- Reference Voltage, V_{REF} .... 5.1V ± 1%
- 100Hz to 500kHz Oscillator Range
- Separate Oscillator Sync Terminal
- Adjustable Deadtime Control
- Internal Soft-Start
- Under-Voltage Lockout
- Latching PWM to Prevent Multiple Pulses
- Dual Source/Sink Output Drivers 500mA
- 16 Pin Dual-in-line Package



UC1840/UC2840/UC3840

- All Control, Driving, Monitoring, and Protection Functions Included
- Feed-Forward Sensing for Constant Volt-Second Operation over a 4 to 1 Input Range
- Low Current, Off-Line Start
- Hysteresis for Separating Start and Run Levels
- Under-Voltage Lockout
- Slow Turn-on
- PWM Latch for Single-Pulse Operation
- Pulse-by-Pulse Current Limiting plus Shutdown for Over-Current Fault
- Shutdown upon Over or Under-Voltage Sensing
- Latch off or Continuous Retry Modes
- Remote, Pulse-Commandable Start/Stop
- Maximum PWM limiting with External Divider
- 200mA PWM Output Switch
- Error Amp Reference Trimmed to ± 1%
- Operation to 500kHz
- 18 Pin Dual-in-line Package



Three Terminal Voltage Regulators, Adjustable

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)	Pkg.
UC117K UC217K UC317K UC317T	1.5A	Pos.	Adjustable from 1.2V to 37V	TO-3 TO-3 TO-3 TO-220
UC137K UC237K UC337K UC337T	1.5A	Neg.	Adjustable from −1.2V to −37V	TO-3 TO-3 TO-3 TO-220
UC150K UC250K UC350K	3.0A	Pos.	Adjustable from 1.2V to 33V	TO-3 TO-3 TO-3

Three Terminal Voltage Regulators, Fixed, Positive

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7800AK SERIES UC7800ACK SERIES UC7800ACT SERIES	1.5A	Pos.	5V ± 1%	12V ± 1%	15V ± 1%	TO-3 TO-3 TO-220
UC7800K SERIES UC7800CK SERIES UC7800CT SERIES	1.5A	Pos.	5V ± 4%	12V ± 4%	15V ± 4%	TO-3 TO-3 TO-220

Three Terminal Voltage Regulators, Fixed, Negative

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7900AK SERIES UC7900ACK SERIES UC7900ACT SERIES	1.5A	Neg.	−5V ± 1%	−12V ± 1%	−15V ± 1%	TO-3 TO-3 TO-220
UC7900K SERIES UC7900CK SERIES UC7900CT SERIES	1.5A	Neg.	−5V ± 4%	−12V ± 4%	−15V ± 4%	TO-3 TO-3 TO-220

II

NPN POWER SWITCHING TRANSISTORS

Plastic Packaging

Type	$V_{CEO(sus)}$ (V)	Min. h_{FE} @ I_C	Max. $V_{CE(sat)}$ @ I_C (V)	Max. Fall Time (t_f) @ $I_C/I_{B1}/I_{B2}$ (μs)	Max. $E_{s/b}$ (μJ)	Pkg.
4.0A						
UMT13004	300	8 @ 2.0	0.6 @ 2.0	0.9 @ 2/.4/.4	—	**TO-220**
UMT13005	400	8 @ 2.0	0.6 @ 2.0	0.9 @ 2/.4/.4	—	**TO-220**
8.0A						
UMT13006	300	6 @ 5.0	1.5 @ 5.0	0.7 @ 5/1/1	—	**TO-220**
UMT13007	400	6 @ 5.0	1.5 @ 5.0	0.7 @ 5/1/1	—	**TO-220**
12.0A						
UMT13008	300	6 @ 8.0	1.5 @ 8.0	0.7 @ 8/1.6/1.6	—	**TO-220**
UMT13009	400	6 @ 8.0	1.5 @ 8.0	0.7 @ 8/1.6/1.6	—	**TO-220**

Metal Can Packaging

Type	$V_{CEO(sus)}$ (V)	Min. h_{FE} @ I_C	Max. $V_{CE(sat)}$ @ I_C (V)	Max. Fall Time (t_f) @ $I_C/I_{B1}/I_{B2}$ (μs)	Max. $E_{s/b}$ (μJ)	Pkg.
3.0A						
2N5838	250	10 @ 2.0	1.0 @ 3.0	1.5 @ 3/.375/.375	450	**TO-3**
2N5839	275	10 @ 2.0	1.5 @ 2.0	1.5 @ 2/.2/.2	450	**TO-3**
2N5840	350	10 @ 2.0	1.5 @ 2.0	1.5 @ 2/.2/.2	450	**TO-3**
5.0A						
2N6542	300	7 @ 3.0	1.0 @ 3.0	0.8 @ 3/.6/.6	180	**TO-3**
2N6671	300	10 @ 5.0	1.0 @ 5.0	0.5 @ 5/1/1	—	**TO-3**
UMT1006	350	7 @ 3.0	1.0 @ 3.0	0.4 @ 3/.6/.6	540	**TO-3**
2N6672	350	10 @ 5.0	1.0 @ 5.0	0.5 @ 5/1/1	—	**TO-3**
UMT1007	400	7 @ 3.0	1.0 @ 3.0	0.4 @ 3/.6/.6	540	**TO-3**
2N6543	400	7 @ 3.0	1.0 @ 3.0	0.8 @ 3/.6/.6	180	**TO-3**
2N6673	400	10 @ 5.0	1.0 @ 5.0	0.5 @ 5/1/1	—	**TO-3**
8.0A						
2N6306	250	15 @ 3.0	0.8 @ 3.0	0.4 @ 3/.6/1.5	180	**TO-3**
2N6307	300	15 @ 3.0	0.8 @ 3.0	0.4 @ 3/.6/1.5	180	**TO-3**
2N6544	300	7 @ 5.0	1.5 @ 5.0	1.0 @ 5/1/1	500	**TO-3**
UMT1008	300	7 @ 5.0	1.5 @ 5.0	0.4 @ 5/1/1	1500	**TO-3**
2N6308	350	12 @ 3.0	1.5 @ 3.0	0.4 @ 3/.6/1.5	180	**TO-3**
2N6545	400	7 @ 5.0	1.5 @ 5.0	1.0 @ 5/1/1	500	**TO-3**
UMT1009	400	7 @ 5.0	1.5 @ 5.0	0.4 @ 5/1/1	1500	**TO-3**
10.0A						
2N6354	120	10 @ 10.0	1.0 @ 10.0	0.2 @ 5/.5/.5	300	**TO-3**
2N6249	200	10 @ 10.0	1.5 @ 10.0	1.0 @ 10/1/1	2500	**TO-3**
2N6250	275	8 @ 10.0	1.5 @ 10.0	1.0 @ 10/1.25/1.25	2500	**TO-3**
2N6674	300	8 @ 10.0	1.0 @ 10.0	1.0 @ 10/2/2	—	**TO-3**
2N6251	350	6 @ 10.0	1.5 @ 10.0	1.0 @ 10/1.67/1.67	2500	**TO-3**
2N6675	400	8 @ 10.0	1.0 @ 10.0	1.0 @ 10/2/2	—	**TO-3**
15.0A						
2N6496	100	12 @ 8.0	1.0 @ 8.0	0.3 @ 8/.8/.8	5700	**TO-3**
2N6546	300	6 @ 10.0	1.5 @ 10.0	0.7 @ 10/2/2	2000	**TO-3**
2N6676	300	8 @ 15.0	1.0 @ 15.0	0.5 @ 15/3/3	—	**TO-3**
UMT1011	350	6 @ 10.0	1.0 @ 10.0	0.4 @ 10/2/2	6000	**TO-3**
2N6677	350	8 @ 15.0	1.0 @ 15.0	0.5 @ 15/3/3	—	**TO-3**
UMT1012	400	6 @ 10.0	1.0 @ 10.0	0.4 @ 10/2/2	6000	**TO-3**
2N6547	400	6 @ 10.0	1.5 @ 10.0	0.7 @ 10/2/2	2000	**TO-3**
2N6678	400	8 @ 15.0	1.0 @ 15.0	0.5 @ 15/3/3	—	**TO-3**
UMT2000	450	7 @ 15.0	1.5 @ 10.0	0.2 @ 10/1/2	—	**TO-3**
20.0A						
2N5039	75	20 @ 10.0	1.0 @ 10.0	0.5 @ 10/1/1	13000	**TO-3**
2N5038	90	20 @ 12.0	1.2 @ 12.0	0.5 @ 12/1.2/1.2	13000	**TO-3**
30.0A						
2N5671	90	20 @ 15.0	0.75 @ 15.0	0.5 @ 15/1.2/1.2	20000	**TO-3**
2N5672	120	20 @ 15.0	0.75 @ 15.0	0.5 @ 15/1.2/1.2	20000	**TO-3**
UMT2003	400	10 @ 15.0	1.5 @ 20.0	0.8 @ 20/4/4	—	**TO-3**

POWER SUPPLY DESIGNERS' GUIDE

SCHOTTKY BARRIER POWER RECTIFIERS

Type	V_{RWM}	V_F	Ratings and Specifications	
1A				
1N5817 1N5818 1N5819	20V 30V 40V	0.45V 0.55V 0.60V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Reverse Current, I_R @ V_{RWM}, 100°C Package: **Axial Leaded Plastic**	25A 150°C 10mA
3A				
1N5820 1N5821 1N5822	20V 30V 40V	0.475V 0.500V 0.525V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Reverse Current, I_R @ V_{RWM}, 100°C Package: **Axial Leaded Plastic**	80A 150°C 20mA

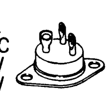
Type	V_{RWM}	Ratings and Specifications	
6A			
USD620 USD635 USD640 USD645	20V 35V 40V 45V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ V_{RWM}, 125°C Package: **Sim. to TO-220**	150A 150°C 0.48V 50mA
8A			
USD720 USD735 USD740 USD745	20V 35V 40V 45V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ V_{RWM}, 125°C Package: **Sim. to TO-220**	200A 150°C 0.48V 50mA
12A			
USD820 USD835 USD840 USD845	20V 35V 40V 45V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ V_{RWM}, 125°C Package: **Sim. to TO-220**	200A 150°C 0.45V 100mA
16A			
USD920 USD935 USD940 USD945	20V 35V 40V 45V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ V_{RWM}, 125°C Package: **Sim. to TO-220**	250A 150°C 0.5V 100mA
25A			
1N6095 1N6096	30V 40V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F @ 78.5A Reverse Current, I_R @ V_{RWM}, 125°C Package: **DO-4**	400A 150°C 0.86V 250mA
30A			
USD420 USD435 USD445	20V 35V 45V	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ V_{RWM}, 125°C Package: **DO-4**	700A 175°C 0.55V 50mA
30A			
SD41	45V @ T_j = 25°C 35V @ T_j = 125°C	Surge Current, I_{FSM} Maximum Junction Temperature, T_j Forward Voltage, V_F Reverse Current, I_R @ 35V, 125°C Package: **DO-4**	600A 150°C 0.55V 125mA

SCHOTTKY BARRIER POWER RECTIFIERS (continued)

Type	V_{RWM}	Ratings and Specifications
50A		
1N6097 1N6098	30V 40V	Surge Current, I_{FSM} .... 800A Maximum Junction Temperature, T_j .... 175°C Forward Voltage, V_F @ 157A.......... 0.86V Reverse Current, I_R @ V_{RWM}, 125°C .... 250mA Package: **DO-5**
60A		
SD51	45V @ T_j = 25°C 35V @ T_j = 125°C	Surge Current, I_{FSM} .... 800A Maximum Junction Temperature, T_j .... 150°C Forward Voltage, V_F .... 0.6V Reverse Current, I_R @ 35V, 125°C.......... 200mA Package: **DO-5**
75A		
USD520 USD535 USD545	20V 35V 45V	Surge Current, I_{FSM} .... 1000A Maximum Junction Temperature, T_j .... 175°C Forward Voltage, V_F @ 60A.......... 0.6V Reverse Current, I_R @ V_{RWM}, 125°C .... 50mA Package: **DO-5**

Schottky Center-Tap Rectifiers

Type	V_{RWM}	Ratings and Specifications
12A		
USD620C USD635C USD640C USD645C	20V 35V 40V 45V	Surge Current, I_{FSM} .... 150A Maximum Junction Temperature, T_j .... 150°C Forward Voltage, V_F .... 0.6V Reverse Current, I_R @ V_{RWM}, 125°C .... 50mA Package: **TO-220AB**
16A		
USD720C USD735C USD740C USD745C	20V 35V 40V 45V	Surge Current, I_{FSM} .... 200A Maximum Junction Temperature, T_j .... 150°C Forward Voltage, V_F .... 0.6V Reverse Current, I_R @ V_{RWM}, 125°C .... 50mA Package: **TO-220AB**
30A		
USD320C USD335C USD345C	20V 35V 45V	Surge Current, I_{FSM} .... 500A Maximum Junction Temperature, T_j .... 175°C Forward Voltage, V_F @ 20A.......... 0.60V Reverse Current, I_R @ V_{RWM}, 125°C .... 50mA Package: **TO-3 Center-Tap**
30A		
SD241	45V @ T_j = 25°C 35V @ T_j = 125°C	Surge Current, I_{FSM} .... 400A Maximum Junction Temperature, T_j .... 150°C Forward Voltage, V_F @ 20A.......... 0.60V Reverse Current, I_R @ 35V, 125°C .... 100mA Package: **TO-3 Center-Tap**
100A		
USM130C USM140C USM145C	30V 40V 45V	Surge Current, I_{FSM} .... 800A Maximum Junction Temperature, T_j .... 150°C Forward Voltage, V_F @ 50A, 125°C.......... 0.58V Forward Voltage, V_F @ 100A, 125°C.......... 0.75V Reverse Current, I_R @ V_{RWM}, 125°C .... 100mA Package: **TO-3 Base**



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P/N JUNCTION RECTIFIERS

Low Voltage, Ultra-Fast Recovery ($t_{rr} \leq 50ns$)

Type	V_{RWM}	Ratings and Specifications	
1A			
UES1001 UES1002 UES1003	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Axial Leaded Glass**	30A 0.895V @ 1A 25ns
2.5A			
UES1101 UES1102 UES1103	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Axial Leaded Glass**	35A 0.895V @ 2A 25ns
6A			
UES1301 UES1302 UES1303	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Axial Leaded Glass**	125A 0.850V @ 6A 30ns
8A			
UES1401 UES1402 UES1403	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Sim. to TO-220**	80A 0.895V @ 8A 35ns
25A			
UES701 UES702 UES703	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **DO-4**	400A 0.825V @ 25A 35ns
70A			
UES801 UES802 UES803	50V 100V 150V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **DO-5**	800A 0.840V @ 70A 50ns

High Voltage, Ultra-Fast Recovery ($t_{rr} \leq 50ns$)

Type	V_{RWM}	Ratings and Specifications	
2A			
UES1104 UES1105 UES1106	200V 300V 400V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Axial Leaded Glass**	20A 1.15V @ 1A 50ns
5A			
UES1304 UES1305 UES1306	200V 300V 400V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **Axial Leaded Glass**	70A 1.15V @ 3A 50ns
20A			
UES704 UES705 UES706	200V 300V 400V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **DO-4**	300A 1.15V @ 20A 50ns
50A			
UES804 UES805 UES806	200V 300V 400V	Surge Current, I_{FSM} Forward Voltage, V_F Reverse Recovery Time, t_{rr} Package: **DO-5**	600A 1.15V @ 50A 50ns

P/N JUNCTION RECTIFIERS (continued)

Ultra-Fast Recovery Center-Tap Rectifiers ($t_{rr} \leq$ 50ns)

Type	V_{RWM}	Ratings and Specifications
16A		
UES2401 UES2402 UES2403	50V 100V 150V	Surge Current, I_{FSM} ... 80A Forward Voltage, V_F ... 0.895V @ 8A Reverse Recovery Time, t_{rr} ... 35ns Package: **TO-220AB**
30A		
UES2601 UES2602 UES2603	50V 100V 150V	Surge Current, I_{FSM} ... 400A Forward Voltage, V_F ... 0.825V @ 15A Reverse Recovery Time, t_{rr} ... 35ns Package: **TO-3 Center-Tap**
UES2604 UES2605 UES2606	200V 300V 400V	Surge Current, I_{FSM} ... 300A Forward Voltage, V_F ... 1.15V @ 15A Reverse Recovery Time, t_{rr} ... 50ns Package: **TO-3 Center-Tap**

Super-Fast Recovery Rectifiers (t_{rr} = 100ns)

Type	V_{RWM}	Ratings and Specifications
2A		
SES5001 SES5002 SES5003	50V 100V 150V	Surge Current, I_{FSM} ... 35A Forward Voltage, V_F ... 0.895V @ 1A Reverse Recovery Time, t_{rr} ... 100ns Package: **Axial Leaded Glass**
5A		
SES5301 SES5302 SES5303	50V 100V 150V	Surge Current, I_{FSM} ... 110A Forward Voltage, V_F ... 0.895V @ 5A Reverse Recovery Time, t_{rr} ... 100ns Package: **Axial Leaded Glass**
8A		
SES5401 SES5402 SES5403	50V 100V 150V	Surge Current, I_{FSM} ... 70A Forward Voltage, V_F ... 0.945V @ 8A Reverse Recovery Time, t_{rr} ... 100ns Package: **Sim. to TO-220**
20A		
SES5701 SES5702 SES5703	50V 100V 150V	Surge Current, I_{FSM} ... 400A Forward Voltage, V_F ... 0.830V @ 20A Reverse Recovery Time, t_{rr} ... 100ns Package: **DO-4**
60A		
SES5801 SES5802 SES5803	50V 100V 150V	Surge Current, I_{FSM} ... 800A Forward Voltage, V_F ... 0.850V @ 60A Reverse Recovery Time, t_{rr} ... 100ns Package: **DO-5**

Super-Fast Recovery Center-Tap Rectifiers (t_{rr} = 100ns)

Type	V_{RWM}	Ratings and Specifications
16A		
SES5401C SES5402C SES5403C	50V 100V 150V	Surge Current, I_{FSM} ... 70A Forward Voltage, V_F ... 0.945V @ 8A Reverse Recovery Time, t_{rr} ... 100ns Package: **TO-220AB**
25A		
SES5601C SES5602C SES5603C	50V 100V 150V	Surge Current, I_{FSM} ... 400A Forward Voltage, V_F ... 0.830V @ 12.5A Reverse Recovery Time, t_{rr} ... 100ns Package: **TO-3 Center-Tap**

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TRANSIENT VOLTAGE SUPPRESSORS

Type	Stand-Off Voltage	Breakdown Voltage, BV(min.)	Ratings and Specification
TVS305	5V	6.0V	
TVS310	10V	11.1V	
TVS312	12V	13.8V	
TVS315	15V	16.7V	Peak Pulse Power (1ms duration) 150W
TVS318	18V	20.4V	Continuous Power 3W
TVS324	24V	28.4V	1 Picosecond Transient Response Time
TVS328	28V	30.7V	Package: **Axial Leaded Glass**
TVS348	48V	54.0V	Additional Voltages Available
TVS360	60V	67.0V	
TVS410	100V	111.0V	
TVS420	200V	234.0V	
TVS430	300V	342.0V	
TVS505	5V	6.0V	
TVS510	10V	11.1V	Peak Pulse Power (1ms duration) 500W
TVS512	12V	13.8V	Continuous Power 5W
TVS515	15V	16.7V	1 Picosecond Transient Response Time
TVS518	18V	20.4V	Package: **Axial Leaded Glass**
TVS524	24V	28.4V	Additional Voltages Available
TVS528	28V	30.7V	

II

SILICON RECTIFIERS

Schottky

TYPE	OUTPUT CURRENT	V_{RWM}	MAXIMUM FORWARD VOLTAGE $T_C = 125°C$	MAXIMUM REVERSE CURRENT $T_C = 125°C$	SURGE CURRENT	PACKAGE
USD345C	30A	45V	0.48V @ 15A	25mA @ 45V	500A	TO-3 C.T.
USD445	40A	45V	0.58V @ 40A	25mA @ 45V	700A	DO-4
USD545(HR2)	75A	45V	0.60V @ 75A	50mA @ 45V	1,000A	DO-5

High Efficiency, Fast Switching

TYPE	OUTPUT CURRENT	V_{RWM}	MAXIMUM FORWARD VOLTAGE	REVERSE RECOVERY TIME	PACKAGE	MIL-S-19500
1N5802 1N5804 1N5806	2.5A	50V 100V 150V	.875V @ 1A	25ns	Axial Axial Axial	/477 * /477 /477
1N5807 1N5809 1N5811	6.0A	50V 100V 150V	.875V @ 4A	30ns	Axial Axial Axial	/477 * /477 /477
1N5812 1N5814 1N5816	20A	50V 100V 150V	.900V @ 10A	35ns	DO-4 DO-4 DO-4	/478 * /478 /478
1N6304 1N6305 1N6306	70A	50V 100V 150V	.975 @ 70A	50ns	DO-5 DO-5 DO-5	/550* /550 /550

*Series available as JAN, JANTX and JANTXV

General Purpose, Fast Recovery

TYPE	OUTPUT CURRENT	V_{RWM}	MAXIMUM FORWARD VOLTAGE	REVERSE RECOVERY TIME	PACKAGE	MIL-S-19500
1N4942	1A	200V	1.3V @ 1A	150ns	Axial	/359 *
1N4944	1A	400V	1.3V @ 1A	150ns	Axial	/359
1N4946	1A	600V	1.3V @ 1A	250ns	Axial	/359
1N5615	1A	200V	1.6V @ 3A	150ns	Axial	/429 *
1N5617	1A	400V	1.6V @ 3A	250ns	Axial	/429
1N5619	1A	600V	1.6V @ 3A	250ns	Axial	/429
1N5186	3A	100V	1.5V @ 9A	150ns	Axial	/424 **
1N5187	3A	200V	1.5V @ 9A	200ns	Axial	/424
1N5188	3A	400V	1.5V @ 9A	250ns	Axial	/424
1N5189	3A	600V	1.5V @ 9A	400ns	Axial	/424
1N5415	3A	50V	1.5V @ 9A	150ns	Axial	/411 *
1N5416	3A	100V	1.5V @ 9A	150ns	Axial	/411
1N5417	3A	200V	1.5V @ 9A	150ns	Axial	/411
1N5418	3A	400V	1.5V @ 9A	150ns	Axial	/411
1N5419	3A	500V	1.5V @ 9A	250ns	Axial	/411
1N5420	3A	600V	1.5V @ 9A	400ns	Axial	/411
1N3909	30A	50V	1.4V @ 95A	200ns	DO-5	/308 **
1N3910	30A	100V	1.4V @ 95A	200ns	DO-5	/308
1N3911	30A	200V	1.4V @ 95A	200ns	DO-5	/308
1N3912	30A	300V	1.4V @ 95A	200ns	DO-5	/308
1N3913	30A	400V	1.4V @ 95A	200ns	DO-5	/308

* Series available at JAN, JANTX and JANTXV
** Series available as JAN and JANTX

UNITRODE

SILICON RECTIFIERS (continued)

General Purpose, Standard Recovery

TYPE	OUTPUT CURRENT	V_{RWM}	MAXIMUM FORWARD VOLTAGE	SURGE CURRENT	PACKAGE	MIL-S-19500
1N457	75mA	60V	1.0V @ 20mA	225mA	DO-7	/193***
1N458	55mA	125V	1.0V @ 7mA	165mA	DO-7	/193
1N459	40mA	175V	1.0V @ 3mA	120mA	DO-7	/193
1N483B	200mA	70V	1.0V @ 100mA	2A	DO-7	/118**
1N485B	200mA	180V	1.0V @ 100mA	2A	DO-7	/118
1N643	40mA	175V	1.0V @ 10mA	500mA	DO-7	/256***
1N645	400mA	270V	1.0V @ 400mA	5A	DO-7	/240**
1N645-1	400mA	270V	1.0V @ 400mA	5A	DO-35	/240*
1N647	400mA	480V	1.0V @ 400mA	5A	DO-7	/240**
1N647-1	400mA	480V	1.0V @ 400mA	5A	DO-35	/240*
1N4245	1A	200V	1.3V @ 3A	25A	Axial	/286*
1N4246	1A	400V	1.3V @ 3A	25A	Axial	/286
1N4247	1A	600V	1.3V @ 3A	25A	Axial	/286
1N4248	1A	800V	1.3V @ 3A	25A	Axial	/286
1N4249	1A	1000V	1.3V @ 3A	25A	Axial	/286
1N5614	1A	200V	1.3V @ 3A	30A	Axial	/427*
1N5616	1A	400V	1.3V @ 3A	30A	Axial	/427
1N5618	1A	600V	1.3V @ 3A	30A	Axial	/427
1N5620	1A	800V	1.3V @ 3A	30A	Axial	/427
1N3611	2A	200V	1.1V @ 1A	20A	Axial	/228**
1N3612	2A	400V	1.1V @ 1A	20A	Axial	/228
1N3613	2A	600V	1.1V @ 1A	20A	Axial	/228
1N3614	2A	800V	1.1V @ 1A	20A	Axial	/228
1N5550	3A	200V	1.2V @ 9A	100A	Axial	/420*
1N5551	3A	400V	1.2V @ 9A	100A	Axial	/420
1N5552	3A	600V	1.2V @ 9A	100A	Axial	/420
1N5553	3A	800V	1.2V @ 9A	100A	Axial	/420

* Series available as JAN and JANTX and JANTXV
** Series available as JAN and JANTX
*** Series available as JAN only

Radiation Tolerant Rectifiers

TYPE	OUTPUT CURRENT	PIV	MAXIMUM FORWARD VOLTAGE	SURGE CURRENT	MAXIMUM RADIATION TOLERANCE	PACKAGE
UR105	1A	50V	1.0 @ 0.5A	20A	$>10^{14}$	Axial
UR110	1A	100V	1.0 @ 0.5A	20A	$>10^{14}$	Axial
UR115	1A	150V	1.0 @ 0.5A	20A	$>10^{14}$	Axial
UR120	1A	200V	1.0 @ 0.5A	20A	$>10^{14}$	Axial
UR125	1A	250V	1.0 @ 0.5A	20A	$>10^{14}$	Axial
UR205	2A	50V	1.0 @ 1A	25A	$>10^{14}$	Axial
UR210	2A	100V	1.0 @ 1A	25A	$>10^{14}$	Axial
UR215	2A	150V	1.0 @ 1A	25A	$>10^{14}$	Axial
UR220	2A	200V	1.0 @ 1A	25A	$>10^{14}$	Axial
UR225	2A	250V	1.0 @ 1A	25A	$>10^{14}$	Axial

High Efficiency, Center-Tap Rectifiers and Doublers

TYPE	V_{RWM}	MAXIMUM FORWARD VOLTAGE	REVERSE RECOVERY TIME	OUTPUT CURRENT	SURGE CURRENT	PACKAGE
UES2601 UES2602 UES2603	50V 100V 150V	.930V @ 15A	35ns	30A	400A	TO-3 TO-3 TO-3
UES2604 UES2605 UES2606	200V 300V 400V	1.15V @ 15A	50ns	30A	400A	TO-3 TO-3 TO-3

II

SWITCHING DIODES

Low Current

TYPE	OUTPUT CURRENT	V_{RWM}	MAXIMUM FORWARD VOLTAGE	REVERSE RECOVERY TIME	PACKAGE	MIL-S-19500
1N251	14mA	40V	1.0V @ 5mA	30ns	DO-7	/188***
1N662	40mA	80V	1.0V @ 10mA	500ns	DO-7	/256***
1N663	100mA	80V	1.0V @ 100mA	500ns	DO-7	/256***
1N914	75mA	100V	1.0V @ 10mA	5ns	DO-35	/116**
1N3064	75mA	75V	1.0V @ 10mA	4ns	DO-7	/144**
1N3070	200mA	200V	1.0V @ 100mA	50ns	DO-35	/169**
1N3595	150mA	150V	.80V @ 10mA	3μs	DO-7	/241*
1N3600	200mA	75V	.74V @ 10mA	4ns	DO-7	/231*
1N4148	150mA	100V	1.0V @ 10mA	5ns	DO-35	/116*
1N4148-1	150mA	100V	1.0V @ 10mA	5ns	DO-35	/116*
1N4150-1	200mA	75V	.74V @ 10mA	4ns	DO-35	/231*
1N4153	150mA	75V	.88V @ 20mA	4ns	DO-35	/337*
1N4153-1	150mA	75V	.88V @ 20mA	4ns	DO-35	/337*
1N4454	200mA	75V	1.0V @ 10mA	4ns	DO-35	/144*
1N4454-1	200mA	75V	1.0V @ 10mA	4ns	DO-35	/144*
1N4500	300mA	80V	.77V @ 20mA	6ns	DO-35	/403*
1N4531	125mA	100V	1.0V @ 10mA	8ns	DO-34	/116*
1N4532	125mA	75V	1.0V @ 10mA	4ns	DO-34	/144*
1N4534	150mA	75V	.88V @ 20mA	4ns	DO-34	/337*
1N4938	150mA	250V	1.0V @ 100mA	50ns	DO-7	/169**

* Series available as JAN, JANTX and JANTXV
** Series available as JAN and JANTX
*** Series available as JAN only

SWITCHING REGULATOR POWER OUTPUT CIRCUITS

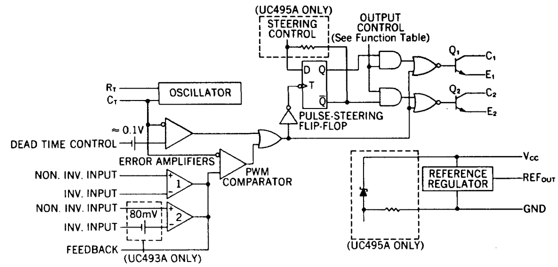
TYPE	OUTPUT CURRENT, PK.	INPUT/OUTPUT VOLTAGE	POLARITY	FALL-TIME VOLTAGE (V)	FALL-TIME CURRENT (ns)	ON-STATE VOLT. @ CURR. (V) @ (I)	PACKAGE
PIC600 PIC601 PIC602 PIC610 PIC611 PIC612	5A	60V 80V 100V 60V 80V 100V	Pos. Pos. Pos. Neg. Neg. Neg.	75	150	1.5 @ 2	4 PIN TO-66 (Isolated)
PIC625 PIC626 PIC627 PIC635 PIC636 PIC637	15A	60V 80V 100V 60V 80V 100V	Pos. Pos. Pos. Neg. Neg. Neg.	175 300	300 300	1.5 @ 7	4 PIN TO-66 (Isolated)
PIC645 PIC646 PIC647 PIC655 PIC656 PIC657	20A	60V 80V 100V 60V 80V 100V	Pos. Pos. Pos. Neg. Neg. Neg.	150 300	300 300	1.5 @ 7	3 PIN TO-3
PIC730 PIC740	30A	30V 40V	Pos. Pos.	350	300	1.0 @ 20	3 PIN TO-3
PIC800 PIC801	8A	350V 400V	Pos. Pos.	200	200	1.5 @ 5	4 PIN TO-66 (Isolated)
PIC810 PIC811	8A	350V 400V	Neg. Neg.	200	200	1.5 @ 5	4 PIN TO-66 (Isolated)

LINEAR INTEGRATED CIRCUITS

Regulating Pulse Width Modulators

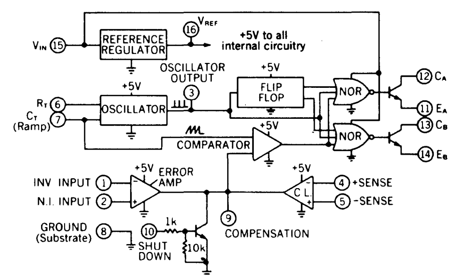
UC493A/UC494A/UC495A

- Fully Interchangeable, Advanced Version of 494 family.
- Uncommitted Outputs for Single-ended or Push-pull Applications
- Supply Voltage, V_{CC} .... 7V to 40V
- Reference Voltage, V_{REF} .... 5V to ±1%
- Dual Error Amplifiers
- Wide Range, Variable Deadtime
- Under-Voltage Lockout
- Double-pulse Protection
- Sawtooth Oscillator Operation to 300kHz
- High Performance Current Limit on UC493A
- Internal 39V Zener for Operation above 40V on UC495A
- Buffered Output Steering Control on UC495A



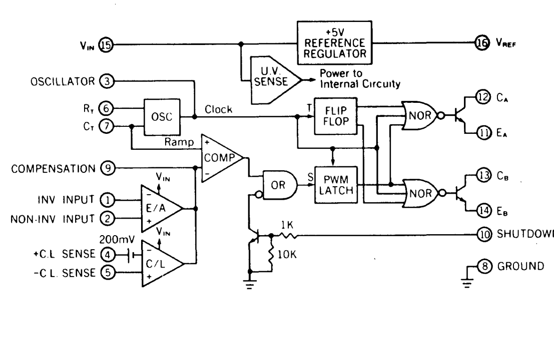
UC1524

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for Single-ended or Push-pull Applications 100mA
- Output Voltage 40V
- Supply Voltage, V_{CC} .... 8V to 40V
- Low Standby Current .... 8mA Typical
- Reference Voltage, V_{REF} .... 5V ± 4%
- Sawtooth Oscillator Operation to 300kHz
- Analog External Shutdown
- Analog Current Limiting
- 16 Pin Dual-in-line Package



UC1524A

- Fully Interchangeable, Advanced Version of UC1524 family
- Output Current 200mA
- Output Voltage 60V
- High-Performance Current Limit
- Under-Voltage Lockout
- Low Standby Current .... 5mA Typical
- Reference Voltage, V_{REF} .... 5V ± 1%
- Wide Common-Mode Input Range for Both Error and Current Limit Amplifiers
- PWM Latch Insures Single Pulse per Period
- 100ns Shutdown
- Guaranteed Frequency Accuracy.
- Sawtooth Oscillator Operation to 500kHz
- 16 Pin Dual-in-line Package

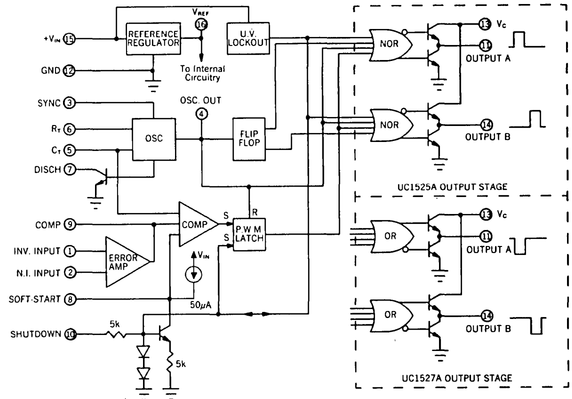


LINEAR INTEGRATED CIRCUITS

Regulating Pulse Width Modulators

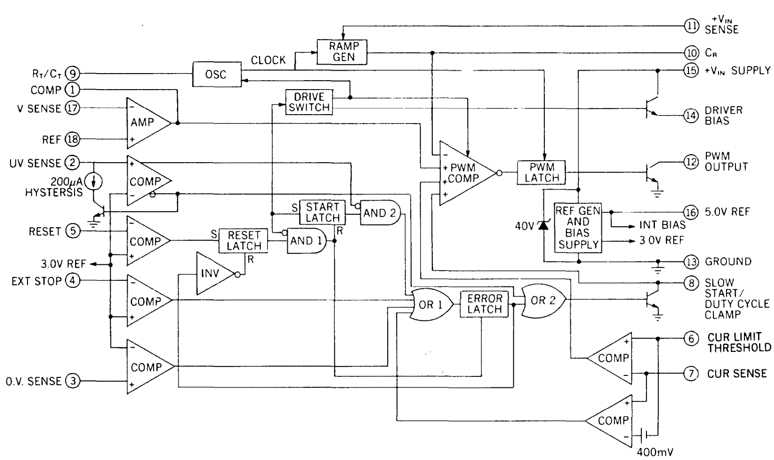
UC1525A/UC1527A

- 8V to 35V Operation
- Reference Voltage, V_{REF} .... 5.1V ± 1%
- 100Hz to 500kHz Oscillator Range
- Separate Oscillator Sync Terminal
- Adjustable Deadtime Control
- Internal Soft-Start
- Under-Voltage Lockout
- Latching PWM to Prevent Multiple Pulses
- Dual Source/Sink Output Drivers 500mA
- 16 Pin Dual-in-line Package



UC1840

- All Control, Driving, Monitoring, and Protection Functions Included
- Feed-Forward Sensing for Constant Volt-Second Operation over a 4 to 1 Input Range
- Low Current, Off-Line Start
- Hystersis for Separating Start and Run Levels
- Under-Voltage Lockout
- Slow Turn-on
- PWM Latch for Single-Pulse Operation
- Pulse-by-Pulse Current Limiting plus Shutdown for Over-Current Fault
- Shutdown upon Over or Under-Voltage Sensing
- Latch off or Continuous Retry Modes
- Remote, Pulse-Commandable Start/Stop
- Maximum PWM limiting with External Divider
- 200mA PWM Output Switch
- Error Amp Reference Trimmed to ± 1%
- Operation to 500kHz
- 18 Pin Dual-in-line Package



LINEAR INTEGRATED CIRCUITS (continued)

Three Terminal Voltage Regulators, Adjustable

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)	Pkg.
UC117K UC217K UC317K	1.5A	Pos.	Adjustable from 1.2V to 37V	TO-3 TO-3 TO-3
UC137K UC237K UC337K	1.5A	Neg.	Adjustable from −1.2V to −37V	TO-3 TO-3 TO-3
UC150K UC250K UC350K	3.0A	Pos.	Adjustable from 1.2V to 33V	TO-3 TO-3 TO-3

Three Terminal Voltage Regulators, Fixed, Positive

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7800AK SERIES UC7800ACK SERIES	1.5A	Pos.	5V ± 1%	12V ± 1%	15V ± 1%	TO-3 TO-3
UC7800K SERIES UC7800CK SERIES	1.5A	Pos.	5V ± 4%	12V ± 4%	15V ± 4%	TO-3 TO-3

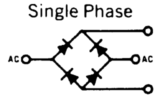
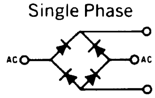
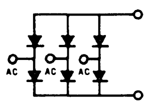
Three Terminal Voltage Regulators, Fixed, Negative

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7900AK SERIES UC7900ACK SERIES	1.5A	Neg.	−5V ± 1%	−12V ± 1%	−15V ± 1%	TO-3 TO-3
UC7900K SERIES UC7900CK SERIES	1.5A	Neg.	−5V ± 4%	−12V ± 4%	−15V ± 4%	TO-3 TO-3

MILITARY DESIGNERS' GUIDE

II

BRIDGE RECTIFIERS
40Hz - 5KHz

TYPE	CONFIGURATION	OUTPUT CURRENT	REVERSE VOLTAGE	SPECIFICATIONS	MIL-S-19500
469-1 469-2 469-3	Single Phase 	10A	200V 400V 600V	V_F@15.7A, 1.35V Max I_R @ V_R, 2μA Max I_{SURGE}, 100A	/469*
SPA25 SPB25 SPC25 SPD25	Single Phase 	25A	100V 200V 400V 600V	V_F @ 39A, 1.4V Max I_R @ V_R, 2μA Max I_{SURGE}, 150A	/446*
483-1 483-2 483-3	Three Phase 	25A	200V 400V 600V	V_F @ 39A, 1.3 V Max I_R @ V_R, 3μA Max I_{SURGE}, 150A	/483**

* Series available as JAN and JANTX
** Series available as JANTX only

HIGH VOLTAGE DOORBELL® MODULES
40Hz - 5KHz

TYPE	OUTPUT CURRENT	REVERSE VOLTAGE	MAXIMUM REVERSE CURRENT @ V_R	MAXIMUM FORWARD VOLTAGE	SURGE CURRENT	MIL-S-19500
1N5597 1N5600 1N5603	1A 2A 5A	10kV 5kV 5kV	1μA 5μA 5μA	19V @ 1A 10V @ 2A 10V @ 5A	30A 80A 200A	/404*

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* Series available as JAN only

MILITARY DESIGNERS' GUIDE

NPN POWER SWITCHING TRANSISTORS

TYPE	MAXIMUM COLLECTOR CURRENT	$V_{CEO(sus)}$ (V)	MINIMUM h_{FE} @ I_C (A)	MAXIMUM $V_{CE(sat)}$ @ I_C (A)	MAXIMUM FALL—TIME (t_f)	PACKAGE	MIL-S-19500
2N5660	2A	200V	40 @ .5A	.4V @ 1A	0.4μs	TO-66	/454 *
2N5661	2A	300V	25 @ .5A	.4V @ 1A	0.6μs	TO-66	/454
2N5662	2A	200V	40 @ .5A	.4V @ 1A	0.4μs	TO-5	/454
2N5663	2A	300V	25 @ .5A	.4V @ 1A	0.6μs	TO-5	/454
2N3418	3A	60V	20 @ 1A	.5V @ 2A	1.2μs	TO-5	/393 *
2N3419	3A	80V	20 @ 1A	.5V @ 2A	1.2μs	TO-5	/393
2N3420	3A	60V	40 @ 1A	.5V @ 2A	1.2μs	TO-5	/393
2N3421	3A	80V	40 @ 1A	.5V @ 2A	1.2μs	TO-5	/393
2N2151	5A	80V	40 @ 1A	1.0V @ 1A	—	TO-59	/277 **
2N2880	5A	80V	40 @ 1A	.25V @ 1A	0.3μs	TO-59	/315 *
2N3749	5A	80V	40 @ 1A	.25V @ 1A	0.3μs	TO-111	/315
2N3996	5A	80V	40 @ 1A	.25V @ 1A	0.8μs	TO-111	/374 *
2N3997	5A	80V	80 @ 1A	.25V @ 1A	1.0μs	TO-111	/374
2N3998	5A	80V	40 @ 1A	.25V @ 1A	0.8μs	TO-59	/374
2N3999	5A	80V	80 @ 1A	.25V @ 1A	1.0μs	TO-59	/374
2N5664	5A	200V	40 @ 1A	.4V @ 3A	0.8μs	TO-66	/455 *
2N5665	5A	300V	25 @ 1A	.4V @ 3A	1.0μs	TO-66	/455
2N5666	5A	200V	40 @ 1A	.4V @ 3A	0.8μs	TO-5	/455
2N5667	5A	300V	25 @ 1A	.4V @ 3A	1.0μs	TO-5	/455
2N6544	8A	300V	7 @ 5A	1.5V @ 3A	0.9μs	TO-3	N/A
UMT1008	8A	300V	7 @ 5A	1.5V @ 3A	0.4μs	TO-3	N/A
2N6545	8A	400V	7 @ 5A	1.5V @ 5A	0.9μs	TO-3	N/A
UMT1009	8A	400V	7 @ 5A	1.5V @ 5A	0.4μs	TO-3	N/A
2N4150	10A	70V	10 @ 10A	0.6V @ 5A	0.4μs	TO-5	/394 *
2N6354	10A	120V	10 @ 10A	1.0V @ 10A	0.2μs	TO-3	N/A
2N6496	15A	100V	12 @ 8A	1.0V @ 8A	0.3μs	TO-3	N/A
2N5038	20A	90V	20 @ 12A	1.2V @ 12A	0.5μs	TO-3	/439 *
2N5039	20A	75V	20 @ 10A	1.0V @ 10A	0.5μs	TO-3	/439
2N5671	30A	90V	20 @ 15A	0.75V @ 15A	0.5μs	TO-3	N/A
2N5672	30A	120V	20 @ 15A	0.75V @ 15A	0.5μs	TO-3	N/A

* Series available as JAN, JANTX, and JANTXV
** Series available as JAN and JANTX

POWER DARLINGTONS

TYPE	D.C. COLLECTOR CURRENT	B_{VCEO}	MINIMUM h_{FE} @ 5A	PACKAGE	MIL-S-19500
2N6350	5A	80V	2000	TO-33	/472 **
2N6351	5A	150V	1000	TO-33	/472
2N6352	5A	80V	2000	TO-66	/472
2N6353	5A	150V	1000	TO-66	/472

*Series available as JAN, JANTX

PROGRAMMABLE UNIJUNCTION TRANSISTORS

TYPE	V_{AK}	PEAK CURRENT	VALLEY CURRENT	PACKAGE	MIL-S-19500
2N6137	40V	2μA @ R_G=1 MEGΩ	1.5mA @ R_G=200Ω	TO-18	/493 *

*Available as JAN, JANTX and JANTXV

MILITARY DESIGNERS' GUIDE

POWER ZENERS AND TRANSIENT SUPPRESSORS

II

TYPE	AVERAGE D.C. POWER	BREAKDOWN VOLTAGE RANGE	PEAK POWER	PACKAGE	MIL-S-19500
1N4461-96	1.5W	6.8V-200V	140W	Axial	/406*
1N6461-68 (TVS)	2.5W	5.6V-54V	500W	Axial	/551*
1N5968-69	5.0W	5.6V-6.2V	900W	Axial	/356*
1N4954-96	5.0W	6.8V-390V	900W	Axial	/356*
1N5610-13 (TVS)	6.0W	33V-191V	1500W	Axial	/434**
UZ7706-7110	10W	6.8V-100V	2000W	Stud Mount	N/A

* Series available as JAN, JANTX and JANTXV
** Series available as JAN and JANTX

THYRISTORS
Silicon Control Rectifiers

TYPE	D.C. ON STATE CURRENT	V_{DRM}	MAXIMUM I_{GT}	MAXIMUM V_{GT}	PACKAGE	MIL-S-19500
2N3027	.5A	30V	20μA	.6V	TO-18	/419 **
2N3028	.5A	60V	20μA	.6V	TO-18	/419
2N3029	.5A	100V	20μA	.6V	TO-18	/419
2N3030	.5A	30V	20μA	.6V	TO-18	/419
2N3031	.5A	60V	20μA	.6V	TO-18	/419
2N3032	.5A	100V	20μA	.6V	TO-18	/419
2N1870A	1.25A	30V	200μA	.8V	TO-9	/198 ***
2N1871A	1.25A	60V	200μA	.8V	TO-9	/198
2N1872A	1.25A	100V	200μA	.8V	TO-9	/198
2N1873A	1.25A	150V	200μA	.8V	TO-9	N/A
2N1874A	1.25A	200V	200μA	.8V	TO-9	/198
2N2323A	1.6A	50V	20μA	.6V	TO-39	/276 *
2N2324A	1.6A	100V	20μA	.6V	TO-39	/276
2N2325A	1.6A	150V	20μA	.6V	TO-39	N/A
2N2326A	1.6A	200V	20μA	.6V	TO-39	/276
2N2327A	1.6A	250V	20μA	.6V	TO-39	N/A
2N2328A	1.6A	300V	20μA	.6V	TO-39	/276
2N2329A	1.6A	400V	20μA	.6V	TO-39	/276

* Series available as JAN and JANTX and JANTXV
** Series available as JAN and JANTX
*** Series available as JAN only

Ultra Fast Switching

TYPE	D.C. ON STATE CURRENT	V_{DRM}	RISE TIME	COMMUTATED TURN-OFF TIME	PACKAGE
GA200	.4A	60V	25ns	2.0μs	TO-18
GA201	.4A	100V	20ns	2.0μs	TO-18
GB200	6A	60V	25ns	2.0μs	TO-59
GB201	6A	100V	20ns	2.0μs	TO-59

Radiation Resistant

TYPE	D.C. ON STATE CURRENT	V_{DRM}	MAXIMUM I_{GT}†	MAXIMUM V_{GT}†	PACKAGE
GA100	0.4A	30V	20mA	1.5V	TO-18
GA101	@	60V	20mA	1.5V	TO-18
GA102	T_C = 100°C	80V	20mA	1.5V	TO-18

† Post 3×10^{14} NVT

LINEAR INTEGRATED CIRCUITS III

III

Three Terminal Voltage Regulators, Adjustable

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)	Pkg.
UC117K UC217K UC317K UC317T	1.5A	Pos.	Adjustable from 1.2V to 37V	TO-3 TO-3 TO-3 TO-220
UC137K UC237K UC337K UC337T	1.5A	Neg.	Adjustable from −1.2V to −37V	TO-3 TO-3 TO-3 TO-220
UC150K UC250K UC350K	3.0A	Pos.	Adjustable from 1.2V to 33V	TO-3 TO-3 TO-3

Three Terminal Voltage Regulators, Fixed, Positive

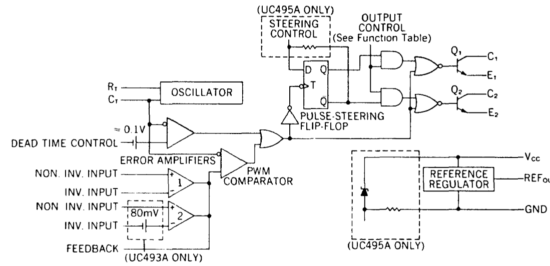
Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7800AK SERIES UC7800ACK SERIES UC7800ACT SERIES	1.5A	Pos.	5V ± 1%	12V ± 1%	15V ± 1%	TO-3 TO-3 TO-220
UC7800K SERIES UC7800CK SERIES UC7800CT SERIES	1.5A	Pos.	5V ± 4%	12V ± 4%	15V ± 4%	TO-3 TO-3 TO-220

Three Terminal Voltage Regulators, Fixed, Negative

Type	Output Current (A)	Polarity	Regulated Output Voltage (V)			Pkg.
UC7900AK SERIES UC7900ACK SERIES UC7900ACT SERIES	1.5A	Neg.	−5V ± 1%	−12V ± 1%	−15V ± 1%	TO-3 TO-3 TO-220
UC7900K SERIES UC7900CK SERIES UC7900CT SERIES	1.5A	Neg.	−5V ± 4%	−12V ± 4%	−15V ± 4%	TO-3 TO-3 TO-220

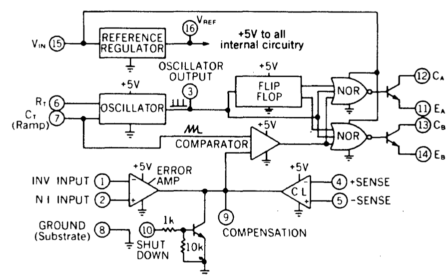
UC493A/UC494A/UC495A
UC493AC/UC494AC/UC495AC

- Fully Interchangeable, Advanced Version of 494 family.
- Uncommitted Outputs for Single-ended or Push-pull Applications
- Supply Voltage, V_{CC} .... 7V to 40V
- Reference Voltage, V_{REF} .... 5V to ±1%
- Dual Error Amplifiers
- Wide Range, Variable Deadtime
- Under-Voltage Lockout
- Double-pulse Protection
- Sawtooth Oscillator Operation to 300kHz
- High Performance Current Limit on UC493A
- Internal 39V Zener for Operation above 40V on UC495A
- Buffered Output Steering Control on UC495A



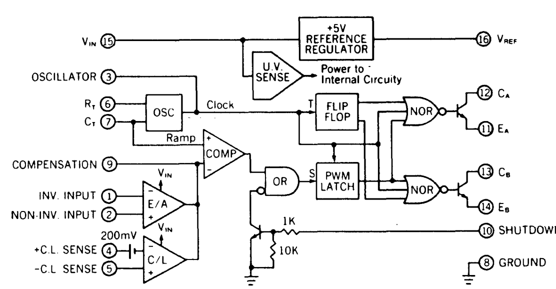
UC1524/UC2524/UC3524

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for Single-ended or Push-pull Applications 100mA
- Output Voltage 40V
- Supply Voltage, V_{CC} .... 8V to 40V
- Low Standby Current ....8mA Typical
- Reference Voltage, V_{REF} ....5V ± 4%
- Sawtooth Oscillator Operation to 300kHz
- Analog External Shutdown
- Analog Current Limiting
- 16 Pin Dual-in-line Package



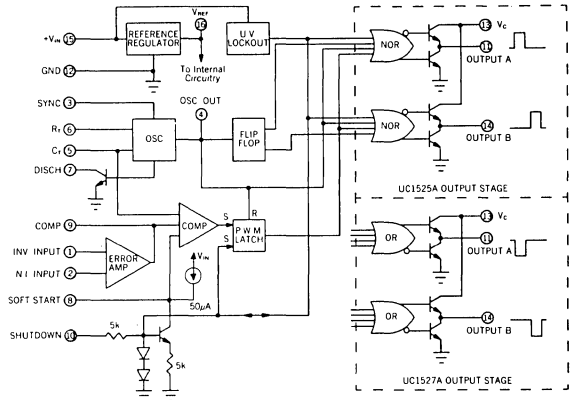
UC1524A/UC2524A/UC3524A

- Fully Interchangeable, Advanced Version of UC1524 family
- Output Current 200mA
- Output Voltage 60V
- High-Performance Current Limit
- Under-Voltage Lockout
- Low Standby Current ....5mA Typical
- Reference Voltage, V_{REF} ....5V ± 1%
- Wide Common-Mode Input Range for Both Error and Current Limit Amplifiers
- PWM Latch Insures Single Pulse per Period
- 100ns Shutdown
- Guaranteed Frequency Accuracy
- Sawtooth Oscillator Operation to 500kHz
- 16 Pin Dual-in-line Package



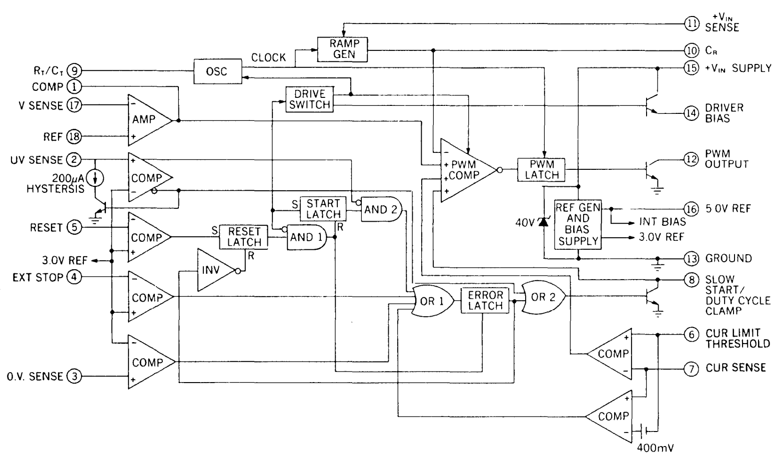
UC1525A/UC2525A/UC3525A
UC1527A/UC2527A/UC3527A

- 8V to 35V Operation
- Reference Voltage, V_{REF} .... 5.1V ± 1%
- 100Hz to 500kHz Oscillator Range
- Separate Oscillator Sync Terminal
- Adjustable Deadtime Control
- Internal Soft-Start
- Under-Voltage Lockout
- Latching PWM to Prevent Multiple Pulses
- Dual Source/Sink Output Drivers 500mA
- 16 Pin Dual-in-line Package



UC1840/UC2840/UC3840*

- All Control, Driving, Monitoring, and Protection Functions Included
- Feed-Forward Sensing for Constant Volt-Second Operation over a 4 to 1 Input Range
- Low Current, Off-Line Start
- Hysteresis for Separating Start and Run Levels
- Under-Voltage Lockout
- Slow Turn-on
- PWM Latch for Single-Pulse Operation
- Pulse-by-Pulse Current Limiting plus Shutdown for Over-Current Fault
- Shutdown upon Over or Under-Voltage Sensing
- Latch off or Continuous Retry Modes
- Remote, Pulse-Commandable Start/Stop
- Maximum PWM limiting with External Divider
- 200mA PWM Output Switch
- Error Amp Reference Trimmed to ± 1%
- Operation to 500kHz
- 18 Pin Dual-in-line Package



*Contact Unitrode for complete specifications.

LINEAR INTEGRATED CIRCUITS

UC117
UC217
UC317

1.5A, Three Terminal Adjustable Positive Voltage Regulators

FEATURES

- Output voltage adjustable from 1.2 to 37V
- Guaranteed 1.5A output current
- Line regulation typically 0.01%/V
- Load regulation typically 0.1%
- Temperature-independent current limit
- Standard 3-lead transistor packages (TO-3, TO-220)

DESCRIPTION

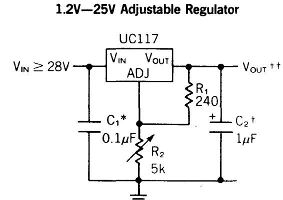
This monolithic integrated circuit is an adjustable 3-terminal positive voltage regulator designed to supply more than 1.5A of load current with an output voltage adjustable over a 1.2 to 37V range. Although ease of setting the output voltage to any desired value with only two external resistors is a major feature of this circuit, exceptional line and load regulation are also offered. In addition, full overload protection consisting of current limiting, thermal shutdown and safe-area control are included in this device which is packaged in TO-3 and TO-220 packages. The UC117 is rated for operation from −55°C to +150°C, the UC217 from −25°C to +150°C and the UC317 from 0°C to +125°C.

ABSOLUTE MAXIMUM RATINGS

Power Dissipation	Internally limited
Input—Output Voltage Differential	40V
Operating Junction Temperature Range	
UC117	−55°C to +150°C
UC217	−25°C to +150°C
UC317	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

TYPICAL APPLICATIONS

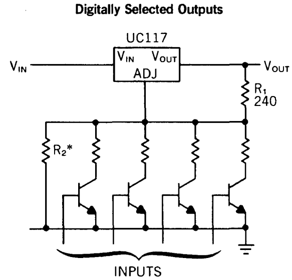
1.2V—25V Adjustable Regulator



*Needed if device is far from filter capacitors
†Optional—improves transient response

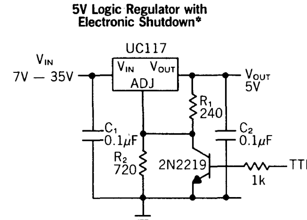
$$†† \; V_{OUT} = 1.25V\left(1 + \frac{R_2}{R_1}\right)$$

Digitally Selected Outputs



*Value determines maximum V_{OUT}

5V Logic Regulator with Electronic Shutdown*



*Min output ≃ 1.2V

UNITRODE

III

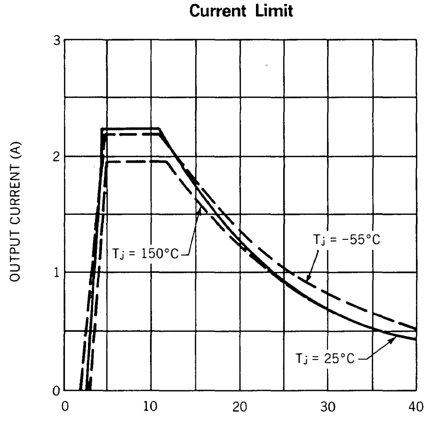
ELECTRICAL CHARACTERISTICS (Note 1)

PARAMETER	TEST CONDITIONS	UC117/UC217			UC317			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Line Regulation	$T_A = 25°C$, $3V \le (V_{IN} - V_{OUT}) \le 40V$, (Note 2)		0.01	0.02		0.01	0.04	%/V
Load Regulation	$T_A = 25°C$, $10mA \le I_{OUT} \le I_{MAX}$ $V_{OUT} \le 15V$, (Note 2) $V_{OUT} \ge 5V$, (Note 2)		 5 0.1	 15 0.3		 5 0.1	 25 0.5	 mV %
Thermal Regulation	$T_A = 25°C$, 20ms Pulse		0.03	0.07		0.04	0.07	%/W
Adjustment Pin Current			50	100		50	100	μA
Adjustment Pin Current Change	$10mA \le I_L \le I_{MAX}$ $2.5V \le (V_{IN} - V_{OUT}) \le 40V$		0.2	5		0.2	5	μA
Reference Voltage	$3 \le (V_{IN} - V_{OUT}) \le 40V$ $10mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$	1.20	1.25	1.30	1.20	1.25	1.30	V
Line Regulation	$3 \le (V_{IN} - V_{OUT}) \le 40V$, (Note 2)		0.02	0.05		0.02	0.07	%/V
Load Regulation	$10mA \le I_{OUT} \le I_{MAX}$, (Note 2) $V_{OUT} \le 5V$ $V_{OUT} \ge 5V$		 20 0.3	 50 1		 20 0.3	 70 1.5	 mV %
Temperature Stability	$T_{MIN} \le T_j \le T_{MAX}$		1			1		%
Minimum Load Current	$V_{IN} - V_{OUT} = 40V$		3.5	5		3.5	10	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$ K Package T Package $(V_{IN} - V_{OUT}) = 40V$ K Package T Package	 1.5 0.5 	 2.2 0.8 0.4 0.07		 1.5 0.5 	 2.2 0.8 0.4 0.07		 A A A A
RMS Output Noise	$T_A = 25°C$, $10Hz \le f \le 10kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120Hz $C_{ADJ} = 10\mu F$	 66	65 80		 66	65 80		dB dB
Long Term Stability	$T_A = 125°C$, 1000 Hrs.		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case	K Package T Package		2.3	3		2.3 12	3	°C/W °C/W

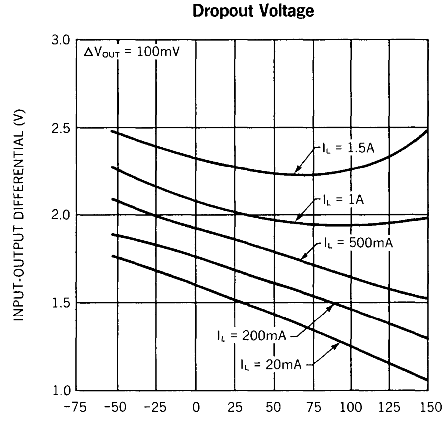
Notes: 1. Unless otherwise noted, the above specifications apply over the following conditions:
UC117: $-55°C \le T_j \le 150°C$
UC217: $-25°C \le T_j \le 150°C$
UC317: $0°C \le T_j \le 125°C$
$(V_{IN} - V_{OUT}) = 5V$, $I_O = 0.5A$, $I_{MAX} = 1.5A$
2. All regulation specifications are measured at constant junction temperatures using low duty-cycle pulse testing.

TYPICAL PERFORMANCE CHARACTERISTICS

Current Limit

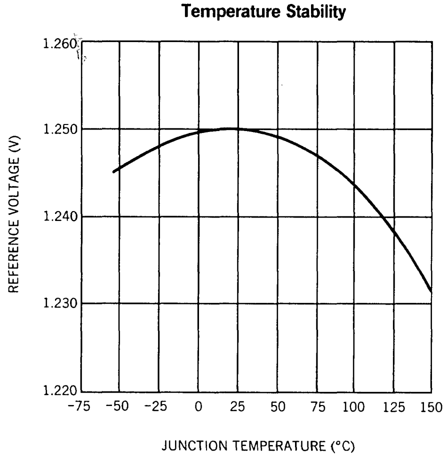


Dropout Voltage

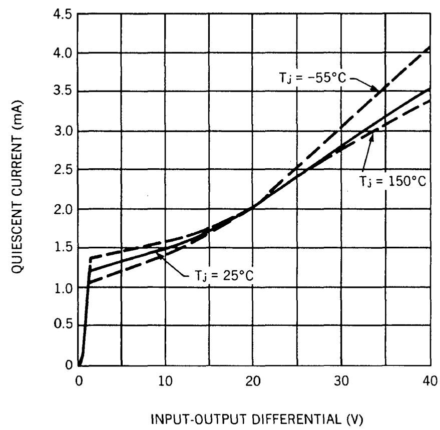


TYPICAL PERFORMANCE CHARACTERISTICS

Temperature Stability

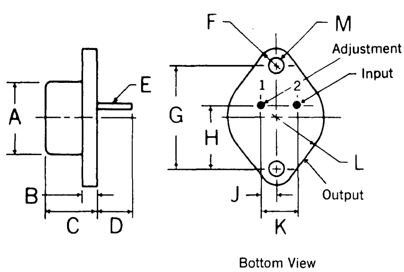


Minimum Operating Current



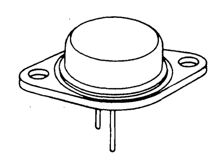
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

UC117 UC217 UC317

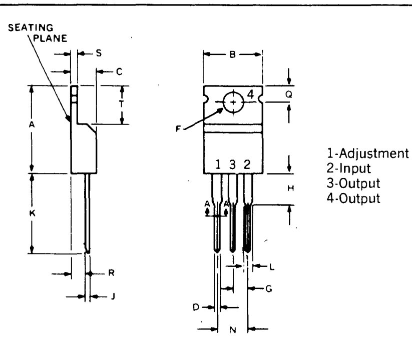


	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)

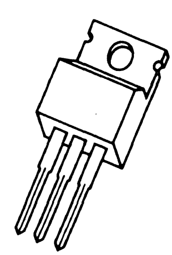


UC317



	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	—	0.250	—	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



Note: When ordering, add suffix "K" (for TO-3 package) or "T" (for TO-220 package) to the Part Number.

APPLICATION HINTS

In operation, the UC117 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R_1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R_2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1+\frac{R_2}{R_1}\right) + I_{ADJ}R_2$$

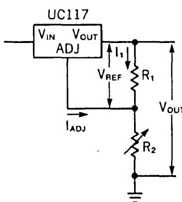


Figure 1

Since the 100μA current from the adjustment terminal represents an error term, the UC117 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

External Capacitors

An input bypass capacitor is recommended. A 0.1μF disc or 1μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the UC117 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10μF bypass capacitor 80 dB ripple rejection is obtainable at any output level.

In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25μF in aluminum electrolytic to equal 1μF solid tantalum at high frequencies.

Although the UC117 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500pF and 5000pF. A 1μF solid tantalum (or 25μF aluminum electrolytic) on the output swamps this effect and insures stability.

Load Regulation

The UC117 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation.

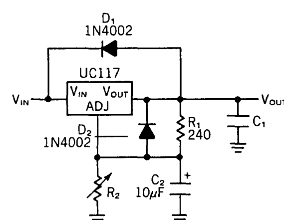
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor by using 2 separate leads to the case. The ground of R_2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

Protection Diodes

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the UC117, this discharge path is through a large junction that is able to sustain 15A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the UC117 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10μF capacitance. *Figure 2* shows a UC117 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



$$V_{OUT} = 1.25V\left(1+\frac{R_2}{R_1}\right) + R_2I_{ADJ}$$

D_1 protects against C_1
D_2 protects against C_2

Figure 2. Regulator with Protection Diodes

LINEAR INTEGRATED CIRCUITS

1.5A, Three Terminal Adjustable Negative Voltage Regulators

UC137
UC237
UC337

FEATURES

- Output voltage adjustable from −1.2 to −37V
- Guaranteed 1.5A output current
- Line regulation typically 0.01%/V
- Load regulation typically 0.3%
- Excellent thermal regulation, 0.002%/W
- 77 dB ripple rejection
- Excellent rejection of thermal transients
- 50 ppm/°C temperature coefficient
- Temperature-independent current limit
- Internal thermal overload protection
- Standard 3-lead transistor packages (TO-3, TO-220)

DESCRIPTION

The UC137/UC237/UC337 are adjustable 3-terminal negative voltage regulators capable of supplying in excess of −1.5A over an output voltage range of −1.2V to −37V. These regulators are exceptionally easy to apply, requiring only 2 external resistors to set the output voltage and 1 output capacitor for frequency compensation. The circuit design has been optimized for excellent regulation and low thermal transients. Further, the UC137 series features internal current limiting, thermal shutdown and safe-area compensation, making them virtually blowout-proof against overloads.

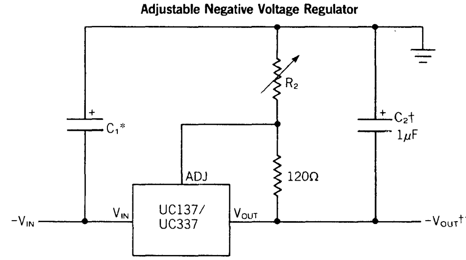
The UC137/UC237/UC337 serve a wide variety of applications including local on-card regulation, programmable-output voltage regulation or precision current regulation. The UC137/UC237/UC337 are ideal complements to the UC117/UC217/UC317 adjustable positive regulators. These devices are available in TO-3 and TO-220 packages. The UC137 is rated for operation from −55°C to +150°C, the UC237 from −25°C to +150°C and the UC337 from 0°C to +125°C.

ABSOLUTE MAXIMUM RATINGS

Power Dissipation	Internally limited
Input—Output Voltage Differential	40V
Operating Junction Temperature Range	
UC137	−55°C to +150°C
UC237	−25°C to +150°C
UC337	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

TYPICAL APPLICATION

Adjustable Negative Voltage Regulator



*C_1 = 1μF solid tantalum is required only if regulator is far from power-supply filter capacitor.
†Optional—improves transient response

†† $-V_{OUT} = -1.25V\left(1 + \frac{R_2}{120\Omega}\right)$

UNITRODE

III

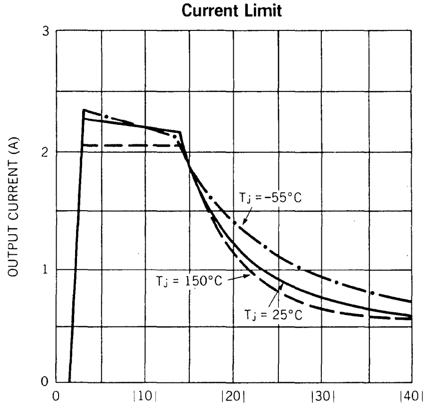
ELECTRICAL CHARACTERISTICS (Note 1)

PARAMETER	TEST CONDITIONS	UC137/UC237			UC337			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Line Regulation	T_A = 25°C, 3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 40V (Note 2)		0.01	0.02		0.01	0.04	%/V
Load Regulation	T_A = 25°C, 10mA ≤ I_{OUT} ≤ I_{MAX} $\|V_{OUT}\|$ ≤5V, (Note 2) $\|V_{OUT}\|$ ≥ 5V, (Note 2)		15 0.3	25 0.5		15 0.3	50 1.0	mV %
Thermal Regulation	T_A = 25°C, 10ms Pulse		0.002	0.02		0.003	0.04	%/W
Adjustment Pin Current			65	100		65	100	μA
Adjustment Pin Current Change	10mA ≤ I_L ≤ I_{MAX} 2.5V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 40V, T_A = 25°C		2	5		2	5	μA
Reference Voltage	T_A = 25°C 3≤ $\|V_{IN} - V_{OUT}\|$ ≤ 40V 10mA ≤ I_{OUT} ≤ I_{MAX}, P ≤ P_{MAX}	-1.225 -1.200	-1.250 -1.250	-1.275 -1.300	-1.213 -1.200	-1.250 -1.250	-1.287 -1.300	V V
Line Regulation	3V ≤ $\|V_{IN} - V_{OUT}\|$ ≤ 40V, (Note 2)		0.02	0.05		0.02	0.07	%/V
Load Regulation	10mA ≤ I_{OUT} ≤ I_{MAX}, (Note 2) $\|V_{OUT}\|$ ≤ 5V $\|V_{OUT}\|$ ≥ 5V		20 0.3	50 1		20 0.3	70 1.5	mV %
Temperature Stability	T_{MIN} ≤ T_j ≤ T_{MAX}		0.6			0.6		%
Minimum Load Current	$\|V_{IN} - V_{OUT}\|$ ≤ 40V $\|V_{IN} - V_{OUT}\|$ ≤ 10V		2.5 1.2	5 3		2.5 1.5	10 6	mA mA
Current Limit	$\|V_{IN} - V_{OUT}\|$ ≤ 15V K Package T Package $\|V_{IN} - V_{OUT}\|$ = 40V K Package T Package	1.5 0.5	2.2 0.8 0.4 0.17		1.5 0.5	2.2 0.8 0.4 0.17		A A A A
RMS Output Noise	T_A = 25°C, 10Hz ≤ f ≤ 10kHz		0.003			0.003		%
Ripple Rejection Ratio	V_{OUT} = -10V, f = 120Hz C_{ADJ} = 10μF	66	60 77		66	60 77		dB dB
Long Term Stability	T_A = 125°C, 1000 Hours		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case	K Package T Package		2.3	3		2.3 12	3	°C/W °C/W

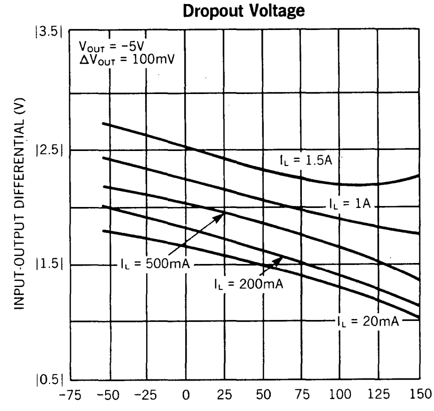
Notes: 1. Unless otherwise noted, the above specifications apply over the following conditions:
UC137: -55°C ≤ T_j ≤ 150°C
UC237: -25°C ≤ T_j ≤ 150°C
UC337: 0°C ≤ T_j ≤ 125°C
$|V_{IN} - V_{OUT}|$ =5V, I_O =0.5A, I_{MAX} =1.5A
2. All regulation specifications are measured at constant junction temperatures using low duty-cycle pulse testing.

TYPICAL PERFORMANCE CHARACTERISTICS

Current Limit

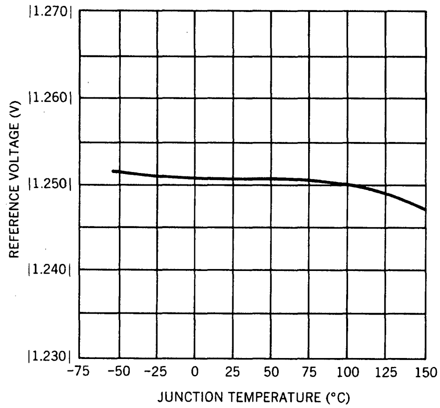


Dropout Voltage

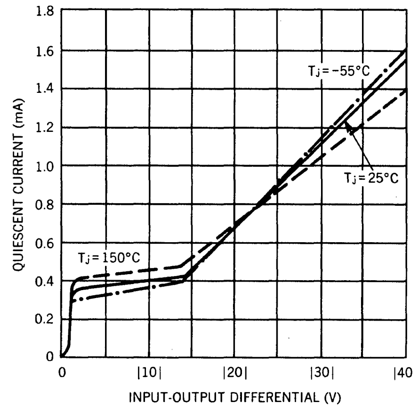


TYPICAL PERFORMANCE CHARACTERISTICS

Temperature Stability

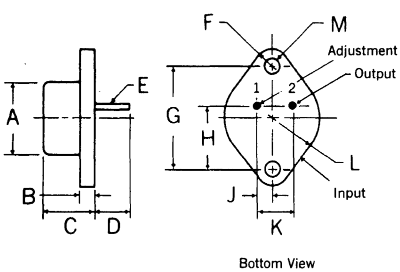


Minimum Operating Current



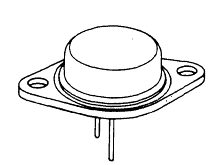
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

UC137 UC237 UC337

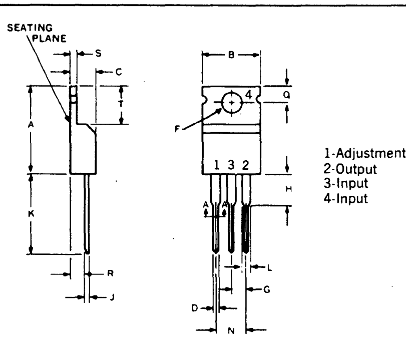


	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)

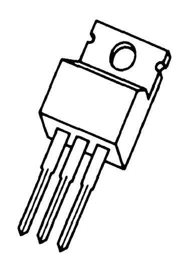


UC337



	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	—	0.250	—	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



Note: When ordering, add suffix "K" (for TO-3 package) or "T" (for TO-220 package) to the Part Number.

LINEAR INTEGRATED CIRCUITS

3A, Three Terminal Adjustable Positive Voltage Regulators

UC150
UC250
UC350

III

FEATURES

- Output voltage adjustable from 1.2V to 33V
- Guaranteed 3A output current
- Line regulation typically 0.005%/V
- Load regulation typically 0.1%
- Guaranteed thermal regulation
- Current limit constant with temperature
- Standard 3-lead transistor package

DESCRIPTION

The UC150/UC250/UC350 are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 3A over a 1.2V to 33V output range. They require only 2 external resistors to set the output voltage. Further, both line and load regulation are comparable to discrete designs.

In addition to higher performance than fixed regulators, the UC150 series offers full overload protection. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is accidentally disconnected.

Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded.

Supplies requiring electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

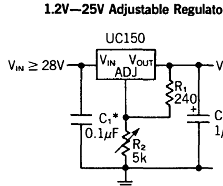
The UC150/UC250/UC350 are packaged in standard TO-3 transistor packages. The UC150 is rated for operation from −55°C to +150°C, the UC250 from −25°C to +150°C and the UC350 from 0°C to +125°C.

ABSOLUTE MAXIMUM RATINGS

Power Dissipation	Internally limited
Input—Output Voltage Differential	35V
Operating Junction Temperature Range	
UC150	−55°C to +150°C
UC250	−25°C to +150°C
UC350	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

TYPICAL APPLICATIONS

1.2V—25V Adjustable Regulator

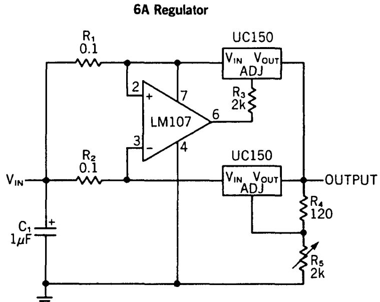


*Needed if regulator is far from power supply filter capacitor
†Optional—improves transient response

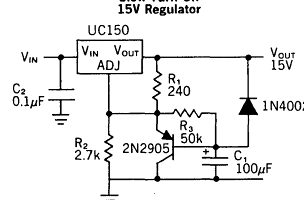
†† $V_{OUT} = 1.25V \left(1 + \frac{R_2}{R_1}\right)$

Note: Usually $R_1 = 240\Omega$ for UC150 and UC250 and $R_1 = 120\Omega$ for UC350

6A Regulator



Slow Turn-On 15V Regulator



UNITRODE

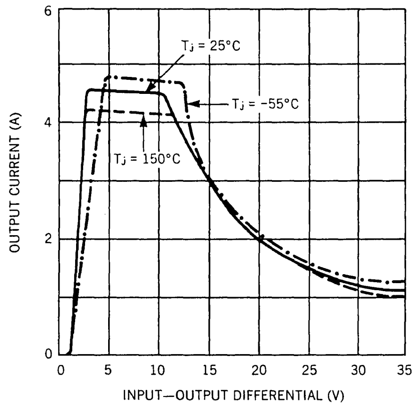
ELECTRICAL CHARACTERISTICS (Note 1)

PARAMETER	TEST CONDITIONS	UC150/UC250			UC350			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Line Regulation	$T_A = 25°C$, $3V \leq (V_{IN} - V_{OUT}) \leq 35V$, (Note 2)		0.005	0.01		0.005	0.03	%/V
Load Regulation	$T_A = 25°C$, $10mA \leq I_{OUT} \leq 3A$ $V_{OUT} \leq 5V$, (Note 2) $V_{OUT} \geq 5V$, (Note 2)		 5 0.1	 15 0.3		 5 0.1	 25 0.1	 mV %
Thermal Regulation	Pulse = 20ms		0.002	0.01		0.002	0.03	%/W
Adjustment Pin Current			50	100		50	100	μA
Adjustment Pin Current Change	$10mA \leq I_L \leq 3A$ $3V \leq (V_{IN} - V_{OUT}) \leq 35V$		0.2	5		0.2	5	μA
Reference Voltage	$3 \leq (V_{IN} - V_{OUT}) \leq 35V$, $10mA \leq I_{OUT} \leq 3A$, $P \leq 30W$	1.20	1.25	1.30	1.20	1.25	1.30	V
Line Regulation	$3 \leq (V_{IN} - V_{OUT}) \leq 35V$, (Note 2)		0.02	0.05		0.02	0.07	%/V
Load Regulation	$V_{OUT} \leq 5V$ $10mA \leq I_{OUT} \leq 3A$, (Note 2) $V_{OUT} \geq 5V$		20 0.3	50 1		20 0.3	70 1.5	mV %
Temperature Stability	$T_{MIN} \leq T_j \leq T_{MAX}$		1			1		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 35V$		3.5	5		3.5	10	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 10V$ $(V_{IN} - V_{OUT}) = 30V$	3.0	4.5 1		3.0	4.5 1		A A
RMS Output Noise	$T_A = 25°C$, $10Hz \leq f \leq 10kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120Hz $C_{ADJ} = 10\mu F$	 66	65 86		 66	65 86		dB dB
Long Term Stability	$T_A = 125°C$, 1000 Hrs.		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case				1.5			1.5	°C/W

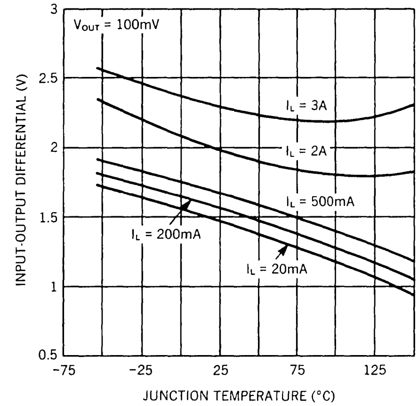
Notes: 1. Unless otherwise noted, the above specifications apply over the following conditions:
UC150: $-55°C \leq T_j \leq 150°C$
UC250: $-25°C \leq T_j \leq 150°C$
UC350: $0°C \leq T_j \leq 125°C$
$(V_{IN} - V_{OUT}) = 5V$, $I_{OUT} = 1.5A$
2. All regulation specifications are measured at constant junction temperatures using low duty-cycle pulse testing.

TYPICAL PERFORMANCE CHARACTERISTICS

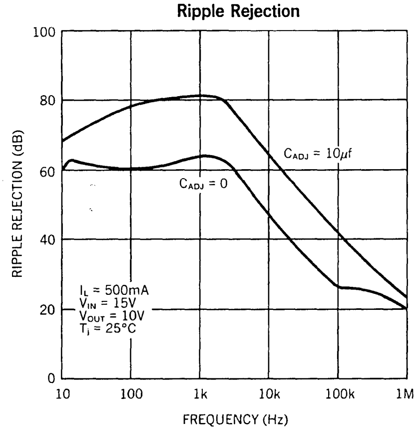
Current Limit



Dropout Voltage

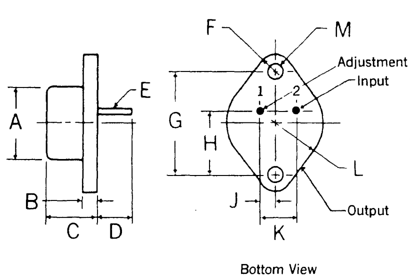


Ripple Rejection



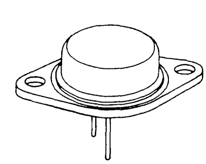
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAM

UC150 UC250 UC350



	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)



APPLICATION HINTS

In operation, the UC150 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R_1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R_2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right) + I_{ADJ}R_2$$

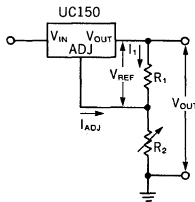


Figure 1

Since the 50μA current from the adjustment terminal represents an error term, the UC150 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

External Capacitors

An input bypass capacitor is recommended. A 0.1μF disc or 1μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the UC150 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10μF bypass capacitor 86 dB ripple rejection is obtainable at any output level.

In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25μF in aluminum electrolytic to equal 1μF solid tantalum at high frequencies.

Although the UC150 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500pF and 5000pF. A 1μF solid tantalum (or 25μF aluminum electrolytic) on the output swamps this effect and insures stability.

Load Regulation

The UC150 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation.

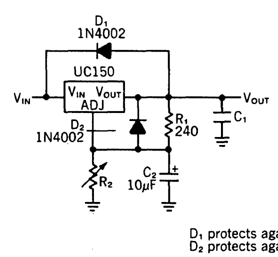
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor by using 2 separate leads to the case. The ground of R_2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

Protection Diodes

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharged current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the UC150, this discharge path is through a large junction that is able to sustain 25A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the UC150 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10μF capacitance. *Figure 2* shows a UC150 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



$$V_{OUT} = 1.25V\left(1 + \frac{R_2}{R_1}\right) + R_2I_{ADJ}$$

Figure 2. Regulator with Protection Diodes

LINEAR INTEGRATED CIRCUITS
Advanced Regulating Pulse Width Modulators

UC493A UC493AC
UC494A UC494AC
UC495A UC495AC

III

FEATURES
- Dual uncommitted 40V, 200mA output transistors
- 1% accurate 5V reference
- Dual error amplifiers
- Wide range, variable dead time
- Single-ended or push-pull operation
- Under-voltage lockout with hysteresis
- Double pulse protection
- Master or slave oscillator operation
- UC493A/UC493AC: Built in 80mV threshold for current limiting
- UC495A/UC495AC: Internal 39V zener diode
- UC495A/UC495AC: Buffered steering control

DESCRIPTION
The UC493A/493AC, UC494A/494AC and UC495A/495AC each provide a complete pulse width modulation system in a single monolithic integrated ciruit. These devices include a 5V reference accurate to ±1%, two independent amplifiers usable for both voltage and current sensing, an externally synchronizable oscillator with its linear ramp generator, and two uncommitted transistor output switches. These two outputs may be operated either in parallel for single-ended operation or alternating for push-pull applications with an externally controlled dead-band. These units are internally protected against double-pulsing of a single output or from extraneous output signals when the input supply voltage is below minimum.

The UC495A and UC495AC also contain an on-chip 39V zener diode for high-voltage applications where V_{CC} would be greater than 40V, and an output steering control that overrides the internal control of the pulse steering flip-flop.

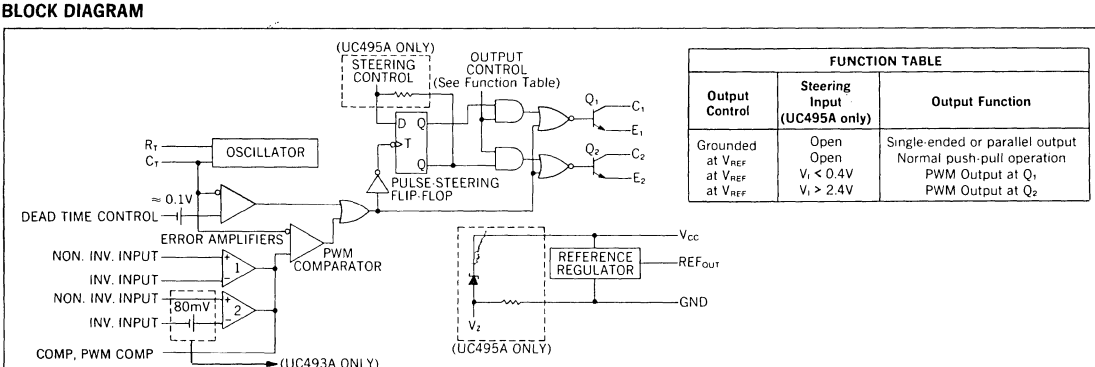
UC493A/493AC and UC494A/494AC are packaged in a 16-pin DIP, while the UC495A/495AC are packaged in an 18-pin DIP. The UC493A, UC494A and UC495A are specified for operation over the full military temperature range of −55°C to +125°C, while the UC493AC, UC494AC and UC495AC are designed for industrial applications from 0°C to +70°C.

ABSOLUTE MAXIMUM RATINGS (Note 1)
Supply Voltage, V_{CC} (Note 2) 41V
Amplifier Input Voltages .... V_{CC} + 0.3V
Collector Output Voltage 41V
Collector Output Current 250mA
Continuous Total Dissipation 1000mW
  @ (or below) 25°C free air
  temperature range (Note 3)
Storage Temperature Range .... −65°C to +150°C
Lead Temperature 1/16" (1.6mm) from case for 60 seconds,
  J Package .... 300°C
Lead Temperature 1/16" (1.6mm) from case for 10 seconds,
  N Package .... 260°C

Notes: 1. Over operating free air temperature range unless otherwise noted.
2. All voltage values are with respect to network ground terminal.
3. For J package, derate at 8.2mW/°C for ambient temperature above +28°C. For N package, derate at 9.2 mW/°C for ambient temperature above +41°C.

RECOMMENDED OPERATING CONDITIONS
Supply Voltage V_{CC} .... 7V to 40V
Error Amplifier Input Voltages .... −0.3V to V_{CC}−2V
Collector Output Voltage 40V
Collector Output Current 200mA
  (each transistor)
Current into Feedback Terminal 0.3mA
Timing Capacitor, C_T .... 0.47nF to 10,000nF
Timing Resistor, R_T .... 1.8KΩ to 500KΩ
Oscillator Frequency .... 1kHz to 300kHz
Operating Free Air Temperature
  UC493A, UC494A, UC495A .... −55°C to +125°C
  UC493AC, UC494AC, UC495AC .... 0°C to +70°C

BLOCK DIAGRAM



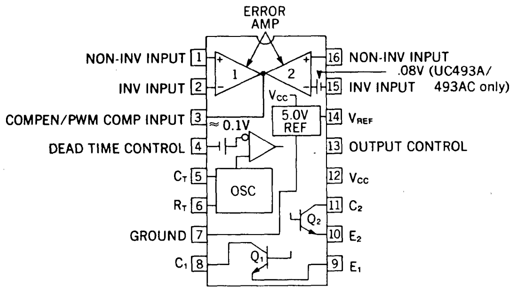
FUNCTION TABLE		
Output Control	**Steering Input (UC495A only)**	**Output Function**
Grounded	Open	Single-ended or parallel output
at V_{REF}	Open	Normal push-pull operation
at V_{REF}	V_I < 0.4V	PWM Output at Q_1
at V_{REF}	V_I > 2.4V	PWM Output at Q_2

UNITRODE

CONNECTION DIAGRAMS

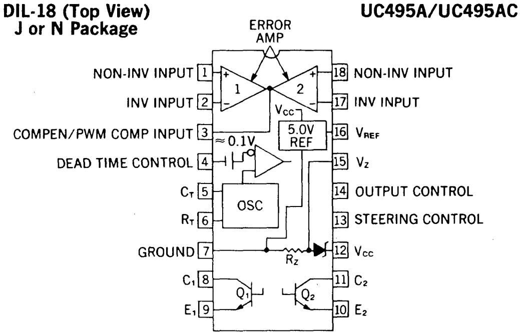
DIL-16 (Top View)
J or N Package

UC493A/UC493AC
UC494A/UC494AC



DIL-18 (Top View)
J or N Package

UC495A/UC495AC



ELECTRICAL CHARACTERISTICS (Unless otherwise stated, over recommended operating free-air temperature range, V_{CC} = 15V, f = 10kHz)

PARAMETER		TEST CONDITIONS	MIN.	TYP.	MAX.	UNITS
Reference Section						
Output Voltage (V_{REF})		I_O = 1mA, T_A = 25°C	4.95	5	5.05	V
Input Regulation		V_{CC} = 7V to 40V		2	25	mV
Output Regulation		I_O = 1mA to 10mA		1	15	mV
Output Voltage over Temperature		ΔT_A = Min. to Max.	4.90		5.10	V
Short Circuit Output Current (Note 1)		V_{REF} = 0, T_A = 25°C	10	35	50	mA
Oscillator Section						
Frequency (Note 2)		C_T = 0.01μF, R_T = 12kΩ		10		kHz
Standard Deviation of Frequency (Note 3)		All values of V_{CC}, C_T, R_T, T_A constant		10		%
Frequency Change with Voltage		V_{CC} = 7V to 40V, T_A = 25°C		0.1		%
Frequency Change with Temperature		C_T = 0.01μF, R_T = 12kΩ ΔT_A = Min. to Max.			2	%
Dead Time Control Section (Output Control Connected to V_{REF})						
Input Bias Current (Pin 4)		$V_{(PIN\ 4)}$ = 0 to 5.25V		-2	-10	μA
Maximum Duty-Cycle (Each Output)		$V_{(PIN\ 4)}$ = 0	45			%
Input Threshold Voltage (PIN 4)		Zero Duty-Cycle		3	3.3	V
		Maximum Duty-Cycle	0			
Amplifier Section (Current limit specifications apply to UC493A/493AC only)						
Input Offset Voltage	Error	$V_{O\ (PIN\ 3)}$ = 2.5V		2	10	mV
	Current Limit		70	80	90	
Input Offset Current		$V_{O\ (PIN\ 3)}$ = 2.5V		25	250	nA
Input Bias Current		$V_{O\ (PIN\ 3)}$ = 2.5V		0.2	1	μA
Common-Mode Input Voltage Range		V_{CC} = 7V to 40V	−0.3 to V_{CC} −2			V
Open-Loop Voltage Gain	Error	ΔV_O = 3V, V_O = 0.5V to 3.5V	70	95		dB
	Current Limit		66	90		
Unity-Gain Bandwidth				800		kHz
Common-Mode Rejection Ratio	Error	V_{CC} = 40V, T_A = 25°C	65	80		dB
	Current-Limit		50	70		
Output Sink Current (Pin 3)		V_{ID} = −15mV to −5V, $V_{(pin\ 3)}$ = 0.7V	0.3	0.7		mA
Output Source Current (Pin 3)		V_{ID} = 15mV to 5V, $V_{(pin\ 3)}$ =3.5V	-2			

ELECTRICAL CHARACTERISTICS (Unless otherwise stated, over recommended operating free-air temperature range, V_{CC} = 15V, f = 10kHz)

PARAMETER		TEST CONDITIONS		MIN.	TYP.	MAX.	UNITS
Output Section							
Collector Off-State Current		V_{CE} = 40V, V_{CC} = 40V			2	100	μA
Emitter Off-State Current		V_{CC} = V_C = 40V, V_E = 0				-100	μA
Collector-Emitter Saturation Voltage	Common-Emitter	V_E = 0, I_C = 200mA			1.1	1.3	V
	Emitter-Follower	V_C = 15V, I_E = −200mA			1.5	2.5	V
Output Control Input Current		V_I = V_{REF}				3.5	mA
PWM Comparator Section							
Input Threshold Voltage (Pin 3)		Zero Duty-Cycle			4	4.5	V
Input Sink Current (Pin 3)		$V_{(pin\ 3)}$ = 0.7V		0.3	0.7		mA
Steering Control (UC495A only, See Function Table)							
Input Current		$V_{(Pin\ 13)}$ = 0.4V				−200	μA
		$V_{(Pin\ 13)}$ = 2.4V				200	μA
Zener Diode Circuit (UC495A only)							
Breakdown Voltage		V_{CC} = 41V, I_Z = 2mA			39		V
Sink Current		$V_{(Pin\ 15)}$ = 1V			0.3		mA
Total Device							
Standby Supply Current		Pin 6 at V_{REF}. All other inputs and outputs open.	V_{CC} = 15V		6	10	mA
			V_{CC} = 40V		9	15	mA
Switching characteristics (T_A = 25°C)							
Output Voltage Rise Time		Common-Emitter Configuration			100	200	ns
Output Voltage Fall Time		R_L = 68Ω, C_L = 15pF			25	100	ns
Output Voltage Rise Time		Emitter-Follower Configuration			100	200	ns
Output Voltage Fall Time		R_L = 68Ω, C_L = 15pF			40	100	ns

Notes: 1. Duration of the short circuit should not exceed one second.

2. Frequency for other values of C_T and R_T is approximately $f \approx \frac{1.1}{R_T C_T}$

3. Standard deviation is a measure of the statistical distribution about the mean as derived from the formula $\sigma = \sqrt{\frac{\sum_{n=1}^{n} (x_n - \bar{x})^2}{n-1}}$

Figure 1 — Output Circuit of Error Amplifiers

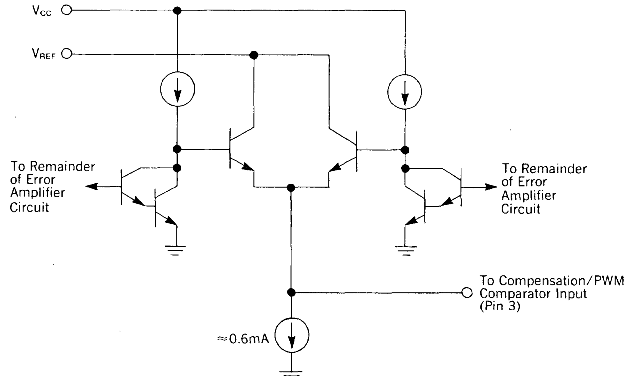
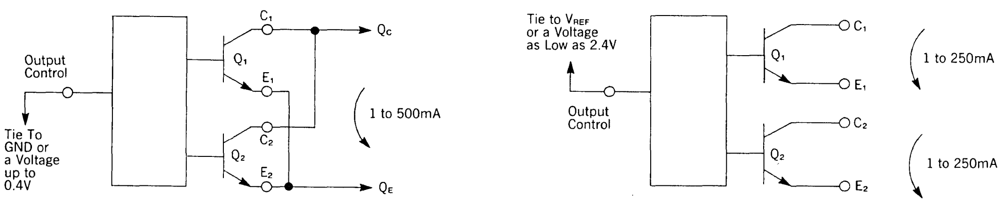


FIGURE 2 — Output Connections for Single-Ended and Push-Pull Configurations



Single-Ended Configuration

Push-Pull Configuration

Figure 3 — Slaving Two or More Control Circuits

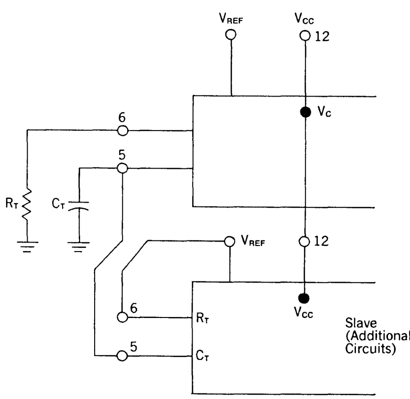


Figure 4 — Operation with V_{IN} > 40V Using Internal Zener (UC495A Only)

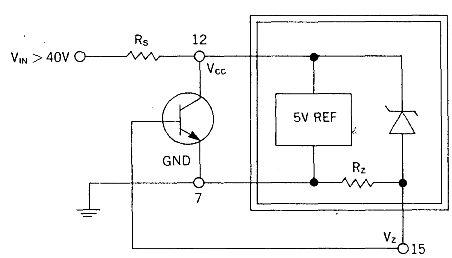
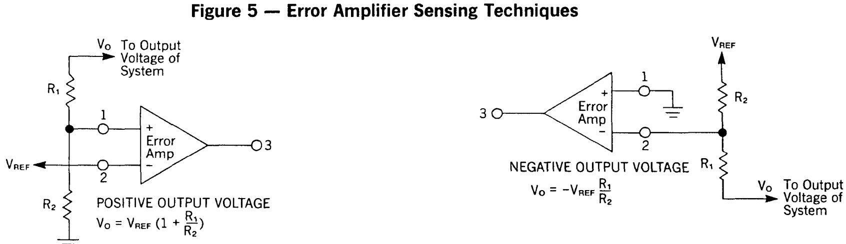


Figure 5 — Error Amplifier Sensing Techniques



LINEAR INTEGRATED CIRCUITS
Regulating Pulse Width Modulators

UC1524
UC2524
UC3524

FEATURES

- Complete PWM Power control circuitry
- Uncommitted outputs for single-ended or push-pull applications
- Low standby current ... 8mA typical
- Interchangeable with SG1524, SG2524 and SG3524, respectively

DESCRIPTION

The UC1524, UC2524 and UC3524 incorporate on a single monolithic chip all the functions required for the construction of regulating power supplies inverters or switching regulators. They can also be used as the control element for high-power-output applications. The UC1524 family was designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers and polarity converter applications employing fixed-frequency, pulse-width modulation techniques. The dual alternating outputs allow either single-ended or push-pull applications. Each device includes an on-chip reference, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted output transistors, a high-gain comparator, and current-limiting and shut-down circuitry. The UC1524 is characterized for operation over the full military temperature range of −55°C to +125°C. The UC2524 and UC3524 are designed for operation from −25°C to +85°C and 0°C to +70°C, respectively.

ABSOLUTE MAXIMUM RATINGS (Note 1)

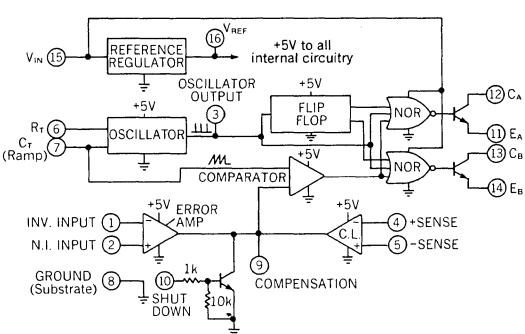
Supply Voltage, V_{CC} (Notes 2 and 3)	40V
Collector Output Current	100mA
Reference Output Current	50mA
Current Through C_T Terminal	−5mA
Power Dissipation at T_A = +25°C (Note 4)	1000mW
Thermal Resistance, Junction to Ambient	100°C/W
Power Dissipation at T_C = +25°C (Note 5)	2000mW
Thermal Resistance, Junction to Case	60°C/W
Operating Junction Temperature Range	−55°C to +150°C
Storage Temperature Range	−65°C to +150°C

Notes:
1. Over operating free-air temperature range unless otherwise noted.
2. All voltage values are with respect to the ground terminal, pin 8
3. The reference regulator may be bypassed for operation from a fixed 5V supply by connecting the V_{CC} and reference output pins both to the supply voltage. In this configuration the maximum supply voltage is 6V.
4. Derate at 10mW/°C for ambient temperatures above +50°C
5. Derate at 16mW/°C for case temperatures above +25°C

RECOMMENDED OPERATING CONDITIONS

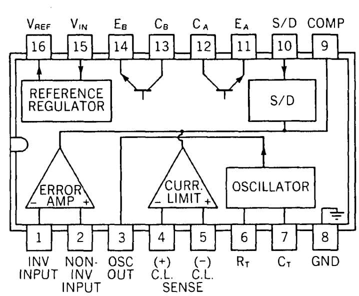
Supply Voltage, V_{CC}	8V to 40V
Reference Output Current	0 to 20mA
Current through C_T Terminal	−0.03mA to −2mA
Timing Resistor, R_T	1.8KΩ to 100KΩ
Timing Capacitor, C_T	0.001μF to 0.1μF
Operating Ambient Temperature Range	
UC1524	−55°C to +125°C
UC2524	−25°C to +85°C
UC3524	0°C to +70°C

BLOCK DIAGRAM



CONNECTION DIAGRAM

DIL-16
J or N Package



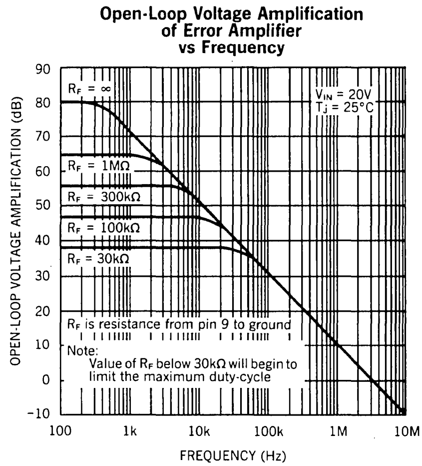
UNITRODE

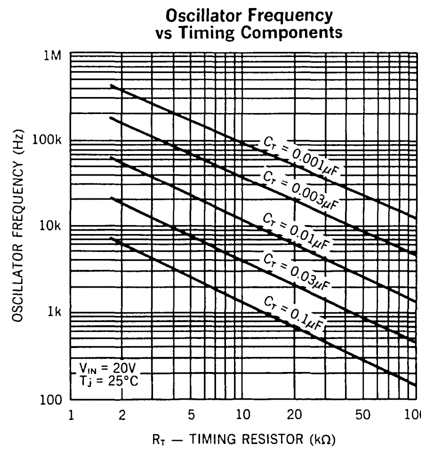
ELECTRICAL CHARACTERISTICS (Unless otherwise stated, these specifications apply for T_j = −55°C to +125°C for the UC1524, −25°C to +85°C for the UC2524, and 0°C to +70°C for the UC3524, V_{IN} = 20V, and f = 20kHz)

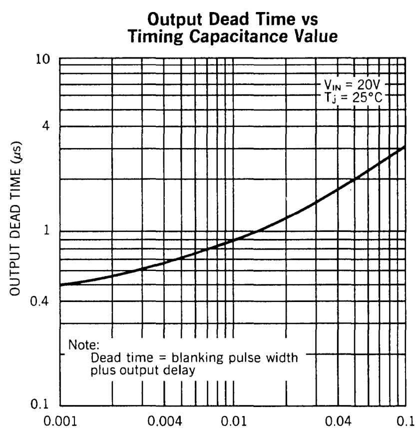
PARAMETER	TEST CONDITIONS	UC1524/UC2524			UC3524			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Reference Section								
Output Voltage		4.8	5.0	5.2	4.6	5.0	5.4	V
Line Regulation	V_{IN} = 8 to 40V		10	20		10	30	mV
Load Regulation	I_L = 0 to 20mA		20	50		20	50	mV
Ripple Rejection	f = 120Hz, T_j = 25°C		66			66		dB
Short Circuit Current Limit	V_{REF} = 0, T_j =25°C		100			100		mA
Temperature Stability	Over Operating Temperature Range		0.3	1		0.3	1	%
Long Term Stability	T_j = 25°C, t = 1000 Hrs.		20			20		mV
Oscillator Section								
Maximum Frequency	C_T = .001mfd, R_T = 2kΩ		300			300		kHz
Initial Accuracy	R_T and C_T Constant		5			5		%
Voltage Stability	V_{IN} = 8 to 40V, T_j = 25°C			1			1	%
Temperature Stability	Over Operating Temperature Range			2			2	%
Output Amplitude	Pin 3, T_j =25°C		3.5			3.5		V
Output Pulse Width	C_T = .01mfd, T_j = 25°C		0.5			0.5		μs
Error Amplifier Section								
Input Offset Voltage	V_{CM} = 2.5V		0.5	5		2	10	mV
Input Bias Current	V_{CM} = 2.5V		2	10		2	10	μA
Open Loop Voltage Gain		72	80		60	80		dB
Common Mode Voltage	T_j = 25°C	1.8		3.4	1.8		3.4	V
Common Mode Rejection Ratio	T_j = 25°C		70			70		dB
Small Signal Bandwidth	A_V = 0dB, T_j = 25°C		3			3		MHz
Output Voltage	T_j = 25°C	0.5		3.8	0.5		3.8	V
Comparator Section								
Duty-Cycle	% Each Output On	0		45	0		45	%
Input Threshold	Zero Duty-Cycle		1			1		V
Input Threshold	Maximum Duty-Cycle		3.5			3.5		V
Input Bias Current			1			1		μA
Current Limiting Section								
Sense Voltage	Pin 9 = 2V with Error Amplifier Set for Maximum Out, T_j = 25°C	190	200	210	180	200	220	mV
Sense Voltage T.C.			0.2			0.2		mV/°C
Common Mode Voltage		−1		+1	−1		+1	V
Output Section (Each Output)								
Collector-Emitter Voltage		40			40			V
Collector Leakage Current	V_{CE} = 40V		0.1	50		0.1	50	μA
Saturation Voltage	I_C = 50mA		1	2		1	2	V
Emitter Output Voltage	V_{IN} = 20V	17	18		17	18		V
Rise Time	R_C = 2K ohm, T_j = 25°C		0.2			0.2		μs
Fall Time	R_C = 2K ohm, T_j = 25°C		0.1			0.1		μs
Total Standby Current (Excluding oscillator charging current, error and current limit dividers, and with outputs open)	V_{IN} = 40V		8	10		8	10	mA

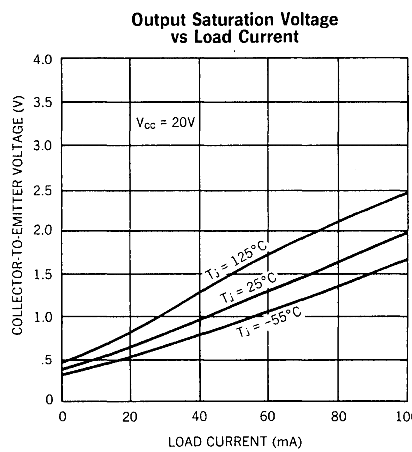
III

TYPICAL CHARACTERISTICS









PRINCIPLES OF OPERATION

The UC1524 is a fixed-frequency pulse-width-modulation voltage regulator control circuit. The regulator operates at a frequency that is programmed by one timing resistor (R_T) and one timing capacitor (C_T). R_T establishes a constant charging current for C_T. This results in a linear voltage ramp at C_T, which is fed to the comparator providing linear control of the output pulse width by the error amplifier. The UC1524 contains an on-board 5V regulator that serves as a reference as well as powering the UC1524's internal control circuitry and is also useful in supplying external support functions. This reference voltage is lowered externally by a resistor divider to provide a reference within the common-mode range of the error amplifier or an external reference may be used. The power supply output is sensed by a second resistor divider network to generate a feedback signal to the error amplifier. The amplifier output voltage is then compared to the linear voltage ramp at C_T. The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q_1 or Q_2) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to assure both outputs are never on simultaneously during the transition times. The width of the blanking pulse is controlled by the value of C_T. The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current limiting and shutdown circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, or to compensate, the error amplifier, or to provide additional control to the regulator.

TYPICAL APPLICATIONS DATA

Oscillator

The oscillator controls the frequency of the UC1524 and is programmed by R_T and C_T according to the approximate formula:

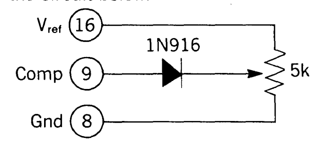
$$f \simeq \frac{1.18}{R_T C_T}$$

where R_T is in kilohms
C_T is in microfarads
f is in kilohertz

Practical values of C_T fall between 0.001 and 0.1 microfarad. Practical values of R_T fall between 1.8 and 100 kilohms. This results in a frequency range typically from 120 hertz to 500 kilohertz.

Blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse width is controlled by the value of C_T. If small values of C_T are required for frequency control, the oscillator output pulse width may still be increased by applying a shunt capacitance of up to 100pF from pin 3 to ground. If still greater dead-time is required, it should be accomplished by limiting the maximum duty cycle by clamping the output of the error amplifier. This can easily be done with the circuit below:

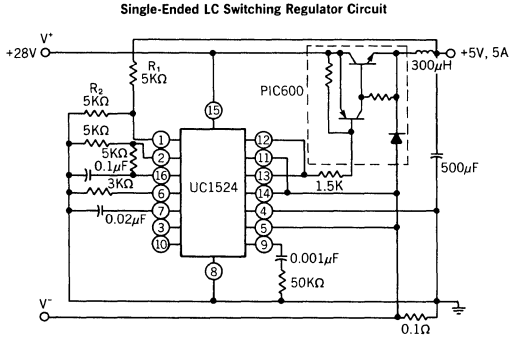


Synchronous Operation

When an external clock is desired, a clock pulse of approximately 3V can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2 kilohms. In this configuration R_T C_T must be selected for a clock period slightly greater than that of the external clock.

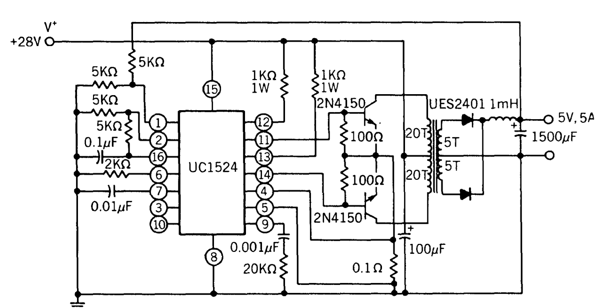
If two or more UC1524 regulators are to be operated synchronously, all oscillator output terminals should be tied together, all C_T terminals connected to a single timing capacitor, and the timing resistor connected to a single R_T terminal. The other R_T terminals can be left open or shorted to V_{REF}. Minimum lead lengths should be used between the C_T terminals.

Single-Ended LC Switching Regulator Circuit

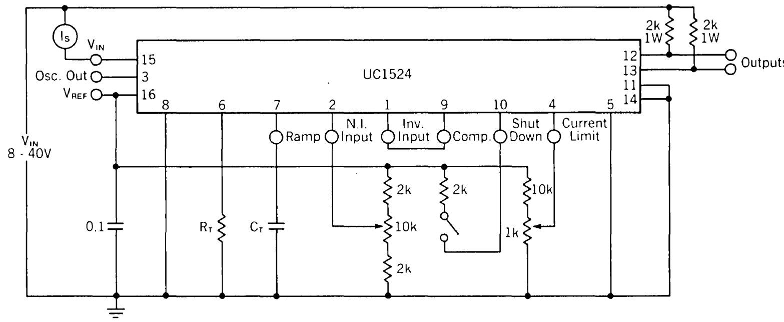


92CM - 32683

Push-Pull Transformer-Coupled Circuit

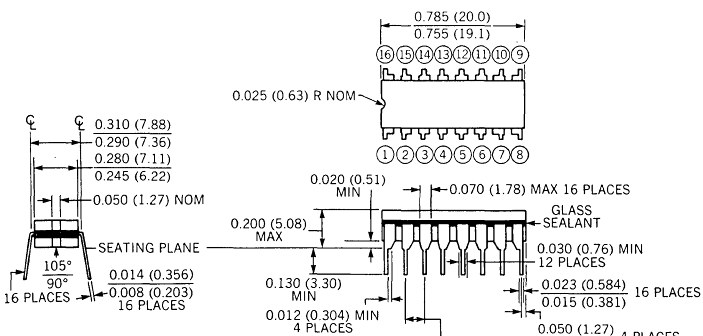


OPEN LOOP TEST CIRCUIT



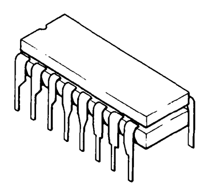
MECHANICAL SPECIFICATIONS

UC1524 UC2524 UC3524

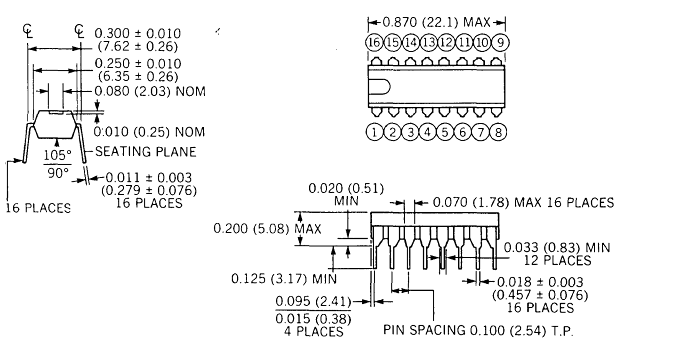


Dimensions in inches and (millimeters)

16-PIN J CERAMIC

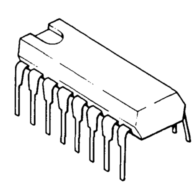


UC2524 UC3524



Dimensions in inches and (millimeters)

16-PIN N PLASTIC



Note: When ordering, add suffix "J" (for 16 pin ceramic package) or "N" (for 16 pin plastic package) to the part number.

LINEAR INTEGRATED CIRCUITS
Advanced Regulating Pulse Width Modulators

UC1524A
UC2524A
UC3524A

FEATURES

- Fully interchangeable with standard UC1524 family
- Precision reference internally trimmed to ±1%
- High-Performance current limit function
- Under-voltage lockout with hysteretic turn-on
- Start-up supply current less than 4mA
- Output current to 200mA
- 60V output capability
- Wide common-mode input range for both error and current limit amplifiers
- PWM latch insures single pulse per period
- 200ns shutdown through PWM latch
- Guaranteed frequency accuracy

DESCRIPTION

The UC1524A family of regulating PWM ICs has been designed to retain the same highly versatile architecture of the industry standard UC1524 (SG1524) while offering substantial improvements to many of its limitations. The UC1524A is pin compatible with "non-A" models and in most existing applications can be directly interchanged with no effect on power supply performance. Using the UC1524A, however, frees the designer from many concerns which typically had required additional circuitry to solve.

The UC1524A includes a precise 5V reference trimmed to ±1% accuracy, eliminating the need for potentiometer adjustments; an error amplifier with an input range which includes 5V, eliminating the need for a reference divider; a current sense amplifier useful in either the ground or power supply output lines; and a pair of 60V, 200mA uncommitted transistor switches which greatly enhance output versatility.

An additional feature of the UC1524A is an under-voltage lockout circuit which disables all the internal circuitry, except the reference, until the input voltage has risen to 8V. This holds standby current low until turn-on, greatly simplifying the design of low power, off-line supplies. The turn-on circuit has approximately 600mV of hysteresis for jitter-free activation.

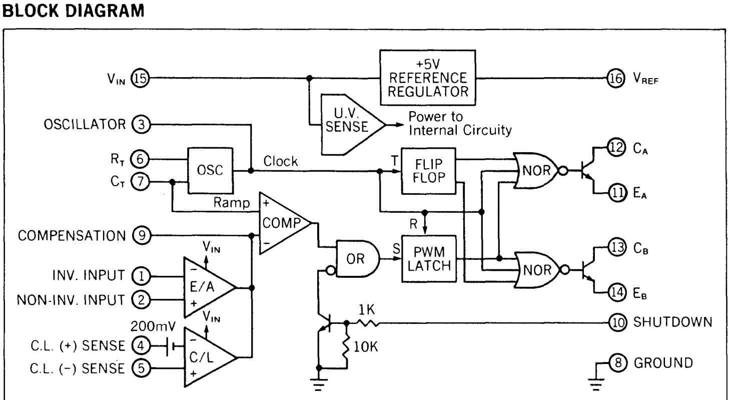
Other product enhancements included in the UC1524A's design include a PWM latch which insures freedom from multiple pulsing within a period even in noisy environments and a shutdown circuit feeding directly to the latch which will disable the outputs within 200ns. The oscillator circuit of the UC1524A is usable beyond 500kHz and is now easier to synchronize with an external clock pulse.

The UC1524A is packaged in a hermetic 16-pin DIP and is rated for operation from −55°C to +125°C. The UC2524A and UC3524A are available in either ceramic or plastic packages and are rated for operation from −25°C to +85°C and 0°C to 70°C, respectively.

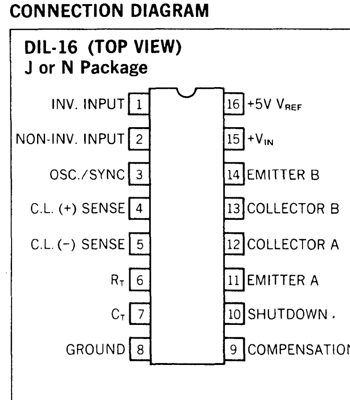
ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{IN})	40V
Collector Supply Voltage (V_C)	
UC1524A, UC2524A	60V
UC3524A	50V
Output Current (Each Output)	200mA
Reference Output Current	50mA
Oscillator Charging Current	5mA
Power Dissipation at T_A = +25°C	1000mW
Derate above +50°C	10mW/°C
Power Dissipation at T_C = +25°C	2000mW
Derate for Case Temperature above +25°C	16mW/°C
Operating Temperature Range	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+300°C

BLOCK DIAGRAM



CONNECTION DIAGRAM



UNITRODE

ELECTRICAL CHARACTERISTICS (Unless otherwise stated, these specifications apply for T_A = −55°C to +125°C for the UC1524A, −25°C to +85°C for the UC2524A, and 0°C to +70°C for the UC3524A; V_{IN} = V_C = 20V.)

PARAMETER	TEST CONDITIONS	UC1524A UC2524A			UC3524A			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Turn-on Characteristics								
Input Voltage	Operating range after Turn-on	8		40	8		40	V
Turn-on Threshold		6	7.5	8.5	6	7.5	8.5	V
Turn-on Current	V_{IN} = 6V		2.5	4		2.5	4	mA
Operating Current	V_{IN} = 8 to 40V		5	10		5	10	mA
Turn-on Hysteresis*			0.6			0.6		V
Reference Section								
Output Voltage	T_j = 25°C	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	V_{IN} = 10 to 40V		10	20		10	30	mV
Load Regulation	I_L = 0 to 20mA		20	50		20	50	mV
Temperature Stabilty*	Over Operating Range		20	50		20	50	mV
Short Circuit Current	V_{REF} = 0, T_j = 25°C		80	100		80	100	mA
Output Noise Voltage*	10hz ≤ f ≤ 10kHz, T_j = 25°C		40			40		μVrms
Long Term Stability*	T_j = 125°C, 1000 Hrs.		20	50		20	50	mV
Oscillator Section (Unless otherwise specified, R_T = 2700Ω, C_T = 0.01 mfd)								
Initial Accuracy	T_j = 25°C	40	43	46		43		kHz
Temperature Stability*	Over Operating Temperature Range		1	2		1	2	%
Minimum Frequency	R_T = 150kΩ, C_T = 0.1 mfd			120			120	Hz
Maximum Frequency	R_T = 2.0kΩ, C_T = 470 pF	500			500			kHz
Output Amplitude*	T_j = 25°C		3.5			3.5		V
Output Pulse Width*	T_j = 25°C		0.5			0.5		μs
Ramp Peak		3.3	3.5	3.7	3.3	3.5	3.7	V
Ramp Valley		0.7	0.9	1.0	0.7	0.9	1.0	V
Error Amplifier Section (Unles otherwise specified, V_{CM} = 2.5V)								
Input Offset Voltage			0.5	5		2	10	mV
Input Bias Current			1	5		1	10	μA
Input Offset Current			.05	1		0.5	1	μA
Common Mode Rejection Ratio	V_{CM} = 1.5 to 5.5V	60	75		60	75		dB
Power Supply Rejection Ratio	V_{IN} = 10 to 40V	50	60		50	60		dB
Output Swing	Minimum Total Range	0.5		5.0	0.5		5.0	V
Open Loop Voltage Gain	ΔV_O = 1 to 4V, R_L ≥ 10 Meg Ω	72	80		60	80		dB
Gain-Bandwidth*	T_j = 25°C, A_V = 0dB		3			3		MHz

* These parameters are guaranteed by design but not 100% tested in production.

ELECTRICAL CHARACTERISTICS (Unless otherwise stated, these specifications apply for T_A = −55°C to +125°C for the UC1524A, −25°C to +85°C for the UC2524A, and 0°C to +70°C for the UC3524A; V_{IN} = V_C = 20V.)

PARAMETER	TEST CONDITIONS	UC1524A UC2524A			UC3524A			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Current Limit Amplifier (Unless otherwise specified, Pin 5 =0V)								
Input Offset Voltage	T_j = 25°C, E/A Set for Maximum Output	190	200	210	180	200	220	mV
Input Offset Voltage	Over Operating Temperature Range	180		220	170		230	mV
Input Bias Current			−1	−10		−1	−10	μA
Common Mode Rejection Ratio	$V_{(Pin\ 5)}$ = −0.3V to +5.5V	50	60		50	60		dB
Power Supply Rejection Ration	V_{IN} = 10 to 40V	50	60		50	60		dB
Output Swing	Minimum Total Range	0.5		5.0	0.5		5.0	V
Open Loop Voltage Gain	ΔV_O = 1 to 4V, $R_L \geq$ 10 Meg Ω	70	80		70	80		dB
Delay Time*	Pin 4 to Pin 9, ΔV_{IN} = 300mV		300			300		ns
Output Section (Each Output)								
Collector Emitter Voltage	I_C = 100μA	60	80		50	80		V
Collector Leakage Current	V_{CE} = 50V		.1	20		.1	20	μA
Saturation Voltage	I_C = 20mA I_C = 200mA		.2 1	.4 2.2		.2 1	.4 2.2	V V
Emitter Output Voltage	I_E = 50mA	17	18		17	18		V
Rise Time*	T_j = 25°C, R = 2K Ω		200			200		ns
Fall Time*	T_j = 25°C, R = 2K Ω		100			100		ns
Comparator Delay*	T_j = 25°C, Pin 9 to Output		300			300		ns
Shutdown Delay*	T_j = 25°C, Pin 10 to Output		200			200		ns
Shutdown Threshold	T_j = 25°C, R_C = 2K Ω	0.5	.7	1.0	0.5	.7	1.0	V

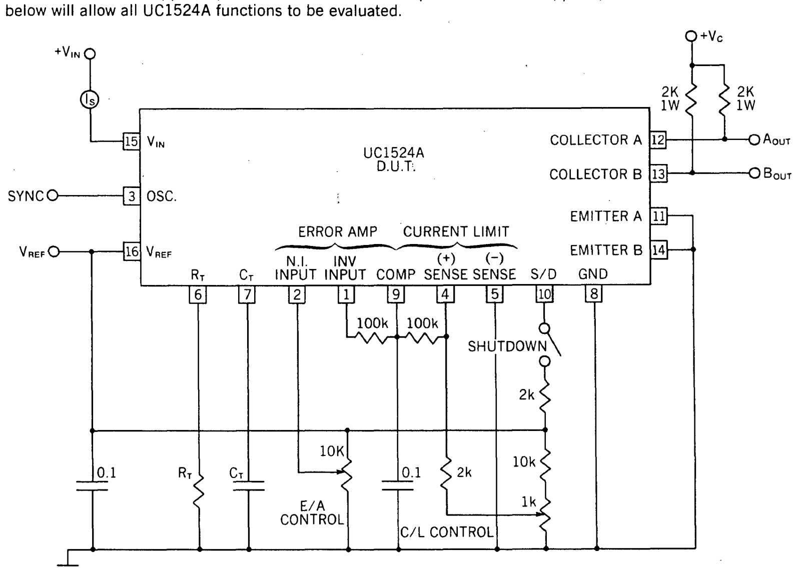
* These parameters are guaranteed by design but not 100% tested in production.

OPEN-LOOP TEST CIRCUIT

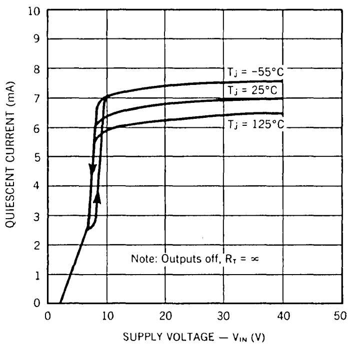
Note: The UC1524A should be able to be tested in any 1524 test circuit with two possible exceptions:

1. The higher gain-bandwidth of the current limit amplifier in the UC1524A may cause oscillations in an uncompensated 1524 test circuit.
2. The effect of the shutdown, pin 10, cannot be seen at the compensation terminal, pin 9, but must be observed at the outputs.

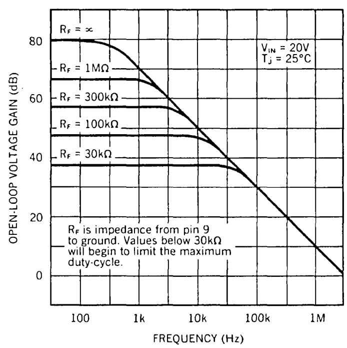
The circuit below will allow all UC1524A functions to be evaluated.



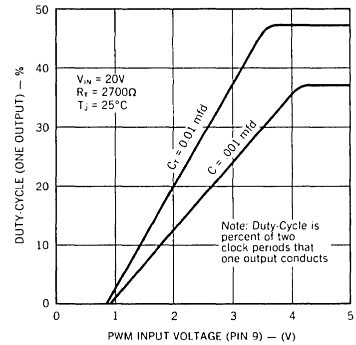
Supply Current vs Voltage



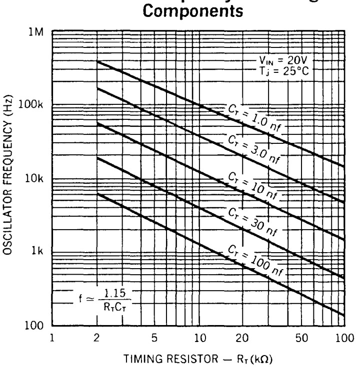
Error Amplifier Voltage Gain vs Frequency



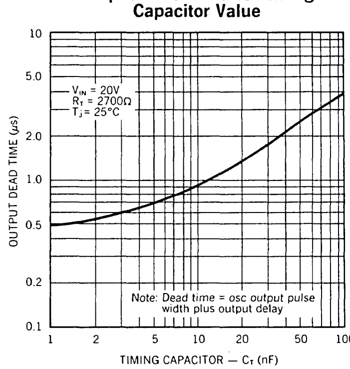
Pulse Width Modulator Transfer Function



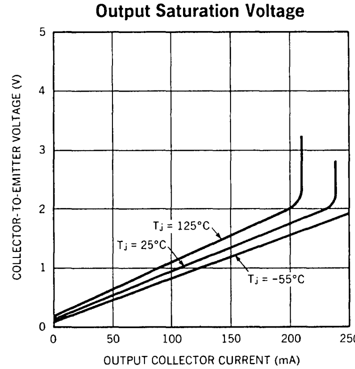
Oscillator Frequency vs Timing Components



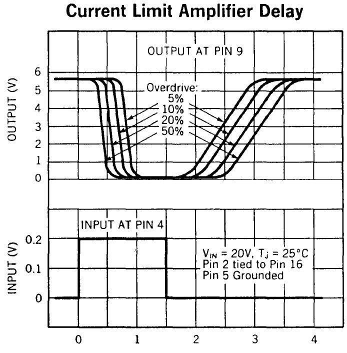
Output Dead Time vs Timing Capacitor Value



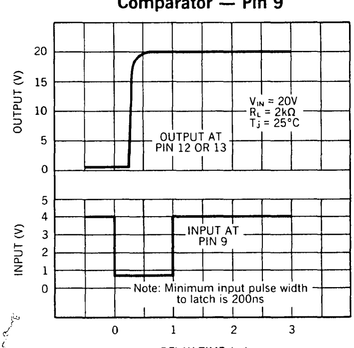
Output Saturation Voltage



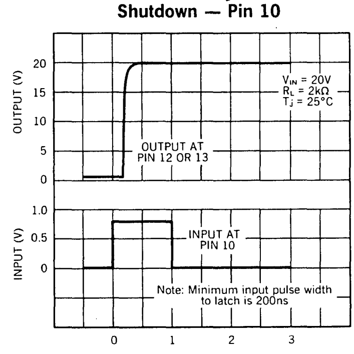
Current Limit Amplifier Delay



Shutdown Delay From PWM Comparator — Pin 9



Turn-Off Delay From Shutdown — Pin 10



LINEAR INTEGRATED CIRCUITS

Regulating Pulse Width Modulators

UC1525A UC1527A
UC2525A UC2527A
UC3525A UC3527A

FEATURES

- 8 to 35V operation
- 5.1V reference trimmed to ±1%
- 100Hz to 500kHz oscillator range
- Separate oscillator sync terminal
- Adjustable deadtime control
- Internal soft-start
- Pulse-by-pulse shutdown
- Input undervoltage lockout with hysteresis
- Latching PWM to prevent multiple pulses
- Dual source/sink output drivers

DESCRIPTION

The UC1525A/1527A series of pulse width modulator integrated circuits are designed to offer improved performance and lowered external parts count when used in designing all typoes of switching power supplies. The on-chip +5.1V reference is trimmed to ±1% and the input common-mode range of the error amplifier includes the reference voltage, elmininatng external resistors. A sync input to the oscillator allows multiple units to be slaved or a single unit to be synchronized to an external system clock. A single resistor between the C_T and the discharge terminals provide a wide range of dead time adjustment. These devices also feature built-in soft-start circuitry with only an external timing capacitor required. A shutdown terminal controls both the soft-start circuity and the output stages, providing instantaneous turn off through the PWM latch with pulsed shutdown, as well as soft-start recycle with longer shutdown commands. These functions are also controlled by an undervoltage lockout which keeps the outputs off and the soft-start capacitor discharged for sub-normal input voltages. This lockout circuitry includes approximately 500mV of hysteresis for jitter-free operation. Another feature of these PMW circuits is a latch following the comparator. Once a PWM pulse has been terminated for any reason, the outputs will remain off for the duration of the period. The latch is reset with each clock pulse. The output stages are totem-pole designs capable of sourcing or sinking in excess of 200mA. The UC1525A output stage features NOR logic, giving a LOW output for an OFF state. The UC1527A utilizes OR logic which results in a HIGH output level when OFF.

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage, (+V_{IN})	+40V
Collector Supply Voltage (V_C)	+40V
Logic Inputs	−0.3V to +5.5V
Analog Inputs	−0.3V to +V_{IN}
Output Current, Source or Sink	500mA
Reference Output Current	50mA
Oscillator Charging Current	5mA
Power Dissipation at T_A= +25°C (Note 2)	1000mW
Thermal Resistance, Junction to Ambient	100°C/W
Power Dissipation at T_C = +25°C (Note 3)	2000mW
Thermal Resistance, Junction to Case	60°C/W
Operating Junction Temperature	−55°C to +150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+300°C

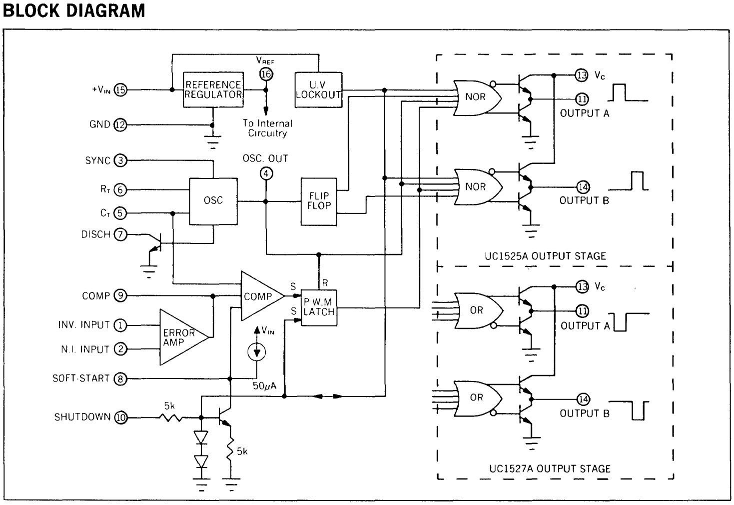
Notes: 1. Values beyond which damage may occur.
2. Derate at 10mW/°C for ambient temperatures above +50°C.
3. Derate at 16mW/°C for case temperatures above +25°C.

RECOMMENDED OPERATING CONDITIONS (Note 4)

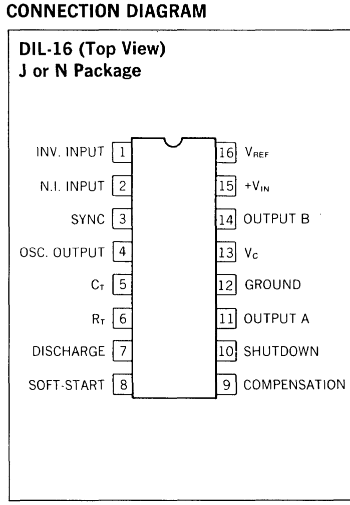
Input Voltage (+V_{IN})	+8V to +35V
Collector Supply Voltage (V_C)	+4.5V to +35V
Sink/Source Load Current (steady state)	0 to 100mA
Sink/Source Load Current (peak)	0 to 400mA
Reference Load Current	0 to 20mA
Oscillator Frequency Range	100Hz to 400kHz
Oscillator Timing Resistor	2kΩ to 150kΩ
Oscillator Timing Capacitor	.001μF to 0.1μF
Dead Time Resistor Range	0 to 500Ω
Operating Ambient Temperature Range	
UC1525A, UC1527A	−55°C to +125°C
UC2525A, UC2527A	−25°C to +85°C
UC3525A, UC3527A	0°C to +70°C

Notes: 4. Range over which the device is functional and parameter limits are guaranteed.

BLOCK DIAGRAM



CONNECTION DIAGRAM



UNITRODE

ELECTRICAL CHARACTERISTICS ($+V_{IN}$ = 20V, and over operating temperature, unless otherwise specified)

III

PARAMETER	TEST CONDITIONS	UC1525A/UC2525A UC1527A/UC2527A			UC3525A UC3527A			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Reference Section								
Output Voltage	T_j = 25°C	5.05	5.10	5.15	5.00	5.10	5.20	V
Line Regulation	V_{IN} = 8 to 35V		10	20		10	20	mV
Load Regulation	I_L = 0 to 20mA		20	50		20	50	mV
Temperature Stability (Note 5)	Over Operating Range		20	50		20	50	mV
Total Output Variation (Note 5)	Line, Load, and Temperature	5.00		5.20	4.95		5.25	V
Short Circuit Current	V_{REF} = 0, T_j =25°C		80	100		80	100	mA
Output Noise Voltage (Note 5)	10Hz $\leq f \leq$ 10kHz, T_j = 25°C		40	200		40	200	μVrms
Long Term Stability (Note 5)	T_j = 125°C, 1000 Hrs.		20	50		20	50	mV
Oscillator Section (Note 6)								
Initial Accuracy (Notes 5 & 6)	T_j = 25°C		±2	±6		±2	±6	%
Voltage Stability (Notes 5 & 6)	V_{IN} = 8 to 35V		±0.3	±1		±1	±2	%
Temperature Stability (Note 5)	Over Operating Range		±3	±6		±3	±6	%
Minimum Frequency	R_T = 200kΩ, C_T = 0.1μF			120			120	Hz
Maximum Frequency	R_T = 2kΩ, C_T = 470pF	400			400			kHz
Current Mirror	I_{RT} = 2mA	1.7	2.0	2.2	1.7	2.0	2.2	mA
Clock Amplitude (Notes 5 & 6)		3.0	3.5		3.0	3.5		V
Clock Width (Notes 5 & 6)	T_j = 25°C	0.3	0.5	1.0	0.3	0.5	1.0	μs
Sync Threshold		1.2	2.0	2.8	1.2	2.0	2.8	V
Sync Input Current	Sync Voltage = 3.5V		1.0	2.5		1.0	2.5	mA
Error Amplifier Section (V_{CM} = 5.1V)								
Input Offset Voltage			0.5	5		2	10	mV
Input Bias Current			1	10		1	10	μA
Input Offset Current				1			1	μA
DC Open Loop Gain	$R_L \geq$ 10 Meg Ω	60	75		60	75		dB
Gain-Bandwidth Product (Note 5)	A_V = 0dB, T_j = 25°C	1	2		1	2		MHz
Output Low Level			0.2	0.5		0.2	0.5	V
Output High Level		3.8	5.6		3.8	5.6		V
Common Mode Rejection	V_{CM} = 1.5 to 5.2V	60	75		60	75		dB
Supply Voltage Rejection	V_{IN} = 8 to 35V	50	60		50	60		dB

Notes: 5. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

6. Tested at f_{osc} = 40khz (R_T = 3.6Ω, C_T = .01μF, R_D = 0Ω). Approximate oscillator frequency is defined by: $f = \frac{1}{C_T(0.7R_T + 3R_D)}$

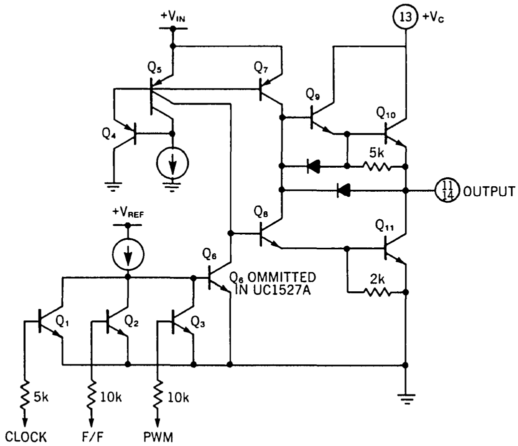
ELECTRICAL CHARACTERISTICS (+V_{IN} = 20V, and over operating temperature, unless otherwise specified)

PARAMETER	TEST CONDITIONS	UC1525A/UC2525A UC1527A/UC2527A			UC3525A UC3527A			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
PWM Comparator								
Minimum Duty-Cycle				0			0	%
Maximum Duty-Cycle		45	49		45	49		%
Input Threshold (Note 6)	Zero Duty-Cycle	0.7	0.9		0.7	0.9		V
Input Threshold (Note 6)	Maximum Duty-Cycle		3.3	3.6		3.3	3.6	V
Input Bias Current (Note 5)			.05	1.0		.05	1.0	μA
Shutdown Section								
Soft Start Current	V_{SD} = 0V, V_{SS} = 0V	25	50	80	25	50	80	μA
Soft Start Low Level	V_{SD} = 2.5V		0.4	0.7		0.4	0.7	V
Shutdown Threshold	To outputs, V_{SS} = 5.1V	0.5	0.8	1.1	0.5	0.8	1.1	V
Shutdown Input Current	V_{SD} = 2.5V		0.4	1.0		0.4	1.0	μA
Shutdown Delay (Note 5)	V_{SD} = 2.5V, T_j =25°C		0.2	0.5		0.2	0.5	μS
Output Drivers (Each Output) (V_C =20V)								
Output Low Level	I_{SINK} = 20mA		0.2	0.4		0.2	0.4	V
	I_{SINK} = 100mA		1.0	2.0		1.0	2.0	V
Output High Level	I_{SOURCE} = 20mA	18	19		18	19		V
	I_{SOURCE} = 100mA	17	18		17	18		V
Undervoltage Lockout	V_{Comp} and V_{SS} = high	6	7	8	6	7	8	V
Collector Leakage	V_C = 35V			200			200	μA
Rise Time (Note 5)	C_L = 1nF, T_j = 25°C		100	600		100	600	ns
Fall Time (Note 5)	C_L = 1nF, T_j = 25°C		50	300		50	300	ns
Total Standby Current								
Supply Current	V_{IN} = 35V		14	20		14	20	mA

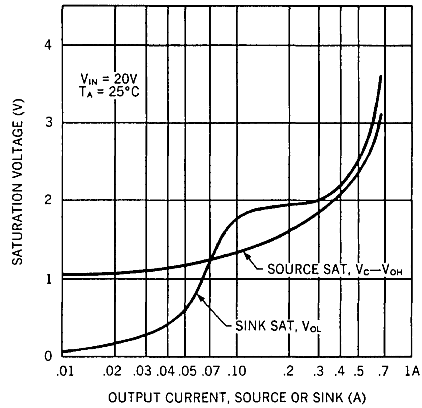
Notes: 5. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.
6. Tested at f_{OSC} = 40khz (R_T =3.6kΩ, C_T = .01μF, R_D =0Ω).

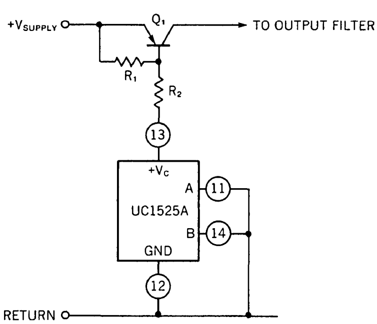
PRINCIPLES OF OPERATION AND TYPICAL CHARACTERISTICS

UC1525A Output Circuit
(½ Circuit Shown)

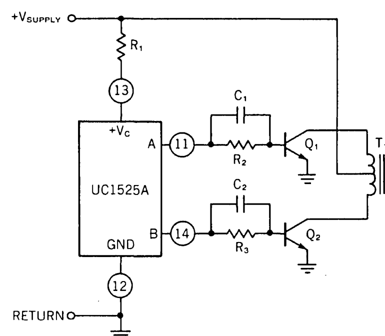


UC1525A Output Saturation Characteristics

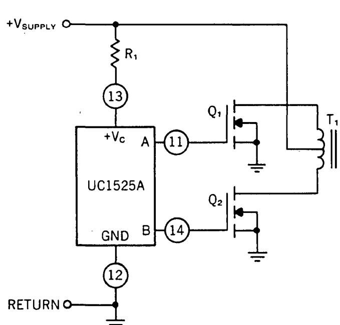




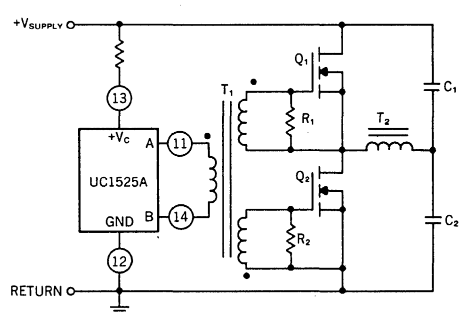
For single-ended supplies, the driver outputs are grounded. The V_C terminal is switched to ground by the totem-pole source transistors on alternate oscillator cycles.



In conventional push-pull bipolar designs, forward base drive is controlled by R_1-R_3. Rapid turn-off times for the power devices are achieved with speed-up capacitors C_1 and C_2.



The low source impedance of the output drivers provides rapid charging of power FET input capacitance while minimizing external components.



Low power transformers can be driven directly by the UC1525A. Automatic reset occurs during dead time, when both ends of the primary winding are switched to ground.

PRINCIPLES OF OPERATION AND TYPICAL CHARACTERISTICS

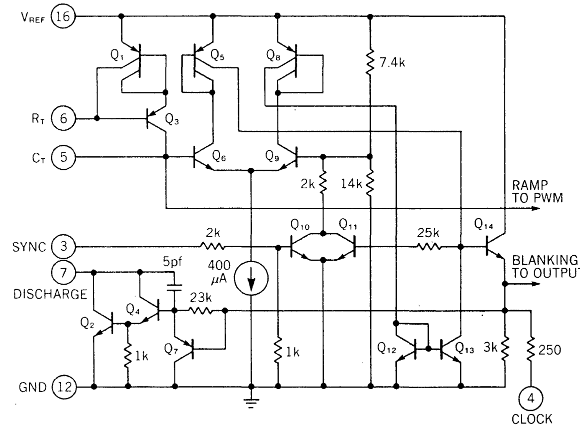
SHUTDOWN OPTIONS (See Block Diagram)

Since both the compensation and soft-start terminals (Pins 9 and 8) have current source pull-ups, either can readily accept a pull-down signal which only has to sink a maximum of 100μA to turn off the outputs. This is subject to the added requirement of discharging whatever external capacitance may be attached to these pins.

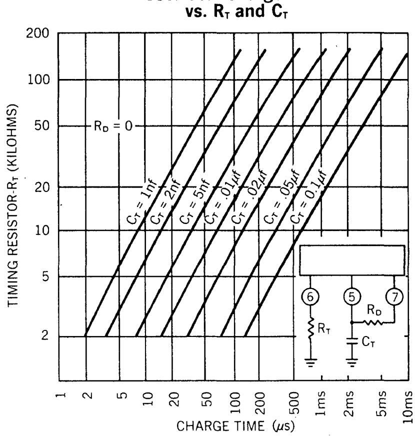
An alternate approach is the use of the shutdown circuitry of Pin 10 which has been improved to enhance the available shutdown options. Activating this circuit by applying a positive signal on Pin 10 performs two functions: the PWM latch is immediately set providing the fastest turn-off signal to the outputs; and a 150μA current sink begins to discharge the external soft-start capacitor. If the shutdown command is short, the PWM signal is terminated without significant discharge of the soft-start capacitor, thus, allowing, for example, a convenient implementation of pulse-by-pulse current limiting. Holding Pin 10 high for a longer duration, however, will ultimately discharge this external capacitor, recycling slow turn-on upon release.

Pin 10 should not be left floating as noise pickup could conceivably interrupt normal operation.

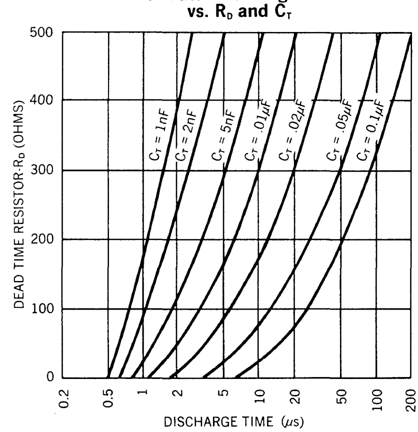
UC1525A Oscillator Schematic



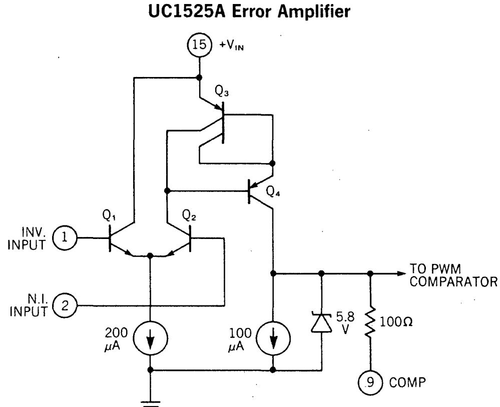
Oscillator Charge Time vs. R_T and C_T



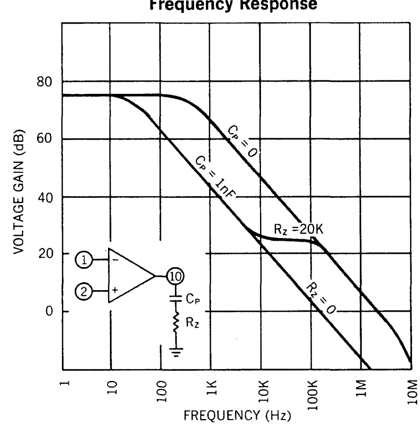
Oscillator Discharge Time vs. R_D and C_T



UC1525A Error Amplifier



Error Amplifier Open-Loop Frequency Response



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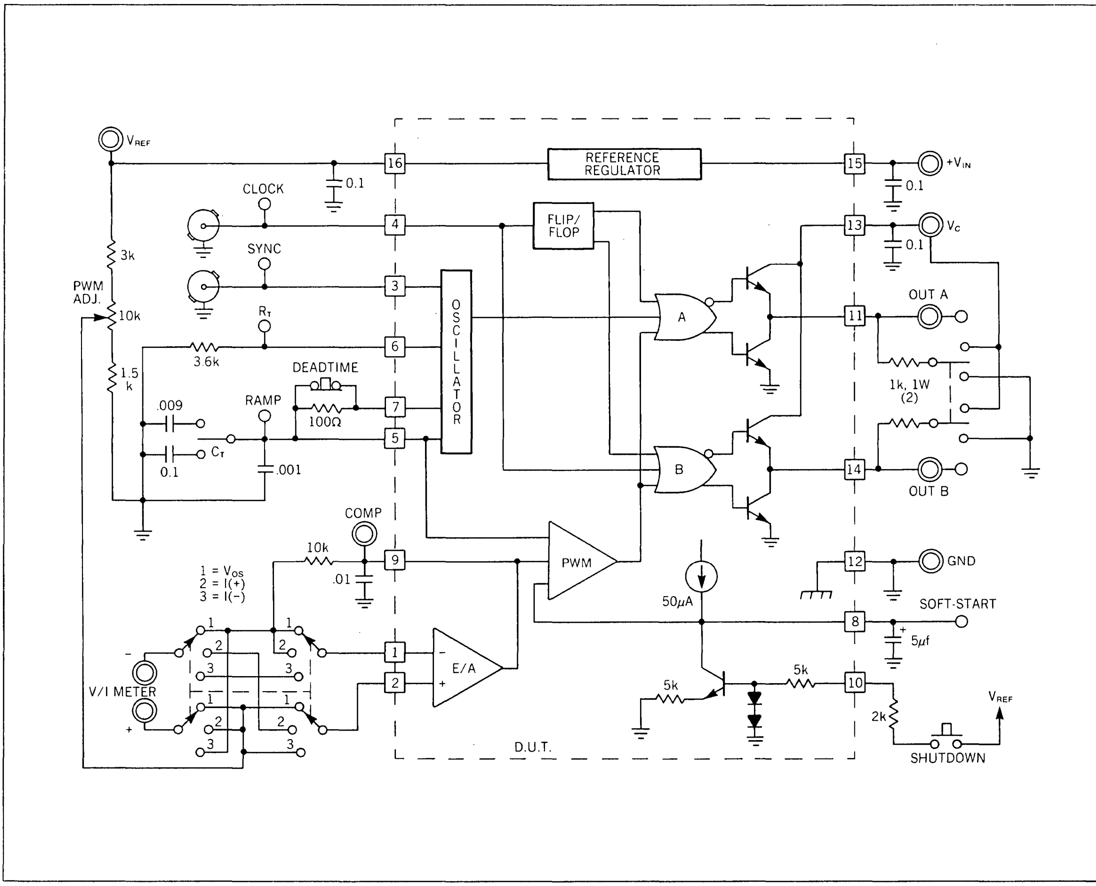
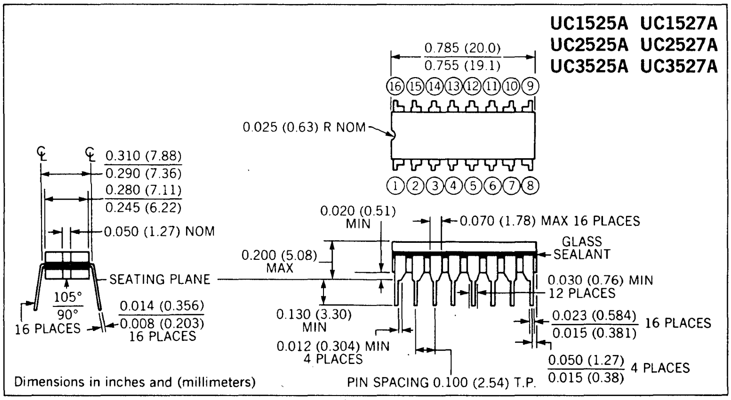
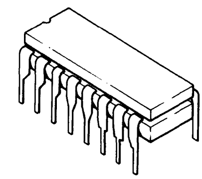
LAB TEST FIXTURE

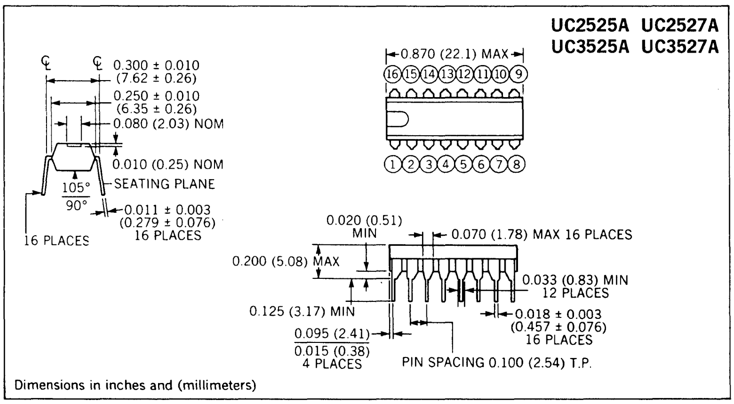


MECHANICAL SPECIFICATIONS

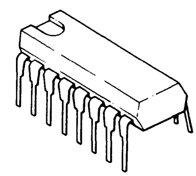


DIL-16 J CERAMIC





DIL-16 N PLASTIC



Note: When ordering, add suffix "J" (for 16 pin ceramic package) or "N" (for 16 pin plastic package) to the part number.

LINEAR INTEGRATED CIRCUITS
Three Terminal Fixed Voltage Positive Regulators

UC7800
UC7800C
SERIES

III

FEATURES
- ±4% preset output voltage
- Complete specifications at 1A load
- No external components
- Internal thermal overload protection
- Internal short circuit current limiting
- Output transistor safe area compensation
- Available in TO-3 and TO-220 packages
- Output voltages of 5, 12 and 15V (For other voltages, please contact the factory)

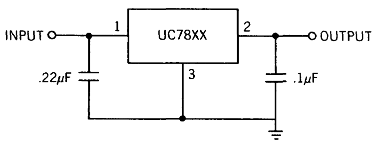
DESCRIPTION
These three terminal monolithic positive voltage regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A of output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents. These units feature an on-chip trimming system to set the output voltages to within ±4% of nominal. Two companion series, the UC7800A and UC7800AC, offer tighter output tolerances, and improved line and load regulation characteristics.

ABSOLUTE MAXIMUM RATINGS

Input Voltage		35V
Power Dissipation		Internally limited
Operating Junction Temperature Range		
UC7800 SERIES		−55°C to +150°C
UC7800C SERIES		0°C to +125°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)		
K (TO-3) package		300°C
T (TO-220) package		230°C
Power/Thermal Characteristics	K (TO-3) Package	T (TO-220) Package
Rated Power @ 25°C		
T_C	20W	15W
T_A	4.3W	2W
Thermal Resistance		
θ_{JC}	3°C/W	3°C/W
θ_{JA}	35°C/W	60°C/W

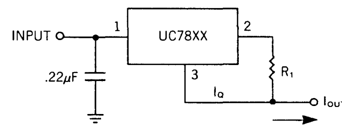
TYPICAL APPLICATIONS

Fixed Output Regulator



Notes: 1. To specify an output voltage, substitute voltage value for "XX".
2. Although no output capacitor is needed for stability, it does improve transient responses.
3. Input capacitor required if regulator is located an appreciable distance from power supply filter.

Current Regulator



$$I_{OUT} = \frac{V_{OUT}}{R_1} + I_Q$$

UNITRODE

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7805			UC7805C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$	4.8		5.2	4.8		5.2	V
	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$ $5mA \leq I_{OUT} \leq 1A$, $P_D \leq 15W$	4.8		5.2	4.77		5.23	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	4.75		5.25	4.75		5.25	V
Line Regulation	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$, $I_O = 500mA$			25			35	mV
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$		10	50		10	50	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = 10V$, $5mA \leq I_O \leq 1.5A$		20	26		20	40	mV
	$V_{IN} = 10V$, $5mA \leq I_O \leq 1A$ Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			50			50	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$		4.5	6		4.5	6	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			6.5			6.5	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = 10V$, $5mA \leq I_O \leq 1A$			.4			.4	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			.5			.5	mA
	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$, $I_O = 500mA$			.8			.8	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			1.0			1.0	mA
Ripple Rejection	$T_j = 25°C$, $8V \leq V_{IN} \leq 18V$, $I_O = 500mA$	63			63			dB
Output Noise Voltage	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$		40			40		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		2			2		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = 10V$		2.1			2.1		A
Peak Output Current	$T_j = 25°C$		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = 10V$, $I_O = 5mA$		−.4			−.4		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = 10V$, $I_O = 5mA$		20			20		mV
Thermal Shutdown	$V_{IN} = 10V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		−55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7812			UC7812C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = 19V, I_O = 1A	11.52		12.48	11.52		12.48	V
	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V 5mA ≤ I_{OUT} ≤ 1A, P_D ≤ 15W	11.52		12.48	11.46		12.54	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	11.40		12.60	11.40		12.60	V
Line Regulation	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V, I_O = 500mA			60			84	mV
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}		20	120		20	120	mV
Load Regulation	T_j = 25°C, V_{IN} = 19V, 5mA ≤ I_O ≤ 1.5A		50	64		50	100	mV
	V_{IN} = 19V, 5mA ≤ I_O ≤ 1A Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			120			120	mV
Quiescent Current	T_j = 25°C, V_{IN} = 19V, I_O = 1A		4.5	7		4.5	7	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			6.5			6.5	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = 19V, 5mA ≤ I_O ≤ 1A			.4			.4	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.5			.5	mA
	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V, I_O = 500mA			.8			.8	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			1.0			1.0	mA
Ripple Rejection	T_j = 25°C, 15V ≤ V_{IN} ≤ 25V, I_O = 500mA	56			56			dB
Output Noise Voltage	T_j = 25°C, V_{IN} = 19V, I_O = 5mA		75			75		μV
Dropout Voltage	T_j = 25°C, I_O = 1A		2			2		V
Short Circuit Current	T_j = 25°C, V_{IN} = 19V		1.5			1.5		A
Peak Output Current	T_j = 25°C		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = 19V, I_O = 5mA		-.8			-.8		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = 19V, I_O = 5mA		50			50		mV
Thermal Shutdown	V_{IN} = 19V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

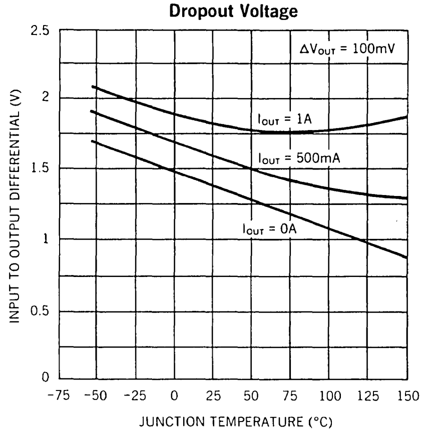
ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7815			UC7815C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = 23V, I_O = 1A	14.4		15.6	14.4		15.6	V
	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V 5mA ≤ I_{OUT} ≤ 1A, P_D ≤ 15W	14.4		15.6	14.3		15.7	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	14.25		15.75	14.25		15.75	V
Line Regulation	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V, I_O = 500mA			75			100	mV
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}		22	150		22	150	mV
Load Regulation	T_j = 25°C, V_{IN} = 23V, 5mA ≤ I_O ≤ 1.5A		50	80		50	120	mV
	V_{IN} = 23V, 5mA ≤ I_O ≤ 1A Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			150			150	mV
Quiescent Current	T_j = 25°C, V_{IN} = 23V, I_O = 1A		4.5	7		4.5	7	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			6.5			6.5	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = 23V, 5mA ≤ I_O ≤ 1A			.4			.4	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.5			.5	mA
	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V, I_O = 500mA			.8			.8	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			1.0			1.0	mA
Ripple Rejection	T_j = 25°C, 18.5V ≤ V_{IN} ≤ 28.5V, I_O = 500mA	54			54			dB
Output Noise Voltage	T_j = 25°C, V_{IN} = 23V, I_O = 5mA		90			90		μV
Dropout Voltage	T_j = 25°C, I_O = 1A		2			2		V
Short Circuit Current	T_j = 25°C, V_{IN} = 23V		1.2			1.2		A
Peak Output Current	T_j = 25°C		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = 23V, I_O = 5mA		-1.0			-1.0		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = 23V, I_O = 5mA		60			60		mV
Thermal Shutdown	V_{IN} = 23V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

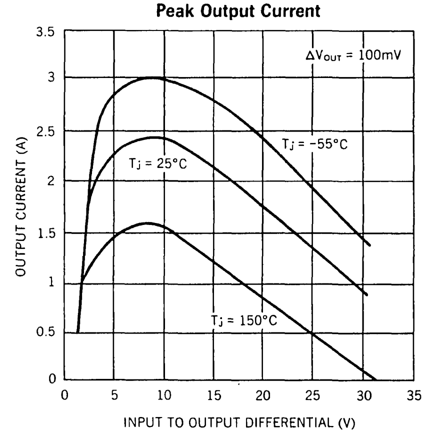
Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

TYPICAL PERFORMANCE CHARACTERISTICS

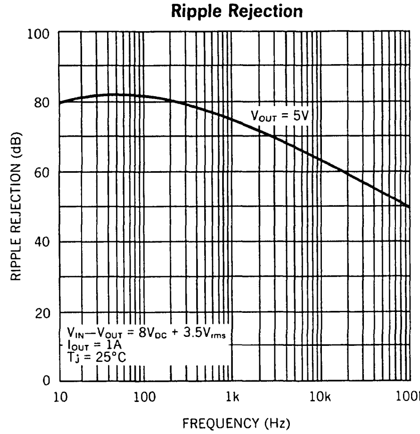
Dropout Voltage



Peak Output Current

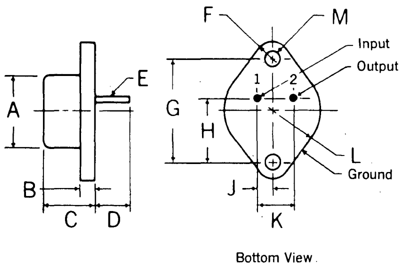


Ripple Rejection



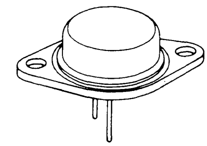
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

UC7800 SERIES
UC7800C SERIES

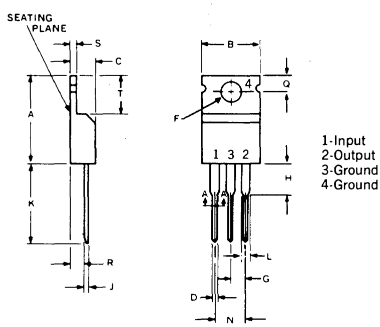


	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)

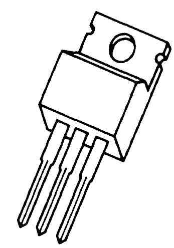


UC7800C SERIES



	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	—	0.250	—	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



ORDERING INFORMATION

OUTPUT VOLTAGE	PACKAGE SUFFIX	
	K(TO-3)	T(TO-220)
5V	UC7805K UC7805CK	—— UC7805CT
12V	UC7812K UC7812CK	—— UC7812CT
15V	UC7815K UC7815CK	—— UC7815CT

LINEAR INTEGRATED CIRCUITS
Three Terminal Fixed Voltage Positive Regulators Precision Version

UC7800A
UC7800AC
SERIES

III

FEATURES
- ±1.0% preset output voltage
- Complete specifications at 1A load
- No external components
- Internal thermal overload protection
- Internal short circuit current limiting
- Output transistor safe area compensation
- Available in TO-3 and TO-220 Packages
- Output voltages of 5, 12, and 15V (For other voltages, please contact the factory)
- Pinout identical to UC7800 series

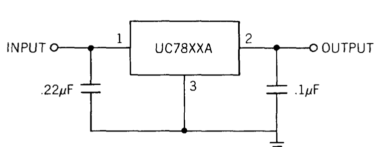
DESCRIPTION
These three terminal monolithic positive voltage regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A of output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents. These units feature an on-chip trimming system to set the output voltages to within ±1.0% of nominal. They also offer improved line and load regulation characteristics over the UC7800 series.

ABSOLUTE MAXIMUM RATINGS
Input Voltage 35V
Power Dissipation .... Internally limited
Operating Junction Temperature Range
  UC7800A SERIES .... −55°C to +150°C
  UC7800AC SERIES .... 0°C to +125°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature (Soldering, 10 seconds)
  K (TO-3) Package .... 300°C
  T (TO-220) Package .... 230°C
Power/Thermal Characteristics

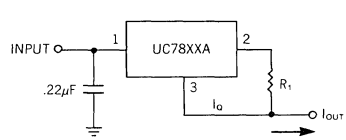
	K (TO-3) Package	T (TO-220) Package
Rated Power @ 25°C		
T_C	20W	15W
T_A	4.3W	2W
Thermal Resistance		
θ_{JC}	3°C/W	3°C/W
θ_{JA}	35°C/W	60°C/W

TYPICAL APPLICATIONS

Fixed Output Regulator



Current Regulator



$$I_{OUT} = \frac{V_{OUT}}{R_1} + I_Q$$

Notes: 1. To specify an output voltage, substitute voltage value for "XX".
2. Although no output capacitor is needed for stability, it does improve transient responses.
3. Input capacitor required if regulator is located an appreciable distance from power supply filter.

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7805A			UC7805AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$	4.95		5.05	4.95		5.05	V
	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$ $5mA \leq I_{OUT} \leq 1A$, $P_D \leq 15W$	4.9		5.1	4.87		5.13	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	4.85		5.15	4.85		5.15	V
Line Regulation	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$, $I_O = 500mA$			5			6	mV
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$		3	10		3	10	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = 10V$, $5mA \leq I_O \leq 1.5A$		10	12		10	17	mV
	$V_{IN} = 10V$, $5mA \leq I_O \leq 1A$ Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			25			25	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$		4.5	6		4.5	6	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			6.5			6.5	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = 10V$, $5mA \leq I_O \leq 1A$			.4			.4	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			.5			.5	mA
	$T_j = 25°C$, $7.5V \leq V_{IN} \leq 20V$, $I_O = 500mA$			.6			.6	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			.8			.8	mA
Ripple Rejection	$T_j = 25°C$, $8V \leq V_{IN} \leq 18V$, $I_O = 500mA$	69			69			dB
Output Noise Voltage	$T_j = 25°C$, $V_{IN} = 10V$, $I_O = 1A$		40			40		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		2			2		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = 10V$		2.1			2.1		A
Peak Output Current	$T_j = 25°C$		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = 10V$, $I_O = 5mA$		-.4			-.4		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = 10V$, $I_O = 5mA$		20			20		mV
Thermal Shutdown	$V_{IN} = 10V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7812A			UC7812AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = 19V, I_O = 1A	11.88		12.12	11.88		12.12	V
	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V 5mA ≤ I_{OUT} ≤ 1A, P_D ≤ 15W	11.76		12.24	11.70		12.30	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	11.64		12.36	11.64		12.36	V
Line Regulation	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V, I_O = 500mA			12			15	mV
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}		4	18		4	18	mV
Load Regulation	T_j = 25°C, V_{IN} = 19V, 5mA ≤ I_O ≤ 1.5A		12	32		12	50	mV
	V_{IN} = 19V, 5mA ≤ I_O ≤ 1A Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			60			60	mV
Quiescent Current	T_j = 25°C, V_{IN} = 19V, I_O = 1A		4.5	6		4.5	6	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			6.5			6.5	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = 19V, 5mA ≤ I_O ≤ 1A			.4			.4	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.5			.5	mA
	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 27V, I_O = 500mA			.6			.6	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.8			.8	mA
Ripple Rejection	T_j = 25°C, 15V ≤ V_{IN} ≤ 25V, I_O = 500mA	62			62			dB
Output Noise Voltage	T_j = 25°C, V_{IN} = 19V, I_O = 5mA		75			75		μV
Dropout Voltage	T_j = 25°C, I_O = 1A		2			2		V
Short Circuit Current	T_j = 25°C, V_{IN} = 19V		1.5			1.5		A
Peak Output Current	T_j = 25°C		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = 19V, I_O = 5mA		−.8			−.8		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = 19V, I_O = 5mA		50			50		mV
Thermal Shutdown	V_{IN} = 19V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		−55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

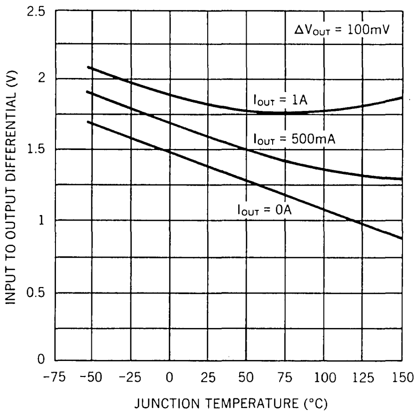
ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7815A			UC7815AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = 23V, I_O = 1A	14.85		15.15	14.85		15.15	V
	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V 5mA ≤ I_{OUT} ≤ 1A, P_D ≤ 15W	14.7		15.3	14.60		15.40	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	14.55		15.45	14.55		14.45	V
Line Regulation	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V, I_O = 500mA			15			19	mV
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}		4	22		4	22	mV
Load Regulation	T_j = 25°C, V_{IN} = 23V, 5mA ≤ I_O ≤ 1.5A		12	35		12	50	mV
	V_{IN} = 23V, 5mA ≤ I_O ≤ 1A Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			75			75	mV
Quiescent Current	T_j = 25°C, V_{IN} = 23V, I_O = 1A		4.5	6		4.5	6	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			6.5			6.5	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = 23V, 5mA ≤ I_O ≤ 1A			.4			.4	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.5			.5	mA
	T_j = 25°C, 17.5V ≤ V_{IN} ≤ 30V, I_O = 500mA			.6			.6	mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			.8			.8	mA
Ripple Rejection	T_j = 25°C, 18.5V ≤ V_{IN} ≤ 28.5V, I_O = 500mA	60			60			dB
Output Noise Voltage	T_j = 25°C, V_{IN} = 23V, I_O = 5mA		90			90		μV
Dropout Voltage	T_j = 25°C, I_O = 1A		2			2		V
Short Circuit Current	T_j = 25°C, V_{IN} = 23V		1.2			1.2		A
Peak Output Current	T_j = 25°C		2.4			2.4		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = 23V, I_O = 5mA		-1.0			-1.0		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = 23V, I_O = 5mA		60			60		mV
Thermal Shutdown	V_{IN} = 23V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

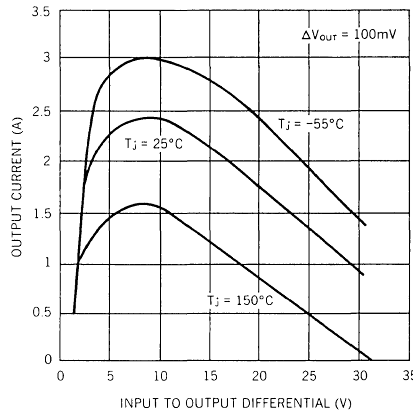
Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

TYPICAL PERFORMANCE CHARACTERISTICS

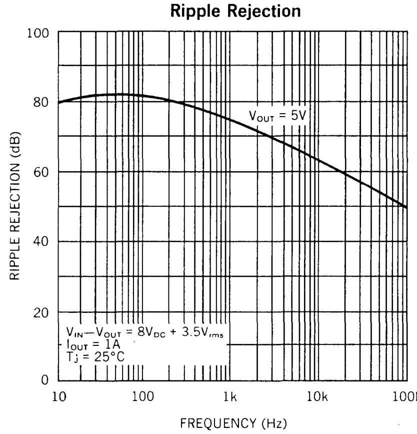
Dropout Voltage



Peak Output Current

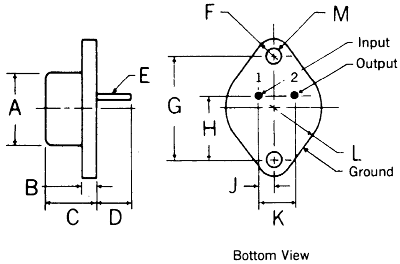


Ripple Rejection



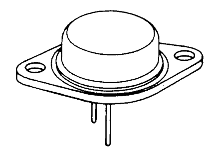
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

UC7800A SERIES
UC7800AC SERIES

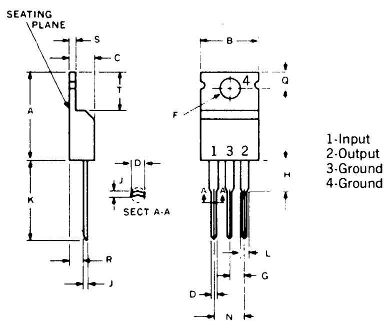


	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)

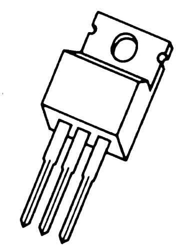


UC7800AC SERIES



	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	—	0.250	—	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



ORDERING INFORMATION

OUTPUT VOLTAGE	PACKAGE SUFFIX	
	K(TO-3)	T(TO-220)
5V	UC7805AK UC7805ACK	—— UC7805ACT
12V	UC7812AK UC7812ACK	—— UC7812ACT
15V	UC7815AK UC7815ACK	—— UC7815ACT

LINEAR INTEGRATED CIRCUITS

Three Terminal Fixed Voltage Negative Regulators

UC7900
UC7900C
SERIES

III

FEATURES

- ±4% preset output voltage
- Output current to 1.5A
- One external component
- Internal thermal overload protection
- Internal short circuit current limiting
- Output transistor safe area compensation
- Available in TO-3 and TO-220 packages
- Output voltages of −5, −12 and −15V (For other voltages, please contact the factory)

DESCRIPTION

These three terminal monolithic negative voltage regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A of output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents. These units feature an on-chip trimming system to set the output voltages to within ±4% of nominal. This regulator series is an optimum complement to the UC7800/7800C line of three terminal positve regulators. Two companion series, the UC7900A and UC7900AC, offer tighter output tolerances, and improved line and load regulation characteristics.

ABSOLUTE MAXIMUM RATINGS

Input Voltage .... −35V
Input-Output Voltage Differential 30V
Power Dissipation .... Internally limited
Operating Junction Temperature Range
UC7900 SERIES .... −55°C to +150°C
UC7900C SERIES .... 0°C to +125°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature (Soldering, 10 seconds)
K (TO-3) package .... 300°C
T (TO-220) package .... 230°C
Power/Thermal Characteristics

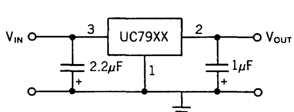
	K (TO-3) Package	T (TO-220) Package
Rated Power @ 25°C		
T_C	20W	15W
T_A	4.3W	2W
Thermal Resistance		
θ_{JC}	3°C/W	3°C/W
θ_{JA}	35°C/W	60°C/W

TYPICAL APPLICATIONS

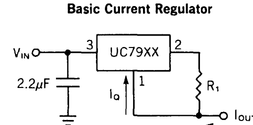
Input bypass capacitors are recommended for stable operation of the UC7900 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2.2μF on the input, 1μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

Fixed Output Regulator



Basic Current Regulator



$$I_{OUT} = \frac{V_{OUT}}{R_1} + I_Q$$

UNITRODE

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7905			UC7905C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = -10V$, $I_O = 5mA$	-5.20		-4.80	-5.20		-4.80	V
	$T_j = 25°C$, $-25V \leq V_{IN} \leq -8V$ $5mA \leq I_{OUT} \leq 1.0A$, $P \leq P_D$	-5.20		-4.80	-5.23		-4.77	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	-5.25		-4.75	-5.25		-4.75	V
Line Regulation	$T_j = 25°C$, $-25V \leq V_{IN} \leq -7V$, $I_O = 5mA$		25	50		25	50	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = -10V$, $5mA \leq I_O \leq 1.5A$			50			100	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = -10V$, $I_O = 500mA$		1	2.5		1	2.5	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			3			3	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = -10V$, $5mA \leq I_O \leq 1.5A$			1.0			1.0	mA
	$T_j = 25°C$, $-25V \leq V_{IN} \leq -8V$, $I_O = 500mA$			.5			.5	mA
Ripple Rejection	$T_j = 25°C$, $-18V \leq V_{IN} \leq -8V$, $I_O = 500mA$	54			54			dB
Output Noise Voltage	f = 10Hz to 100KHz, $C_L = 1\mu f$ $T_j = 25°C$, $V_{IN} = -10V$, $I_O = 500mA$		100			100		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		2.0			2.0		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = -10V$		1.8			1.8		A
Peak Output Current	$T_j = 25°C$		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = -10V$, $I_O = 5mA$		-.4			-.4		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = -10V$, $I_O = 5mA$		20			20		mV
Thermal Shutdown	$V_{IN} = -10V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.
$P_D = 20W$ for TO-3 (K) and 15W for TO-220 (T); Min $|V_O - V_{IN}|$ @ $-55°C = 2.5V$.

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7912			UC7912C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = −17V, I_O = 5mA	−12.48		−11.52	−12.58		−11.52	V
	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V 5mA ≤ I_{OUT} ≤ 1.0A, P ≤ P_D	−12.48		−11.52	−12.54		−11.46	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	−12.60		−11.40	−12.60		−11.40	V
Line Regulation	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V, I_O = 5mA		30	80		30	80	mV
Load Regulation	T_j = 25°C, V_{IN} = −17V, 5mA ≤ I_O ≤ 1.5A			120			240	mV
Quiescent Current	T_j = 25°C, V_{IN} = −17V, I_O = 500mA		3			3		mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			4			4	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = −17V, 5mA ≤ I_O ≤ 1.5A			.8			.8	mA
	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V, I_O = 500mA			.5			.5	mA
Ripple Rejection	T_j = 25°C, −25V ≤ V_{IN} ≤ −15V, I_O = 500mA	56			56			dB
Output Noise Voltage	f = 10Hz to 100KHz, C_L = 1µf T_j = 25°C, V_{IN} = −17V, I_O = 500mA		200			200		µV
Dropout Voltage	T_j = 25°C, I_O = 1A		1.1			1.1		V
Short Circuit Current	T_j = 25°C, V_{IN} = −17V		1.3			1.3		A
Peak Output Current	T_j = 25°C		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = −17V, I_O = 5mA		−.9			−.9		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = −17V, I_O = 5mA		48			48		mV
Thermal Shutdown	V_{IN} = −17V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		−55			0		°C

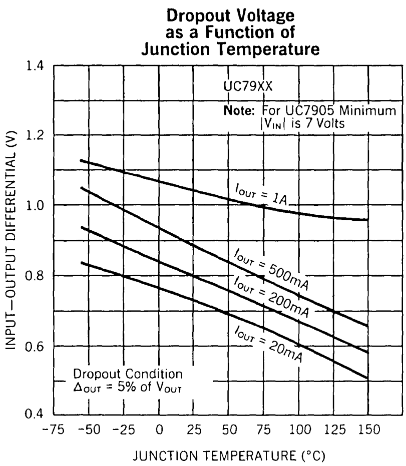
Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.
P_D = 20W for TO-3 (K) and 15W for TO-220 (T).

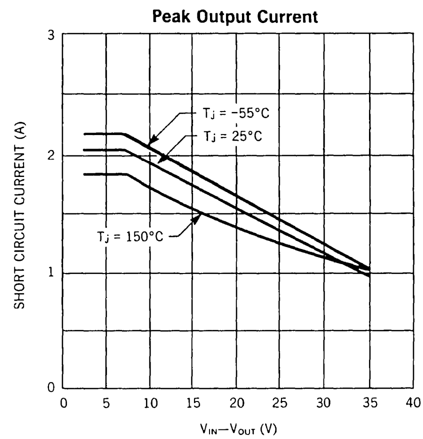
ELECTRICAL CHARACTERISTICS

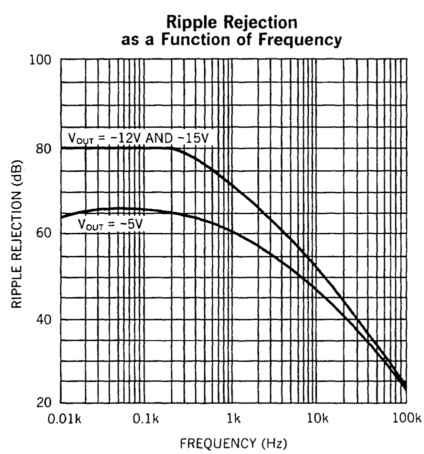
PARAMETER	TEST CONDITIONS	UC7915			UC7915C			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = -20V$, $I_O = 5mA$	-15.60		-14.40	-15.00		-14.40	V
	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$ $5mA \leq I_{OUT} \leq 1.0A$, $P \leq P_D$	-15.60		-14.40	-15.68		-14.32	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	-15.75		-14.25	-15.75		-14.25	V
Line Regulation	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$, $I_O = 5mA$		35	100		35	100	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = -20V$, $5mA \leq I_O \leq 1.5A$			150			300	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = -20V$, $I_O = 500mA$		3			3		mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			4			4	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = -20V$, $5mA \leq I_O \leq 1.5A$			.8			.8	mA
	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$, $I_O = 500mA$			.5			.5	mA
Ripple Rejection	$T_j = 25°C$, $-28V \leq V_{IN} \leq -18V$, $I_O = 500mA$	56			56			dB
Output Noise Voltage	f = 10Hz to 100KHz, $C_L = 1\mu f$ $T_j = 25°C$, $V_{IN} = -17V$, $I_O = 500mA$		250			250		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		1.1			1.1		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = -20V$		1.1			1.1		A
Peak Output Current	$T_j = 25°C$		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = -20V$, $I_O = 5mA$		-1.0			-1.0		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = -20V$, $I_O = 5mA$		60			60		mV
Thermal Shutdown	$V_{IN} = -20V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.
P_D = 20W for TO-3 (K) and 15W for TO-220 (T).

TYPICAL PERFORMANCE CHARACTERISTICS

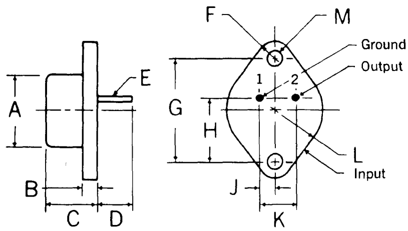






MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

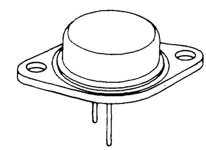
UC7900 SERIES
UC7900C SERIES



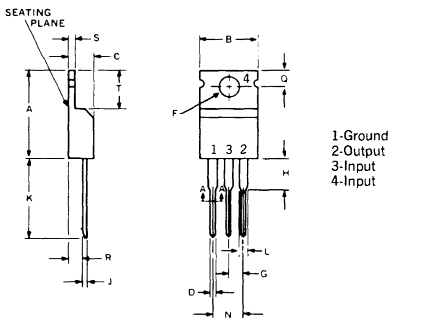
Bottom View

	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)



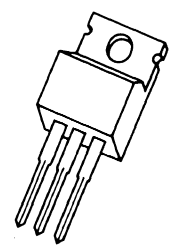
UC7900C SERIES



1-Ground
2-Output
3-Input
4-Input

	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	—	0.250	—	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



ORDERING INFORMATION

OUTPUT VOLTAGE	PACKAGE SUFFIX	
	K(TO-3)	T(TO-220)
-5V	UC7905K UC7905CK	—— UC7905CT
-12V	UC7912K UC7912CK	—— UC7912CT
-15V	UC7915K UC7915CK	—— UC7915CT

LINEAR INTEGRATED CIRCUITS

Three Terminal Fixed Voltage Negative Regulators Precision Version

UC7900A
UC7900AC
SERIES

III

FEATURES

- ±1.0% preset output voltage
- Output current to 1.5A
- One external component
- Internal thermal overload protection
- Internal short circuit current limiting
- Output transistor safe area compensation
- Available in TO-3 and TO-220 packages
- Output voltages of −5, −12 and −15V (For other voltages, please contact the factory)

DESCRIPTION

These three terminal monolithic negative voltage regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A of output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents. These units feature an on-chip trimming system to set the output voltages to within ±1.0% of nominal. They also offer improved line and load regulation characteristics over the UC7900 series.

ABSOLUTE MAXIMUM RATINGS

Input Voltage .... −35V
Input-Output Voltage Differential 30V
Power Dissipation .... Internally limited
Operating Junction Temperature Range
  UC7900A SERIES .... −55°C to +150°C
  UC7900AC SERIES .... 0°C to +125°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature (Soldering, 10 seconds)
  K (TO-3) package .... 300°C
  T (TO-220) package .... 230°C
Power/Thermal Characteristics

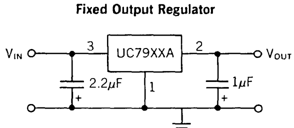
	K (TO-3) Package	T (TO-220) Package
Rated Power @ 25°C		
T_C	20W	15W
T_A	4.3W	2W
Thermal Resistance		
θ_{JC}	3°C/W	3°C/W
θ_{JA}	35°C/W	60°C/W

TYPICAL APPLICATIONS

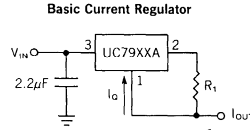
Input bypass capacitors are recommended for stable operation of the UC7900 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2.2μF on the input, 1μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

Fixed Output Regulator



Basic Current Regulator



$$I_{OUT} = \frac{V_{OUT}}{R_1} + I_Q$$

UNITRODE

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7905A			UC7905AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = -10V$, $I_O = 5mA$	-5.05		-4.95	-5.05		-4.95	V
	$T_j = 25°C$, $-25V \leq V_{IN} \leq -8V$ $5mA \leq I_{OUT} \leq 1.0A$, $P \leq P_D$	-5.10		-4.90	-5.13		-4.87	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	-5.15		-4.85	-5.15		-4.85	V
Line Regulation	$T_j = 25°C$, $-25V \leq V_{IN} \leq -7V$, $I_O = 5mA$		10	15		10	25	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = -10V$, $5mA \leq I_O \leq 1.5A$		20	50		20	100	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = -10V$, $I_O = 500mA$		1	2		1	2	mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			2.5			2.5	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = -10V$, $5mA \leq I_O \leq 1.5A$			.4			.4	mA
	$T_j = 25°C$, $-25V \leq V_{IN} \leq -8V$, $I_O = 500mA$			.4			.4	mA
Ripple Rejection	$T_j = 25°C$, $-18V \leq V_{IN} \leq -8V$, $I_O = 500mA$	54			54			dB
Output Noise Voltage	f = 10Hz to 100KHz, $C_L = 1\mu f$ $T_j = 25°C$, $V_{IN} = -10V$, $I_O = 500mA$		100			100		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		2.0			2.0		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = -10V$		1.8			1.8		A
Peak Output Current	$T_j = 25°C$		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = -10V$, $I_O = 5mA$		-.4			-.4		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = -10V$, $I_O = 5mA$		20			20		mV
Thermal Shutdown	$V_{IN} = -10V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.
P_D = 20W for TO-3 (K) and 15W for TO-220 (T); Min $|V_O - V_{IN}|$ @ -55°C = 2.5V.

III

ELECTRICAL CHARACTERISTICS

PARAMETER	TEST CONDITIONS	UC7912A			UC7912AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	T_j = 25°C, V_{IN} = −17V, I_O = 5mA	−12.12		−11.88	−12.12		−11.88	V
	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V 5mA ≤ I_{OUT} ≤ 1.0A, P ≤ P_D	−12.24		−11.76	−12.30		−11.70	V
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}	−12.36		−11.64	−12.36		−11.64	V
Line Regulation	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V, I_O = 5mA		10	20		10	30	mV
Load Regulation	T_j = 25°C, V_{IN} = −17V, 5mA ≤ I_O ≤ 1.5A		40	80		40	80	mV
Quiescent Current	T_j = 25°C, V_{IN} = −17V, I_O = 500mA		3			3		mA
	Over Temperature, T_{MIN} ≤ T_j ≤ T_{MAX}			4			4	mA
Quiescent Current Change	T_j = 25°C, V_{IN} = −17V, 5mA ≤ I_O ≤ 1.5A			.4			.4	mA
	T_j = 25°C, −32V ≤ V_{IN} ≤ −14V, I_O = 500mA			.4			.4	mA
Ripple Rejection	T_j = 25°C, −25V ≤ V_{IN} ≤ −15V, I_O = 500mA	56			56			dB
Output Noise Voltage	f = 10Hz to 100KHz, C_L = 1μf T_j = 25°C, V_{IN} = −17V, I_O = 500mA		200			200		μV
Dropout Voltage	T_j = 25°C, I_O = 1A		1.1			1.1		V
Short Circuit Current	T_j = 25°C, V_{IN} = −17V		1.3			1.3		A
Peak Output Current	T_j = 25°C		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	0°C ≤ T_j ≤ T_{MAX}, V_{IN} = −17V, I_O = 5mA		−.9			−.9		mV/°C
Long Term Stability	1000 Hrs. @ T_j = 125°C, V_{IN} = −17V, I_O = 5mA		48			48		mV
Thermal Shutdown	V_{IN} = −17V, I_O = 5mA		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		−55			0		°C

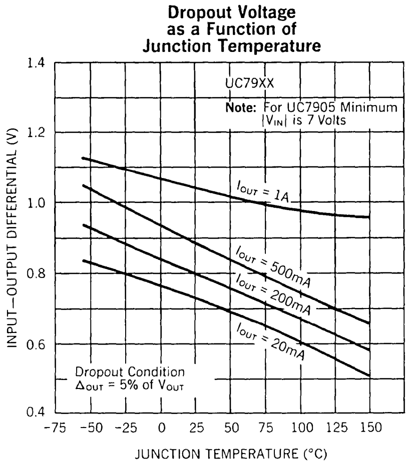
Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t_w ≤ 10ms, duty-cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.
P_D = 20W for TO-3 (K) and 15W for TO-220 (T).

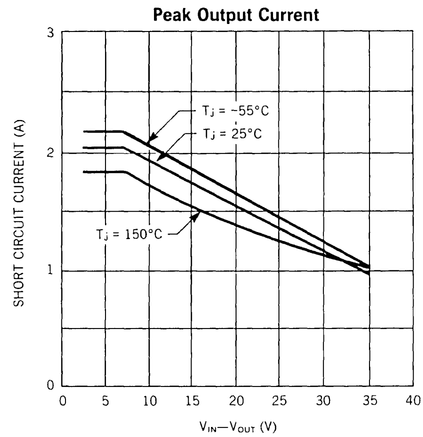
ELECTRICAL CHARACTERISTICS

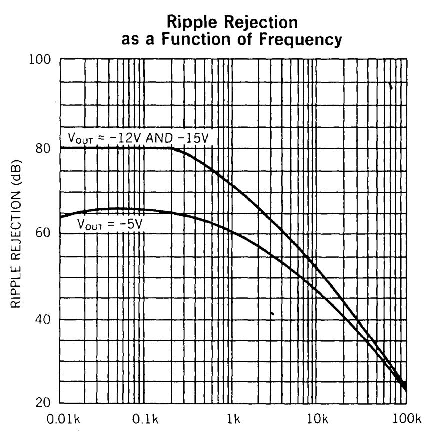
PARAMETER	TEST CONDITIONS	UC7915A			UC7915AC			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Output Voltage	$T_j = 25°C$, $V_{IN} = -20V$, $I_O = 5mA$	-15.15		-14.85	-15.15		-14.85	V
	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$ $5mA \leq I_{OUT} \leq 1.0A$, $P \leq P_D$	-15.30		-14.70	-15.38		-14.63	V
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$	-15.45		-14.55	-15.45		-14.55	V
Line Regulation	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$, $I_O = 5mA$		10	20		10	30	mV
Load Regulation	$T_j = 25°C$, $V_{IN} = -20V$, $5mA \leq I_O \leq 1.5A$		50	80		50	80	mV
Quiescent Current	$T_j = 25°C$, $V_{IN} = -20V$, $I_O = 500mA$		3			3		mA
	Over Temperature, $T_{MIN} \leq T_j \leq T_{MAX}$			4			4	mA
Quiescent Current Change	$T_j = 25°C$, $V_{IN} = -20V$, $5mA \leq I_O \leq 1.5A$			.4			.4	mA
	$T_j = 25°C$, $-35V \leq V_{IN} \leq -17V$, $I_O = 500mA$			.4			.4	mA
Ripple Rejection	$T_j = 25°C$, $-28V \leq V_{IN} \leq -18V$, $I_O = 500mA$	56			56			dB
Output Noise Voltage	f = 10Hz to 100KHz, $C_L = 1\mu f$ $T_j = 25°C$, $V_{IN} = -17V$, $I_O = 500mA$		250			250		μV
Dropout Voltage	$T_j = 25°C$, $I_O = 1A$		1.1			1.1		V
Short Circuit Current	$T_j = 25°C$, $V_{IN} = -20V$		1.1			1.1		A
Peak Output Current	$T_j = 25°C$		2.0			2.0		A
Avg. Temp. Variation of V_{OUT}	$0°C \leq T_j \leq T_{MAX}$, $V_{IN} = -20V$, $I_O = 5mA$		-1.0			-1.0		mV/°C
Long Term Stability	1000 Hrs. @ $T_j = 125°C$, $V_{IN} = -20V$, $I_O = 5mA$		60			60		mV
Thermal Shutdown	$V_{IN} = -20V$, $I_O = 5mA$		175			175		°C
	T_{MAX}		150			125		°C
	T_{MIN}		-55			0		°C

Note: All characteristics except noise voltage and ripple rejection are measured using pulse techniques ($t_w \leq 10ms$, duty-cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.
P_D = 20W for TO-3 (K) and 15W for TO-220 (T).

TYPICAL PERFORMANCE CHARACTERISTICS

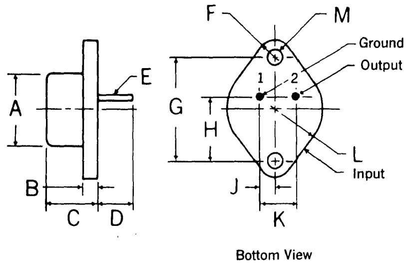






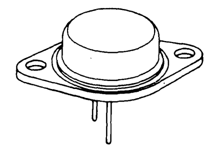
MECHANICAL SPECIFICATIONS AND CONNECTION DIAGRAMS

UC7900A SERIES
UC7900AC SERIES

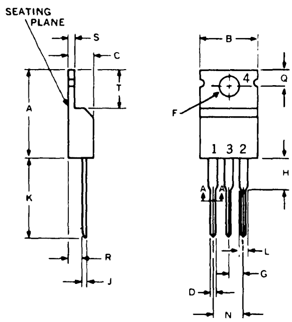


	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

K(TO-3)



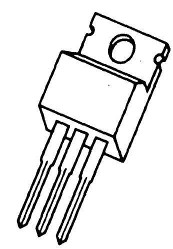
UC7900AC SERIES



1-Ground
2-Output
3-Input
4-Input

	INCHES		MILIMETERS	
	MIN	MAX	MIN	MAX
A	0.560	0.625	14.23	15.87
B	0.380	0.420	9.66	10.66
C	0.140	0.190	3.56	4.82
D	0.020	0.045	0.51	1.14
F	0.139	0.147	3.531	3.733
G	0.090	0.110	2.29	2.79
H	–	0.250	–	6.35
J	0.015	0.025	0.38	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.070	1.14	1.77
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.115	2.04	2.92
S	0.045	0.055	1.14	1.39
T	0.230	0.270	5.85	6.85

T(TO-220)



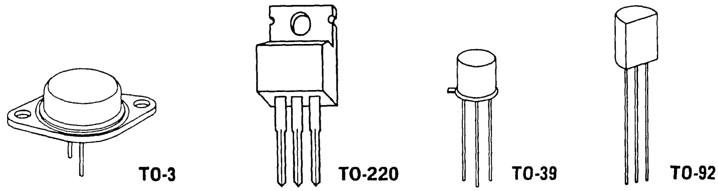
ORDERING INFORMATION

OUTPUT VOLTAGE	PACKAGE SUFFIX	
	K(TO-3)	T(TO-220)
-5V	UC7905AK UC7905ACK	—— UC7905ACT
-12V	UC7912AK UC7912ACK	—— UC7912ACT
-15V	UC7915AK UC7915ACK	—— UC7915ACT

POWER TRANSISTORS & DARLINGTONS IV

N-CHANNEL POWER MOSFETS

PRODUCT SELECTION GUIDE



LOW VOLTAGE

Continuous Drain Current $T_C = 25°C$		2AMP		12AMP		14AMP		33AMP	40AMP
Package Style		**TO-39**	**TO-92**	**TO-3**	**TO-220**	**TO-3**	**TO-220**	**TO-3**	**TO-3**
BREAKDOWN VOLTAGE V_{DS}	60V	UFN13A1	UFN11A1	UFN24A3	UFN26A3	UFN24A1	UFN26A1	UFN45A3	UFN45A1*
	90V	UFN13A2	UFN11A2						
	100V			UFN24A4	UFN26A4	UFN24A2	UFN26A2	UFN45A4	UFN45A2*
	120V	UFN13A3	UFN11A3						
$R_{DS(ON)}$ Max.		1.5Ω	1.5Ω	.25Ω	.25Ω	.18Ω	.18Ω	.08Ω	0.55Ω

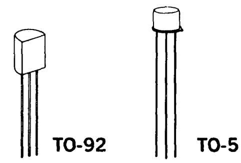
*This series features an all copper base with .063" (1.60mm) diameter pins.

HIGH VOLTAGE

Continuous Drain Current $T_C = 25°C$		5AMP		6AMP		13AMP	15AMP
Package Style		**TO-3**	**TO-220**	**TO-3**	**TO-220**	**TO-3**	**TO-3**
BREAKDOWN VOLTAGE V_{DS}	350V	UFN24C3	UFN26C3	UFN24C1	UFN26C1	UFN44C3	UFN44C1
	400V	UFN24C4	UFN26C4	UFN24C2	UFN26C2	UFN44C4	UFN44C2
$R_{DS(ON)}$ Max.		1.5Ω	1.5Ω	1.0Ω	1.0Ω	0.4Ω	0.3Ω

Contact Unitrode for complete specifications.

NPN BIPOLAR POWER SWITCHING TRANSISTORS
.5-30A, 60-500V



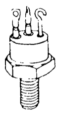
LOW VOLTAGE

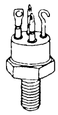
Maximum Collector Current		1 AMP (PEAK)	2 AMP	3 AMP	
Package Style		**TO-92**	**TO-5**	**TO-5**	
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\,(sus)}$	60V		UPT212	2N3418*	2N3420*
	80V		UPT213	2N3419*	2N3421*
	100V	UPTA510	UPT214 UPT215		
h_{FE} Minimum		20 @ 1A	30 @ .5A	20 @ 1A	40 @ 1A
V_{CE} (sat) Max.		1V @ .5A	1V @ 2A	.5V @ 2A	.5V @ 2A
t_f Maximum		0.2μs (typical)	0.1μs (typical)	1.2μs ($t_{OFF} = t_s + t_f$)	

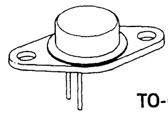
HIGH VOLTAGE

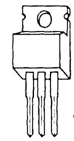
Maximum Collector Current		.5 AMP (PEAK)	1 AMP (PEAK)	2 AMP	
Package Style		**TO-92**	**TO-92**	**TO-5**	
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\,(sus)}$	150V			UPT311	
	200V	UPTB520	UPTA520	UPT312	2N5662*
	250V			UPT313	
	275V				
	300V	UPTB530	UPTA530	UPT314 UPT315	2N5663*
	350V				
	400V	UPTB540			
	500V	UPTB550			
h_{FE} Minimum		20 @ 25mA	25 @ .1A	30 @ .5A	40 @ .5A (2N5662) 25 @ .5A (2N5663)
V_{CE} (sat) Max.		1.2v @ 50mA	1V @ .5A	1V @ 2A	.4V @ 1A
t_f Maximum		1.0μs (typical)	0.2μs (typical)	0.3μs (typical)	0.4μs (2N5662) 0.6μs (2N5663)

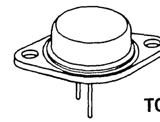
*Available as JAN, JANTX, JANTXV.


TO-59


TO-111


TO-66


TO-220AB


TO-3

IV

LOW VOLTAGE

Maximum Collector Current		5 AMP				
Package Style		**TO-5**	**TO-59**		**TO-111**	
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\ (SUS)}$	60V	UPT612				
	80V	UPT613	2N2151** 2N2880* 2N3998*	2N3999*	2N3749* 2N3996*	2N3997*
	100V	UPT614 UPT615				
h_{FE} Minimum		30 @ 1A	40 @ 1A	80 @ 1A	40 @ 1A	80 @ 1A
V_{CE} (sat) Max.		1V @ 5A	.25V @ 1A (1V @ 1A for 2N2151)			
t_f Maximum		0.1μs (typical)	0.3μs (2N2880) / 0.8μs (2N3998)	1.0μs	0.3μs (2N3749) / 0.8μs (2N3996)	1.0μs

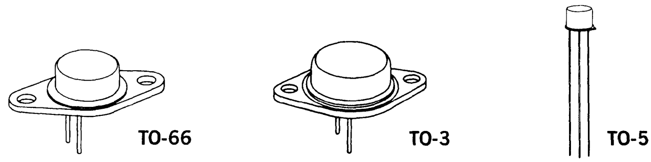
HIGH VOLTAGE

Maximum Collector Current		2 AMP			3 AMP			4 AMP	8 AMP
Package Style		**TO-66**		**TO-220AB**	**TO-66**	**TO-220AB**	**TO-3**	**TO-220AB**	**TO-3**
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\ (SUS)}$	150V	UPT321			UPT521				
	200V	UPT322	2N5660*		UPT522				
	250V	UPT323		UMT3584	UPT523		2N5838		
	275V						2N5839		
	300V	UPT324 UPT325	2N5661*	UMT3585	UPT524 UPT525	UMT1203		UMT13004	2N6671
	350V						2N5840		2N6672
	400V					UMT1204		UMT13005	2N6673
	500V								
h_{FE} Minimum		30 @ .5A	40 @ .5A (2N5660) / 25 @ .5A (2N5661)	25 @ 1A	25 @ 1A	7 @ 2A	10 @ 2A	8 @ 2A	10 @ 5A
V_{CE} (sat) Max.		1V @ 2A	.4V @ 1A	0.75V @ 1A	1V @ 3A	3V @ 3A	1.5V @ 2A	0.6V @ 2A	1.0 @ 5A
t_f Maximum		0.3μs (typical)	0.4μs (2N5660) / 0.6μs (2N5661)	3.0μs	0.4μs (typical)	0.7μs	1.5μs	0.9μs	0.4μs

*Available as JAN, JANTX, JANTXV.
**Available as JAN, JANTX.

NPN BIPOLAR POWER SWITCHING TRANSISTORS

.5-30A, 60-500V



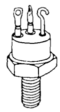
LOW VOLTAGE

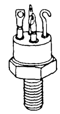
Maximum Collector Current		10 AMP		
Package Style		**TO-5**		**TO-3**
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\ (SUS)}$	70V	2N4150**		
	75V			
	80V		2N5552	
	90V			
	100V			
	120V			2N6354
h_{FE} Minimum		50 @ 5A	50 @ 5A	10 @ 10A
V_{CE} (sat) Max.		0.6V @ 5A	0.5V @ 5A	1.0V @ 10A
t_f Maximum		0.5μs	0.45μs	0.2μs

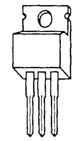
HIGH VOLTAGE

Maximum Collector Current		5 AMP							8AMP		
Package Style		**TO-5**		**TO-66**			**TO-3**		**TO-220AB**	**TO-3**	
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\ (SUS)}$	150V					UPT721					
	200V	2N5666*		2N5664*		UPT722					
	250V					UPT723				2N6306	
	275V										
	300V		2N5667*		2N5665*	UPT724 UPT725	2N6542		UMT13006	2N6307	
	350V							UMT1006			2N6308
	400V						2N6543	UMT1007	UMT13007		
	450V										
h_{FE} Minimum		40 @ 1A	25 @ 1A	40 @ 1A	25 @ 1A	25 @ 1A	7 @ 3A	7 @ 3A	6 @ 5A	15 @ 3A	12 @ 3A
V_{CE} (sat) Max.				0.4V @ 3A		1V @ 3A	1.0V @ 3A	1.0V @ 3A	1.5V @ 5A	0.8V @ 3A	1.5V @ 3A
t_f Maximum		0.8μs	1.0μs	0.8μs	1.0μs	0.5μs (typical)	0.8μs	0.4μs	0.7μs	0.4μs	

*Available as JAN, JANTX, JANTXV.


TO-59


TO-111


TO-220AB

IV

LOW VOLTAGE

Maximum Collector Current		10 AMP		15 AMP	20 AMP		30 AMP
Package Style		**TO-59**	**TO-111**	**TO-3**	**TO-3**		**TO-3**
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO\ (SUS)}$	70V						
	75V					2N5039*	
	80V	2N5658	2N5659				
	90V				2N5038*		2N5671
	100V			2N6496			
	120V						2N5672
h_{FE} Minimum		50 @ 5A		12 @ 8A	20 @ 12A	20 @ 10A	20 @ 15A
V_{CE} (sat) Max.		0.5V @ 5A		1.0V @ 8A	1.2V @ 12A	1.0V @ 10A	0.75V @ 15A
t_f Maximum		0.5μs		0.5μs	0.5μs	0.5μs	0.5μs

*Available as JAN, JANTX, JANTXV.

GH VOLTAGE

8 AMP	10 AMP				12 AMP	15 AMP				30 AMP
TO-3	**TO-3**				**TO-220AB**	**TO-3**				**TO-3**
	2N6249									
			2N6250							
UMT1008 2N6544		2N6674			UMT13008		2N6546		2N6676	
				2N6251		UMT1011			2N6677	
UMT1009 2N6545		2N6675			UMT13009	UMT1012	2N6547		2N6678	UMT2003
								UMT2000		
7 @ 5A	10 @ 10A	8 @ 10A	8 @ 10A	6 @ 10A	6 @ 8A	6 @ 10A	6 @ 10A	7 @ 15A	8 @ 15A	5 @ 20A
1.5V @ 5A	1.5V @ 10A	1.0V @ 10A	1.5V @ 10A	1.5V @ 10A	1.5V @ 8A	1.0V @ 10A	1.5V @ 10A	3.0V @ 10A	1.0 @ 15A	1.5 @ 20A
0.9μs 2N6544, 5) 0.4μs JMT1008,9)	1.0μs	0.5μs	1.0μs	1.0μs	0.7μs	0.4μs	0.7μs	0.15μs	0.5μs	0.8μs

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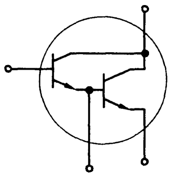
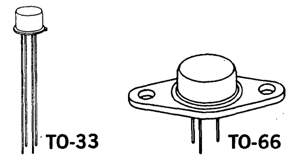


External bias types — for fast switching or other special purpose applications

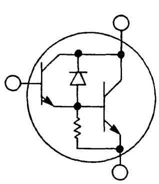


TO-33 TO-66 (3-Pin)

NPN Power Darlingtons

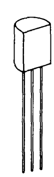
Maximum Collector Current		2A				5A			
Package Style		**TO-33**		**TO-66 (3-Pin)**		**TO-33**		**TO-66 (3-Pin)**	
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO(sus)}$	60V	U2T301		U2T401					
	80V					2N6350* U2T101		2N6352* U2T201	
	150V		U2T305		U2T405		2N6351* U2T105		2N6353* U2T205
h_{FE} Minimum		1000 @ 2A		1000 @ 2A		2000 @ 5A	1000 @ 5A	2000 @ 5A	1000 @ 5A
V_{CE}(sat) Maximum		1.5V @ 2A	2.5V @ 2A	1.5V @ 2A	2.5V @ 2A	1.5V @ 5A	2.5V @ 5A	1.5V @ 5A	2.5V @ 5A
t_f Typical		0.3μs				0.5μs			

*Available as JAN and JANTX types.



Plastic Package types with integral bias resistance and shunt diode for maximum economy in standard applications

Plastic NPN Power Darlingtons



TO-92

Maximum Collector Current		5A (PEAK)
Package Style		**TO-92**
COLLECTOR-EMITTER SUSTAINING VOLTAGE $V_{CEO(sus)}$	60V	U2TA506
	80V	U2TA508
	100V	U2TA510
h_{FE} Minimum		500 @ 3A
V_{CE}(sat) Maximum		1.5V @ 3A
t_f Typical		0.8μs

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POWER TRANSISTORS
2 Amp, 80V, Planar NPN

JAN & JANTX 2N2151

IV

FEATURES
- Meets MIL-S-19500/277
- Collector-Base Voltage: up to 150V
- D.C. Collector Current: 2A
- Beta Guaranteed at 3 Current Levels
- Characterized for Safe Operating Area

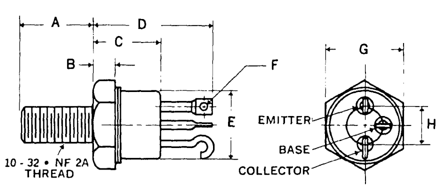
DESCRIPTION
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO}	150V
Collector-Emitter Voltage, V_{CEO}	100V
Emitter-Base Voltage, V_{EBO}	8V
D.C. Collector Current, I_C	2A
Base Current, I_B	2A
Power Dissipation	
100°C Case	30W
Operating Temperature Range	—55°C to 175°C
Storage Temperature Range	—65°C to 200°C

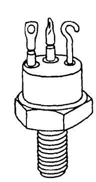
MECHANICAL SPECIFICATIONS

JAN & JANTX2N2151



	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	.055 ± .010/.015	1.40 ± .254/.381
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

TO-59



UNITRODE

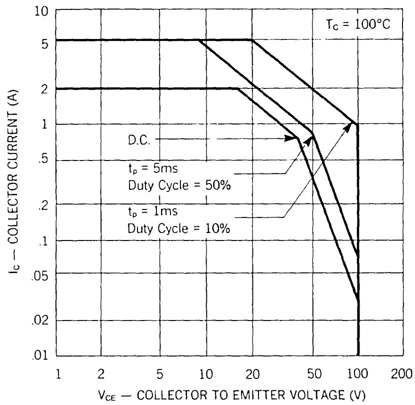
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Max.	Units	/277C Sub-group	Method	MIL-STD-750 Test Conditions
25°C							
Collector-Base Breakdown Voltage	BV_{CBO}	150	—	Vdc	A-2	3001	$I_C = 100uAdc$, Cond. D
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}	100	—	Vdc	A-2	3011	$I_C = 50mAdc$, Cond. D
Collector-Emitter Cutoff Current	I_{CES}	—	5	uAdc	A-2	3041	$V_{CE} = 120Vdc$, $V_{BE} = 0$, Cond. C
Collector-Emitter Cutoff Current	I_{CEX}	—	5	uAdc	A-2	3041	$V_{CE} = 120Vdc$, $V_{EB} = 1Vdc$, Cond. A
Collector-Emitter Cutoff Current	I_{CEO}	—	10	uAdc	A-2	3041	$V_{CE} = 80Vdc$, Cond. D
Collector-Base Cutoff Current	I_{CBO}	—	5	uAdc	A-2	3036	$V_{CB} = 120Vdc$, Cond. D
Emitter-Base Cutoff Current	I_{EBO}	—	2	uAdc	A-2	3061	$V_{EB} = 8Vdc$, Cond. D
D.C. Current Gain (Note 1)	h_{FE}	40	120	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	40	120	—	A-3	3076	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	40	—	—	A-3	3076	$I_C = 0.1Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	0.1	1.0	Vdc	A-3	3071	$I_C = 1Adc$, $I_B = 0.1Adc$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.2	Vdc	A-3	3066	$I_C = 1Adc$, $I_B = 0.1Adc$, Cond. A
Base-Emitter Voltage (Note 1)	V_{BE}	—	1.2	Vdc	A-3	3066	$I_C = 1Adc$, $V_{CE} = 5Vdc$, Cond. B
A.C. Current Gain	h_{fe}	40	160	—	A-5	3206	$I_C = 0.1Adc$, $V_{CE} = 30Vdc$, $f = 1kHz$
Gain-Bandwidth Product	f_T	10	70	MHz	A-5	3306	$I_C = 0.1Adc$, $V_{CE} = 30Vdc$, $f = 10MHz$
Output Capacitance	C_{ob}	—	160	pf	A-5	3236	$V_{CB} = 20Vdc$, $I_E = 0$, $f = 1MH_Z$
Thermal Resistance	Θ_{J-C}	—	2.5	°C/W	C-1	3151	
100°C							
Forward-Biased Second Breakdown	$I_{S/B}$	2	—	Adc	B-9	—	$V_{CE} = 15Vdc$, $t = 60$ sec, see curve
Forward-Biased Second Breakdown	$I_{S/B}$	200	—	mAdc	B-9	—	$V_{CE} = 57Vdc$, $t = 60$ sec, see curve
Forward-Biased Second Breakdown	$I_{S/B}$	25	—	mAdc	B-9	—	$V_{CE} = 100Vdc$, $t = 60$ sec, see curve
Unclamped Inductive Sweep	$E_{S/B}$	20	—	mj	B-5	—	$I_C = 2Adc$, $L = 10mh$
Clamped Inductive Sweep	$E_{S/B}$	80	—	mj	B-6	—	$I_C = 2Adc$, $L = 40mh$, $V_{clamp} = 150V$
150°C							
Collector-Emitter Cutoff Current	I_{CES}	—	100	uAdc	A-4	3041	$V_{CE} = 120Vdc$, $V_{BE} = 0$, Cond. C
Collector-Emitter Cutoff Current	I_{CEX}	—	100	uAdc	A-4	3041	$V_{CE} = 120Vdc$, $V_{EB} = 1Vdc$
Emitter-Base Cutoff Current	I_{EBO}	—	20	uAdc	A-4	3061	$V_{EB} = 8Vdc$, Cond. D
—55°C							
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	A-4	3076	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$

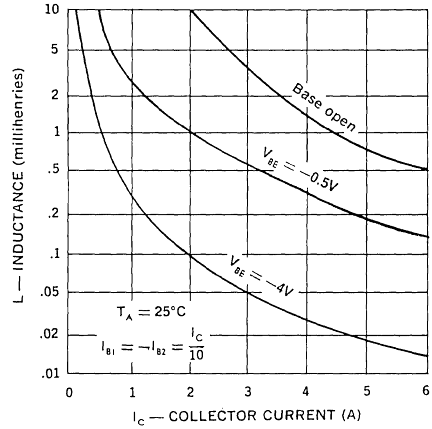
Note: 1. Pulse width = 300μs; duty cycle $\leq$ 2%.

IV

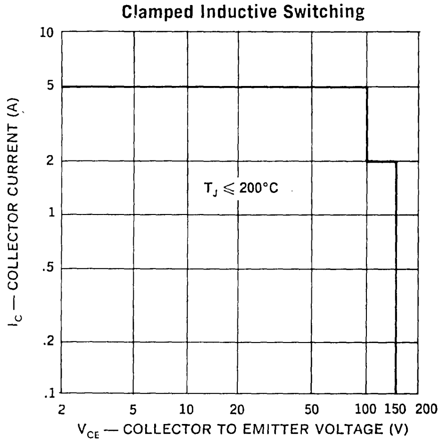
Forward Bias Safe Operating Area



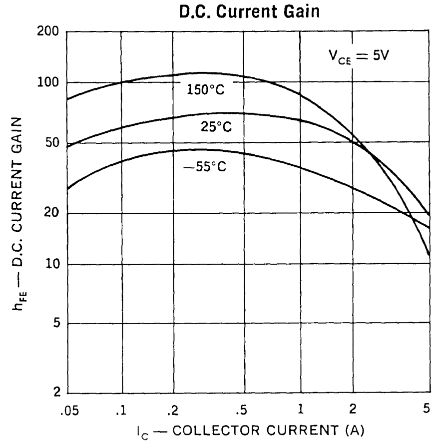
Unclamped Reverse Bias Second Breakdown



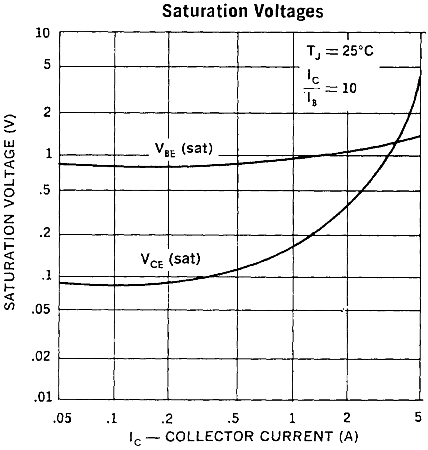
Reverse Bias Safe Operating Area Clamped Inductive Switching



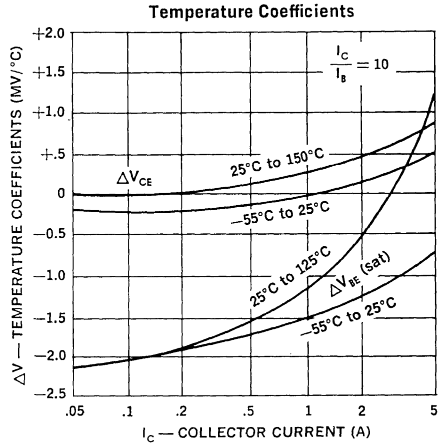
D.C. Current Gain



Saturation Voltages



Saturation Voltage Temperature Coefficients



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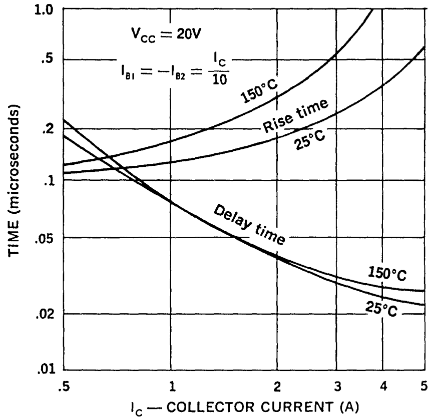
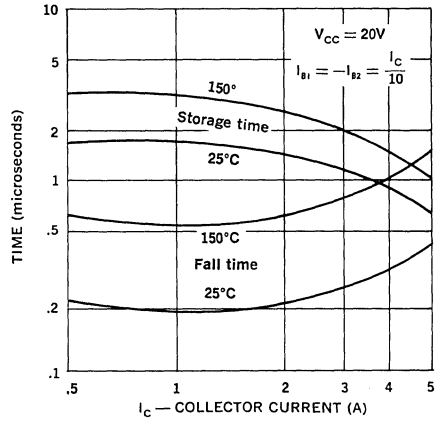
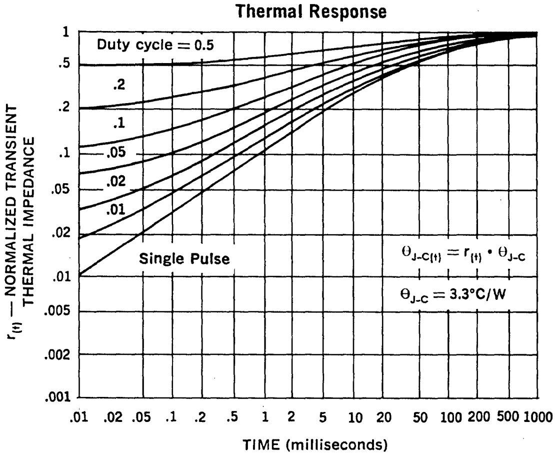
Switching Speed Characteristics



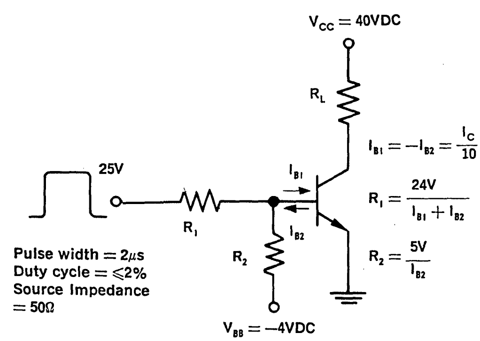
Switching Speed Characteristics



Thermal Response



Switching Speed Circuit



POWER TRANSISTORS

5 Amp, 80V, Planar, NPN

JAN, JANTX, & JANTXV 2N2880
JAN, JANTX, & JANTXV 2N3749

FEATURES

- Meets MIL-S-19500/315
- Collector-Base Voltage: 110V
- Fast Switching: t_r, t_f = 300nSec max
- Low Saturation Voltage: 0.25V max @ 1A

DESCRIPTION

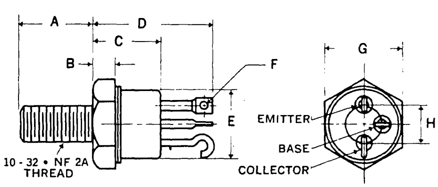
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply, pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO} 110V
Collector-Emitter Voltage, V_{CEO} 80V
Emitter-Base Voltage, V_{EBO} 8V
D.C. Collector Current, I_C 5A
Power Dissipation
25°C Ambient 2W
100°C Case 30W
Operating and Storage Temperature Range .... −65°C to +200°C

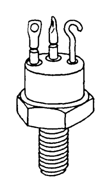
MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 2N2880

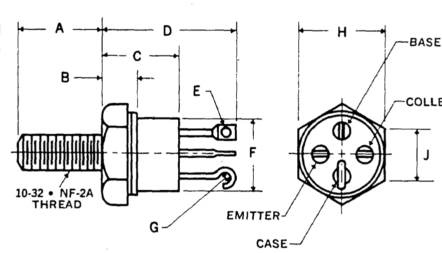


	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	.055 ± .010/.015	1.40 ± .254/.381
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

TO-59

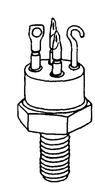


JAN, JANTX, & JANTXV 2N3749



	INCHES	MILLIMETERS
A	.400 - .455	10.16 - 11.55
B	.090 - .250	2.28 - 6.35
C	.320 - .468	8.13 - 11.88
D	.570 - .763	14.48 - 19.38
E	.065 - .090	1.65 - 2.28
F	.313 - .318	7.95 - 8.07
G	.070 - .090	1.77 - 2.28
H	.423 - .438	10.74 - 11.12
J	.135 - .215	3.43 - 5.46

TO-111



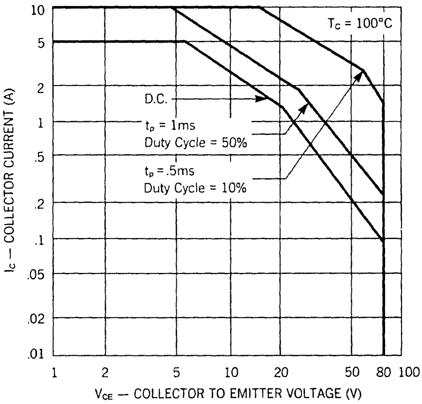
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

TEST	SYMBOL	MIN.	MAX.	UNITS	/315 Sub group	MIL - STD - 750 METHOD	MIL - STD - 750 TEST CONDITIONS
Visual and Mechanical	—	—	—		A-1	2071	See Mechanical Data
Collector-Base Voltage	BV_{CBO}	110	—	Vdc	A-2	3001	$I_C = 10\mu Adc$, Cond. D
Collector-Emitter Voltage (1.)	BV_{CEO}	80	—	Vdc	A-2	3011	$I_C = 0.1Adc$, Cond. D
Emitter-Base Voltage	BV_{EBO}	8	—	Vdc	A-2	3026	$I_E = 10\mu Adc$, Cond. D
Collector-Emitter Cutoff Current	I_{CEO}	—	100	μAdc	A-2	3041	$V_{CE} = 60Vdc$, Cond. D
Collector-Emitter Cutoff Current	I_{CEX}	—	10	μAdc	A-2	3041	$V_{CE} = 110Vdc$, $V_{EB} = 0.5Vdc$, Cond. A
Collector-Base Cutoff Current	I_{CBO}	—	0.4	μAdc	A-2	3036	$V_{CB} = 80Vdc$, Cond. D
Emitter-Base Cutoff Current	I_{EBO}	—	0.4	μAdc	A-2	3061	$V_{EB} = 6Vdc$, Cond. D
D.C. Current Gain (1.)	h_{FE}	40	—	—	A-3	3076	$I_C = 50mAdc$, $V_{CE} = 5Vdc$
D.C. Current Gain (1.)	h_{FE}	40	120	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (1.)	h_{FE}	15	—	—	A-3	3076	$I_C = 5Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (1.)	$V_{CE(sat)}$	—	0.25	Vdc	A-3	3071	$I_C = 1Adc$, $I_B = 0.1Adc$
Collector Saturation Voltage (1.)	$V_{CE(sat)}$	—	1.5	Vdc	A-3	3071	$I_C = 5Adc$, $I_B = 0.5Adc$
Base Saturation Voltage (1.)	$V_{BE(sat)}$	—	1.2	Vdc	A-3	3066	$I_C = 1Adc$, $I_B = 0.1Adc$
Base On-Voltage (1.)	$V_{BE(on)}$	—	1.2	Vdc	A-3	3066	$I_C = 1Adc$, $V_{CE} = 2Vdc$
A.C. Current Gain	h_{FE}	40	120	—	A-4	3206	$I_C = 50mAdc$, $V_{CE} = 5Vdc$, f = 1KHz
Gain-Bandwidth Product	f_T	20	120	MHz	A-4	3306	$I_C = 1Adc$, $V_{CE} = 10Vdc$, f = 10MHz
Output Capacitance	C_{ob}	—	150	pf	A-4	3236	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
Switching Parameters							
Delay Time	t_d	—	60	ns	A-4	—	See Switching Speed Circuit
Rise Time	t_r	—	300	ns	A-4	—	See Switching Speed Circuit
Storage Time	t_s	—	1.7	μs	A-4	—	See Switching Speed Circuit
Fall Time	t_f	—	300	ns	A-4	—	See Switching Speed Circuit
Thermal Resistance	θ_{JC}	—	3.33	°C/W	C-1	3151	
100°C							
Forward-Biased Second Breakdown	$I_{S/B}$	5	—	Adc	B-5	3051	$V_{CE} = 6Vdc$, t = 60Sec, $T_C = 100°C$
Forward-Biased Second Breakdown	$I_{S/B}$	80	—	mAdc	B-5	3051	$V_{CE} = 80Vdc$, t = 60Sec, $T_C = 100°C$
Clamped Reverse-Biased Second Breakdown	$E_{S/B}$	12.5	—	mj	B-7	—	$I_C = 5A$, L = 1mH, $V_{Clamp} = 110V$, $T_C = 100°C$
Unclamped Revers -Biased Second Breakdown	$E_{S/B}$	12.5	—	mj	B-6	3053	$I_C = 5A$, L = 1mH Base Open
Unclamped Reverse-Biased Second Breakdown	$E_{S/B}$	12.8	—	mj	B-6	3053	$I_C = 1.6A$, L = 10mH Base Open
150°C							
Collector-Emitter Cutoff Current	I_{CEX}	—	50	μA	A-5	3041	$V_{CE} = 80Vdc$, $V_{EB} = 0.5Vdc$ Cond. A, $T_A = 150°C$
−65°C							
D.C. Current Gain (1.)	h_{FE}	15	—	—	A-5	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$ $T_A = -65°C$

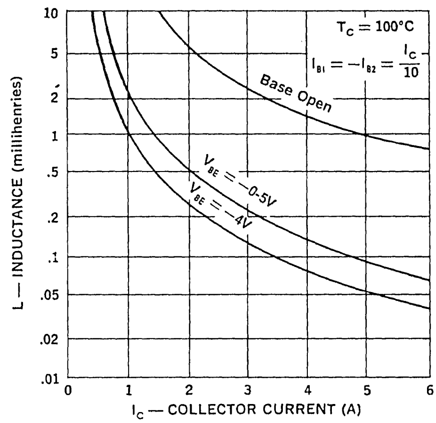
Note 1. Pulse Width = 300μSec, duty cycle ⩽ 2%

IV

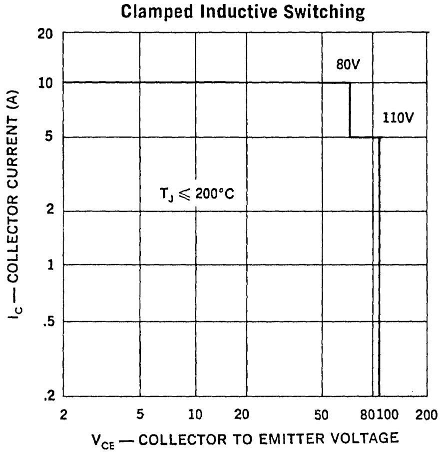
Forward Bias Safe Operating Area



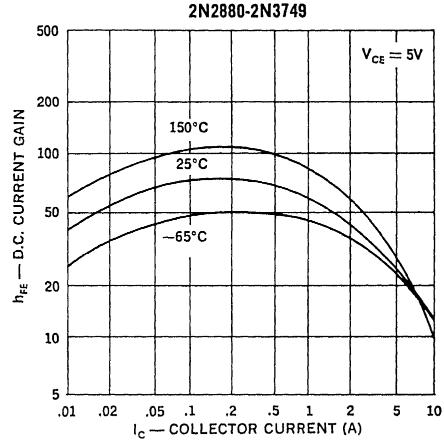
Unclamped Reverse Bias Second Breakdown



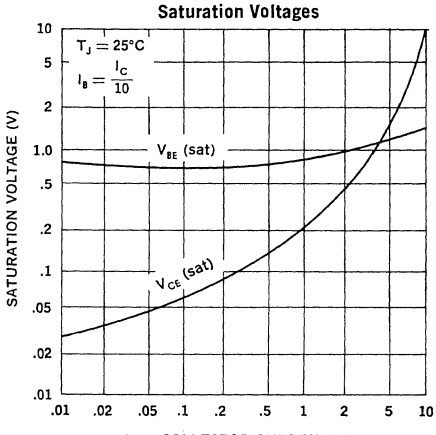
Reverse Bias Safe Operating Area Clamped Inductive Switching



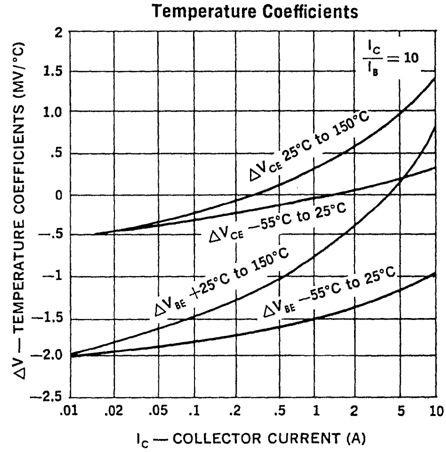
D.C. Current Gain 2N2880-2N3749



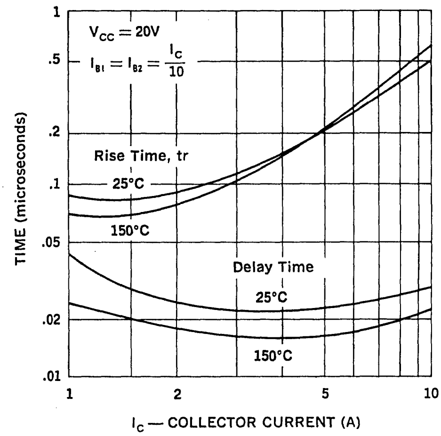
Saturation Voltages



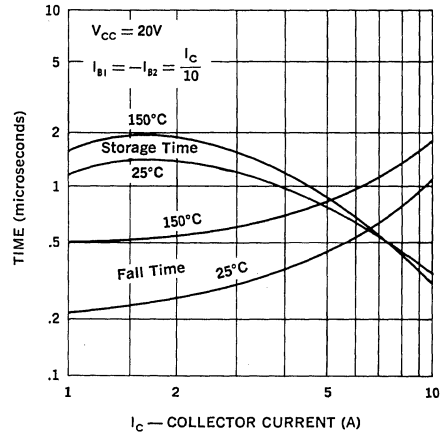
Saturation Voltage Temperature Coefficients



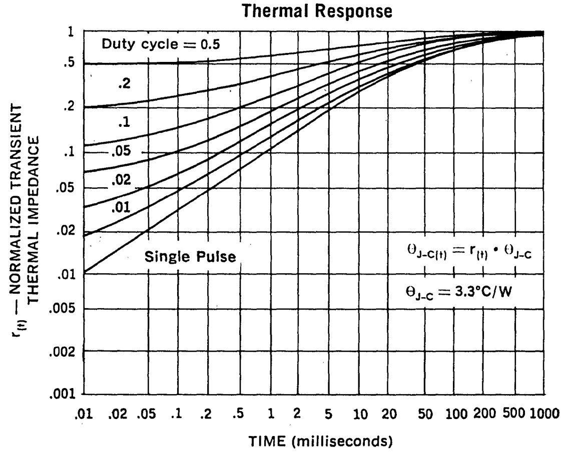
Switching Speed Characteristics



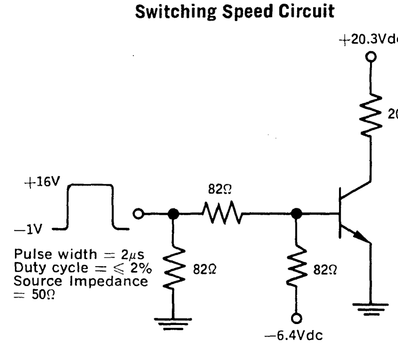
Switching Speed Characteristics



Thermal Response



Switching Speed Circuit



NOTES:

1. $I_C \approx 1A$, $I_{B1} \approx -I_{B2} \approx 100mA$
2. The values of collector current and base current are nominal. The actual values will vary slightly with transistor parameters.

POWER TRANSISTORS

3 Amp, 80V, Planar NPN

JAN, JANTX, & JANTXV 2N3418
JAN, JANTX, & JANTXV 2N3419
JAN, JANTX, & JANTXV 2N3420
JAN, JANTX, & JANTXV 2N3421

FEATURES

- Meets MIL-S-19500/393
- Collector-Base Voltage: up to 125V
- Peak Collector Current: 5A
- High Power Dissipation in TO-5: 15W @ $T_C = 100°C$
- Fast Switching

DESCRIPTION

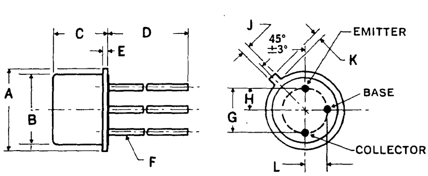
Unitrode power transistors provide a unique combination of low saturation voltage, high gain, and fast switching. They are ideally suited for power supply, pulse amplifier and similar high frequency power switching applications.

ABSOLUTE MAXIMUM RATINGS

	JAN, JANTX, & JANTXV 2N3418 2N3420	JAN, JANTX, & JANTXV 2N3419 2N3421
Collector-Base Voltage, V_{CBO}	85V	125V
Collector-Emitter Voltage, V_{CEO}	60V	80V
Emitter-Base Voltage, V_{EBO}	8V	8V
D.C. Collector Current, I_C	3A	3A
Peak Collector Current, I_C	5A	5A
Power Dissipation		
25°C Ambient	1.0W	1.0W
100°C Case	15W	15W
Operating and Storage Temperature Range	−65°C to +200°C	

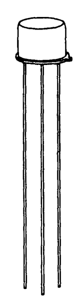
MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 2N3418-2N3421



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



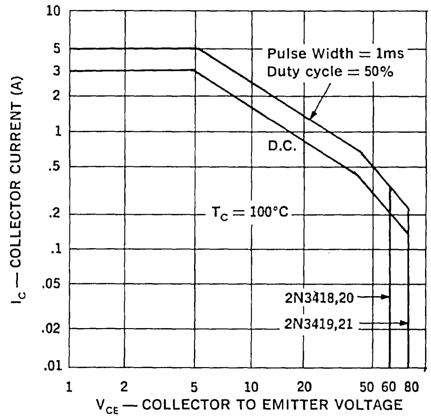
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

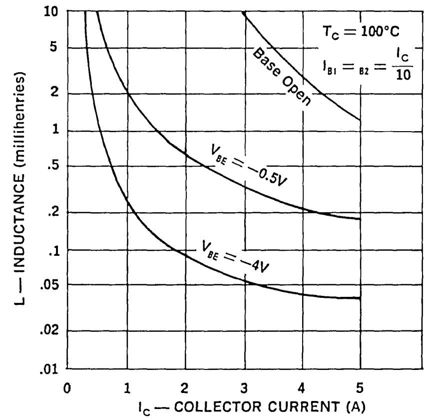
TEST	SYMBOL	MIN.	MAX.	UNITS	/393 Sub-group	MIL-STD-750 METHOD	MIL-STD-750 TEST CONDITIONS
Visual and Mechanical	—	—	—	—	A-1	2071	See Mechanical Data
Collector-Emitter Breakdown Voltage (1.)	BV_{CEO}				A-2	3011	$I_C = 50mAdc$, Cond. D
2N3418, 2N3420		60	—	Vdc			
2N3419, 2N3421		80	—	Vdc			
Collector-Emitter Cutoff Current	I_{CEX}				A-2	3041	$V_{EB} = 0.5Vdc$, Cond. A
2N3418, 2N3420		—	0.5	μAdc			$V_{CE} = 80Vdc$
2N3419, 2N3421		—	0.5	μAdc			$V_{CE} = 120Vdc$
Collector-Emitter Cutoff Current	I_{CEO}				A-2	3041	Cond. D
2N3418, 2N3420		—	5.0	μAdc			$V_{CE} = 45Vdc$
2N3419, 2N3421		—	5.0	μAdc			$V_{CE} = 60Vdc$
Emitter-Base Cutoff Current	I_{EBO}	—	0.5	μAdc	A-2	3061	$V_{EB} = 6Vdc$, Cond. D
Emitter-Base Cutoff Current	I_{EBO}	—	10	μAdc	A-2	3061	$V_{EB} = 8Vdc$, Cond. D
D.C. Current Gain (1.)	h_{FE}				A-3	3076	$I_C = 100mAdc, V_{CE} = 2Vdc$
2N3418, 2N3419		20	—	—			
2N3420, 2N3421		40	—	—			
D.C. Current Gain (1.)	h_{FE}				A-3	3076	$I_C = 1Adc, V_{CE} = 2Vdc$
2N3418, 2N3419		20	60	—			
2N3420, 2N3421		40	120	—			
D.C. Current Gain (1.)	h_{FE}				A-3	3076	$I_C = 2Adc, V_{CE} = 2Vdc$
2N3418, 2N3419		15	—	—			
2N3420, 2N3421		30	—	—			
D.C. Current Gain (1.)	h_{FE}				A-3	3076	$I_C = 5Adc, V_{CE} = 5Vdc$
2N3418, 2N3419		10	—	—			
2N3420, 2N3421		15	—	—			
Collector-Emitter Saturation Voltage (1.)	$V_{CE(sat)}$	—	0.25	Vdc	A-3	3071	$I_C = 1Adc, I_B = 0.1Adc$
Collector-Emitter Saturation Voltage (1.)	$V_{CE(sat)}$	—	0.5	Vdc	A-3	3071	$I_C = 2Adc, I_B = 0.2Adc$
Base-Emitter Saturation Voltage (1.)	$V_{BE(sat)}$	0.6	1.2	Vdc	A-3	3066	$I_C = 1Adc, I_B = 0.1Adc$
Base-Emitter Saturation Voltage (1.)	$V_{BE(sat)}$	0.7	1.4	Vdc	A-3	3066	$I_C = 2Adc, I_B = 0.2Adc$
Gain Bandwidth Product	f_T	40	160	MHz	A-4	3306	$I_C = 0.1Adc, V_{CE} = 10Vdc, f = 20MHz$
Output Capacitance	C_{ob}	—	150	pf	A-4	3236	$V_{CB} = 10Vdc, I_E = 0, f = 1MHz$
Switching Parameters							
Turn-on Time	t_{on}	—	0.3	μS	A-4	—	$I_C = 1Adc, I_{B1} = -I_{B2} = 0.1Adc$
Turn-off Time	t_{off}	—	1.2	μS	A-4	—	See Switching Speed Circuit
100°C							
Forward Biased Second Breakdown	$I_{S/b}$	3	—	Adc	B-6	3005	$V_{CE} = 5Vdc, t = 60sec, T_C = 100°C$
Forward Biased Second Breakdown	$I_{S/b}$	1	—	Adc	B-6	3005	$V_{CE} = 15Vdc, t = 60sec, T_C = 100°C$
Forward Biased Second Breakdown	$I_{S/b}$	0.4	—	Adc	B-6	3005	$V_{CE} = 37Vdc, t = 60sec, T_C = 100°C$
Forward Biased Second Breakdown	$I_{S/b}$				B-6	3005	$t = 60sec, T_C = 100°C$
2N3418, 2N3420		185	—	mAdc			$V_{CE} = 60Vdc$
2N3419, 2N3421		120	—	mAdc			$V_{CE} = 80Vdc$
Unclamped Reverse Biased Second Breakdown	$E_{S/b}$	45	—	mj	B-7	—	$I_C = 3Adc, L = 10mH$, Base Open
Clamped Reverse Biased Second Breakdown	$E_{S/b}$	180	—	mj	B-8	—	$I_C = 3Adc, L = 40mH$, V clamp = Rated V_{CBO}
150°C							
Collector-Emitter Cutoff Current	I_{CEX}				A-5	3041	$V_{EB} = 0.5Vdc$, Cond. A, $T_A = 150°C$
2N3418, 2N3420		—	50	μAdc			$V_{CE} = 80Vdc$,
2N3419, 2N3421		—	50	μAdc			$V_{CE} = 120Vdc$,
—55°C							
D.C. Current Gain (1.)	h_{FE}	10	—	—	A-5	3076	$I_C = 1Adc, V_{CE} = 2Vdc, T_A = -55°C$

Note: 1. Pulse width = 300μSec, duty cycle ⩽ 2%.

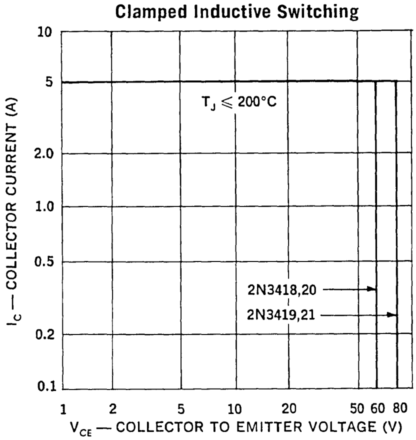
Forward Bias Safe Operating Area



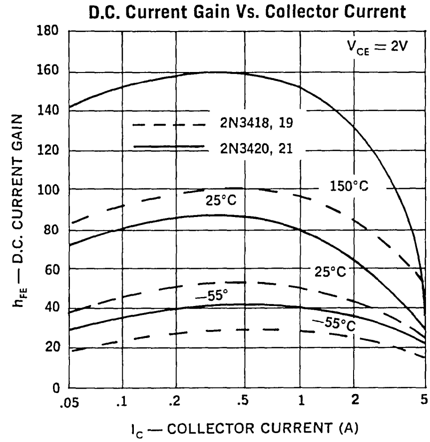
Unclamped Reverse Bias Second Breakdown



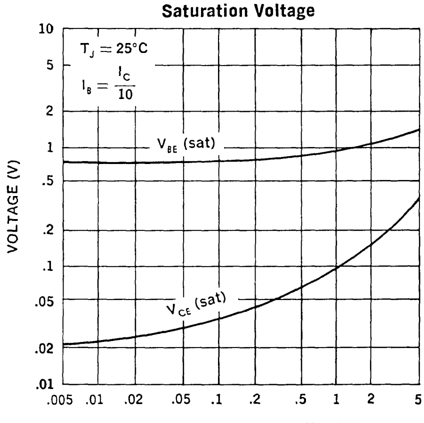
Reverse Bias Safe Operating Area Clamped Inductive Switching



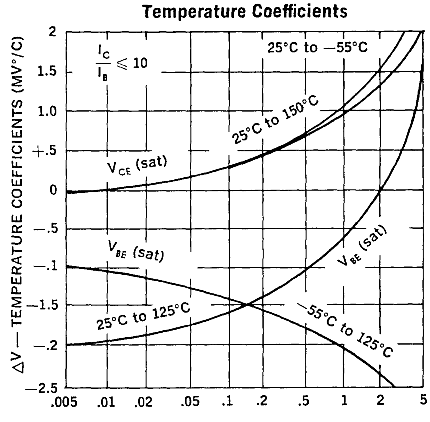
D.C. Current Gain Vs. Collector Current



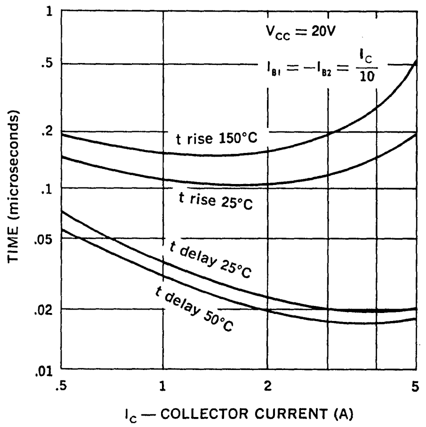
Saturation Voltage



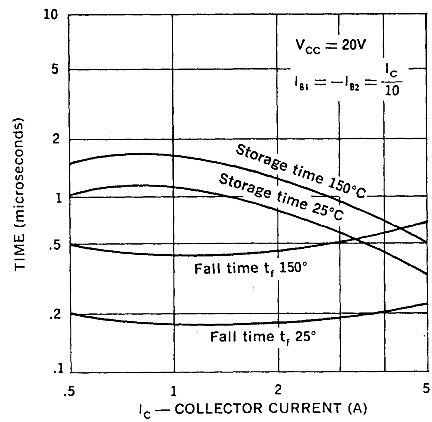
Saturation Voltage Temperature Coefficients



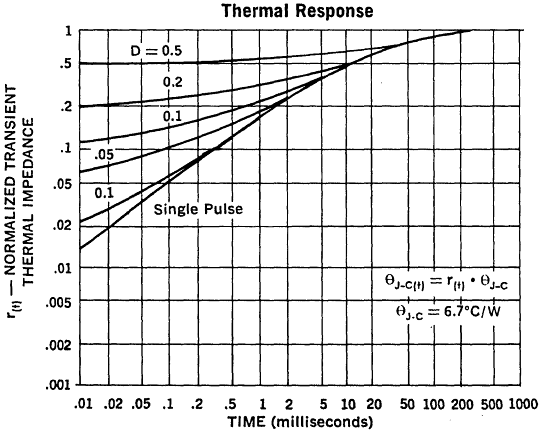
Switching Speed Characteristics



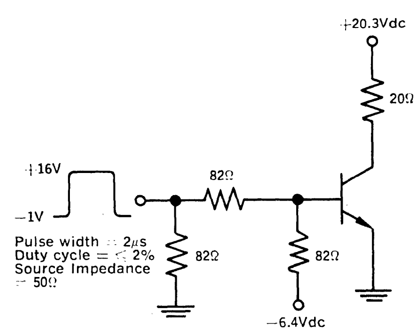
Switching Speed Characteristics



Thermal Response



Switching Speed Circuit



UNITRODE CORPORATION • 5 FORBES ROAD
LEXINGTON, MA 02173 • TEL. (617) 861-6540
TWX (710) 326-6509 • TELEX 95-1064

POWER TRANSISTORS
5 Amp, 80V, Planar NPN

JAN, JANTX, & JANTXV 2N3996
JAN, JANTX, & JANTXV 2N3997
JAN, JANTX, & JANTXV 2N3998
JAN, JANTX, & JANTXV 2N3999

IV

FEATURES
- Meets MIL-S-19500/374*
- Collector-Base Voltage: Up to 100V
- D.C. Collector Current: 5A
- Fast Switching
- Beta Guaranteed at 3 Current Levels

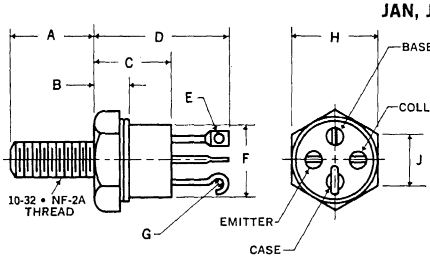
DESCRIPTION
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO} 100V
Collector-Emitter Voltage, V_{CER} 80V
Emitter-Base Voltage, V_{EBO} 8V
D.C. Collector Current, I_C 5A
Peak Collector Current, I_C 10A
Power Dissipation
25°C Ambient 2W
100°C Case 30W
Operating and Storage Temperature Range .... —65°C to 200°C

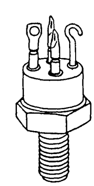
MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 2N3996, 2N3997

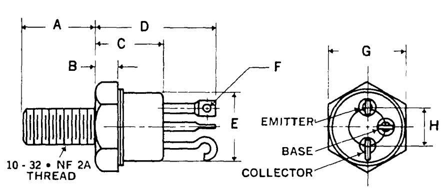


	INCHES	MILLIMETERS
A	.400 - .455	10.16 - 11.55
B	.090 - .250	2.28 - 6.35
C	.320 - .468	8.13 - 11.88
D	.570 - .763	14.48 - 19.38
E	.065 - .090	1.65 - 2.28
F	.313 - .318	7.95 - 8.07
G	.070 - .090	1.77 - 2.28
H	.423 - .438	10.74 - 11.12
J	.135 - .215	3.43 - 5.46

TO-111

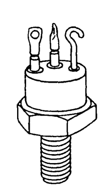


JAN, JANTX, & JANTXV 2N3998, 2N3999



	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	$.055 \pm ^{.010}_{.015}$	$1.40 \pm ^{.254}_{.381}$
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

TO-59



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

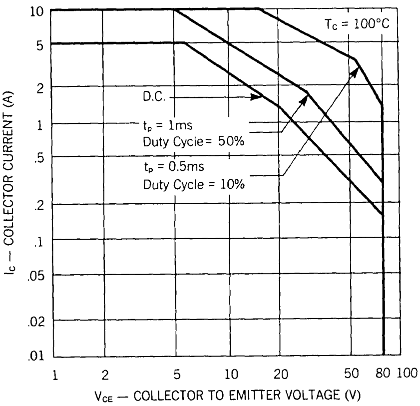
Test	Symbol	2N3996* 2N3998* Min.	Max.	2N3997* 2N3999* Min.	Max.	Units	Test Conditions
D.C. Current Gain	h_{FE}	30	—	60	—	—	I_C=50 mA, V_{CE}=2V
D.C. Current Gain (Note 1)	h_{FE}	40	120	80	240	—	I_C=1A, V_{CE}=2V
D.C. Current Gain (Note 1)	h_{FE}	15	—	20	—	—	I_C=5A, V_{CE}=5V
D.C. Current Gain, —55°C (Note 1)	h_{FE}	10	—	20	—	—	I_C=1A, V_{CE}=2V
Collector Saturation Voltage (Note 1)	V_{CF} (sat)	—	0.25	—	0.25	V	I_C=1A, I_B=100 mA
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	2	—	2	V	I_C=5A, I_B=500 mA
Base Saturation Voltage (Note 1)	V_{BE} (sat)	0.6	1.2	0.6	1.2	V	I_C=1A, I_B=100 mA
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.6	—	1.6	V	I_C=5A, I_B=500 mA
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}	80	—	80	—	V	I_C=50 mA, I_B=0
Emitter-Base Cutoff Current	I_{EBO}	—	0.2	—	0.2	μA	V_{BE}=5V, I_C=0
Emitter-Base Cutoff Current	I_{EBO}	—	10	—	10	μA	V_{BE}=8V, I_C=0
Collector Cutoff Current	I_{CES}	—	5	—	5	μA	V_{CE}=90V, R_{BE}=0
Collector Cutoff Current	I_{CEO}	—	10	—	10	μA	V_{CE}=60V, I_B=0
Collector Cutoff Current, 150°C	I_{CES}	—	50	—	50	μA	V_{CE}=90, R_{BE}=0
Collector Capacitance	C_{ob}	—	150	—	150	pf	V_{CB}=10V, I_E=0, f=1 MHz
A.C. Current Gain (High Frequency)	h_{fe}	4	—	4	—	—	I_C=1A, V_{CE}=5V, f=10 MHz
Switching Speeds Turn-on Time	t_{on}	—	0.3	—	0.3	μs	I_C=1A
Switching Speeds Turn-off Time	t_{off}	—	1.5	—	2	μs	I_{b1}=100mA, I_{b2}= —100 mA

Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
† All values in this table are JEDEC registered.

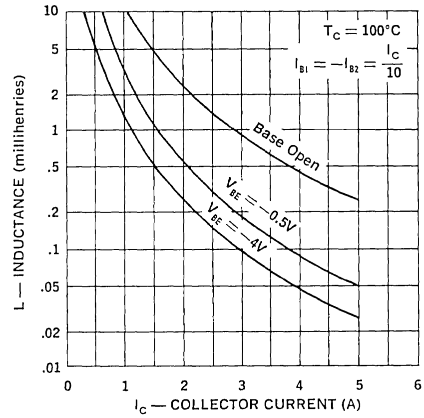
*Also applicable to JAN and JANTX versions

IV

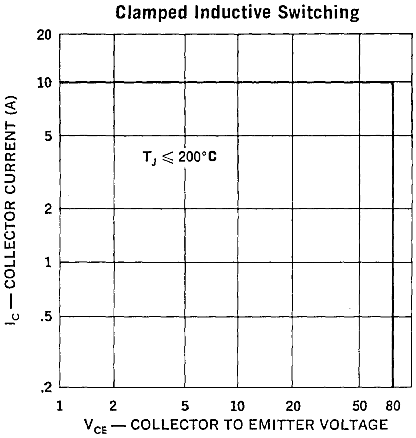
Forward Bias
Safe Operating Area



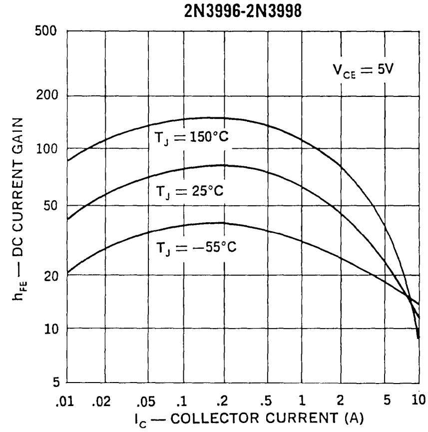
Unclamped Reverse Bias
Second Breakdown



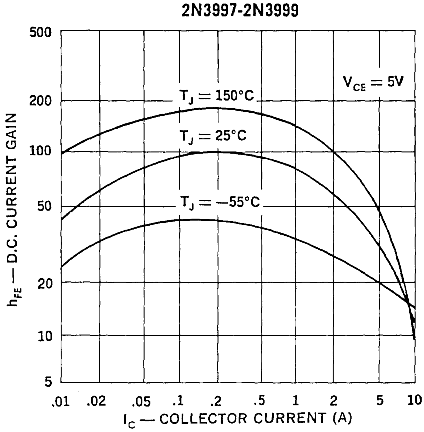
Reverse Bias
Safe Operating Area
Clamped Inductive Switching



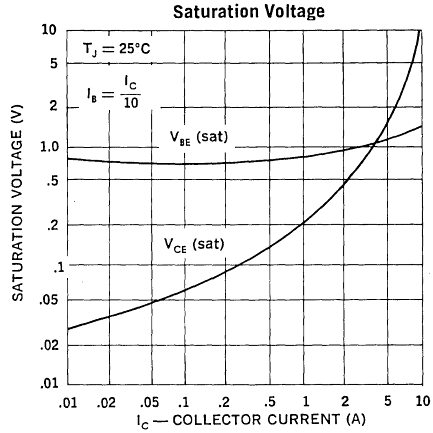
D.C. Current Gain
2N3996-2N3998



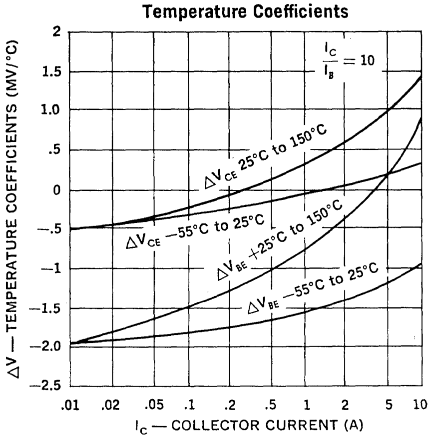
D.C. Current Gain
2N3997-2N3999



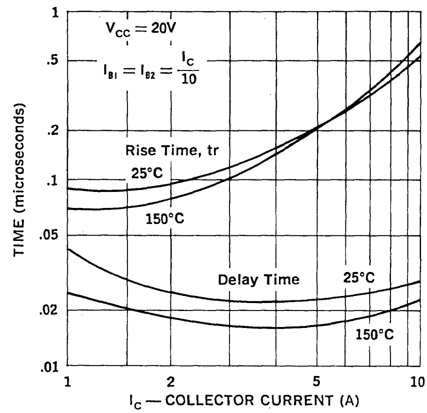
Saturation Voltage



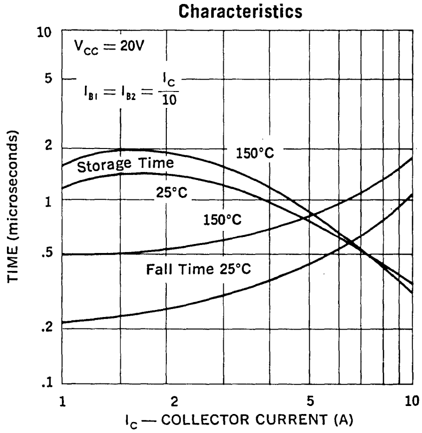
Saturation Voltage Temperature Coefficients



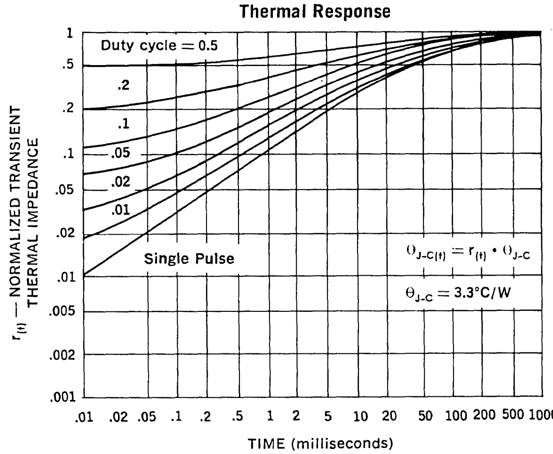
Switching Speed Characteristics



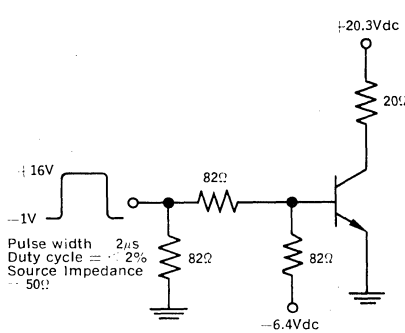
Switching Speed Characteristics



Thermal Response



Switching Speed Circuit



NOTES:

1. $I_C \approx 1A$, $I_{B1} \approx -I_{B2} \approx 100mA$
2. The values of collector current and base current are nominal. The actual values will vary slightly with transistor parameters.

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POWER TRANSISTORS
10 Amp, 70V, Planar NPN

JAN, JANTX & JANTXV 2N4150

FEATURES
- Meets MIL-S-19500/394
- Collector-Base Voltage: up to 100V
- Peak Collector Current: 10A
- Fast Switching
- Low Saturation Voltage

DESCRIPTION
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

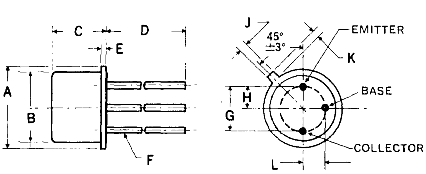
IV

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO}	100V
Collector-Emitter Voltage, V_{CEO}	70V
Emitter-Base Voltage, V_{EBO}	7V
Peak Collector Current, I_C	10A
Power Dissipation	
25°C Ambient	1.5W
100°C Case	5W
Operating and Storage Temperature Range	—65°C to 200°C

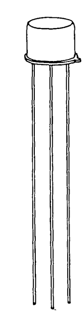
MECHANICAL SPECIFICATIONS

JAN, JANTX & JANTXV 2N4150



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



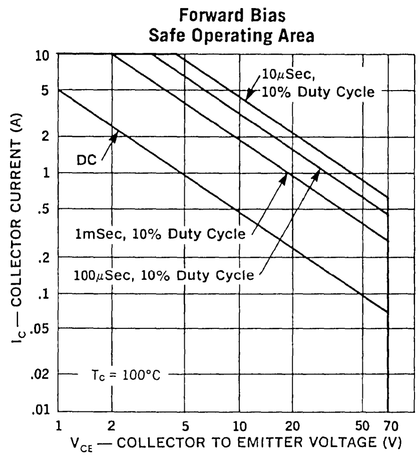
UNITRODE

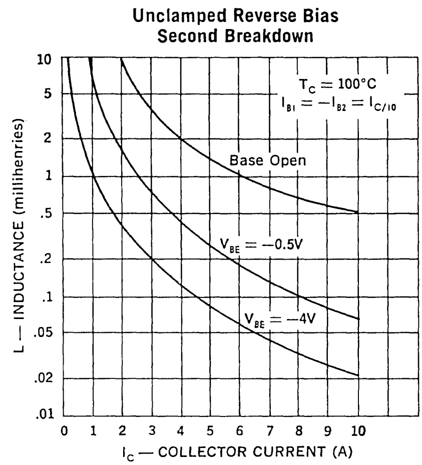
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

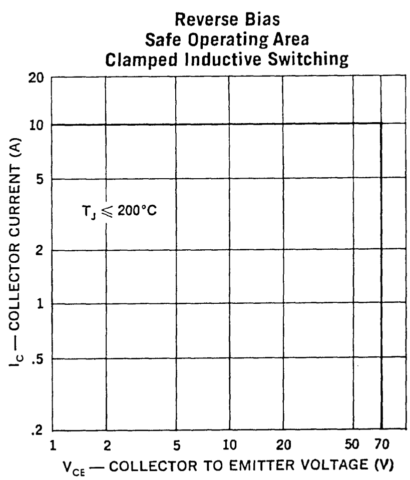
Test	Symbol	Min.	Max.	Units	/394 Sub group	Method	MIL-STD-750 Test conditions
Visual and Mechanical					A-1	2071	See Mechanical Data
25°C							
Collector-Base Breakdown Voltage	BV_{CBO}	100	—	Vdc	A-2	3001	$I_C = 10uAdc$; Cond. D
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}	70	—	Vdc	A-2	3011	$I_C = 0.1Adc$; Cond. D
Emitter-Base Breakdown Voltage	BV_{EBO}	7	—	Vdc	A-2	3026	$I_E = 10uAdc$; Cond. D
Collector-Emitter Cutoff Current	I_{CEO}	—	10	μAdc	A-2	3041	$V_{CE} = 60Vdc$; Cond. D
Collector-Emitter Cutoff Current	I_{CEX}	—	10	μAdc	A-2	3041	$V_{CE} = 100Vdc$, $V_{EB} = 0.5Vdc$; Cond. A
Collector-Base Cutoff Current	I_{CBO}	—	0.1	μAdc	A-2	3036	$V_{CB} = 80Vdc$; Cond. D
Emitter-Base Cutoff Current	I_{EBO}	—	0.1	μAdc	A-2	3061	$V_{EB} = 5Vdc$; Cond. D
D.C. Current Gain (Note 1)	h_{FE}	40	120	—	A-3	3076	$I_C = 5Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	A-3	3076	$I_C = 10Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	50	—	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	0.6	Vdc	A-4	3071	$I_C = 5Adc$, $I_B = 0.5Adc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	2.5	Vdc	A-4	3071	$I_C = 10Adc$, $I_B = 1Adc$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	A-4	3066	$I_C = 5Adc$, $I_B = 0.5Adc$; Cond. A
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	2.5	Vdc	A-4	3066	$I_C = 10Adc$, $I_B = 1Adc$; Cond. A
A.C. Current Gain	h_{fe}	40	160	—	A-4	3206	$I_C = 50mAdc$, $V_{CE} = 5Vdc$, f = 1KHz
Gain-Bandwidth Product	f_T	15	75	MHz	A-4	3306	$I_C = 0.2Adc$, $V_{CE} = 10Vdc$, f = 10 MHz
Output Capacitance	C_{ob}	—	350	pf	A-4	3236	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
Thermal Resistance	θ_{J-C}	—	20	°C/W	C-1	3151	
Switching Speeds: Delay Time	t_d	—	50	ns	A-4	—	$V_{CC} = 20V$, $I_C = 5A$, $I_{B1} = I_{B2}$, $I_{B1} = 0.5A$
Switching Speeds: Rise Time	t_r	—	500	ns	A-4	—	
Switching Speeds: Storage Time	t_s	—	1.5	μs	A-4	—	
Switching Speeds: Fall Time	t_f	—	500	ns	A-4	—	
100°C							
Forward-Biased Second Breakdown	$I_{S/B}$	5	—	Adc	B-6	3005	$V_{CE} = 1Vdc$, t = 60Sec,
Forward-Biased Second Breakdown	$I_{S/B}$	70	—	mAdc	B-6	3005	$V_{CE} = 1Vdc$, t = 60Sec,
Unclamped Reverse Biased Second Breakdown	$E_{S/B}$	12.5	—	mj	B-7	—	$I_C = 5Adc$, L = 1mh
Clamped Reverse Biased Second Breakdown	$E_{S/B}$	200	—	mj	B-8	—	$I_C = 5Adc$, L = 40mh, $V_{clamp} = 70V$
150°C							
Collector-Emitter Cutoff Current	I_{CEX}	—	100	μAdc	A-5	3041	$V_{CE} = 80Vdc$, $V_{EB} = 0.5Vdc$, Cond. A
—55°C							
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	A-5	3076	$I_C = 5Adc$, $V_{CE} = 5Vdc$

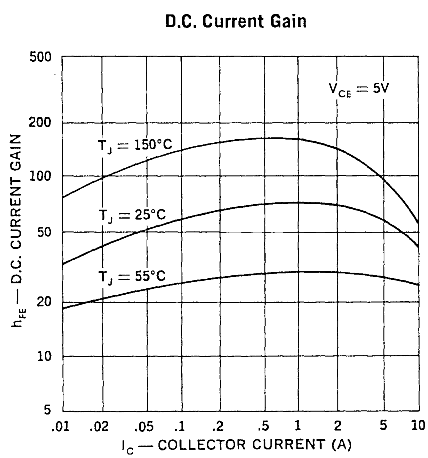
Note:
1. Pulse width = 300μS; duty cycle ≤2%.

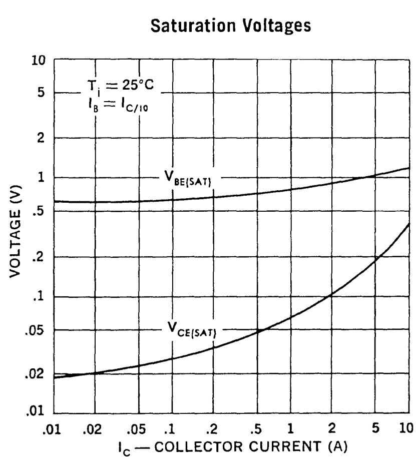
IV

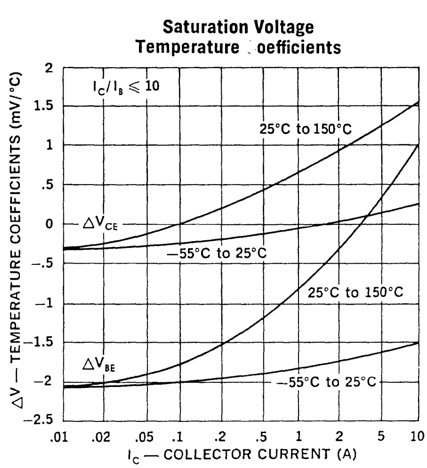

Forward Bias
Safe Operating Area
10μSec, 10% Duty Cycle
DC
1mSec, 10% Duty Cycle
100μSec, 10% Duty Cycle
Tc = 100°C
IC — COLLECTOR CURRENT (A)
VCE — COLLECTOR TO EMITTER VOLTAGE (V)


Unclamped Reverse Bias
Second Breakdown
TC = 100°C
IB1 = −IB2 = IC/10
Base Open
VBE = −0.5V
VBE = −4V
L — INDUCTANCE (millihenries)
IC — COLLECTOR CURRENT (A)

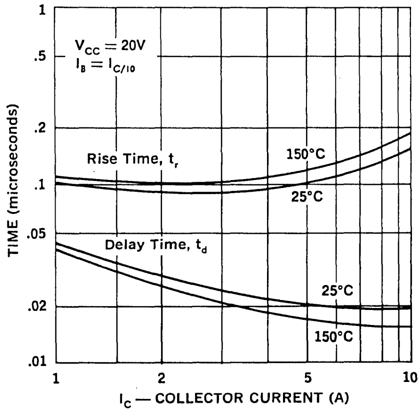

Reverse Bias
Safe Operating Area
Clamped Inductive Switching
TJ ≤ 200°C
IC — COLLECTOR CURRENT (A)
VCE — COLLECTOR TO EMITTER VOLTAGE (V)


D.C. Current Gain
VCE = 5V
TJ = 150°C
TJ = 25°C
TJ = 55°C
hFE — D.C. CURRENT GAIN
IC — COLLECTOR CURRENT (A)

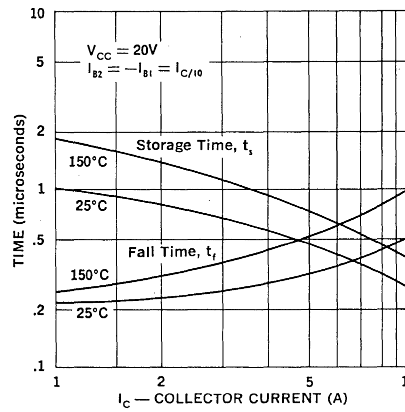

Saturation Voltages
Tj = 25°C
IB = IC/10
VBE(SAT)
VCE(SAT)
VOLTAGE (V)
IC — COLLECTOR CURRENT (A)


Saturation Voltage
Temperature Coefficients
IC/IB ≤ 10
25°C to 150°C
ΔVCE
−55°C to 25°C
25°C to 150°C
ΔVBE
−55°C to 25°C
ΔV — TEMPERATURE COEFFICIENTS (mV/°C)
IC — COLLECTOR CURRENT (A)

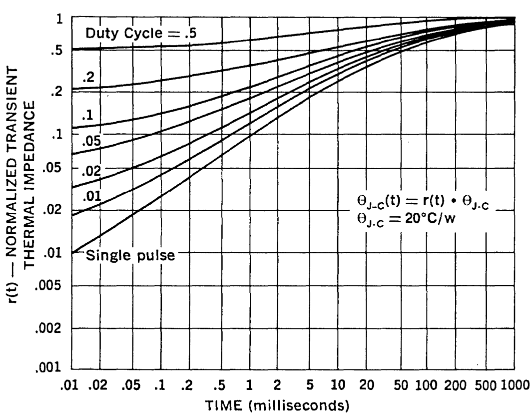
Switching Speed Characteristics



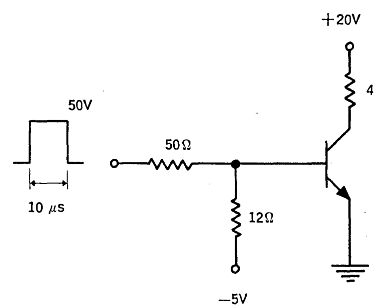
Switching Speed Characteristics



Thermal Response



Switching Speed Circuit



$I_C = 5A$, $I_{B1} = -I_{B2} = .5A$

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POWER TRANSISTORS

20 Amp, 150V, Double Diffused NPN Mesa

JAN, JANTX, JANTXV 2N5038
JAN, JANTX, JANTXV 2N5039

IV

FEATURES

- Collector-Base Voltage: up to 150V
- Peak Collector Current: 30A
- t_{on} Time ≤500 nS
- t_{off} Time ≤2 μS
- Qualified to MIL-S-19500/439

DESCRIPTION

These MIL approved double diffused glass passivated mesa power transistors combine fast-switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in switching regulators, converters, inverters and switching-control amplifiers.

ABSOLUTE MAXIMUM RATINGS

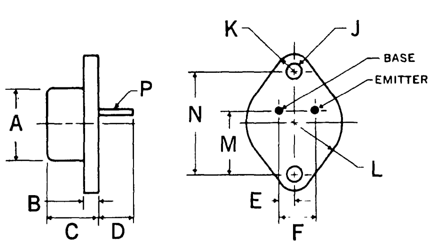
	JAN, JANTX & JANTXV 2N5038	JAN, JANTX & JANTXV 2N5039
Collector-Base Voltage, V_{CBO}	150V	125V
Collector-Emitter Sustaining Voltage, $V_{CER(SUS)}$ (1)	110V	95V
$V_{CEO(SUS)}$	90V	75V
Emitter-Base Voltage, V_{EBO}	7V	7V
Collector Current, I_C continuous	20A	20A
Collector Current, I_{CM} peak	30A	30A
Base Current, I_B continuous	5A	5A
Power Dissipation, 25°C Case	140W	140W
Operating and Storage Temperature Range	–65 to 200°C	

(1) With $R_{BE} \leqslant 50\Omega$

MECHANICAL SPECIFICATIONS

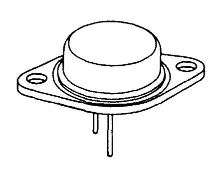
JAN, JANTX, JANTXV 2N5038, 2N5039

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm
A	.875 MAX.	2.22 MAX.
B	.135 MAX.	0.34 MAX.
C	.250—.450	0.64—1.14
D	.312 MIN.	0.79 MIN.
E	.205—.225	0.52—0.57
F	.420—.440	1.07—1.12
J	.151—.161 DIA.	0.38—0.41
K	.188 MAX. RAD.	0.48 MAX. RAD.
L	.525 MAX. RAD.	1.33 MAX. RAD.
M	.655—.675	1.66—1.71
N	1.177—1.197	2.99—3.04
P	.038—.043 DIA.	0.10—0.11 DIA.

TO-3



UNITRODE

Electrical Specifications (at 25°C unless noted)

Test	Symbol	2N5038 MIN.	2N5038 MAX.	2N5039 MIN.	2N5039 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	50	—	30	—	—	$I_C = 0.5$, $V_{CE} = 5V$
		50	200	30	150		$I_C = 2A$, $V_{CE} = 5V$
D.C. Current Gain (Note 1)	h_{FE}	—	—	20	—	—	$I_C = 10A$, $V_{CE} = 5V$
		20	—	—	—		$I_C = 12A$, $V_{CE} = 5V$
D.C. Current Gain −65°C	h_{FE}	—	—	10	—	—	$I_C = 10A$, $V_{CE} = 5V$
		10	—	—	—		$I_C = 12A$, $V_{CE} = 5V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	—	—	1.0	V	$I_C = 10A$, $I_B = 1.0A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	—	V	$I_C = 12A$, $I_B = 1.2A$
		—	2.5	—	2.5		$I_C = 20A$, $I_B = 5A$
Base-Emitter Voltage (Note 1)	V_{BE}	—	—	—	1.8	V	$I_C = 10A$, $V_{CE} = 5V$
		—	1.8	—	—	V	$I_C = 12A$, $V_{CE} = 5V$
Collector-Emitter Sustaining Voltage (Notes 2, 3)	$V_{CEO(sus)}$	90	—	75	—	V	$I_C = 0.2A$, $L = 15mH$
Collector-Emitter Sustaining Voltage (Notes 2, 3)	$V_{CEX(sus)}$	150	—	125	—	V	$I_C = 0.2A$, $L = 2mH$ $V_{BE} = -1.5V$ $I_B = 0$ $R_{BE} = 100\,\Omega$
Collector-Emitter Sustaining Voltage (Notes 2, 3)	$V_{CER(sus)}$	110	—	95	—	V	$R_{BE} = 50\,\Omega$, $I_C = 0.2A$, $L = 15mH$
Emitter-Base Voltage	V_{EBO}	7.0	—	7.0	—	V	$I_E = 25mA$
Collector Cutoff Current	I_{CBO}	—	—	—	25	mA	$V_{CB} = 125V$
		—	25	—	—		$V_{CB} = 150V$
Collector Cutoff Current	I_{CEO}	—	—	—	10	mA	$V_{CE} = 55V$
		—	10	—	—		$V_{CE} = 70V$
Collector Cutoff Current	I_{CEX}	—	—	—	5.0	mA	$V_{CE} = 85V$, $V_{BE} = -1.5V$
		—	5.0	—	—		$V_{CE} = 100V$, $V_{BE} = -1.5V$
Collector Cutoff Current, 150°C	I_{CEX}	—	—	—	10	mA	$V_{CE} = 85V$, $V_{BE} = -1.5V$
		—	10	—	—		$V_{CE} = 100V$, $V_{BE} = -1.5V$
Emitter Cutoff Current	I_{EBO}	—	5.0	—	5.0	mA	$V_{BE} = -5V$
Magnitude of Small Signal Forward — Current Transfer Ratio	$\lvert h_{fe} \rvert$	12	48	12	48	—	$V_{CE} = 10V$, $I_C = 2A$, $f = 5\,MHz$
Collector Capacitance	C_{ob}	—	500	—	500	pF	$V_{CB} = 10V$, $f = 1\,MHz$
Thermal Resistance: Junction-to-Case	$R\Theta_{JC}$	—	1.25	—	1.25	°C/W	$V_{CE} = 10V$, $I_C = 10A$

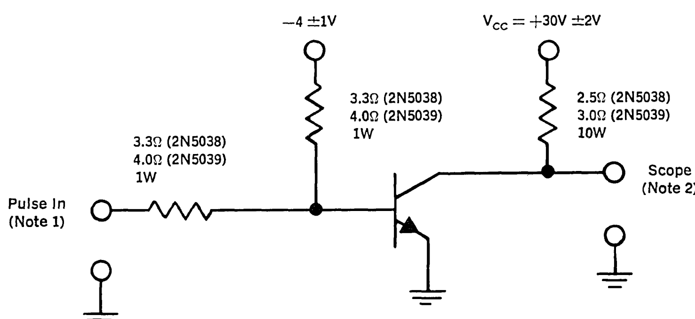
Notes:
1. Pulse width = 250μS; duty cycle $\leq$1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length $\cong$ 50μS; duty cycle $\leq$ 1%. Voltage clamped at maximum collector-emitter voltage.
3. Unclamped inductive load.

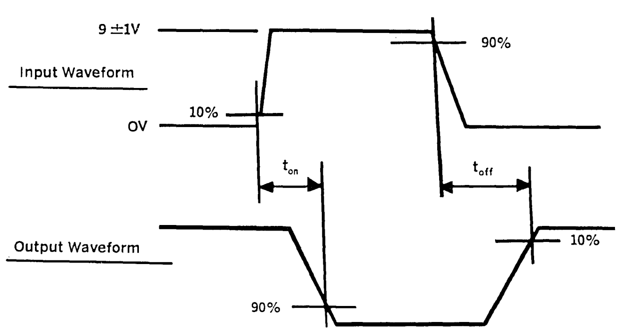
IV

Electrical Specifications (at 25°C unless noted)

Test	Symbol	2N5038 MIN.	2N5038 MAX.	2N5039 MIN.	2N5039 MAX.	Units	Test Conditions
Second Breakdown Energy	$E_{s/b}$ clamped	14	—	14	—	mJ	$I_C = 20Adc$, $L = 70\mu H$, 0.1Ω; $V_{CC} = 75V, 90V$; $R_L = 3.75\Omega, 4.5\Omega$
	$E_{s/b}$ unclamped	5.06	—	5.06	—		$I_C = 4.5Adc$, $L = 500\mu H$, 0.1Ω; $V_{CC} = 10Vdc$
Forward Bias Second Breakdown Collector Current	$I_{s/b}$	5.0	—	5.0	—	A	$V_{CE} = 28V$, $t = 1s$, non-rep.
		0.9	—	0.9	—		$V_{CE} = 45V$, $t = 1s$, non-rep.
Switching Speeds Turn-on Time	t_{on}	—	0.5	—	—	μS	$I_C = 12Adc$; $I_{B1} = I_{B2} = 1.2Adc$; $V_{CC} = 30Vdc \pm 2V$
Turn-on Time	t_{on}	—	—	—	0.5	μS	$I_C = 10Adc$; $I_{B1} = I_{B2} = 1Adc$; $V_{CC} = 30Vdc \pm 2V$
Turn-off Time	t_{off}	—	—	—	2.0	μS	$I_C = 10Adc$; $I_{B1} = I_{B2} = 1.0Adc$; $V_{CC} = 30Vdc \pm 2V$
Turn-off Time	t_{off}	—	2.0	—	—	μS	$I_C = 12Adc$; $I_{B1} = I_{B2} = 1.2Adc$; $V_{CC} = 30Vdc \pm 2V$

Switching Time Test Circuit





Notes

1. The rise time (t_r) and fall time (t_f) of the applied pulse shall be each ⩽20 nanoseconds; duty cycle ⩽2%; generator source impedance shall be 50 ohms; Pulse width = 20 μS
2. Output sampling oscilloscope: Z_{in} ⩾100K ohms; C_{in} ⩽50pf; rise time ⩽20 nanoseconds.

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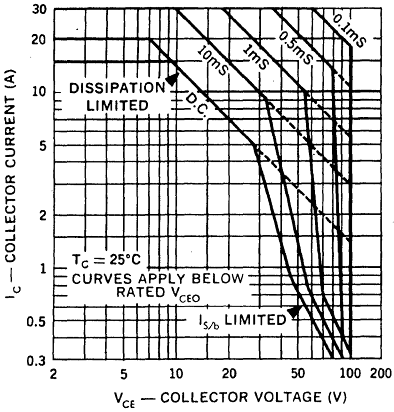
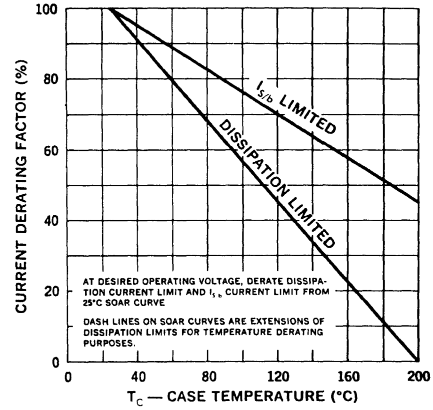
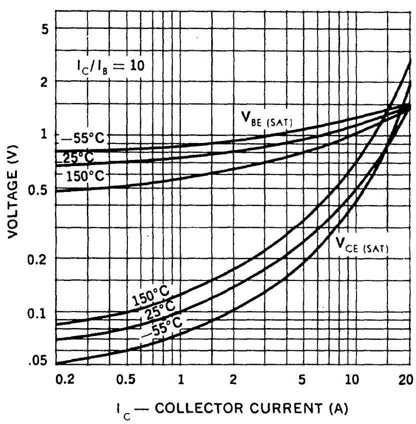
Forward Bias Safe Operating Area for 2N5038 and 2N5039



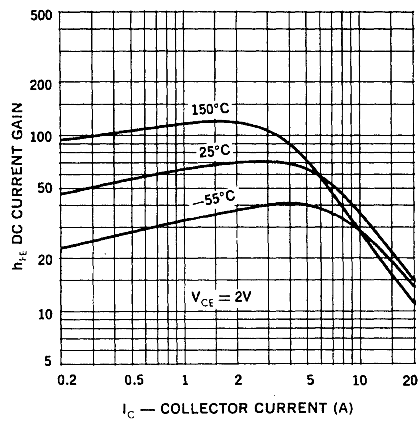
Power Derating



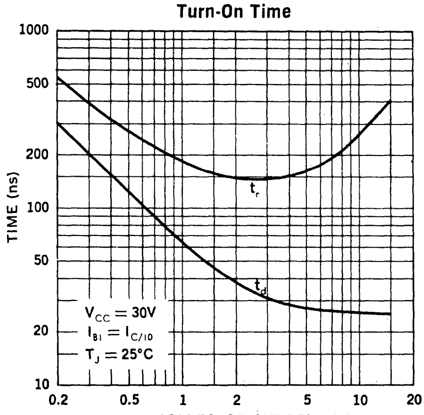
Saturation Voltages



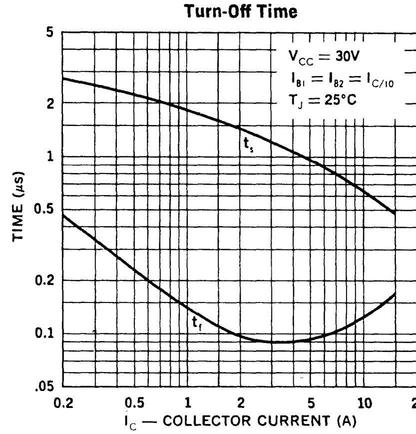
DC Current Gain



Turn-On Time



Turn-Off Time



POWER TRANSISTORS

10 Amp, 120V, Planar NPN

FEATURES

- Collector-Base Voltage: up to 120V
- Peak Collector Current: 10A
- Fast Switching
- Beta Guaranteed at 3 Current Levels

DESCRIPTION

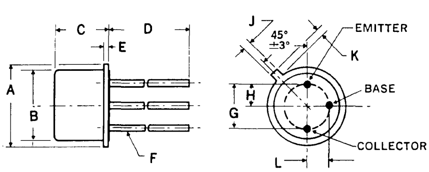
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO}	120V
Collector-Emitter Voltage, V_{CEO}	80V
Emitter-Base Voltage, V_{EBO}	7V
D.C. Collector Current, I_C	10A
Power Dissipation	
25°C Ambient	1.25W
100°C Case	5W
Operating and Storage Temperature Range	—65°C to 200°C

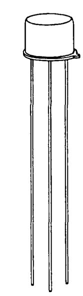
MECHANICAL SPECIFICATIONS

2N5552

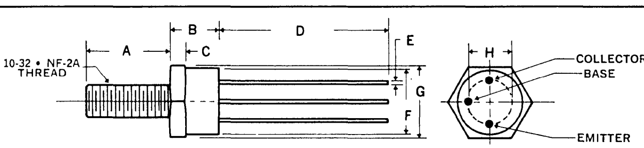


	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5

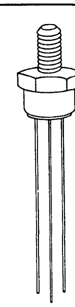


5552-4



	INCHES	MILLIMETERS
A	.340 - .360	8.63 - 9.14
B	.315 - .335	8.00 - 8.51
C	.095 - .115	2.41 - 2.92
D	1.5 MIN.	38.10 MIN.
E	.017 ± .001	.432 ± .0254
F	.337 - .387	9.57 - 9.83
G	.424 - .437	10.77 - 11.10
H	.200	5.08

TO-5 (Stud)



UNITRODE

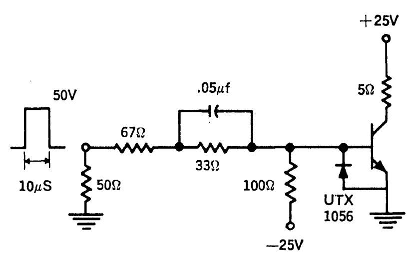
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Test		Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain		h_{FE}	40	250	—	$I_C = 0.5A$, $V_{CE} = 2V$
D.C. Current Gain (Note 2)		h_{FE}	50	150	—	$I_C = 5A$, $V_{CE} = 5V$
D.C. Current Gain (Note 2)		h_{FE}	30	—	—	$I_C = 10A$, $V_{CE} = 5V$
Collector Saturation Voltage (Note 2)		V_{CE} (sat)	—	0.5	V	$I_C = 5A$, $I_B = 0.5A$
Collector Saturation Voltage (Note 2)		V_{CE} (sat)	—	1.0	V	$I_C = 10A$, $I_B = 1A$
Base Saturation Voltage (Note 2)		V_{BE} (sat)	—	1.3	V	$I_C = 5A$, $I_B = 0.5A$
Base Saturation Voltage (Note 2)		V_{BE} (sat)	—	1.8	V	$I_C = 10A$, $I_B = 1A$
Collector-Emitter Sustaining Voltage (Note 2)		BV_{CER}	120	—	V	$I_C = 100mA$, $R_{BE} = 10\Omega$
Collector-Emitter Sustaining Voltage (Note 2)		V_{CEO} (sus)	80	—	V	$I_C = 100mA$, $I_B = 0$
Collector-Emitter Voltage (Note 2)		BV_{CES}	120	—	V	$I_C = 0.2\mu A$, $R_{BE} = 0$
Emitter-Base Breakdown Voltage		BV_{EBO}	7	—	V	$I_E = 10\mu A$, $I_C = 0$
Collector Cutoff Current		I_{CES}	—	0.2	μA	$V_{CE} = 120V$, $R_{BE} = 0$
Collector Cutoff Current, 150°C		I_{CES}	—	0.1	mA	$V_{CE} = 80$, $R_{BE} = 0$, $T = 150°C$
Collector Capacitance		C_{obo}	—	150	pf	$V_{CB} = 10$, $I_E = 0$, $f = 1MHz$
A.C. Current Gain		h_{fe}	3	—	—	$I_C = 0.5A$, $V_{CE} = 5V$ $f = 10MHz$
Switching Speeds	Turn-on Time	t_{on}	—	100	ns	$I_C = 5A$
	Turn-off Time	t_{off}	—	700	ns	$I_{b1} = 250ma$ $I_{b2} = -250ma$

Notes:
1. The device may be switched between maximum rated collector current and maximum rated collector-emitter voltage along a resistive load line provided the switching time is less than 10 microseconds. Switching at low speed through regions of high instantaneous power dissipation may cause second breakdown to occur, with consequent damage to the device.
2. Pulse width = 300μs; duty cycle ≤2%.

† All values in this table are JEDEC registered.

Switching Speed Circuit



POWER TRANSISTORS
20 Amp, 80V, Planar NPN

2N5658
2N5659

IV

FEATURES
- Collector-Base Voltage: up to 120V
- Peak Collector Current: 20A
- High Gain
- Fast Switching

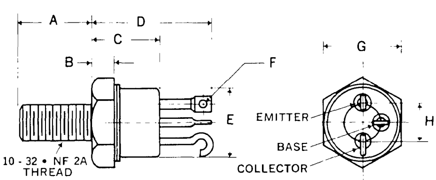
DESCRIPTION
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

Collector-Base Voltage, V_{CBO}	120V
Collector-Emitter Voltage, V_{CEO}	80V
Emitter-Base Voltage, V_{EBO}	7V
Peak Collector Current, I_C	20A
Power Dissipation	
100°C Case	30W
Operating and Storage Temperature Range	—65°C to 200°C

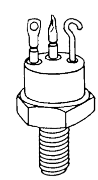
MECHANICAL SPECIFICATIONS

2N5658

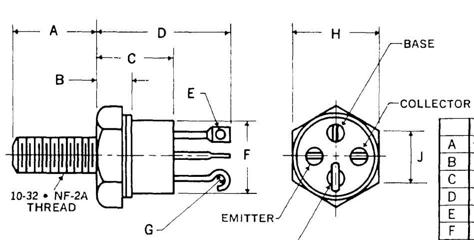


	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	.055 ± .010 / .015	1.40 ± .254 / .381
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

TO-59



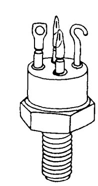
2N5659



	INCHES	MILLIMETERS
A	.400 - .455	10.16 - 11.55
B	.090 - .250	2.28 - 6.35
C	.320 - .468	8.13 - 11.88
D	.570 - .763	14.48 - 19.38
E	.065 - .090	1.65 - 2.28
F	.313 - .318	7.95 - 8.07
G	.070 - .090	1.77 - 2.28
H	.423 - .438	10.74 - 11.12
J	.135 - .215	3.43 - 5.46

Collector Isolated from Case.

TO-111



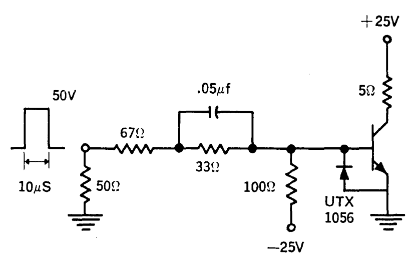
UNITRODE

Electrical Specifications (at 25°C unless noted)†

Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain	h_{FE}	40	250	—	$I_C = 0.5A$, $V_{CE} = 2V$
D.C. Current Gain	h_{FE}	50	150	—	$I_C = 5A$, $V_{CE} = 5V$ (Note 1)
D.C. Current Gain	h_{FE}	30		—	$I_C = 10A$, $V_{CE} = 5V$ (Note 1)
Collector Saturation Voltage	V_{CE} (sat)		.5	V	$I_C = 5A$, $I_B = 0.5A$ (Note 1)
Collector Saturation Voltage	V_{CE} (sat)		1.0	V	$I_C = 10A$, $I_B = 1A$ (Note 1)
Base Saturation Voltage	V_{BE} (sat)		1.3	V	$I_C = 5A$, $I_B = 0.5A$ (Note 1)
Base Saturation Voltage	V_{BE} (sat)		1.8	V	$I_C = 10A$, $I_B = 1A$ (Note 1)
Collector-Emitter Breakdown Voltage	BV_{CER}	120		V	$I_C = 100mA$, $R_{BE} = 10\Omega$
Collector-Emitter Breakdown Voltage	BV_{CES}	120		V	$I_C = 0.2\mu A$, $R_{BE} = 0$
Collector-Emitter Breakdown Voltage	BV_{CEO}	80		V	$I_C = 100mA$, $I_B = 0$ (Note 1)
Emitter-Base Breakdown Voltage	BV_{EBO}	7		V	$I_E = 10\mu A$, $I_C = 0$
Collector Cutoff Current	I_{CES}		0.2	μA	$V_{CE} = 120V$, $R_{BE} = 0$
Collector Cutoff Current, 150°C	I_{CES}		0.1	mA	$V_{CE} = 80V$, $R_{BE} = 0$, $T = 150°C$
Collector Capacitance	C_{obo}		150	pf	$V_{CB} = 10V$, $I_E = 0$, $f = 1MHz$
A.C. Current Gain	h_{fe}	3			$I_C = 0.5A$, $V_{CE} = 5V$, $f = 10MHz$
Switching Speeds — Turn-on Time	t_{on}		150	ns	$I_C = 5A$
Switching Speeds — Turn-off Time	t_{off}		800	ns	$I_{b1} = 250mA$ $I_{b2} = -250mA$ Note 2.

Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
2. Measured in saturated switching speed circuit.
† All values in this table are JEDEC registered.

Switching Speed Circuit



UNITRODE CORPORATION • 5 FORBES ROAD
LEXINGTON, MA 02173 • TEL. (617) 861-6540
TWX (710) 326-6509 • TELEX 95-1064

POWER TRANSISTORS
2 Amp, 300V, Planar NPN

JAN, JANTX, & JANTXV 2N5660
JAN, JANTX, & JANTXV 2N5661
JAN, JANTX, & JANTXV 2N5662
JAN, JANTX, & JANTXV 2N5663

IV

FEATURES
- Meets MIL-S-19500/454
- Collector-Base Voltage: up to 400V
- D.C. Collector Current: 5A
- Peak Collector Current: 10A
- Fast Switching

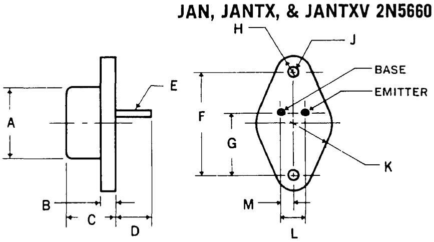
DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

ABSOLUTE MAXIMUM RATINGS

	JAN, JANTX, & JANTXV 2N5660	JAN, JANTX, & JANTXV 2N5661	JAN, JANTX, & JANTXV 2N5662	JAN, JANTX, & JANTXV 2N5663
Collector-Base Voltage, V_{CBO}	250V	400V	250V	400V
Collector-Emitter Voltage, V_{CEO}	200V	300V	200V	300V
Emitter-Base Voltage, V_{EBO}	6V	6V	6V	6V
D.C. Collector Current, I_C	2A	2A	2A	2A
Peak Collector Current, I_C	5A	5A	5A	5A
Power Dissipation				
25°C Ambient	2.0W	2.0W	1.2W	1.2W
100°C Case	20W	20W	15W	15W
Operating and Storage Temperature Range	—65°C to 200°C			

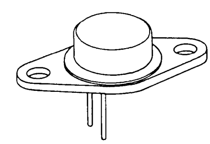
MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 2N5660 JAN, JANTX, & JANTXV 2N5661

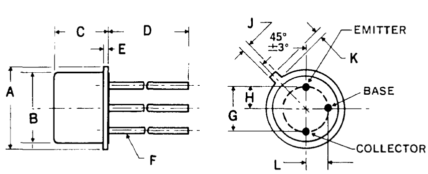


	INCHES	MILLIMETERS
A	.620 MAX.	15.75 MAX.
B	.050 - .075	1.27 - 1.90
C	.250 - .340	6.35 - 8.63
D	.360 MIN.	9.14 MIN.
E	.028 - .034 DIA.	.711 - .863
F	.958 - .962	24.33 - 24.43
G	.570 - .590	14.47 - 14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142 - .152 DIA.	3.60 - 3.86 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190 - .210	4.82 - 5.33
M	.093 - .107	2.36 - 2.72

TO-66

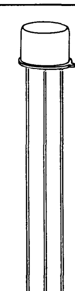


JAN, JANTX, & JANTXV 2N5662 JAN, JANTX, & JANTXV 2N5663



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	$.017 \pm ^{.002}_{.001}$	$.432 \pm ^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N5660, 2N5662

Test	Symbol	Min.	Max.	Units	/454 Sub group	MIL-STD-750 Method	MIL-STD-750 Test conditions
Visual and mechanical					A-1	2071	See Mechanical Data
25°C							
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}*	250	—	Vdc	A-2	3011	I_C = 10mAdc; R_{BE} = 100Ω; Cond. B
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}*	200	—	Vdc	A-2	3011	I_C = 10mAdc; Cond. D
Emitter-Base Breakdown Voltage	BV_{EBO}*	6	—	Vdc	A-2	3026	I_E = 10μAdc; Cond. D
Collector-Emitter Cutoff Current	I_{CES}*	—	0.2	μAdc	A-2	3041	V_{CE} = 200Vdc; Cond. C
Collector-Base Cutoff Current	I_{CBO}	—	0.1	μAdc	A-2	3036	V_{CB} = 200Vdc; Cond. D
Collector-Base Cutoff Current	I_{CBO}	—	1.0	mAdc	A-2	3036	V_{CB} = 250Vdc; Cond. D
D.C. Current Gain (Note 1)	h_{FE}*	40	—	—	A-3	3076	I_C = 50mAdc, V_{CE} = 2Vdc
D.C. Current Gain (Note 1)	h_{FE}*	40	120	—	A-3	3076	I_C = 0.5Adc, V_{CE} = 5Vdc
D.C. Current Gain (Note 1)	h_{FE}*	15	—	—	A-3	3076	I_C = 1Adc, V_{CE} = 5Vdc
D.C. Current Gain (Note 1)	h_{FE}	5	—	—	A-3	3076	I_C = 2Adc, V_{CE} = 5Vdc
Collector Saturation Voltage (Note 1)	$V_{CE}(sat)$*	—	0.4	Vdc	A-3	3071	I_C = 1Adc, I_B = 0.1Adc
Collector Saturation Voltage (Note 1)	$V_{CE}(sat)$	—	0.8	Vdc	A-3	3071	I_C = 2Adc, I_B = 0.4Adc
Base Saturation Voltage (Note 1)	$V_{BE}(sat)$*	—	1.2	Vdc	A-3	3066	I_C = 1Adc, I_B = 0.1Adc; Cond. A
Base Saturation Voltage (Note 1)	$V_{BE}(sat)$	—	1.5	Vdc	A-3	3066	I_C = 2Adc, I_B = 0.4Adc; Cond. A
Gain-Bandwidth Product	f_T*	20	70	MHz	A-4	3306	I_C = 0.1Adc, V_{CE} = 5Vdc, f = 10MHz
Output Capacitance	C_{ob}	—	45	pf	A-4	3236	V_{CB} = 10Vdc, I_E = 0, f = 1MHz
Thermal Resistance	Θ_{J-C}				C-1	3151	
2N5660		—	5.0	°C/W			
2N5662		—	6.7	°C/W			
Switching Speeds — Turn-on time	t_{on}*	—	0.25	μs	A-4	—	I_C = 0.5Adc
Switching Speeds — Turn-off time	t_{off}*	—	0.85	μs	A-4	—	
100°C							
Forward Biased Second Breakdown							
2N5660	$I_{S/B}$	2	—	Adc	B-6	3051	V_{CE} = 10Vdc, t = 1Sec
	$I_{S/B}$	0.5	—	Adc	B-6	3051	V_{CE} = 40Vdc, t = 1Sec
	$I_{S/B}$	36	—	mAdc	B-6	3051	V_{CE} = 200Vdc, t = 1Sec
2N5662	$I_{S/B}$	2	—	Adc	B-7	3051	V_{CE} = 7.5 Vdc, t = 1Sec
	$I_{S/B}$	0.6	—	Adc	B-7	3051	V_{CE} = 25Vdc, t = 1Sec
	$I_{S/B}$	27	—	mAdc	B-7	3051	V_{CE} = 200Vdc, t = 1Sec
Unclamped Reverse Biased Second Breakdown	$E_{S/B}$	0.2	—	mj	B-8	3053	I_C = 2Adc, L = 0.1 mh
Clamped Reverse Biased Second Breakdown	$E_{S/B}$	80	—	mj	B-9	3053	I_C = 2Adc, L = 40mh, V_{clamp} = 200V
150°C							
Collctor-Emitter Cutoff Current	I_{CES}*	—	100	μAdc	A-5	3041	V_{CE} = 200Vdc, Cond. C
—65°C							
D.C. Current Gain (Note 1)	h_{FE}	15	—	—	A-6	3076	I_C = 0.5Adc, V_{CE} = 5Vdc

Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
* Those parameters marked with a * are JEDEC registered and devices meeting these specifications are available as commercial 2N devices.

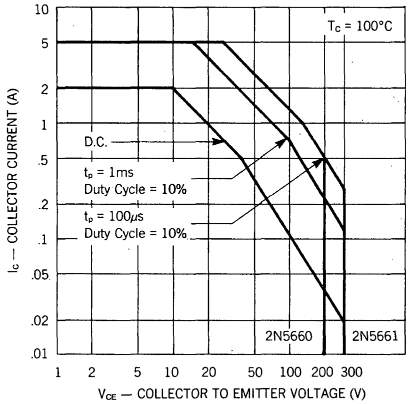
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N5661, 2N5663

IV

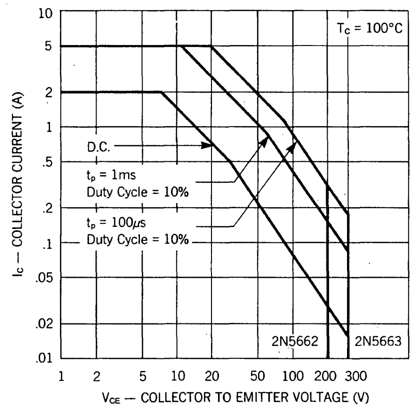
Test	Symbol	Min.	Max.	Units	/454 Sub group	MIL-STD-750 Method	MIL-STD-750 Test conditions
Visual and mechanical					A-1	2071	See Mechanical Data
25°C							
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}*	400	—	Vdc	A-2	3011	$I_C = 10mAdc$; $R_{BE} = 100\Omega$; Cond. B
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}*	300	—	Vdc	A-2	3011	$I_C = 10mAdc$; Cond. D
Emitter-Base Breakdown Voltage	BV_{EBO}*	6	—	Vdc	A-2	3026	$I_E = 10\mu Adc$; Cond. D
Collector-Emitter Cutoff Current	I_{CES}*	—	1.0	μAdc	A-2	3041	$V_{CE} = 400Vdc$; Cond. C
Collector-Base Cutoff Current	I_{CBO}	—	0.1	μAdc	A-2	3036	$V_{CB} = 300Vdc$; Cond. D
Collector-Base Cutoff Current	I_{CBO}	—	1.0	mAdc	A-2	3036	$V_{CB} = 400Vdc$; Cond. D
D.C. Current Gain (Note 1)	h_{FE}*	25	—	—	A-3	3076	$I_C = 50mAdc$, $V_{CE} = 2Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	25	75	—	A-3	3076	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	15	—	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	5	—	—	A-3	3076	$I_C = 2Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	$V_{CE}(sat)$*	—	0.4	Vdc	A-3	3071	$I_C = 1Adc$, $I_B = 0.1Adc$
Collector Saturation Voltage (Note 1)	$V_{CE}(sat)$	—	0.8	Vdc	A-3	3071	$I_C = 2Adc$, $I_B = 0.4Adc$
Base Saturation Voltage (Note 1)	$V_{BE}(sat)$*	—	1.2	Vdc	A-3	3066	$I_C = 1Adc$, $I_B = 0.1Adc$; Cond. A
Base Saturation Voltage (Note 1)	$V_{BE}(sat)$	—	1.5	Vdc	A-3	3066	$I_C = 2Adc$, $I_B = 0.4Adc$; Cond. A
Gain-Bandwith Product	f_T*	20	70	MHz	A-4	3306	$I_C = 0.2Adc$, $V_{CE} = 10Vdc$, $f = 10MHz$
Output Capacitance	C_{ob}	—	45	pf	A-4	3236	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Thermal Resistance	Θ_{J-C}				C-1	3151	
2N5661		—	5.0	°C/W			
2N5663		—	6.7	°C/W			
Switching Speeds — Turn-on time	t_{on}*	—	0.25	μs	A-4	—	$I_C = 0.5Adc$
Switching Speeds — Turn-off time	t_{off}*	—	0.85	μs	A-4	—	
100°C							
Forward Biased Second Breakdown							
2N5661	$I_{S/B}$	2	—	Adc	B-6	3051	$V_{CE} = 10Vdc$, $t = 1Sec$
	$I_{S/B}$	0.5	—	Adc	B-6	3051	$V_{CE} = 40Vdc$, $t = 1Sec$
	$I_{S/B}$	19	—	mAdc	B-6	3051	$V_{CE} = 300Vdc$, $t = 1Sec$
2N5663	$I_{S/B}$	2	—	Adc	B-7	3051	$V_{CE} = 7.5 Vdc$, $t = 1Sec$
	$I_{S/B}$	0.6	—	Adc	B-7	3051	$V_{CE} = 25Vdc$, $t = 1Sec$
	$I_{S/B}$	14	—	mAdc	B-7	3051	$V_{CE} = 300Vdc$, $t = 1Sec$
Unclamped Reverse Biased Second Breakdown	$E_{S/B}$	0.2	—	mj	B-8	3053	$I_C = 2Adc$, $L = 0.1 mh$
Clamped Reverse Biased Second Breakdown	$E_{S/B}$	80	—	mj	B-9	3053	$I_C = 2Adc$, $L = 40mh$, $V_{clamp} = 300V$
150°C							
Collector-Emitter Cutoff Current	I_{CES}*	—	100	μAdc	A-5	3041	$V_{CE} = 250Vdc$, Cond. C
—65°C							
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	A-6	3076	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$

Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
* Those parameters marked with a * are JEDEC registered and devices meeting these specifications are available as commercial 2N devices.

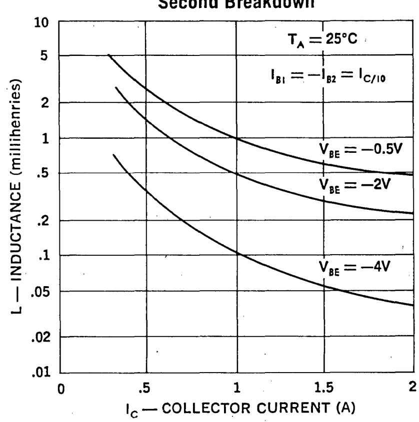
**Forward Bias
Safe Operating Area
2N5660, 2N5661**



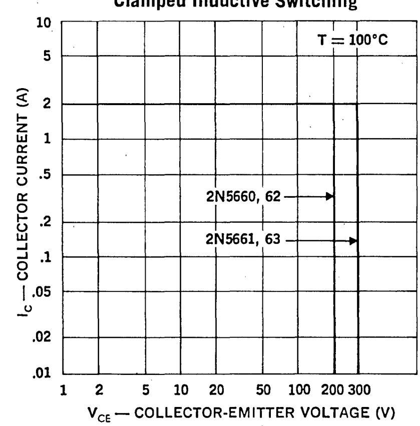
**Forward Bias
Safe Operating Area
2N5662, 2N5663**



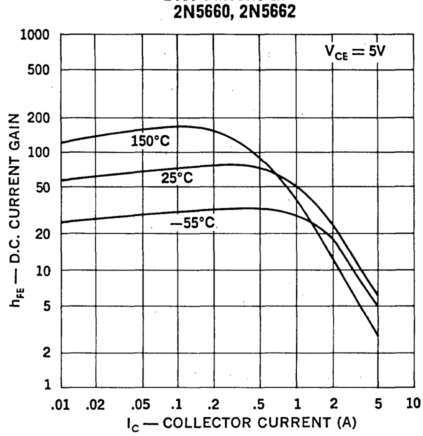
**Unclamped Reverse Bias
Second Breakdown**



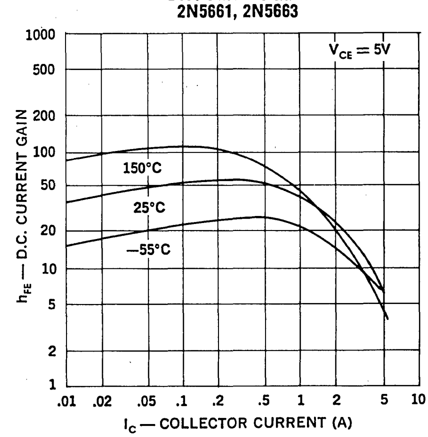
**Reverse Bias
Safe Operating Area
Clamped Inductive Switching**



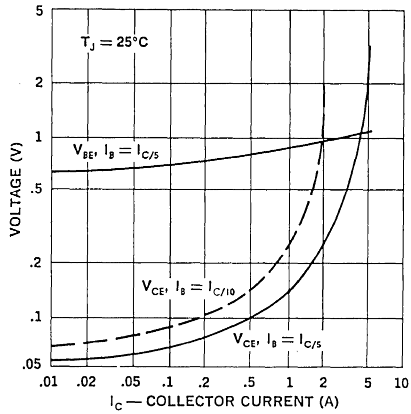
**D.C. Current Gain
2N5660, 2N5662**



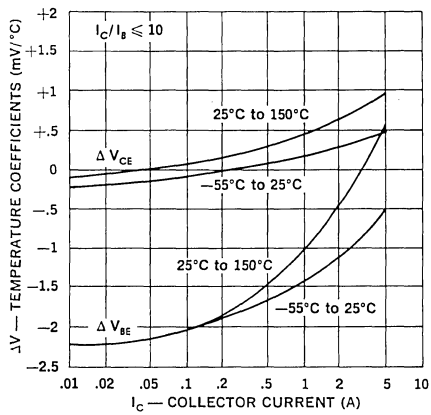
**D.C. Current Gain
2N5661, 2N5663**



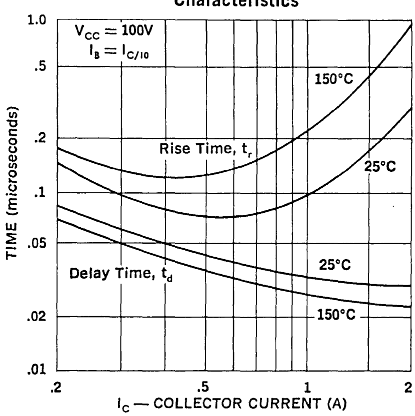
Saturation Voltages



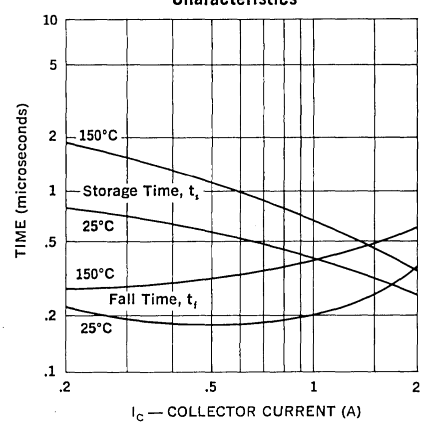
Saturation Voltage Temperature Coefficients



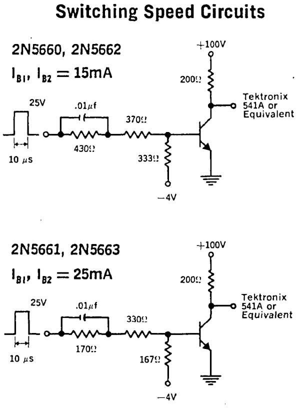
Switching Speed Characteristics



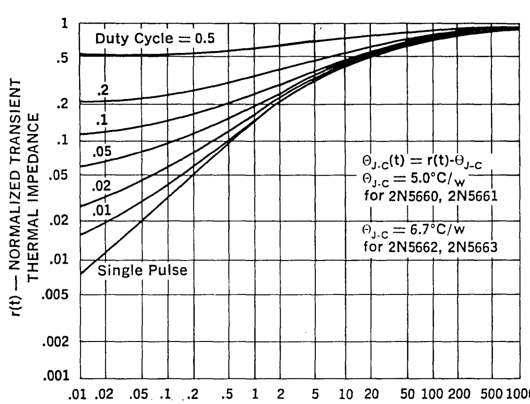
Switching Speed Characteristics



Switching Speed Circuits



Thermal Response



POWER TRANSISTORS
5 Amp, 300V, Planar NPN

JAN, JANTX, & JANTXV 2N5664
JAN, JANTX, & JANTXV 2N5665
JAN, JANTX, & JANTXV 2N5666
JAN, JANTX, & JANTXV 2N5667

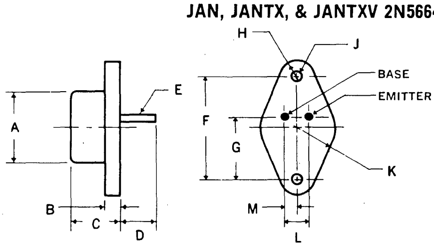
FEATURES
- Meets MIL-S-19500/455
- Collector-Base Voltage: up to 400V
- D.C. Collector Current: 5A
- Peak Collector Current: 10A
- Fast Switching

DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

ABSOLUTE MAXIMUM RATINGS	JAN, JANTX, & JANTXV 2N5664	JAN, JANTX, & JANTXV 2N5665	JAN, JANTX, & JANTXV 2N5666	JAN, JANTX & JANTXV 2N5667
Collector-Base Voltage, V_{CBO}	250V	400V	250V	400V
Collector-Emitter Voltage, V_{CEO}	200V	300V	200V	300V
Emitter-Base Voltage, V_{EBO}	6V	6V	6V	6V
D.C. Collector Current, I_C	5A	5A	5A	5A
Peak Collector Current, I_C	10A	10A	10A	10A
Power Dissipation				
25°C Ambient	2.5W	2.5W	1.2W	1.2W
100°C Case	30W	30W	15W	15W
Operating and Storage Temperature Range	−65°C to 200°C			

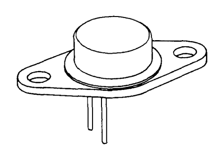
MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 2N5664 JAN, JANTX, & JANTXV 2N5665

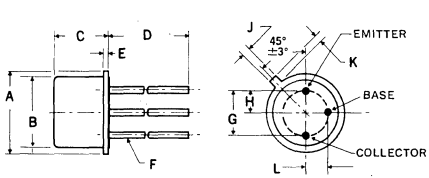


	INCHES	MILLIMETERS
A	.620 MAX.	15.75 MAX.
B	.050 - .075	1.27 - 1.90
C	.250 - .340	6.35 - 8.63
D	.360 MIN.	9.14 MIN.
E	.028 - .034 DIA.	.711 - .863
F	.958 - .962	24.33 - 24.43
G	.570 - .590	14.47 - 14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142 - .152 DIA.	3.60 - 3.86 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190 - .210	4.82 - 5.33
M	.093 - .107	2.36 - 2.72

TO-66

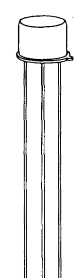


JAN, JANTX, & JANTXV 2N5666 JAN, JANTX, & JANTXV 2N5667



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	$.017 \pm ^{.002}_{.001}$	$.432 \pm ^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N5664, 2N5666

Test	Symbol	Min.	Max.	Units	/455 Sub group	MIL-STD-750 Method	Test conditions
Visual and mechanical					A-1	2071	See Mechanical Data
25°C							
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}*	250	—	Vdc	A-2	3011	$I_C = 10mAdc$; $R_{BE} = 100\,\Omega$, Cond. B
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}*	200	—	Vdc	A-2	3011	$I_C = 10mAdc$; Cond. D
Emitter-Base Breakdown Voltage	BV_{EBO}*	6.0	—	Vdc	A-2	3026	$I_E = 10\mu Adc$; Cond. D
Collector-Emitter Cutoff Current	I_{CES}*	—	1.0	μAdc	A-2	3041	$V_{CE} = 250Vdc$; Cond. C
Collector-Base Cutoff Current	I_{CBO}	—	0.1	μAdc	A-2	3036	$V_{CB} = 200Vdc$; Cond. D
Collector-Base Cutoff Current	I_{CBO}	—	1.0	mAdc	A-2	3036	$V_{CB} = 250Vdc$; Cond. D
D.C. Current Gain (Note 1)	h_{FE}*	40	—	—	A-3	3076	$I_C = 0.5Adc$, $V_{CE} = 2Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	40	120	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	15	—	—	A-3	3076	$I_C = 3Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	5	—	—	A-3	3076	$I_C = 5Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)*	—	0.4	Vdc	A-3	3071	$I_C = 3Adc$, $I_B = 0.3Adc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	A-3	3071	$I_C = 5Adc$, $I_B = 1Adc$
Base Saturation Voltage (Note 1)	V_{BE} (sat)*	—	1.2	Vdc	A-3	3066	$I_C = 3Adc$, $I_B = 0.3Adc$; Cond. A
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	A-3	3066	$I_C = 5Adc$, $I_B = 1Adc$; Cond. A
Gain-Bandwith Product	f_T*	20	70	MHz	A-4	3306	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$, f = 10MHz
Output Capacitance	C_{ob}	—	120	pf	A-4	3236	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
Thermal Resistance	θ_{J-C}				C-1	3151	
2N5664		—	3.3	°C/W			
2N5666		—	6.7	°C/W			
Switching Speeds — Turn-on Time	t_{on}*	—	0.25	μs	A-4	—	$I_C = 1Adc$
Switching Speeds — Turn-off Time	t_{off}*	—	1.5	μs	A-4	—	
100°C							
Forward Biased Second Breakdown 2N5664	$I_{S/B}$	5	—	Adc	B-6	3051	$V_{CE} = 6Vdc$, t = 1sec
	$I_{S/B}$	0.75	—	Adc	B-6	3051	$V_{CE} = 40Vdc$, t = 1sec
	$I_{S/B}$	43	—	mAdc	B-6	3051	$V_{CE} = 200Vdc$, t = 1sec
2N5666	$I_{S/B}$	5	—	Adc	B-7	3051	$V_{CE} = 3Vdc$, t = 1sec
	$I_{S/B}$	0.4	—	Adc	B-7	3051	$V_{CE} = 37.5Vdc$, t = 1sec
	$I_{S/B}$	27	—	mAdc	B-7	3051	$V_{CE} = 200Vdc$, t = 1sec
Unclamped Reverse Biased Second Breakdown	$E_{S/B}$	1.25	—	mj	B-8	3053	$I_C = 5Adc$, L = .065mh
Clamped Reverse Biased Second Breakdown	$E_{S/B}$	500	—	mj	B-9	3053	$I_C = 5Adc$, L = 40mh, $V_{clamp} = 200V$
150°C							
Collector-Emitter Cutoff Current	I_{CES}*	—	100	μAdc	A-5	3041	$V_{CE} = 175Vdc$, Cond. C
−65°C							
D.C. Current Gain (Note 1)	h_{FE}	15	—	—	A-6	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$

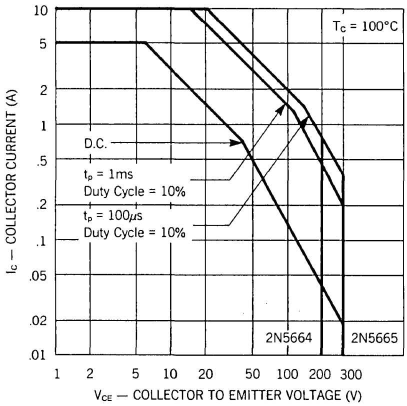
Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
* Those parameters marked with a * are JEDEC registered and devices meeting these specifications are available as commercial 2N devices.

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N5665, 2N5667

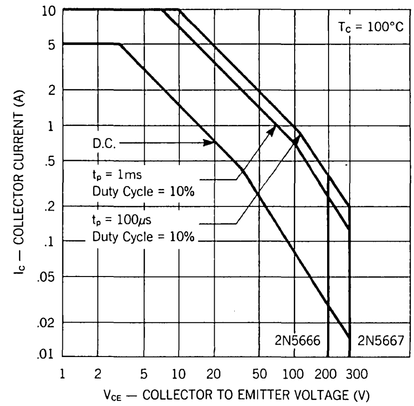
Test	Symbol	Min.	Max.	Units	/455 Sub group	MIL-STD-750 Method	Test conditions
Visual and mechanical					A-1	2071	See Mechanical Data
25°C							
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}*	400	—	Vdc	A-2	3011	$I_C = 10mAdc$; $R_{BE} = 100\ \Omega$, Cond. B
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}*	300	—	Vdc	A-2	3011	$I_C = 10mAdc$; Cond. D
Emitter-Base Breakdown Voltage	BV_{EBO}*	6	—	Vdc	A-2	3026	$I_E = 10\mu Adc$; Cond. D
Collector-Emitter Cutoff Current	I_{CES}*	—	1.0	μAdc	A-2	3041	V_{CE} = 400Vdc; Cond. C
Collector-Base Cutoff Current	I_{CBC}	—	0.1	μAdc	A-2	3036	$V_{CB} = 300Vdc$; Cond. D
Collector-Base Cutoff Current	I_{CBO}	—	1.0	mAdc	A-2	3036	$V_{CB} = 400Vdc$; Cond. D
D.C. Current Gain (Note 1)	h_{FE}*	25	—	—	A-3	3076	$I_C = 0.5Adc$, $V_{CE} = 2Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	25	75	—	A-3	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}*	15	—	—	A-3	3076	I_C = 3Adc, V_{CE} = 10Vdc
D.C. Current Gain (Note 1)	h_{FE}	5	—	—	A-3	3076	$I_C = 5Adc$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)*	—	0.4	Vdc	A-3	3071	$I_C = 3Adc$, $I_B = 0.6Adc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	A-3	3071	$I_C = 5Adc$, $I_B = 1Adc$
Base Saturation Voltage (Note 1)	V_{BE} (sat)*	—	1.2	Vdc	A-3	3066	$I_C = 3Adc$, $I_B = 0.6Adc$; Cond. A
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	A-3	3066	$I_C = 5Adc$, $I_B = 1Adc$; Cond. A
Gain-Bandwith Product	f_T*	20	70	MHz	A-4	3306	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Output Capacitance	C_{ob}	—	90	pf	A-4	3236	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Thermal Resistance	θ_{J-C}				C-1	3151	
2N5665		—	3.3	°C/W			
2N5667		—	6.7	°C/W			
Switching Speeds — Turn-on time	t_{on}*	—	0.25	μs	A-4	—	$I_C = 1Adc$
Switching Speeds — Turn-off time	t_{off}*	—	2.0	μs	A-4	—	
100°C							
Forward Biased Second Breakdown 2N5665	$I_{S/B}$	5	—	Adc	B-6	3051	$V_{CE} = 6Vdc$, $t = 1sec$
	$I_{S/B}$	0.75	—	Adc	B-6	3051	$V_{CE} = 40Vdc$, $t = 1$ sec
	$I_{S/B}$	21	—	mAdc	B-6	3051	$V_{CE} = 300Vdc$, $t = 1sec$
2N5667	$I_{S/B}$	5	—	Adc	B-7	3051	$V_{CE} = 3Vdc$, $t = 1sec$
	$I_{S/B}$	0.4	—	Adc	B-7	3051	$V_{CE} = 37.5Vdc$, $t = 1sec$
	$I_{S/B}$	14	—	mAdc	B-7	3051	$V_{CE} = 300Vdc$, $t = 1sec$
Unclamped Reverse Biased Second Breakdown	$E_{S/B}$	1.25	—	mj	B-8	3053	I_C = 5Adc, L = .065mh
Clamped Reverse Biased Second Breakdown	$E_{S/B}$	500	—	mj	B-9	3053	$I_C = 5Adc$, $L = 40mh$, $V_{clamp} = 300V$
150°C							
Collector-Emitter Cutoff Current	I_{CES}*	—	100	μAdc	A-5	3041	V_{CE} = 250Vdc, Cond. C
−65°C							
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	A-6	3076	$I_C = 1Adc$, $V_{CE} = 5Vdc$

Notes:
1. Pulse width = 300μS; duty cycle ≤2%.
* Those parameters marked with a * are JEDEC registered and devices meeting these specifications are available as commercial 2N devices.

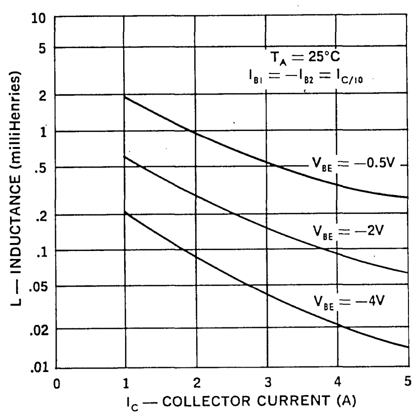
Forward Bias Safe Operating Area 2N5664, 2N5665



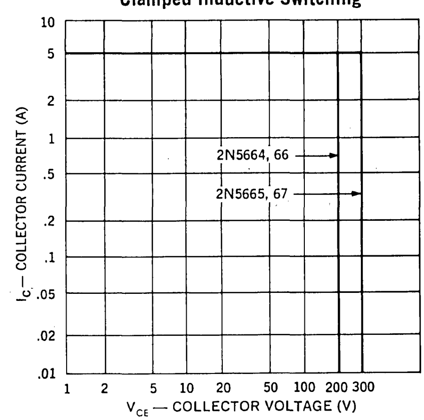
Forward Bias Safe Operating Area 2N5666, 2N5667



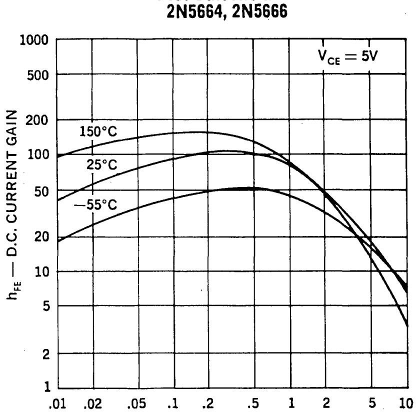
Unclamped Reverse Bias Second Breakdown



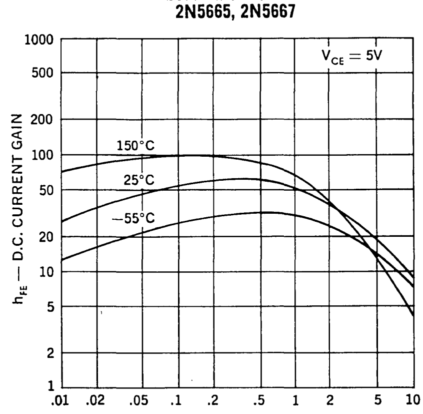
Reverse Bias Safe Operating Area Clamped Inductive Switching



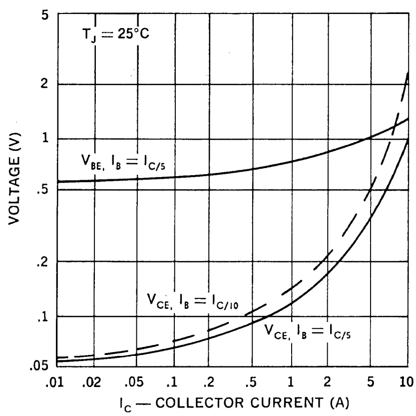
D.C. Current Gain 2N5664, 2N5666



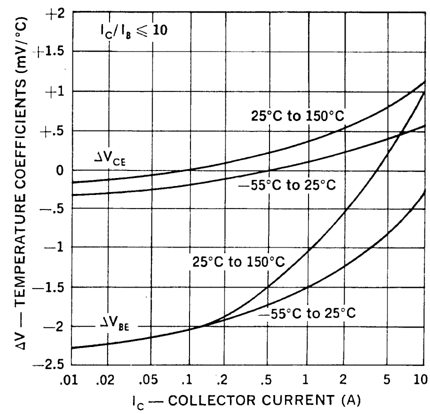
D.C. Current Gain 2N5665, 2N5667



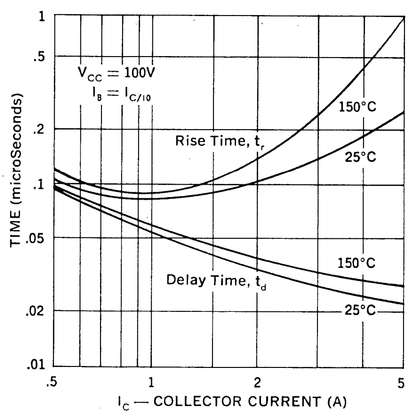
Saturation Voltages



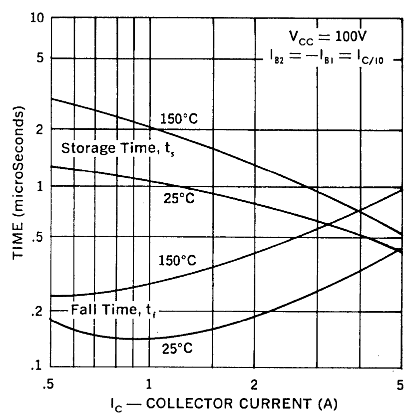
Saturation Voltage Temperature Coefficients



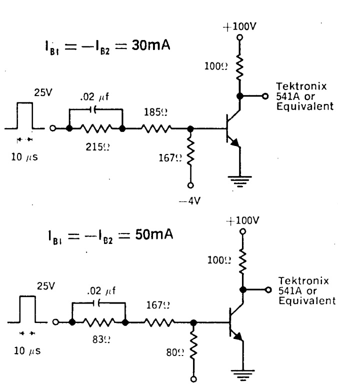
Switching Speed Characteristics



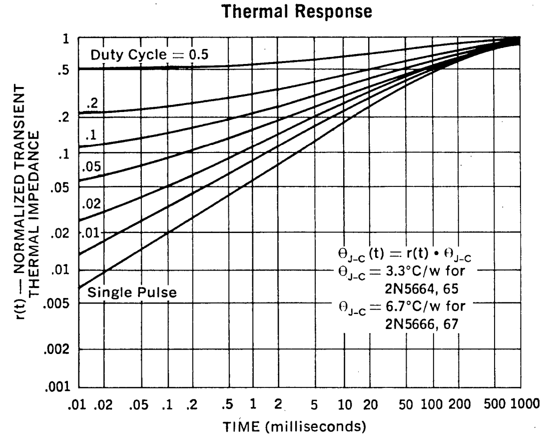
Switching Speed Characteristics



Switching Speed Circuits



Thermal Response



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TWX (710) 326-6509 • TELEX 95-1064

POWER TRANSISTORS

30A, 150V, Fast Switching, Silicon NPN Mesa

2N5671
2N5672

IV

FEATURES

- Collector-Base Voltage: up to 150V
- DC Collector Current = 30A
- Low $V_{CE\,(SAT)}$ = 0.75V Max.
- t_{on} = 0.5μS } @ I_C = 15A
- t_{fall} = 0.5μS } @ I_C = 15A

DESCRIPTION

These glass passivated power transistors combine fast-switching, low saturation voltage and rugged $E_s/_b$ capability. They are designed for use in switching regulators, converters, inverters and switching-control amplifiers.

ABSOLUTE MAXIMUM RATINGS *

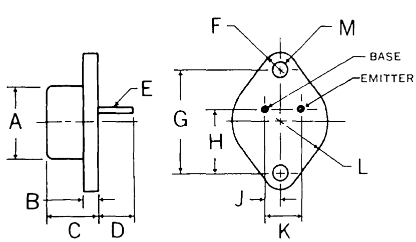
	2N5671	2N5672
* Collector-to-Base Voltage, V_{CBO}	120V	150V
Collector-Emitter Sustaining Voltage, $V_{CEX\,(SUS)}$	120V	150V
$V_{CER\,(SUS)}$	110V	140V
$V_{CEO\,(SUS)}$	90V	120V
* Emitter-Base Voltage, V_{EBO}	7V	7V
* Collector Current, I_C continuous	30A	30A
* Base Current, I_B continuous	10A	10A
* Power Dissipation, 25°C Case	140W	140W
* Operating and Storage Temperature Range	—65 to 200°C	

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

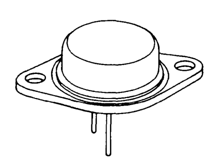
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N5671 -2N5672



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

	Test	Symbol	2N5671 MIN.	2N5671 MAX.	2N5672 MIN.	2N5672 MAX.	Units	Test Conditions
*	D.C. Current Gain (Note 1)	h_{FE}	20	100	20	100		$I_C = 15A, V_{CE} = 2V$
	D.C. Current Gain (Note 1)	h_{FE}	20	—	20	—		$I_C = 20A, V_{CE} = 5V$
*	Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	0.75	—	0.75	V	$I_C = 15A, I_B = 1.2A$
*	Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	1.5	—	1.5	V	$I_C = 15A, I_B = 1.2A$
	Base to Emitter Voltage (Note 1)	V_{BE}	—	1.6	—	1.6	V V	$I_C = 15A, V_{CE} = 5V$
*	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	90	—	120	—	V	$I_C = 0.2A, I_B = 0$
*	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEX\,(sus)}$	120	—	150	—	V	$I_C = 0.2A$ $V_{BE} = -1.5V$ $I_B = 0$
	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CER\,(sus)}$	110	—	140	—	V	$R_{BE} = 50\Omega, I_C = 0.2A$
*	Emitter-Cutoff Current	I_{EBO}	10	—	10	—	mA	$V_{EB} = 7.0V$
	Collector Cutoff Current	I_{CEO}	—	10	—	10	mA	$V_{CE} = 80V$
*	Collector Cutoff Current	I_{CEV}	— — —	12 — 15	— — —	— 10 10	mA	$V_{CE} = 110V, V_{BE} = -1.5V$ $V_{CE} = 135V, V_{BE} = -1.5V$ $V_{CE} = 100V, V_{BE} = -1.5V, T_C = 150°C$
	Magnitude of Small Signal Forward — Current Transfer Ratio	h_{fe}	10	—	10	—		$V_{CE} = 10V, I_C = 2A, f = 5MHz$
	Collector Capacitance	C_{ob}	—	900	—	900	pF	$V_{CB} = 10V, f = 1\ MHz$
*	Second Breakdown Energy	$E_{s/b}$	20	—	20	—	mJ	$V_{BE} = 4V, I_C = 15A$ $R_{BE} = 20\Omega, L = 180\mu H$
	Forward Bias Second Breakdown Collector Current	$I_{s/b}$	5.8 0.9	— —	5.8 0.9	— —	A	$V_{CE} = 24V, t = 1s$, non-rep. $V_{CE} = 45V, t = 1s$, non-rep.
*	Switching Speeds: Turn-on Time (Delay + Rise)	t_{on}	—	0.5	—	0.5	μS	$I_C = 15A$ $I_{B1} = I_{B2} = 1.2A$ $V_{CC} = 30V$
	Storage Time	t_s	—	1.5	—	1.5	μS	
	Fall Time	t_f	—	0.5	—	0.5	μS	
	Thermal Resistance: Junction-to-Case	$R_{\Theta JC}$	—	1.25	—	1.25	°C/W	$V_{CE} = 40V, I_C = 0.5A$

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.
* JEDEC registered values.

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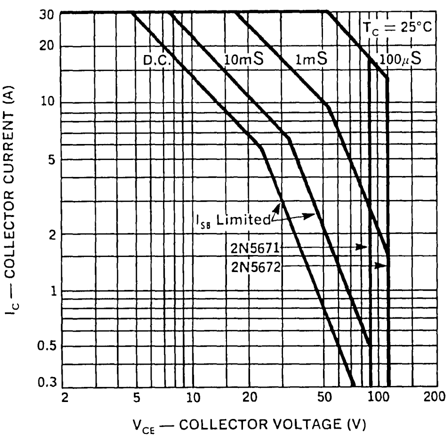
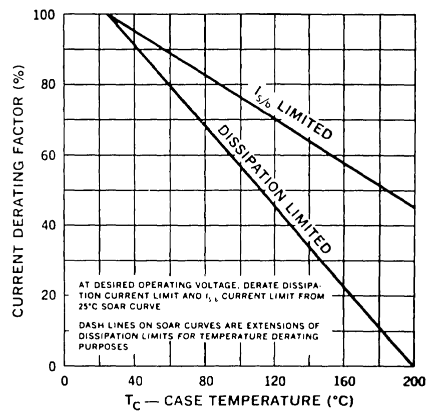
IV

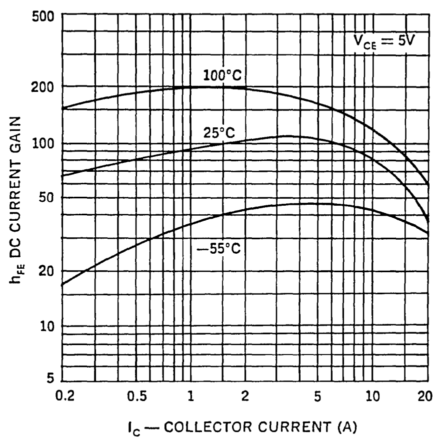
Forward Bias Safe Operating Area



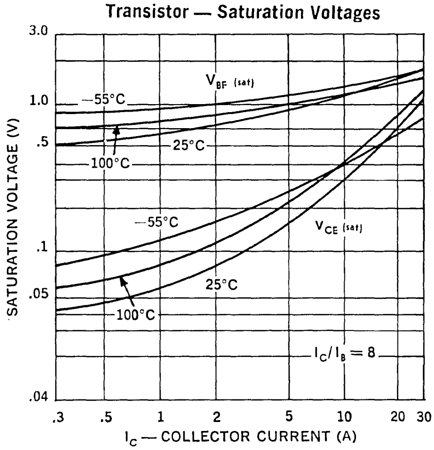
Power Derating



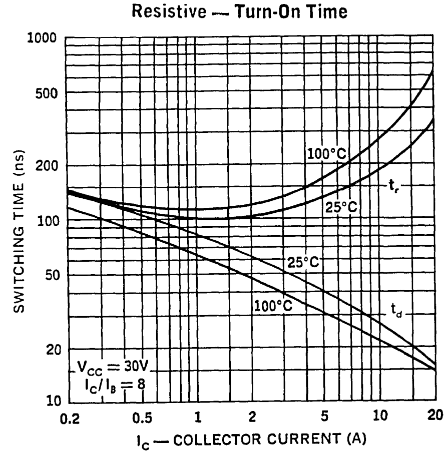
DC Current Gain



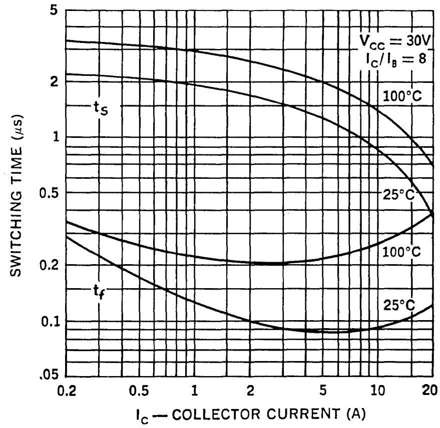
Transistor — Saturation Voltages



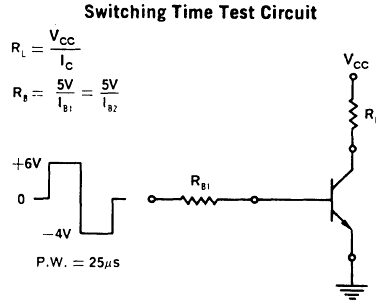
Resistive — Turn-On Time



Resistive Turn-Off Time



Switching Time Test Circuit



POWER TRANSISTORS

3A, 375V
Silicon NPN Mesa

2N5838
2N5839
2N5840

IV

FEATURES

- Collector-Base Voltage: up to 375V
- Peak Collector Current: 5A
- Low Saturation Voltage
- High Second Breakdown Energy

DESCRIPTION

These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

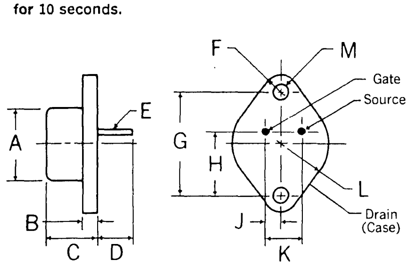
ABSOLUTE MAXIMUM RATINGS *

	2N5838	2N5839	2N5840
Collector-Base Voltage, V_{CBO}	275V	300V	375V
Collector-Emitter Voltage, V_{CEO}	250V	275V	350V
Emitter-Base Voltage, V_{EBO}	6V	6V	6V
Collector Current, I_C continuous	3A	3A	3A
Collector Current, I_{CM}, peak	5A	5A	5A
Base Current, I_B, continuous	1.5A	1.5A	1.5A
Power Dissipation, P_T 25°C Case	100W	100W	100W
Operating and Storage Temperature Range	—65 to +200°C		

* JEDEC registered values.

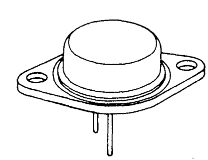
MECHANICAL SPECIFICATIONS

NOTE:
Leads may be soldered to within ¹/₁₆" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	0.057-0.063 DIA.	1.45-1.60 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3 (Copper)



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

	Test	Symbol	2N5838 MIN.	2N5838 MAX.	2N5839 MIN.	2N5839 MAX.	2N5840 MIN.	2N5840 MAX.	Units	Test Conditions
	D.C. Current Gain (Note 1)	h_{FE}	20	—	20	—	20	—		$I_C = 0.5A, V_{CE} = 5V$
*	D.C. Current Gain (Note 1)	h_{FE}	—	—	10	50	10	50		$I_C = 2A, V_{CE} = 3V$
*	D.C. Current Gain (Note 1)	h_{FE}	8	40	—	—	—	—	V	$I_C = 3A, V_{CE} = 2V$
*	Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	—	—	1.5	—	1.5	V	$I_C = 2A, I_B = 0.2A$
*	Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	—	—	—	V	$I_C = 3A, I_B = 0.375A$
*	Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	—	—	2.0	—	2.0	V	$I_C = 2A, I_B = 0.2A$
*	Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	2.0	—	—	—	—	V	$I_C = 3A, I_B = 0.375A$
*	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(SUS)}$	250	—	275	—	350	—	V	$I_C = 200mA, I_B = 0$
*	Collector-Emitter Sustaining Voltage	V_{CEX}	275	—	300	—	375	—	V	$I_C = 0.1A, V_{BE} = -1.5V$, $L = 10mH$
*	Emitter-Base Cutoff Current	I_{EBO}	—	1.0	—	1.0	—	1.0	mA	$V_{EB} = 6V$
	Collector Cutoff Current	I_{CEO}	—	2.0	—	—	—	—	—	$V_{CE} = 200V$
			—	—	—	2.0	—	2.0	mA	$V_{CE} = 250V$
*	Collector Cutoff Current	I_{CEV}	—	5.0	—	—	—	—		$V_{CE} = 265V$
			—	—	—	2.0	—	—	mA	$V_{CE} = 290V$ $V_{BE} = -1.5V$
			—	—	—	—	—	2.0		$V_{CE} = 360V$
*	Collector Cutoff Current, 150°C	I_{CEV}	—	8.0	—	—	—	—		$V_{CE} = 265V$
			—	—	—	5.0	—	—	mA	$V_{CE} = 290V$ $V_{BE} = -1.5V$
			—	—	—	—	—	5.0		$V_{CE} = 360V$
	Forward Bias Second Breakdown	$I_{S/b}$	—	2.5A	—	2.5A	—	2.5A		$V_{CE} = 40V, t_p = 1$ Sec.
*	Second Breakdown Energy	$E_{S/b}$	0.45	—	0.45	—	0.45	—	mJ	$R_{BE} = 50\Omega, L = 100\mu H$
	Collector Capacitance	C_{ob}	—	150	—	150	—	150	pF	$V_{CB} = 10V, I_E = 0, f = 1$ MHz
*	Small Signal High Frequency Gain	h_{fe}	5	—	5	—	5	—	MHz	$I_C = .2A, V_{CE} = 10V, f = 1$ MHz
*	Switching Speeds:									
	Delay Time	t_d	—	—	—	0.7	—	0.7	μS	$I_C = 2A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (0.2A)$
		t_d	—	0.6	—	—	—	—		$I_C = 3A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (.375A)$
	Rise Time	t_r	—	—	—	1.5	—	1.75	μS	$I_C = 2A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (0.2A)$
		t_r	—	1.5	—	—	—	—		$I_C = 3A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (.375A)$
	Storage Time	t_s	—	—	—	3.75	—	3.75	μS	$I_C = 2A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (0.2A)$
		t_s	—	3.0	—	—	—	—		$I_C = 3A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (.375A)$
	Fall Time	t_f	—	—	—	1.5	—	1.5	μS	$I_C = 2A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (0.2A)$
		t_f	—	1.5	—	—	—	—		$I_C = 3A, V_{CE} = 200V$, $I_{B1} = I_{B2} = (.375A)$
	Thermal Resistance	$R\Theta_{JC}$	—	1.75	—	1.75	—	1.75	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

* JEDEC registered values.

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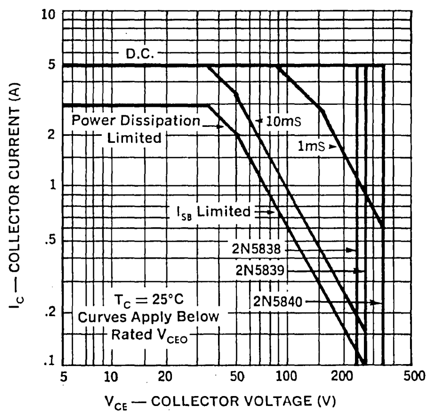
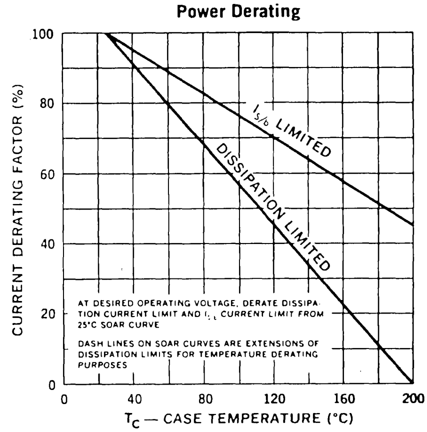
IV

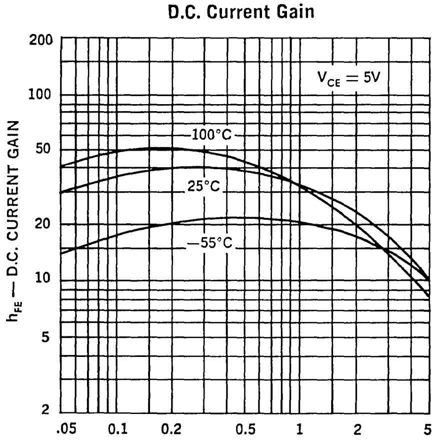
Forward Bias Safe Operating Area



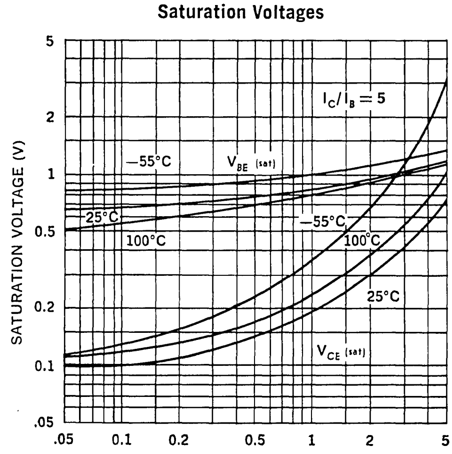
Power Derating



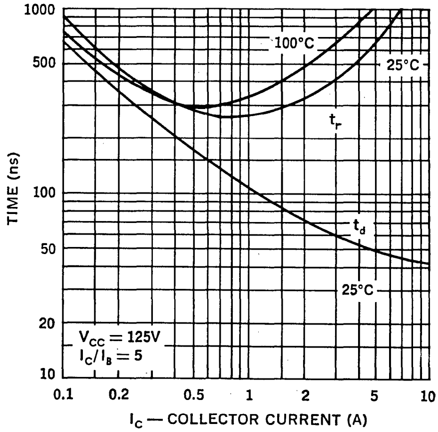
D.C. Current Gain



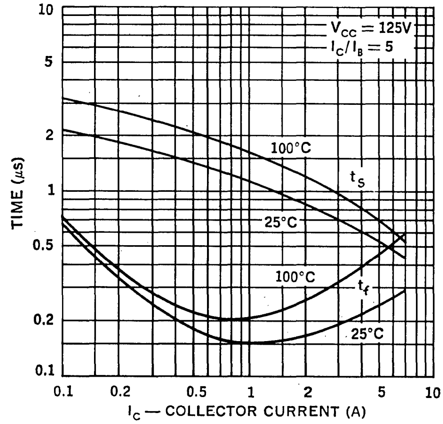
Saturation Voltages



Resistive — Turn-On Time



Resistive — Turn-Off Time

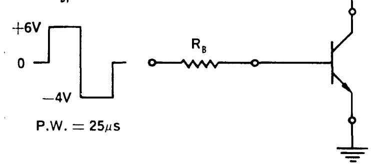


Switching Time Test Circuit

$R_L = \frac{200V}{I_C}$

$I_{B1} = \frac{5V}{R_{B1}}$

$I_{B2} = \frac{6V}{R_{B1}}$



POWER TRANSISTORS

10A, 450V, Fast Switching, Silicon NPN Mesa

2N6249
2N6250
2N6251

IV

FEATURES

- Collector-Base Voltage: up to 450V
- Peak Collector Current: 30A
- Low Saturation Voltage
- Maximum Safe Area of Operation

DESCRIPTION

These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS

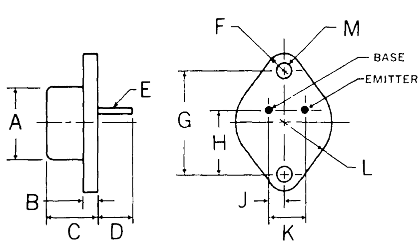
	2N6249	2N6250	2N6251
* Collector-Base Voltage, V_{CBO}	300V	375V	450V
* Collector-Emitter Voltage, V_{CEO}	200V	275V	350V
Emitter-Base Voltage, V_{EBO}	6V	6V	6V
* Collector Current, I_C continuous	10A	10A	10A
Collector Current, I_{CM}, peak	30A	30A	20A
* Base Current, I_B, continuous	10A	10A	10A
* Power Dissipation, P_T 25°C Case	175W	175W	175W
* Operating and Storage Temperature Range	−65 to +200°C		

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

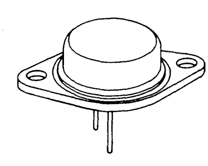
2N6249-2N6251

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



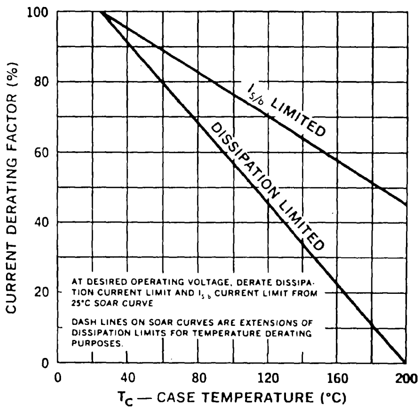
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

	Test	Symbol	2N6249 MIN.	2N6249 MAX.	2N6250 MIN.	2N6250 MAX.	2N6251 MIN.	2N6251 MAX.	Units	Test Conditions
*	D.C. Current Gain (Note 1)	h_{FE}	10	50	8	50	6	50		$I_C = 10A$, $V_{CE} = 3.0V$
*	Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	1.5	—	1.5	—	1.5	V	$I_C = 10A$ $I_B = 1.0A$ (2N6249) $I_B = 1.25A$ (2N6250) $I_B = 1.67A$ (2N6251)
*	Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	2.25	—	2.25	—	2.25	V	
*	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	200	—	275	—	350	—	V	$I_C = 200mA$
*	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEX\,(sus)}$	225	—	300	—	375	—	V	$I_C = 200mA$, $R_{BE} = 50\Omega$ $L = 14mH$
*	Emitter Base Cutoff Current	I_{EBO}	—	1.0	—	1.0	—	1.0	mA	$V_{EB} = 6V$
	Collector Cutoff Current	I_{CEO}	—	5.0	—	5.0	—	5.0	mA	$V_{CE} = 50V$ less than rated $V_{CEO\,(SUS)}$
*	Collector Cutoff Current	I_{CEV}	—	5.0	—	5.0	—	5.0	mA	$V_{BE} = -1.5V$ $V_{CE} =$ rated $V_{CER\,(SUS)}$
*	Collector Cutoff Current, 125°	I_{CEV}	—	10	—	10	—	10	mA	
*	Second Breakdown Energy	$E_{S/b}$	—	2.5	—	2.5	—	2.5	mJ	$I_C = 10A$, $L = 50\mu H$ $R_{BE} = 50\Omega$, $V_{BE\,(off)} = -4V$
*	Forward Bias Second Breakdown	$I_{S/b}$	5.8 0.3	— —	5.8 0.3	— —	5.8 0.3	— —	A	$V_{CE} = 30V$ $V_{CE} = 100V$
*	Thermal Resistance	$R\Theta_{JC}$	—	1.0	—	1.0	—	1.0	°C/W	$V_{CE} = 10V$, $I_C = 5A$
*	High Frequency Gain	$\|h_{FE}\|$	2.5	—	2.5	—	2.5	—		$I_C = 1A$, $V_{CE} = 10V$, $f = 1$ MHz
*	Switching Speeds:								μS	$I_C = 10A$
	Rise Time	t_r	0.8	2.0	0.8	2.0	0.8	2.0	μS	$I_{B1} = I_{B2} = 1.0A$ (2N6249)
	Storage Time	t_s	1.8	3.5	1.8	3.5	1.8	3.5	μS	$I_{B1} = I_{B2} = 1.25A$ (2N6250)
	Fall Time	t_f	0.5	1.0	0.5	1.0	0.5	1.0	μS	$I_{B1} = I_{B2} = 1.67A$ (2N6251)

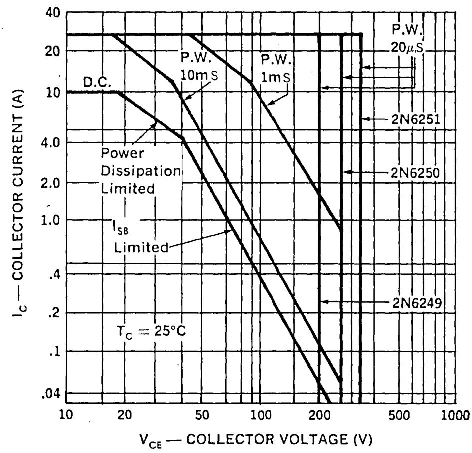
Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

* JEDEC registered values.

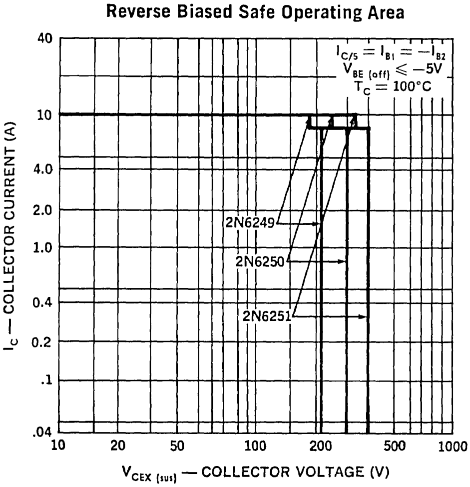
Power Derating



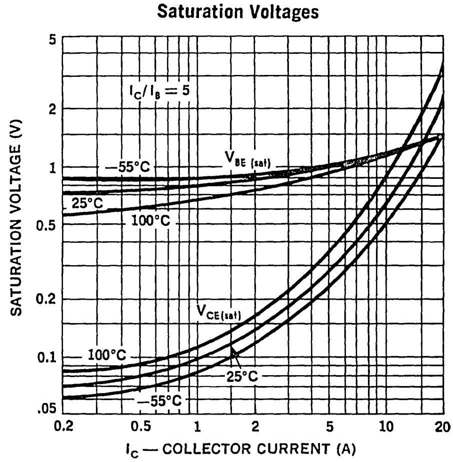
Forward Bias Safe Operating Area



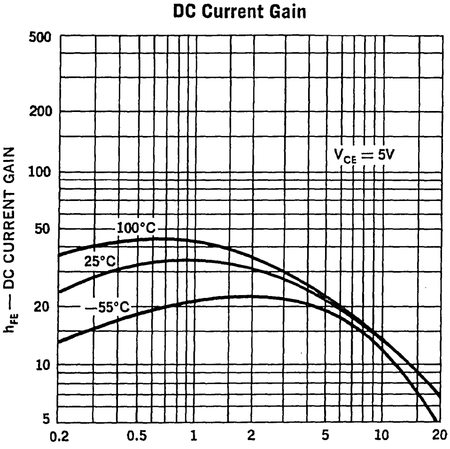
Reverse Biased Safe Operating Area



Saturation Voltages



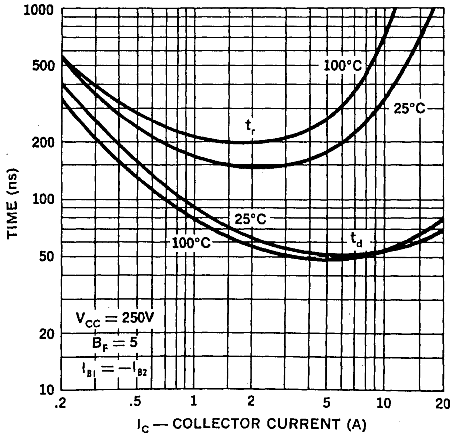
DC Current Gain



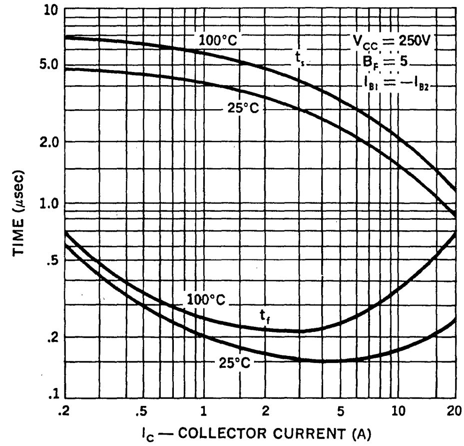
Typical Inductive Load Switching Performance

I_C Amps	T_J °C	t_s μS	t_{fv} nS	t_{fi} nS
3	25 100	.8 1.10	.14 .18	.025 .035
5	25 100	.9 1.2	.14 .16	.025 .030
10	25 100	1.2 1.5	.05 .12	.050 .100

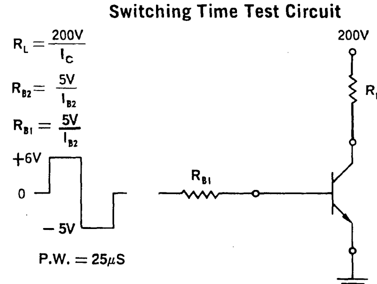
Resistive Turn-On Time



Resistive Turn-Off Time



Switching Time Test Circuit



POWER TRANSISTORS

8 Amp, 700V, Triple Diffused NPN Mesa

2N6306
2N6307
2N6308

FEATURES

- Collector-Base Voltage: up to 700V
- Peak Collector Current: 16A
- Rise Time: ⩽ 600 ns } @ $I_C = 3A$
- Fall Time: ⩽ 400 ns }

DESCRIPTION

These high voltage triple diffused glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

IV

ABSOLUTE MAXIMUM RATINGS *

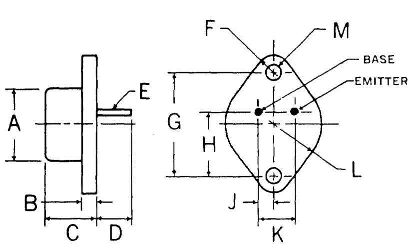
	2N6306	2N6307	2N6308
Collector-Base Voltage, V_{CBO}	500V	600V	700V
Collector-Emitter Voltage, V_{CEO}	250V	300V	350V
Emitter-Base Voltage, V_{EBO}	8V	8V	8V
Collector Current, I_C continuous	8A	8A	8A
Collector Current, I_{CM}, peak	16A	16A	16A
Base Current, I_B, continuous	4A	4A	4A
Power Dissipation, P_T 25°C Case	125W	125W	125W
Operating and Storage Temperature Range		−65 to +200°C	

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

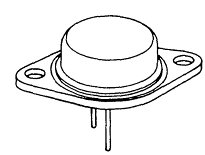
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6306 2N6307 2N6308



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



UNITRODE

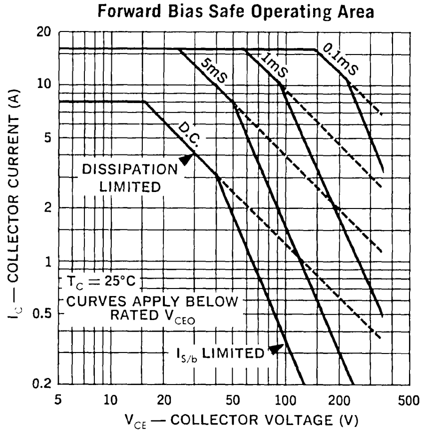
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

Test	Symbol	2N6306 MIN.	2N6306 MAX.	2N6307 MIN.	2N6307 MAX.	2N6308 MIN.	2N6308 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	15	75	15	75	12	60		$I_C = 3A, V_{CE} = 5V$
D.C. Current Gain (Note 1)	h_{FE}	4	—	4	—	3	—		$I_C = 8A, V_{CE} = 5V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	0.8	—	1.0	—	1.5	V	$I_C = 3A, I_B = 0.6A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5.0	—	5.0	—	—	V	$I_C = 8A, I_B = 2A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	—	—	—	—	5.0	V	$I_C = 8A, I_B = 2.67A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	2.3	—	2.3	—	—	V	$I_C = 8A, I_B = 2A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	—	—	—	—	2.5	V	$I_C = 8A, I_B = 2.67A$
Base-Emitter Voltage (Note 1)	$V_{BE(on)}$	—	1.3	—	1.3	—	1.5	V	$I_C = 3A, V_{CE} = 5V$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(SUS)}$	250	—	300	—	350	—	V	$I_C = 100mA, I_B = 0$
Emitter-Base Cutoff Current	I_{EBO}	—	1.0	—	1.0	—	1.0	mA	$V_{EB} = 8V$
Collector Cutoff Current	I_{CEO}	—	0.5	—	—	—	—	mA	$V_{CE} = 250V$
		—	—	—	0.5	—	—		$V_{CE} = 300V$
		—	—	—	—	—	0.5		$V_{CE} = 350V$
Collector Cutoff Current	I_{CEV}	—	0.5	—	—	—	—	mA	$V_{CE} = 500V$, $V_{BE} = -1.5V$
		—	—	—	0.5	—	—		$V_{CE} = 600V$, $V_{BE} = -1.5V$
		—	—	—	—	—	0.5		$V_{CE} = 700V$, $V_{BE} = -1.5V$
Collector Cutoff Current, 150°C	I_{CEV}	—	2.5	—	—	—	—	mA	$V_{CE} = 500V$, $V_{BE} = -1.5V$
		—	—	—	2.5	—	—		$V_{CE} = 600V$, $V_{BE} = -1.5V$
		—	—	—	—	—	2.5		$V_{CE} = 700V$, $V_{BE} = -1.5V$
Second Breakdown Energy	$E_{S/b}$	—	180	—	180	—	180	mJ	$I_C = 3.0A, L = 40\ mH$ $R_{BE} = 3K\Omega, V_{BB2} = 1.5V$
Collector Capacitance	C_{ob}	—	250	—	250	—	250	pF	$V_{CB} = 10V, I_E = 0, f = 1\ MHz$
Gain-Bandwidth Product	f_T	5	—	5	—	5	—	MHz	$I_C = .3A, V_{CE} = 10V, f = 1\ MHz$
Switching Speeds:									
Rise Time	t_r	—	0.6	—	0.6	—	0.6	μs	$V_{CC} = 125V, I_C = 3A$ $I_{B1} = 0.6A$
Storage Time	t_s	—	1.6	—	1.6	—	1.6	μs	$V_{CC} = 125V, I_C = 3A$ $I_{B1} = 0.6A, I_{B2} = 1.5A$ Pulse Width = 25 μs
Storage Time	t_s	—	0.8	—	0.8	—	0.8	μs	$V_{CC} = 125V, I_C = 3A$ $I_{B1} = 0.6A, I_{B2} = 1.5A$ Pulse Width = 5.0 μs
Fall Time	t_f	—	0.4	—	0.4	—	0.4	μs	$V_{CC} = 125V, I_C = 3A$ $I_{B1} = 0.6A, I_{B2} = 1.5A$
Thermal Resistance	$R_{\theta JC}$	—	1.0	—	1.0	—	1.0	°C/W	

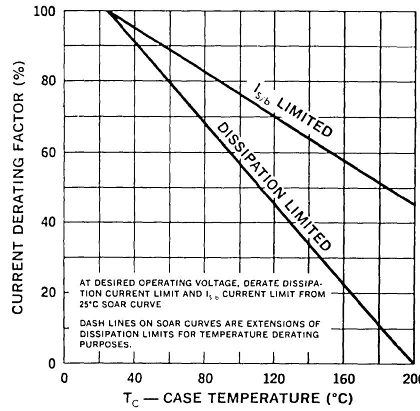
Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

* JEDEC registered values.

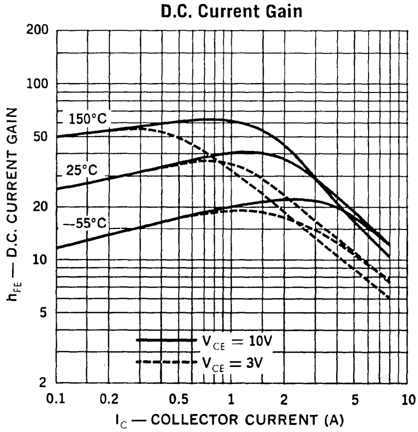
Forward Bias Safe Operating Area



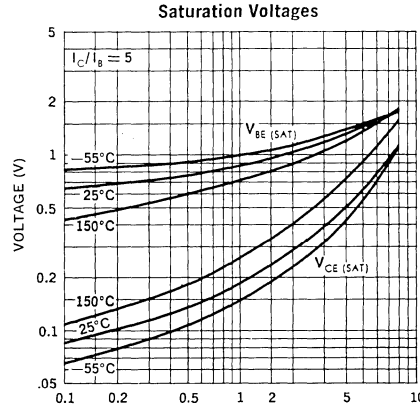
Power Derating



D.C. Current Gain



Saturation Voltages



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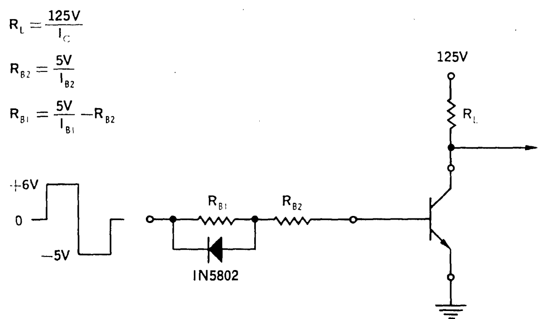
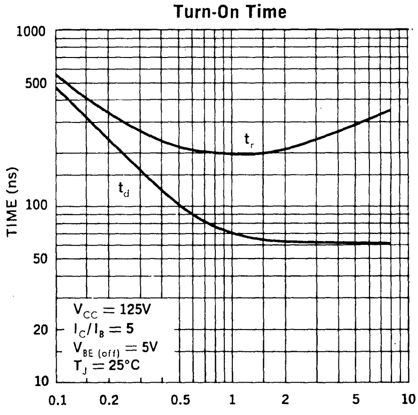
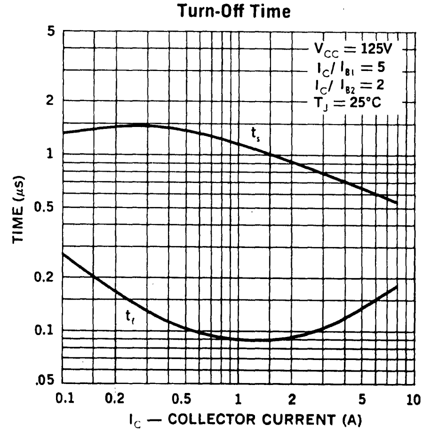
Switching Time Test Circuit



Turn-On Time



Turn-Off Time



POWER DARLINGTONS

5 Amp, 150V, NPN

JAN & JANTX 2N6350
JAN & JANTX 2N6351
JAN & JANTX 2N6352
JAN & JANTX 2N6353

FEATURES

- High Current Gain: up to 2000 min. @ $I_C = 5A$
- Low Saturation Voltage: as low as 1.5V max. @ $I_C = 2A$
- Peak Current: to 10A
- JAN/JANTX versions meet MIL-S-19500/472

DESCRIPTION

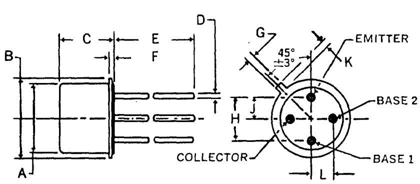
Unitrode NPN Darlingtons consist of a two transistor circuit on a single monolithic planar chip. The 2N6350 series is characterized for fast switching applications.

ABSOLUTE MAXIMUM RATINGS

	TO-33 JAN & JANTX 2N6350	TO-33 JAN & JANTX 2N6351	3 PIN TO-66 JAN & JANTX 2N6352	3 PIN TO-66 JAN & JANTX 2N6353
Collector — Emitter Voltage	80V	150V	80V	150V
Emitter — Base Voltages				
V_{EB2}	6V	6V	6V	6V
V_{EB1}	12V	12V	12V	12V
D.C. Collector Current	5A	5A	5A	5A
Peak Collector Current	10A	10A	10A	10A
Base 1 Current	0.5A	0.5A	0.5A	0.5A
Power Dissipation				
25°C Ambient	1W	1W	2W	2W
100°C Case	5W	5W	25W	25W
Thermal Resistance				
Junction-to-Case	20°C/W		4°C/W	
Operating and Storage Temperature Range	—65°C to 200°C		—65°C to 200°C	

MECHANICAL SPECIFICATIONS

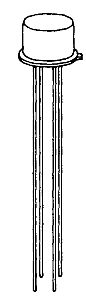
JAN & JANTX 2N6350 JAN & JANTX 2N6351



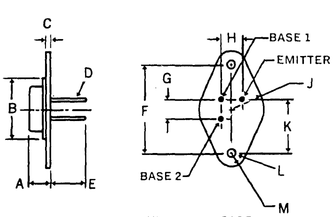
	ins.	mm
A	.305-.335	7.75-8.51
B	.335- 370	8 51-9.40
C	.240- 260	6.10-6.60
D	017 ± 002/.001	.432 ± .051/.025
E	1 5 MIN	38.10 MIN
F	018 MAX	0.46 MAX.
G	031 ± 003	0 79 ± 08
H	200	1 02
J	100	2 54
K	029-.045	0 74-1.14
L	100	2.54

COLLECTOR CONNECTED TO CASE

TO-33



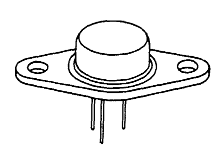
JAN & JANTX 2N6352 JAN & JANTX 2N6353



	ins	mm
A	.250-.340	6.35-8.64
B	.620 MAX.	15 75 MAX.
C	.050-.075	1.27-1.91
D	.028-.034	0.71-0.86
E	.360 MIN.	9 14 MIN.
F	.958-.962	24.33-24.43
G	.190-.210	4.83-5.33
H	.190-.210	4.83-5.33
J	.350 MAX. RAD.	8.89 MAX. RAD.
K	.570-.590	14.48-14.99
L	.142-.152	3.61-3.86
M	.145 MAX. RAD.	3.68 MAX. RAD.

COLLECTOR CONNECTED TO CASE

3 PIN TO-66

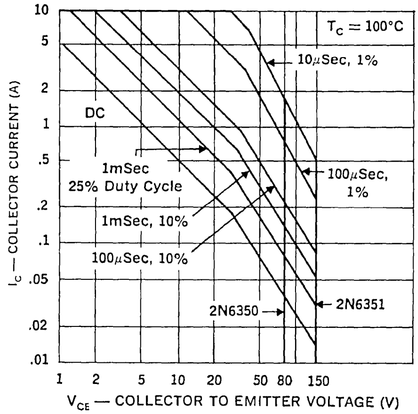


UNITRODE

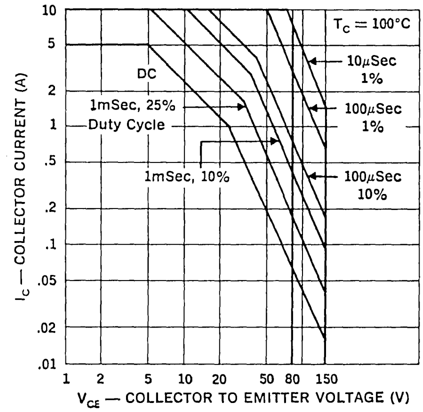
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Max.	Units	MIL-STD-750 Method	MIL-STD-750 Test Conditions
Visual and Mechanical					2071	See Mechanical Data
25°C Collector-Emitter Breakdown Voltage 2N6350, 2N6352 2N6351, 2N6353	BV_{CER}	 80 150		 Vdc Vdc	3011	$I_C = 25mA$, $R_{BE1} = 2.2K$, $R_{BE2} = 100$ Ohms
Emitter Base Breakdown Voltage, Base 1 Emitter Base Breakdown Voltage, Base 2 Collector — Emitter Cutoff Current D.C. Current Gain 2N6350, 2N6352 2N6351, 2N6353	BV_{EBO1} BV_{EBO2} I_{CEX} h_{FE}	12 6 2000 1000	 1.0	Vdc Vdc μAdc	3026 3026 3041 3076	$I_E = 12mA$ Base 1 Open $I_E = 12mA$ Base 2 Open $V_{CE} = BV_{CER}$ Rating $V_{CE} = 5Vdc$; $I_C = 1.0A$ (pulse) $R_{BE2} = 1K$
D.C. Current Gain 2N6350, 2N6352 2N6351, 2N6353	h_{FE}	 2000 1000	 10000 10000		3076	$V_{CE} = 5Vdc$; $I_C = 5.0Adc$ (pulse) $R_{BE2} = 100$ Ohms
D.C. Current Gain 2N6350, 2N6352 2N6351, 2N6353	h_{FE}	 400 200			3076	$V_{CE} = 5Vdc$; $I_C = 10Adc$ (pulse) $R_{BE2} = 100$ Ohms
Collector Saturation Voltage 2N6350, 2N6352 2N6351, 2N6353	V_{CE} (sat)		 1.5 2.5	 Vdc Vdc	3071	$I_C = 5.0Adc$, $R_{BE2} = 100$ Ohms $I_{B1} = 5mAdc$ (pulse) $I_{B1} = 10mAdc$ (pulse)
Base Saturation Voltage A.C. Current Gain Output Capacitance	V_{BE1} (on) $\lvert h_{FE} \rvert$ C_{OBO1}	 5	2.5 25 120	Vdc pf	3066 3066 3236	$I_C = 5.0Adc$ (pulse), $V_{CE} = 5Vdc$ $R_{BE2} = 100$ Ohms $V_{CE} = 10Vdc$, $I_C = 1.0Adc$, $f = 10MHz$ $R_{BE2} = 100$ Ohms $V_{CB1} = 10Vdc$, $100KHz \leqslant f \leqslant 1MHz$ Base 2 open
Turn-on Time Turn-off Time	t_{on} t_{off}		0.5 1.2	μs μs	3251 3251	$V_{CC} = 30Vdc$; $I_C = 5.0Adc$ See Switching Speed Circuit $V_{CC} = 30Vdc$; $I_C = 5.0Adc$ See Switching Speed Circuit
150°C Collector-Emitter Cutoff Current	I_{CEX}		1.0	μAdc	3041	$V_{EB1} = 2Vdc$, $R_{BE2} = 100$ Ohms $V_{CE} = BV_{CER}$ Rating
—65°C D.C. Current Gain 2N6350, 2N6352 2N6351, 2N6353	h_{FE}	 400 200			3076	$V_{CE} = 5Vdc$, $I_C = 5.0Adc$ (pulse) $R_{BE2} = 100$ Ohms

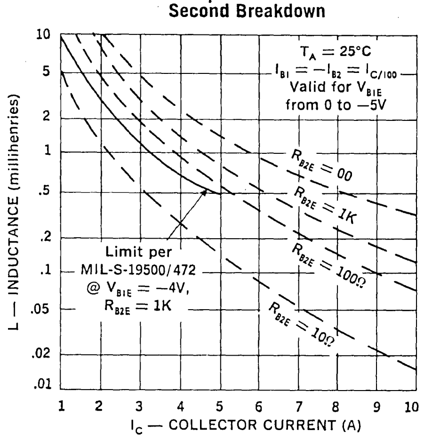
Forward Bias Safe Operating Area 2N6350, 2N6351



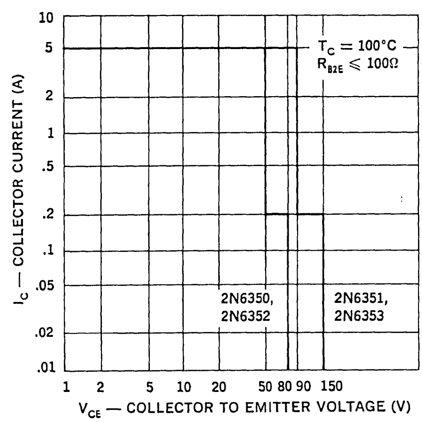
Forward Bias Safe Operating Area 2N6352, 2N6353



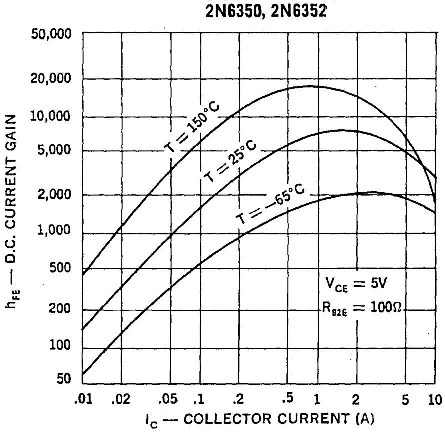
Unclamped Reverse Bias Second Breakdown



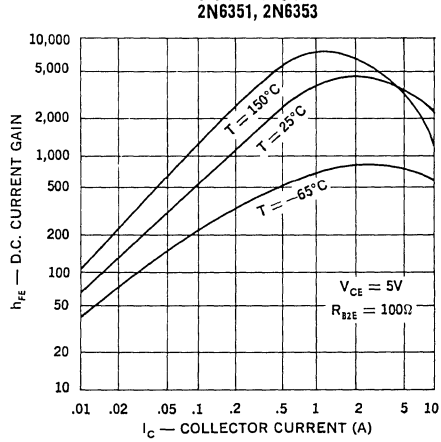
Reverse Bias Safe Operating Area Clamped Inductive Switching



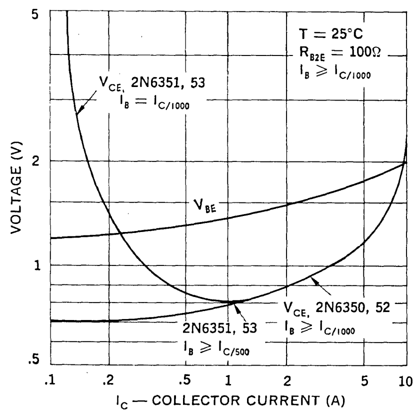
D.C. Current Gain 2N6350, 2N6352



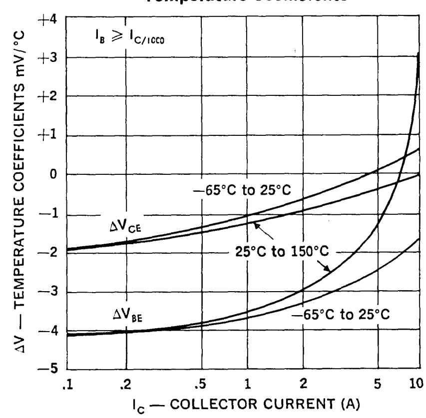
D.C. Current Gain 2N6351, 2N6353



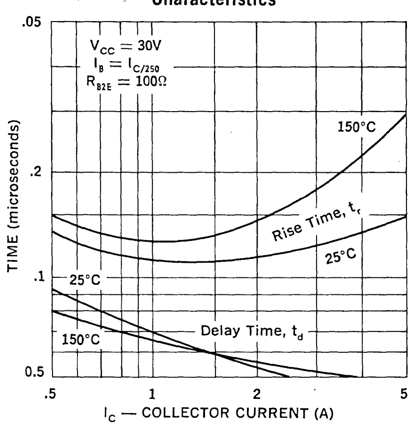
Saturation Voltages



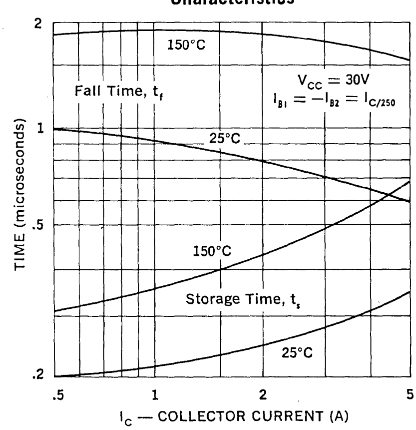
Saturation Voltage Temperature Coefficients



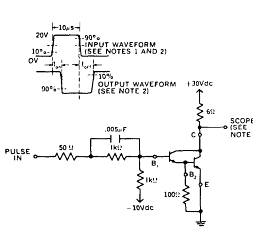
Switching Speed Characteristics



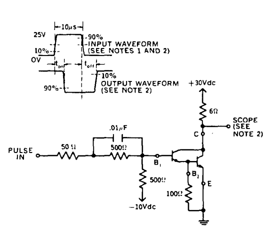
Switching Speed Characteristics



2N6350 & 52 Switching Speed Circuit

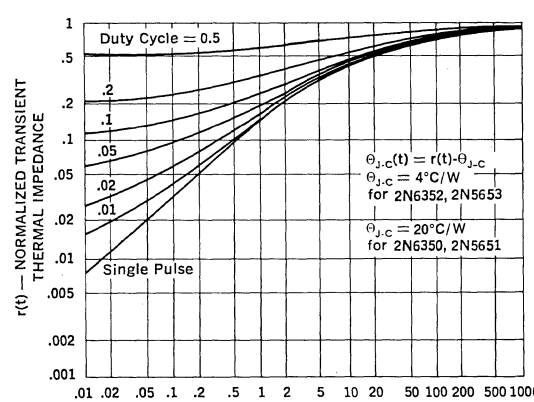


2N6351 & 3 Switching Speed Circuit

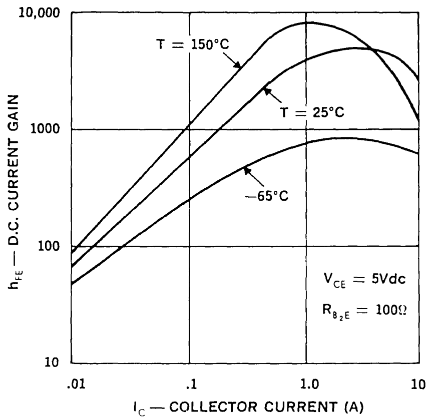


NOTES:
1. The input waveform is supplied by a pulse generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\Omega$, PW = 10 μs, Duty cycle ≤ 2%.
2. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $Z_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
3. Resistors shall be noninductive types.
4. The DC power supplies may require additional by-passing in order to minimize ringing.

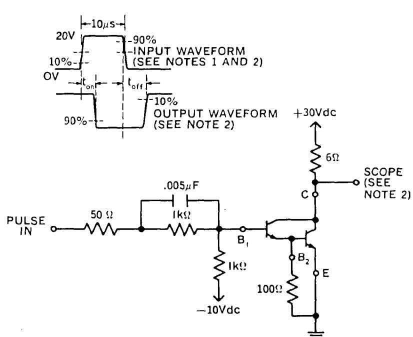
Thermal Response



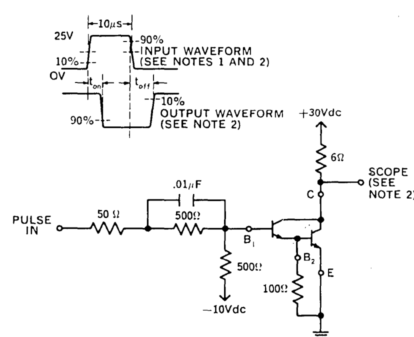
D.C. Current Gain vs. Collector Current
2N6350 — 2N6353



2N6350 & 52 Switching Speed Circuit



2N6351 & 3 Switching Speed Circuit



NOTES:
1. The input waveform is supplied by a pulse generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\Omega$, PW = 10 μs, Duty cycle ⩽ 2%.
2. Output waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $Z_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.
3. Resistors shall be noninductive types.
4. The DC power supplies may require additional by-passing in order to minimize ringing.

POWER TRANSISTORS

20 Amp, 150 V, Double Diffused NPN Mesa

FEATURES

- Collector-Base Voltage: up to 150V
- Peak Collector Current: 30A
- Rise Time: ⩽ 500ns } @ I_C up to 12A
- Fall Time: ⩽ 500ns } @ I_C up to 12A

DESCRIPTION

These double diffused glass passivated mesa power transistors combine fast-switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in switching regulators, converters, inverters and switching-control amplifiers.

ABSOLUTE MAXIMUM RATINGS*

	2N6354	2N6496
Collector-Base Voltage, V_{CBO}	150V	150V
Collector-Emitter Sustaining Voltage, $V_{CER\ (SUS)}$ (1)	—	130V
$V_{CEO\ (SUS)}$	120V	110V
Emitter-Base Voltage, V_{EBO}	6.5V	7V
Collector Current, I_C continuous	10A	15A
Collector Current, I_{CM} peak	12A	—
Base Current, I_B continuous	5A	5A
Power Dissipation, 25°C Case	140W	140W
Operating and Storage Temperature Range	—65 to 200°C	

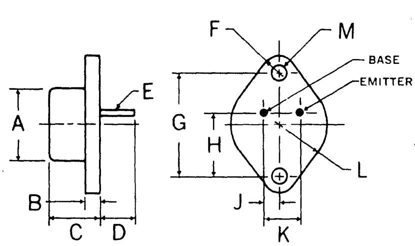
(1) With $R_{BE} \leqslant 50\Omega$

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

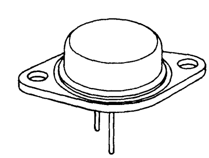
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6354, 2N6496



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



UNITRODE

Electrical Specifications (at 25°C unless noted)

	Test	Symbol	2N6354 MIN.	2N6354 MAX.	2N6496 MIN.	2N6496 MAX.	Units	Test Conditions
*	D.C. Current Gain (Note 1)	h_{FE}	—	—	—	—		$I_C = 2A$, $V_{CE} = 5V$
			20	150	—	—		$I_C = 5A$, $V_{CE} = 2V$
*	D.C. Current Gain (Note 1)	h_{FE}	—	—	12	100		$I_C = 8A$, $V_{CE} = 2V$
			10	100	—	—		$I_C = 10A$, $V_{CE} = 2V$
*	D.C. Current Gain (Note 1)	h_{FE}	—	—	—	—		$I_C = 10A$, $V_{CE} = 5V$
			—	—	—	—		$I_C = 12A$, $V_{CE} = 5V$
*	Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	0.5	—	—	V	$I_C = 5A$, $I_B = .5A$
			—	—	—	1.0		$I_C = 8A$, $I_B = .8A$
	Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	1.0	—	—	V	$I_C = 10A$, $I_B = 1.0A$
	Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	—	—	—	V	$I_C = 12A$, $I_B = 1.2A$
			—	—	—	—		$I_C = 20A$, $I_B = 5A$
	Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	1.3*	—	—	V	$I_C = 5A$, $I_B = 0.5A$
			—	—	—	2.0		$I_C = 8A$, $I_B = 0.8A$
*	Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	2.0	—	—	V	$I_C = 10A$, $I_B = 1A$
			—	—	—	—	V	$I_C = 20A$, $I_B = 5A$
	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	120	—	100	—	V	$I_C = 0.2A$
	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEX\,(sus)}$	—	—	—	—	V	$I_C = 0.2A$, $V_{BE} = -1.5V$, $I_B = 0$, $R_{BE} = 100\ \Omega$
	Collector-Emitter Sustaining Voltage (Note 2)	$V_{CER\,(sus)}$	—	—	130	—	V	$R_{BE} = 50\ \Omega$, $I_C = 0.2A$
			130	—	—	—		$R_{BE} = 100\ \Omega$, $I_C = 0.2A$
*	Emitter-Base Voltage	V_{EBO}	6.5	—	—	—	V	$I_E = 5mA$
			—	—	7.0	—		$I_E = 50mA$
*	Collector Cutoff Current	I_{CBO}	—	5	—	—	mA	$V_{CB} = 150V$
	Collector Cutoff Current	I_{CEO}	—	—	—	—	mA	$V_{CE} = 55V$
			—	—	—	—		$V_{CE} = 70V$
			—	20	—	—		$V_{CE} = 100V$
*	Collector Cutoff Current	I_{CEV}	—	—	—	—	mA	$V_{CE} = 110V$, $V_{BE} = -1.5V$
			—	—	—	20		$V_{CE} = 130V$, $V_{BE} = 0$
			—	—	—	—		$V_{CE} = 140V$, $V_{BE} = -1.5V$
			—	10	—	—		$V_{CE} = 140V$, $V_{BE} = 0$
*	Collector Cutoff Current, 125°C	I_{CEV}	—	20	—	—	mA	$V_{CE} = 140V$
*	Collector Cutoff Current, 150°C	I_{CEV}	—	—	—	—	mA	$V_{CE} = 85V$, $V_{BE} = -1.5V$
			—	—	—	—		$V_{CE} = 100V$, $V_{BE} = -1.5V$
			—	—	—	25		$V_{CE} = 130V$, $V_{BE} = 0V$
*	Emitter Cutoff Current	I_{EBO}	—	—	—	—	mA	$V_{BE} = -5V$
			—	5.0	—	—		$V_{BE} = -6.5V$
			—	—	—	50		$V_{BE} = -7V$
	Magnitude of Small Signal Forward — Current Transfer Ratio	$\|h_{fe}\|$	—	—	12	—		$V_{CE} = 10V$, $I_C = 2A$, $f = 5\ MHz$
			8.0	—	—	—		$V_{CE} = 10V$, $I_C = 1A$, $f = 10\ MHz$
	Collector Capacitance	C_{ob}	—	300	—	300	pF	$V_{CB} = 10V$, $f = 1\ MHz$
	Thermal Resistance: Junction-to-Case	$R_{\Theta JC}$	—	—	—	1.25	°C/W	$V_{CE} = 10V$, $I_C = 10A$
			—	1.25	—	—		$V_{CE} = 20V$, $I_C = 1A$

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%.
   Voltage clamped at maximum collector-emitter voltage.

* JEDEC registered values.

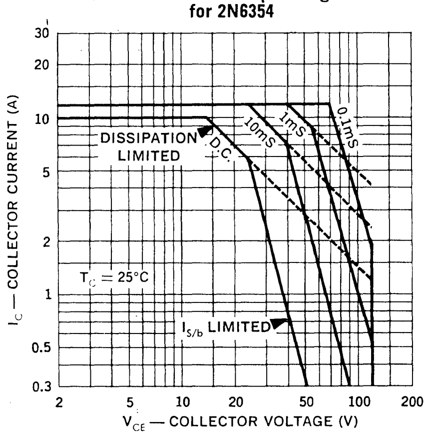
IV

Electrical Specifications (at 25°C unless noted)

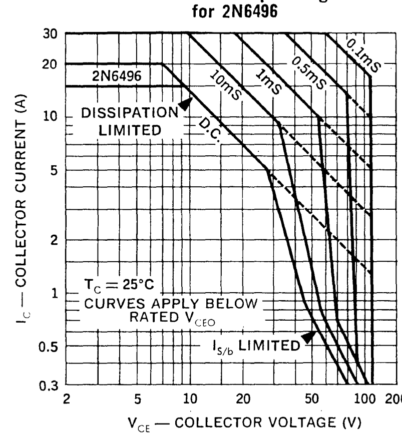
Test	Symbol	2N6354 MIN.	2N6354 MAX.	2N6496 MIN.	2N6496 MAX.	Units	Test Conditions
Second Breakdown Energy	$E_{S/b}$	0.3	—	—	—	mJ	$I_C = 5A$, $V_{BE} = -1.0V$ $R_{BE} = 51\ \Omega$, $L = 25\mu H$
		—	—	5.7	—		$I_C = 8A$, $V_{BE} = -4.0V$ $R_{BE} = 20\ \Omega$, $L = 180\mu H$
		—	—	—	—		$I_C = 13A$, $V_{BE} = -4.0V$ $R_{BE} = 20\ \Omega$, $L = 180\mu H$
Forward Bias Second Breakdown Collector Current	$I_{S/b}$	5.5	—	—	—	A	$V_{CE} = 25V$, $t = 1s$, non-rep.
		—	—	5.0	—		$V_{CE} = 28V$, $t = 1s$, non-rep.
		—	—	0.9	—		$V_{CE} = 45V$, $t = 1s$, non-rep.
* Switching Speeds							
Rise Time	t_r	—	0.3	—	—	μs	$I_C = 5A$
Storage Time	t_s	—	1.0	—	—		$I_{B1} = I_{B2} = .5A$
Fall Time	t_f	—	0.2	—	—		$V_{CC} = 30V$
Rise Time	t_r	—	—	—	0.5	μs	$I_C = 8A$
Storage Time	t_s	—	—	—	1.5		$I_{B1} = I_{B2} = .8A$
Fall Time	t_f	—	—	—	0.5		$V_{CC} = 30V$
Rise Time	t_r	—	—	—	—	μs	$I_C = 10A$
Storage Time	t_s	—	—	—	—		$I_{B1} = I_{B2} = 1.0A$
Fall Time	t_f	—	—	—	—		$V_{CC} = 30V$
Rise Time	t_r	—	—	—	—	μs	$I_C = 12A$
Storage Time	t_s	—	—	—	—		$I_{B1} = I_{B2} = 1.2A$
Fall Time	t_f	—	—	—	—		$V_{CC} = 30V$

* JEDEC registered values.

Forward Bias Safe Operating Area for 2N6354

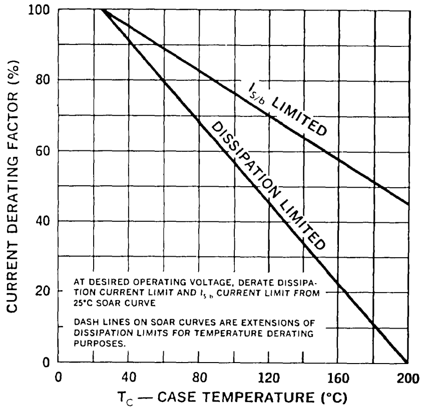


Forward Bias Safe Operating Area for 2N6496

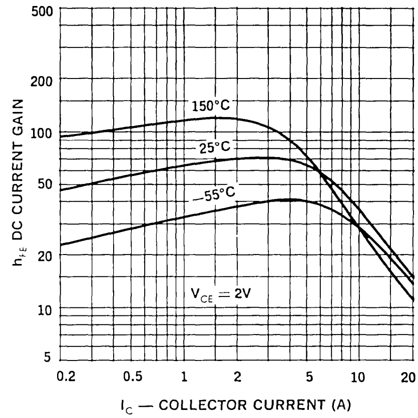


IV

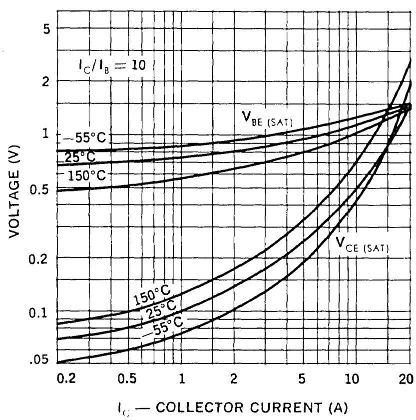
Power Derating



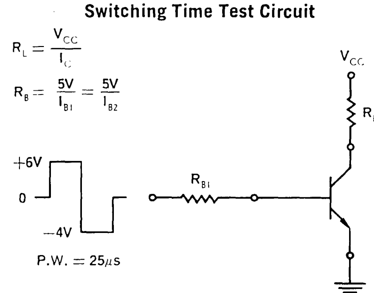
DC Current Gain



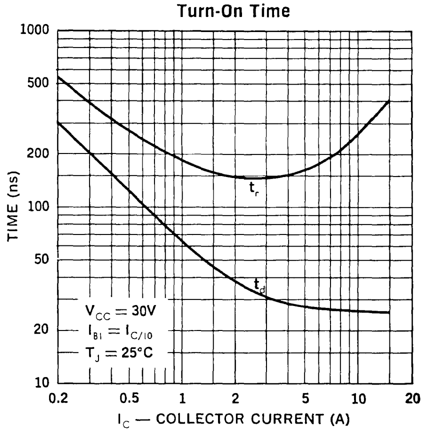
Saturation Voltages



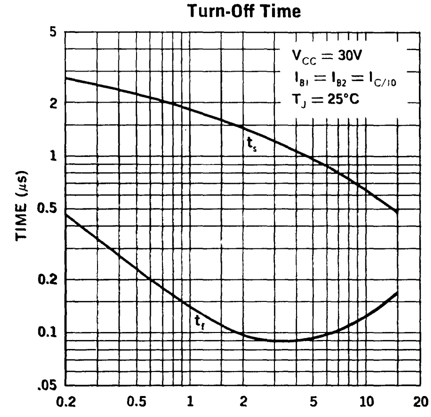
Switching Time Test Circuit



Turn-On Time



Turn-Off Time



POWER TRANSISTORS

7 Amp, 400V, Triple Diffused NPN Mesa

2N6510
2N6511
2N6512
2N6513
2N6514

FEATURES

- Collector-Base Voltage: up to 400V
- Peak Collector Current: 10A
- Rise Time: $\leqslant 1.5\mu s$ } @ $I_C = 4A$
- Fall Time: $\leqslant 1.5\mu s$ } @ $I_C = 4A$

DESCRIPTION

These high voltage triple diffused glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS

	2N6510	2N6511	2N6512	2N6513	2N6514
*Collector Base Voltage, V_{CPO}	250V	300V	350V	400V	350V
Collector-Emitter Sustaining Voltage, $V_{CER\ (sus)\ (1)}$	250V	300V	350V	400V	350V
*Collector-Emitter Sustaining Voltage, $V_{CEO\ (sus)}$	200V	250V	300V	350V	300V
*Emitter-Base Voltage, V_{EBO}	6V	6V	6V	6V	6V
*Collector Current, I_C continuous	7A	7A	7A	7A	7A
*Base Current, I_B	10A	10A	10A	10A	10A
*Emitter Current, I_E	3A	3A	3A	3A	3A
*Power Dissipation, P_T 25°C Case	120W	120W	120W	120W	120W
*Operating and Storage Temperature Range	–65 to +200°C				

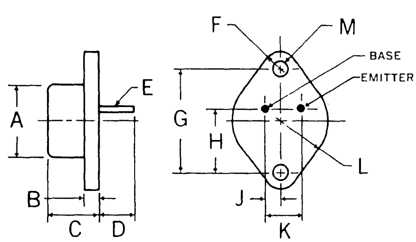
(1) $R_{BE} = 50\Omega$

*JEDEC registered values

MECHANICAL SPECIFICATIONS

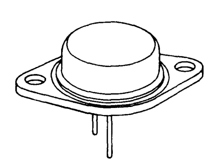
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6510 2N6511 2N6512 2N6513 2N6514



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	2N6510 Min.	2N6510 Max.	2N6514 Min.	2N6514 Max.	Units	Test Conditions
*D.C. Current Gain (Note 1)	h_{FE}	10	50	—	—		$I_C = 3A, V_{CE} = 3V$
		—	—	10	50		$I_C = 5A, V_{CE} = 3V$
*Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.5	—	—	V	$I_C = 3A, I_B = 0.6A$
		—	—	—	1.5		$I_C = 5A, I_B = 1A$
		—	2.5	—	2.5		$I_C = 7A, I_B = 3A$
*Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.7	—	—	V	$I_C = 3A, I_B = 0.6A$
		—	—	—	1.7		$I_C = 5A, I_B = 1A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	200 *	—	300 *	—	V	$I_C = 0.2A$
	$V_{CER(sus)}$	250	—	350	—	V	$I_C = 0.2A, R_{BE} = 50\Omega$
*Collector Cutoff Current	I_{CEV}	—	5.0	—	—	mA	$V_{CE} = 250V, V_{BE} = -1.5V$
		—	—	—	5.0		$V_{CE} = 350V, V_{BE} = -1.5V$
*Collector Cutoff Current 100°C	I_{CEV}	—	10	—	—	mA	$V_{CE} = 250V, V_{BE} = -1.5V$
		—	—	—	10		$V_{CE} = 350V, V_{BE} = -1.5V$
*Switching Speeds							
Delay Time	t_d	—	0.2	—	—	μS	$V_{CC} = 200V$, $I_C = 3A$, $I_{B1} = I_{B2} = 0.6A$
Rise Time	t_r	—	1.5	—	—		
Storage Time	t_s	—	5.0	—	—		
Fall Time	t_f	—	1.5	—	—		
Delay Time	t_d	—	—	—	0.2	μS	$V_{CC} = 200V$, $I_C = 5A$, $I_{B1} = I_{B2} = 1A$
Rise Time	t_r	—	—	—	1.5		
Storage Time	t_s	—	—	—	5.0		
Fall Time	t_f	—	—	—	1.5		

IV

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	2N6511 Min.	2N6511 Max.	2N6512 Min.	2N6512 Max.	2N6513 Min.	2N6513 Max.	Units	Test Conditions
*D.C. Current Gain (Note 1)	h_{FE}	10	50	10	50	10	50		$I_C = 4A, V_{CE} = 3V$
*Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.5	—	1.5	—	1.5	V	$I_C = 4A, I_B = 0.8A$
		—	2.5	—	2.5	—	2.5		$I_C = 7A, I_B = 3A$
*Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.7	—	1.7	—	1.7	V	$I_C = 4A, I_B = 0.8A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	250	—	300	—	350	—	V	$I_C = 0.2A$
	$V_{CER(sus)}$	300	—	350	—	400	—	V	$I_C = 0.2A, R_{BE} = 50\Omega$
*Collector Cutoff Current	I_{CEV}	—	5.0	—	—	—	—	mA	$V_{CE} = 300V, V_{BE} = -1.5V$
		—	—	—	5.0	—	—		$V_{CE} = 350V, V_{BE} = -1.5V$
		—	—	—	—	—	5.0		$V_{CE} = 400V, V_{BE} = -1.5V$
*Collector Cutoff Current, 100°C	I_{CEV}	—	10	—	—	—	—	mA	$V_{CE} = 300V, V_{BE} = -1.5V$
		—	—	—	10	—	—		$V_{CE} = 300V, V_{BE} = -1.5V$
		—	—	—	—	—	10		$V_{CE} = 400V, V_{BE} = -1.5V$
*Switching Speeds									
Delay Time	t_d	—	0.2	—	0.2	—	0.2	μS	$V_{CC} = 200V$, $I_C = 4A$, $I_{B1} = I_{B2} = 0.8A$
Rise Time	t_r	—	1.5	—	1.5	—	1.5		
Storage Time	t_s	—	5.0	—	5.0	—	5.0		
Fall Time	t_f	—	1.5	—	1.5	—	1.5		

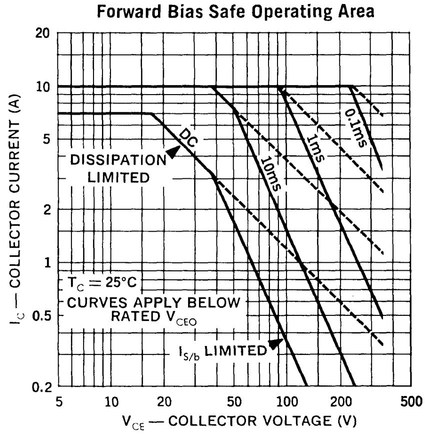
Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.
* JEDEC registered values.

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

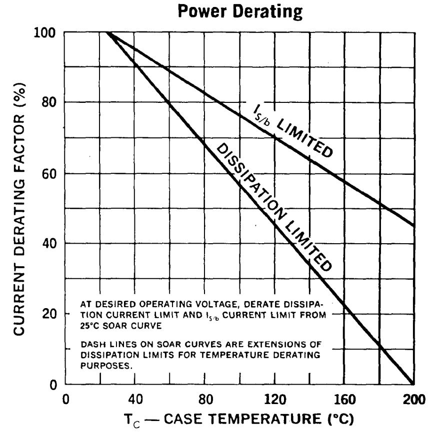
Test	Symbol	All Types Min.	All Types Max.	Units	Test Conditions
Emitter-Base Cutoff Current	I_{EBO}	—	3.0	mA	$V_{EB} = 6V$
Magnitude of Common Emitter Small-Signal Short Circuit Forward Current Transfer Ratio	$\|h_{fe}\|$	3	9		$I_C = 1A$, $V_{CE} = 10V$, $f = 1MHz$
Forward-Bias Second Breakdown Collector Current	$I_{s/b}$	3.16	—	A	$V_{CE} = 35V$, $t = 1s$, non-rep.
		0.1	—	A	$V_{CE} = 200V$, $t = 1s$, non-rep.
Collector Capacitance	C_{ob}	100	200	pF	$V_{CB} = 10V$, $f = 1MHz$
Thermal Resistance, Junction-to-Case	$R\theta_{JC}$	—	1.46	°C/W	$V_{CE} = 20V$, $I_C = 5A$

* All values in this table are JEDEC registered.

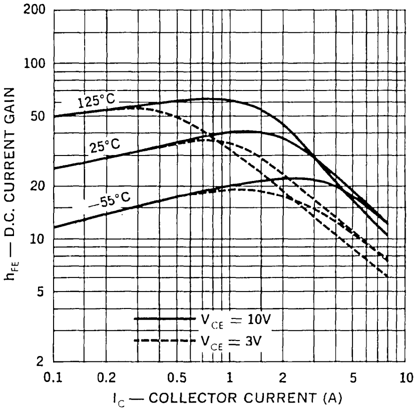
Forward Bias Safe Operating Area



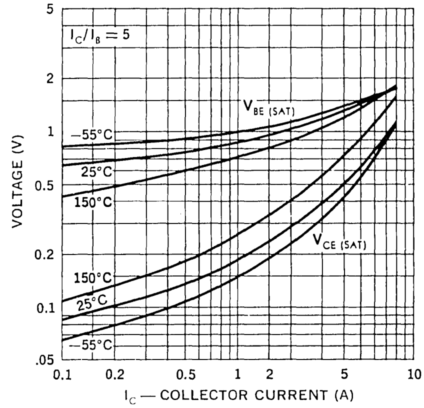
Power Derating



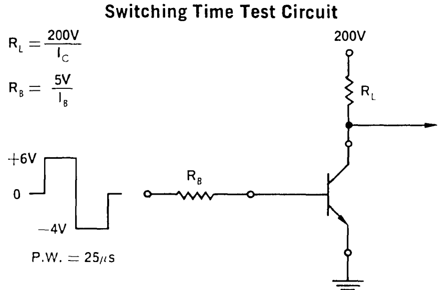
D.C. Current Gain



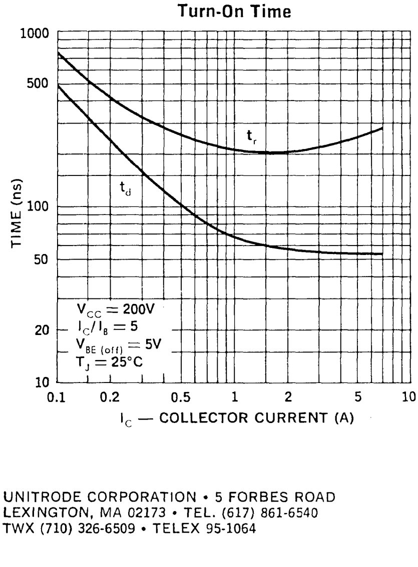
Saturation Voltages



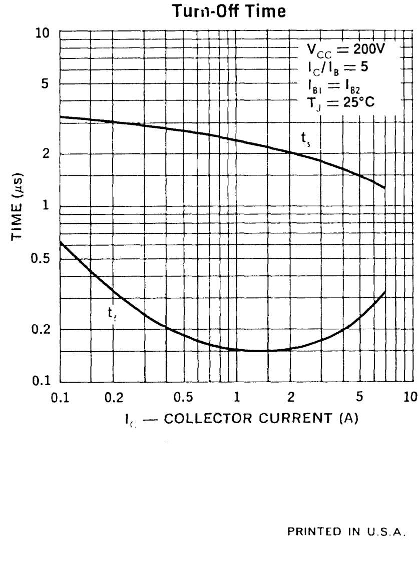
Switching Time Test Circuit



Turn-On Time



Turn-Off Time



POWER TRANSISTORS
5A, 850V, Fast Switching, Silicon NPN Mesa

FEATURES
- Collector-Base Voltage: up to 850V
- Peak Collector Current: 10A
- Rise Time: ≤0.7μS } @ I_C = 3A
- Fall Time: ≤0.8μS } @ I_C = 3A
- Key Parameters characterized at 100°C

DESCRIPTION
These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged E_{S/I_b} capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS *

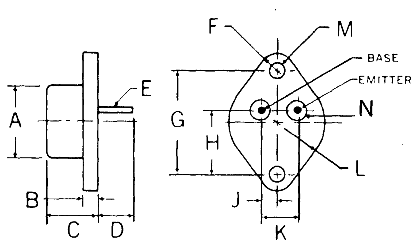
	2N6542	2N6543
Collector-Base Voltage, V_{CBO}	650V	850V
Collector-Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter-Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C, continuous	5A	5A
Collector Current, I_C peak	10A	10A
Base Current, I_B, continuous	5A	5A
Power Dissipation, 25°C Case	100W	100W
Derating Factor	.571W/°C	.571W/°C
Operating and Storage Temperature Range	—65 to 200°C	

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

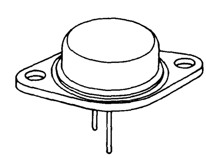
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6542 2N6543



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.
N	.190-.210	4.83-5.33

TO-3



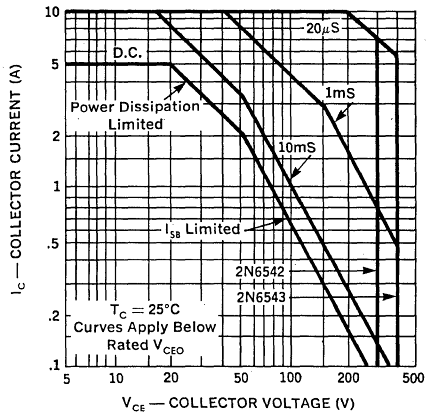
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

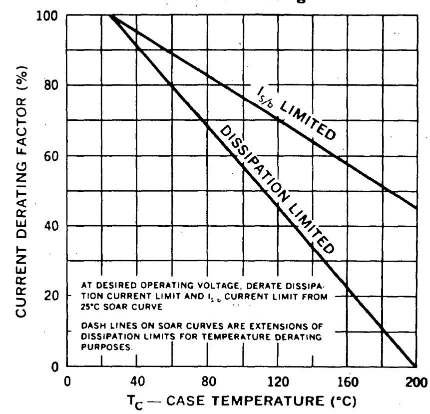
Test	Symbol	2N6542 MIN.	2N6542 MAX.	2N6543 MIN.	2N6543 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 1.5A, V_{CE} = 2V$
D.C. Current Gain (Note 1)	h_{FE}	7	35	7	35		$I_C = 3.0A, V_{CE} = 2V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 3.0A, I_B = 0.6A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE(sat)}$	—	2.0	—	2.0	V	$I_C = 3.0A, I_B = 0.6A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5.0	—	5.0	V	$I_C = 5.0A, I_B = 1.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.4	—	1.4	V	$I_C = 3.0A, I_B = 0.6A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE(sat)}$	—	1.4	—	1.4	V	$I_C = 3.0A, I_B = 0.6A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 0.1A, I_B = 0$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX(sus)}$	350	—	450	—	V	$L = 180\mu H, I_C = 2.6A$ $V_{BE} = -5V$ V_{CE} clamped to rated $V_{CEX(sus)}$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX(sus)}$	200	—	300	—	V	$L = 180\mu H, I_C = 5A$ $V_{BE(off)} = -5V$ V_{CE} clamp to V_{CEO} —100V
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	0.5	—	—	mA	$V_{CE} = 650V, V_{BE} = -1.5V$
		—	—	—	0.5		$V_{CE} = 850V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	2.5	—	—	mA	$V_{CE} = 650V, V_{BE} = -1.5V$
		—	—	—	2.5		$V_{CE} = 850V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	—	3.0	—	—	mA	$V_{CE} = 650V, R = 50\Omega$
		—	—	—	3.0		$V_{CE} = 850V, R = 50\Omega$
Output Capacitance, Common Base	C_{obo}	50	150	50	150	pF	$V_{CB} = 10V, f = 1$ MHz
Gain-Bandwidth Product	F_T	6	24	6	24	MHz	$V_{CE} = 10V, I_C = 0.2A, f = 1$ MHz
Forward Bias Second Breakdown	$I_{s/b}$	200	—	200	—	mA	P.W. = 1 sec. single shot $V_{CE} = 100V$
Energy Second Breakdown (unclamped)	$E_{s/b}$	180	—	180	—	μJ	$I_C = 3.0A$ $L = 40\mu H, V_{BE(off)} = 4.0$ Vdc
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 0.05 0.7 4.0 0.8	 — — — —	 0.05 0.7 4.0 0.8	μS	$I_C = 3.0A, t_p = 100\mu sec$ $V_{CC} = 125V$ $I_{B1} = I_{B2} = 0.6A$ $V_{BE(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_f t_s	 — —	 4.0 0.8	 — —	 4.0 0.8	μS	$I_C = 3.0A$ $I_B = 0.6A, V_{BE(off)} = 5.0$ Vdc $V_{BE(off)} = 5V$ V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R_{\Theta JC}$	—	1.75	—	1.75	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.
* JEDEC registered values.

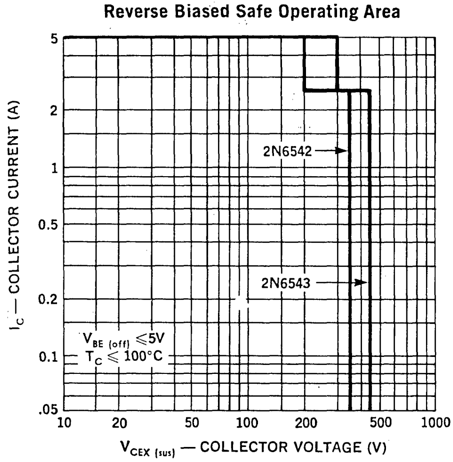
Forward Bias Safe Operating Area



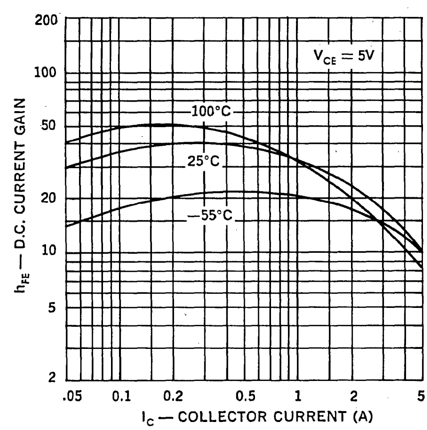
Power Derating



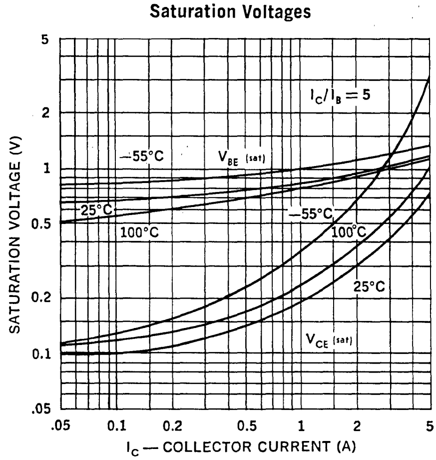
Reverse Biased Safe Operating Area



D.C. Current Gain



Saturation Voltages

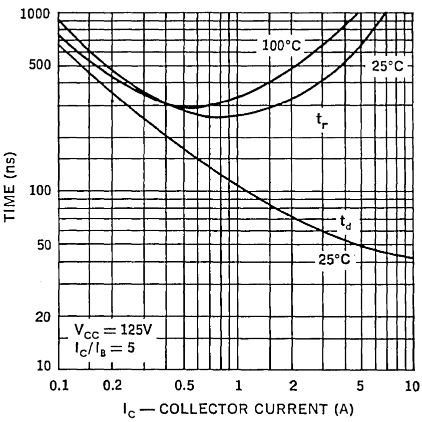


Typical Inductive Load Switching Performance

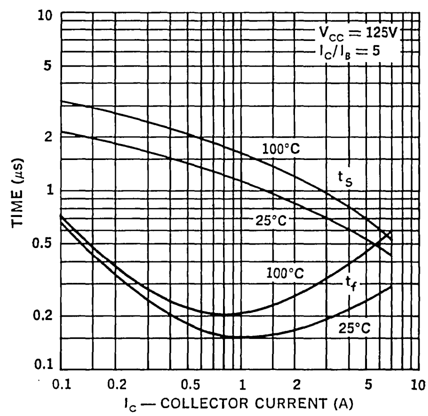
I_C Amps	T_J °C	t_s μS	t_{fv} nS	t_{fi} nS
3.0	25 100	.45 .575	70 100	10 20
5.0	25 100	.475 .60	25 45	4 10
8.0	25 100	.525 .625	20 45	10 15

IV

Resistive Turn-On Time



Resistive Turn-Off Time



TEST CONDITIONS FOR DYNAMIC PERFORMANCE

	$V_{CEO(SUS)}$	$V_{CEX(SUS)}$ AND INDUCTIVE SWITCHING	$E_{S/b}$	RESISTIVE SWITCHING
INPUT CONDITIONS	+10V, 20Ω, 1, 0, 2; PW Varied to Attain $I_C = 100mA$	Drive Circuit: +4V, PW, −4V, 1k, 0.01μF, 20, 100, 0.1μF, 20, 0.5μF, 100, Q1, Q2, Q3, Q4, $+V_{in}$, 1, 2, −5V. Set $+V_{in}$ to Obtain a Forced $h_{FE} = 5$ and Adjust PW to Attain Specified Peak I_C. Duty Cycle ≤ 3%, f = 1kHz. Q1 2N6408, Q3 2N5875, Q2 2N6406, Q4 2N5877, Diodes 1N4933	$I_{B1} = 1A$, +22.5V, 0, 15Ω, 1, 50Ω, 4V, 2; PW Varied to Attain I_C	≈ +13V, 0, ≈ −11V, 1, 2; $I_C = 3A$; PW ≤ 100μs; t_r ≤ 5ns; t_f ≤ 50ns; Duty Cycle ≤ 2%
CIRCUIT VALUES	L_{coil} = 80mH V_{CC} = 10V; R_{coil} = 0.7Ω; V_{clamp} (Unclamped)	L_{coil} = 180μH; R_{coil} = 0.05Ω; V_{CC} = 20V; f_o = 500kHz; V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40μH V_{CC} = 10V; R_{coil} = 0.2Ω; V_{clamp} (Unclamped)	V_{CC} = 250V; R_L = 83Ω; D1 = 1N5820 or Equiv.; R_B = 20Ω
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT: TUT, 1, Input, 2, 1N4937 or Equivalent, R_{coil}, L_{coil}, V_{clamp}, V_{CC}, R_S 0.1Ω. See Above For Detailed Conditions	OUTPUT WAVEFORMS: I_C, $I_{C(pk)}$, t_f Clamped, t_f Unclamped ≈ t_2, t, t_1, t_f; V_{CE}, V_{CE} or V_{clamp}, Time, t_2	t_1 Adjusted to Obtain I_C; $t_1 \approx \frac{L_{coil}(I_{Cpk})}{V_{CC}}$; $t_2 \approx \frac{L_{coil}(I_{Cpk})}{V_{clamp}}$; Test Equipment Tektronix Scope 475 or Equivalent	RESISTIVE TEST CIRCUIT: R_B, TUT, 1, 2, D1, −5V, R_L, V_{CC}

POWER TRANSISTORS

8 Amp, 850V, Triple Diffused, NPN, Mesa

2N6544
2N6545

FEATURES

- Collector-Base Voltage: up to 850V
- Peak Collector Current: 16A
- Rise Time: ≤ 1.0µs } @ I_C = 5A
- Fall Time: ≤ 1.0µs } @ I_C = 5A
- Key Parameters characterized at 100°C

DESCRIPTION

These high voltage triple diffused glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS *

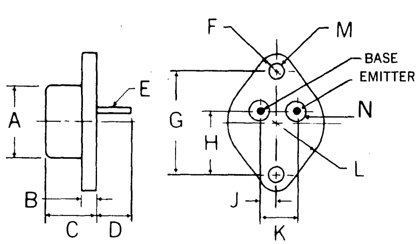
	2N6544	2N6545
Collector-Base Voltage, V_{CBO}	650V	850V
Collector-Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter-Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C, continuous	8A	8A
Base Current, I_B, continuous	8A	8A
Emitter Current, I_E, continuous	16A	16A
Power Dissipation, 25°C Case	125W	125W
Derating Factor	.714W/°C	.714W/°C
Operating and Storage Temperature Range	—65 to 200°C	

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

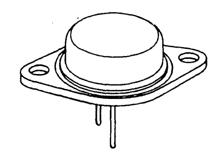
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6544 2N6545



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.
N	.190-.210	4.83-5.33

TO-3



UNITRODE

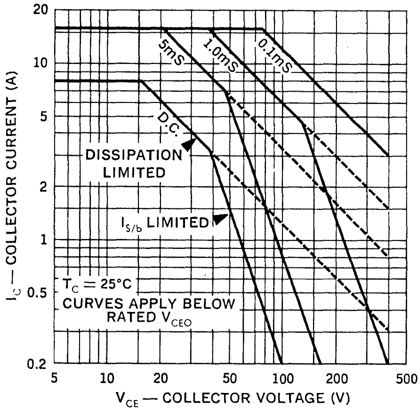
IV

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

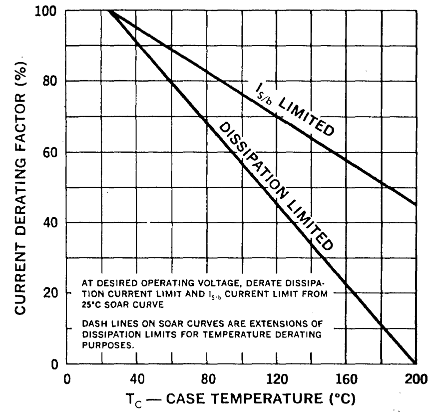
Test	Symbol	2N6544 MIN.	2N6544 MAX.	2N6545 MIN.	2N6545 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 2.5A, V_{CE} = 3V$
D.C. Current Gain (Note 1)	h_{FE}	7	35	7	35		$I_C = 5.0A, V_{CE} = 3V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.5	—	1.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE(sat)}$	—	2.5	—	2.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5.0	—	5.0	V	$I_C = 8.0A, I_B = 2.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A, I_B = 1.0A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A, I_B = 1.0A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 0.1A$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX(sus)}$	350	—	450	—	V	$L = 180\mu H, I_C = 4.5A$ $V_{BE} = -5V$ V_{CE} clamped to rated $V_{CEX(sus)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	0.5	—	—	mA	$V_{CE} = 650V, V_{BE} = -1.5V$
		—	—	—	0.5		$V_{CE} = 850V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	2.5	—	—	mA	$V_{CE} = 650V, V_{BE} = -1.5V$
		—	—	—	2.5		$V_{CE} = 850V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	—	3.0	—	—	mA	$V_{CE} = 650V, R = 50\Omega$
		—	—	—	3.0		$V_{CE} = 850V, R = 50\Omega$
Output Capacitance, Common Base	C_{obo}	100	200	100	200	pF	$V_{CB} = 10V, f = 1\ MHz$
Gain-Bandwidth Product	F_T	6	24	6	24	MHz	$V_{CE} = 10V, I_C = 0.3A, f = 1\ MHz$
Energy Second Breakdown (unclamped)	$E_{S/b}$	500	—	500	—	μJ	$I_C = 5.0A$ $I_B = 1.0A$ $L = 40\mu H$
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 0.05 1.0 4.0 1.0	 — — — —	 0.05 1.0 4.0 1.0	μS	$I_C = 5.0A$ $V_{CC} = 125V$ $I_{B1} = I_{B2} = 1.0A$ $V_{BE(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 4.0 0.9	 — —	 4.0 0.9	μS	$I_C = 5.0A$ $I_B = 1.0A$ $V_{BE(off)} = 5V$ V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	—	1.4	—	1.4	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.
* JEDEC registered values.

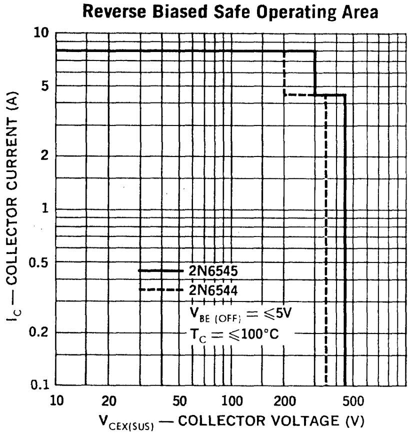
Forward Bias Safe Operating Area



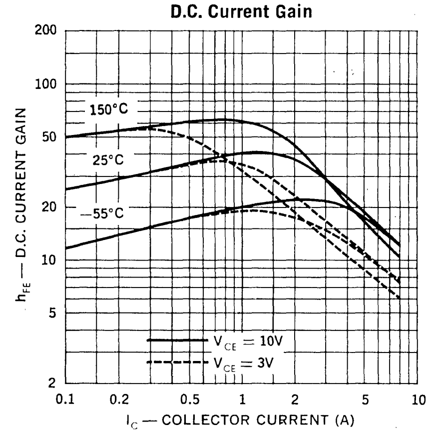
Power Derating



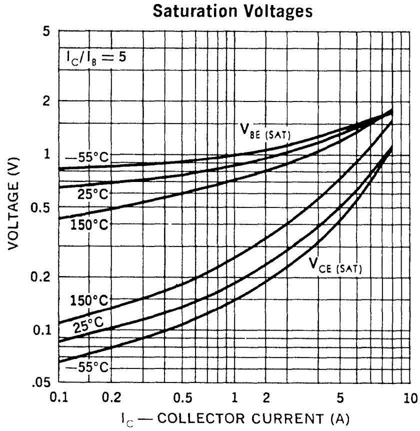
Reverse Biased Safe Operating Area



D.C. Current Gain



Saturation Voltages



Inductive Load Switching Performance

I_C Amps	T_J °C	t_s µs	t_{fv} µs	t_{fi} µs
3.0	25 100	.90 1.40	.07 .12	.07 .15
5.0	25 100	.98 1.52	.10 .15	.11 .20
8.0	25 100	1.10 1.70	.14 .20	.11 .18

t_{fv} = voltage fall time; 10-90%
t_{fi} = current fall time; 10-90%

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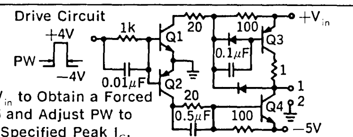
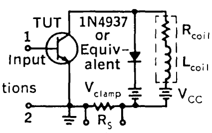
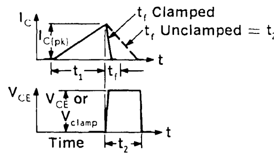
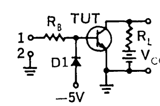
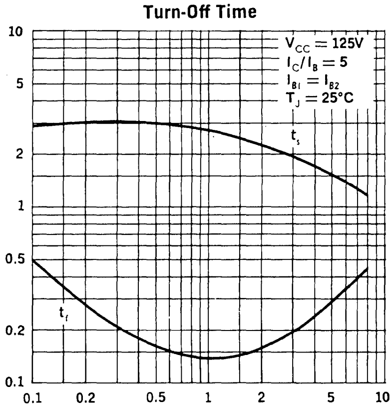
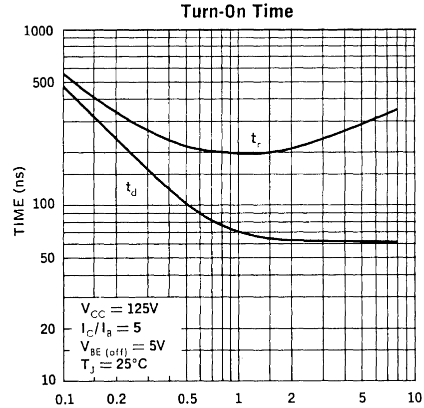
IV

TEST CONDITIONS FOR DYNAMIC PERFORMANCE

	$V_{CEO(SUS)}$	$V_{CEX\ (SUS)}$ AND INDUCTIVE SWITCHING	$E_{S/b}$	RESISTIVE SWITCHING
INPUT CONDITIONS	+10V, 20Ω, 1, 0, 2 PW Varied to Attain $I_C = 100mA$	Drive Circuit  Set $+V_{in}$ to Obtain a Forced $h_{FE} = 5$ and Adjust PW to Attain Specified Peak I_C. Duty Cycle ≤ 3% f = 1kHz Q1 2N6408 Q3 2N5875 Q2 2N6406 Q4 2N5877 Diodes 1N4933	$I_{B1} = 1A$, 15Ω, 1, +22.5V, 50Ω, 0, 4V, 2 PW Varied to Attain I_C	≈ +13V, 1, 0, ≈ −11V, 2 $I_C = 3A$ PW ≤ 100μs t_r ≤ 5ns t_f ≤ 50ns Duty Cycle ≤ 2%
CIRCUIT VALUES	$L_{coil} = 80mH$ $V_{CC} = 10V$ $R_{coil} = 0.7Ω$ V_{clamp} (Unclamped)	$L_{coil} = 180μH$ $R_{coil} = 0.05Ω$ $V_{CC} = 20V$ $f_o = 500kHz$ V_{clamp} = Rated V_{CEX} Value	$L_{coil} = 40μH$ $V_{CC} = 10V$ $R_{coil} = 0.2Ω$ V_{clamp} (Unclamped)	$V_{CC} = 250V$ $R_L = 83Ω$ D1 = 1N5820 or Equiv. $R_B = 20Ω$
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  See Above For Detailed Conditions	OUTPUT WAVEFORMS 	t_1 Adjusted to Obtain I_C $t_1 \approx \frac{L_{coil}\ (I_{Cpk})}{V_{CC}}$ $t_2 \approx \frac{L_{coil}\ (I_{Cpk})}{V_{clamp}}$ Test Equipment Tektronix Scope 475 or Equivalent	RESISTIVE TEST CIRCUIT 





POWER TRANSISTORS

15A, 850V, Fast Switching, Silicon NPN Mesa

2N6546
2N6547

FEATURES

- Collector-Base Voltage: up to 850V
- Peak Collector Current: 30A
- Rise Time: $\leqslant 0.7\mu S$ } @ $I_C = 10A$
- Fall Time: $\leqslant 0.7\mu S$ } @ $I_C = 10A$
- Key Parameters characterized at 100°C

DESCRIPTION

These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS *

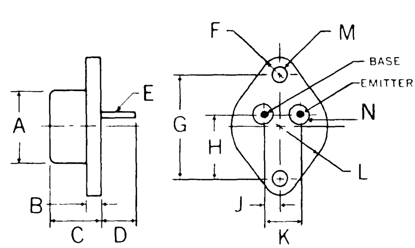
	2N6546	2N6547
Collector-Base Voltage, V_{CBO}	650V	850V
Collector-Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter-Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C, continuous	15A	15A
Collector Current, I_C peak	30A	30A
Base Current, I_B, continuous	10A	10A
Emitter Current, I_E, continuous	25A	25A
Power Dissipation, 25°C Case	175W	175W
Derating Factor	1W/°C	1W/°C
Operating and Storage Temperature Range	−65 to 200°C	

* JEDEC registered values.

MECHANICAL SPECIFICATIONS

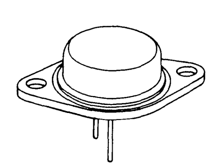
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6546 2N6547



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.
N	.190-.210	4.83-5.33

TO-3



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

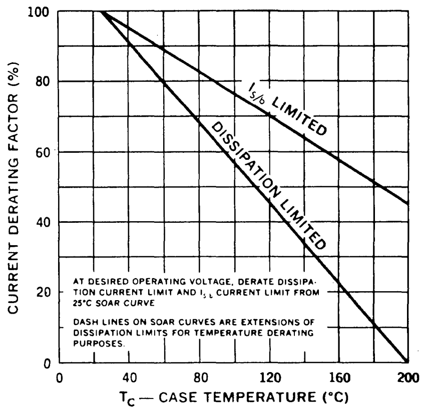
IV

Test	Symbol	2N6546 MIN.	2N6546 MAX.	2N6547 MIN.	2N6547 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 5.0A$, $V_{CE} = 2.0V$
D.C. Current Gain (Note 1)	h_{FE}	6	30	6	30		$I_C = 10A$, $V_{CE} = 2.0V$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	1.5	—	1.5	V	$I_C = 10A$, $I_B = 2.0A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE\,(sat)}$	—	2.5	—	2.5	V	$I_C = 10A$, $I_B = 2.0A$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	5.0	—	5.0	V	$I_C = 15A$, $I_B = 3.0A$
Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	1.6	—	1.6	V	$I_C = 10A$, $I_B = 2.0A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE\,(sat)}$	—	1.6	—	1.6	V	$I_C = 10A$, $I_B = 2.0A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	300	—	400	—	V	$I_C = 0.1A$, $I_B = 0$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX\,(sus)}$	350	—	450	—		$L = 180\mu H$, $I_C = 8.0A$ $V_{BE} = 5V$, $I_B = 2.0A$ V_{CE} clamped to rated $V_{CEX\,(sus)}$
Collector-Emitter Sustaining Voltage $T_C = 100°C$	$V_{CEX\,(sus)}$	200	—	300	—	V	$L = 180\mu H$, $I_C = 15A$ $V_{BE} = -5V$, $I_B = 3.0A$ V_{CE} clamp to V_{CEO} −100V
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	— —	1 —	— —	— 1	mA	$V_{CE} = 650V$, $V_{BE} = -1.5V$ $V_{CE} = 850V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	— —	4 —	— —	— 4	mA	$V_{CE} = 650V$, $V_{BE} = -1.5V$ $V_{CE} = 850V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	— —	5 —	— —	— 5	mA	$V_{CE} = 650V$, $R = 50\Omega$ $V_{CE} = 850V$, $R = 50\Omega$
Output Capacitance, Common Base	C_{obo}	180	360	180	360	pF	$V_{CB} = 10V$, $f = 1$ MHz
Gain-Bandwidth Product	F_T	6	24	6	24	MHz	$V_{CE} = 10V$, $I_C = 0.5A$, $f = 1$ MHz
Energy Second Breakdown (unclamped)	$E_{S/b}$	2	—	2	—	mJ	$I_C = 10A$ $V_{BE\,(off)} = 4.0V$ $L = 40\mu H$
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 0.05 0.7 4.0 0.7	 — — — —	 0.05 0.7 4.0 0.7	μS	$I_C = 10A$ $V_{CC} = 250V$ $I_{B1} = I_{B2} = 2.0A$ $V_{BE\,(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 5.0 1.5	 — —	 5.0 1.5	μS	$I_C = 10A$ $I_B = 2.0A$ $V_{BE\,(off)} = 5V$ V_{CE} clamp = rated $V_{CEX\,(sus)}$
Inductive Switching Speeds $T_C = 25°C$ Storage Time Fall Time	 t_s t_f	 2.0 typical 0.09 typical				μS	$I_C = 10A$ (pk) V_{CE} clamp = rated V_{CEX} $I_{B1} = 2.0A$ $V_{BE\,(off)} = 5.0$ Vdc $T_C = 25°C$
Thermal Resistance, Junction-to-Case	$R\Theta_{JC}$	—	1.0	—	1.0	°C/W	

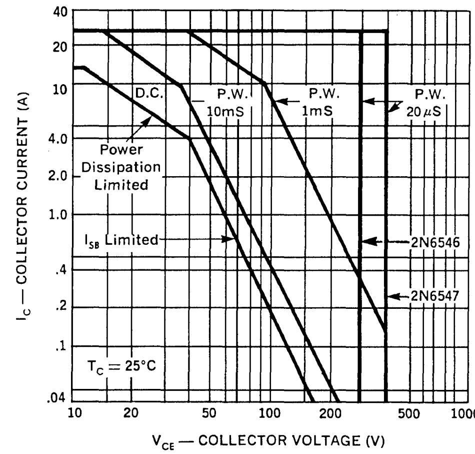
Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

* JEDEC registered values.

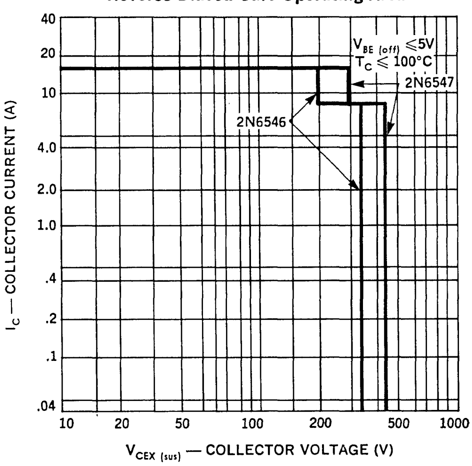
Power Derating



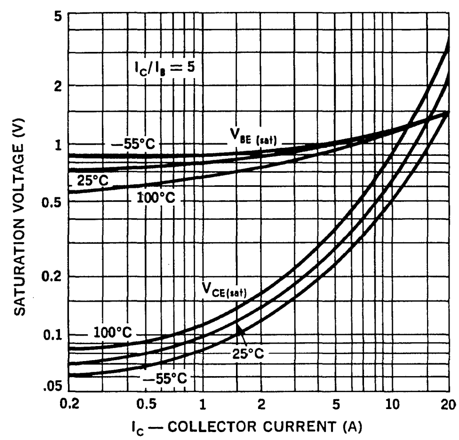
Forward Bias Safe Operating Area



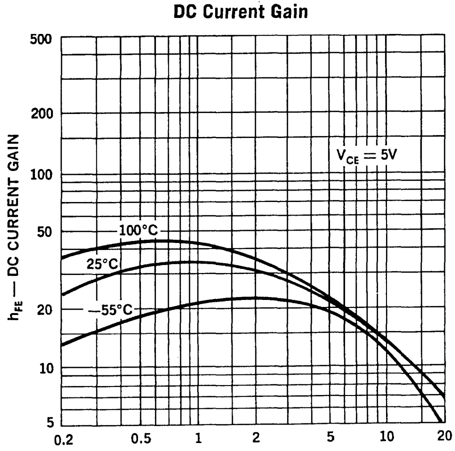
Reverse Biased Safe Operating Area



Saturation Voltages



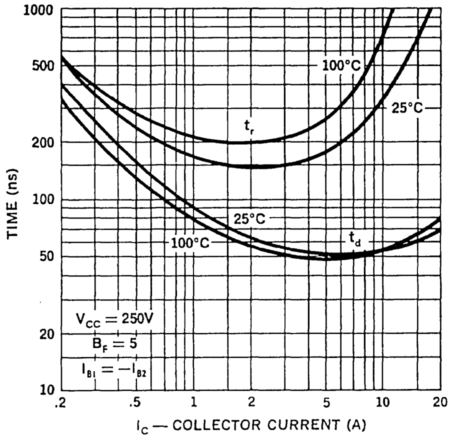
DC Current Gain



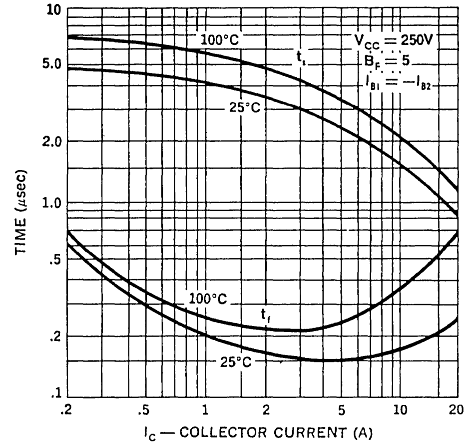
Typical Inductive Load Switching Performance

I_C Amps	T_J °C	t_s µS	t_{fv} nS	t_{fi} nS
3	25 100	.8 1.10	.14 .18	.025 .030
5	25 100	.90 1.20	.14 .16	.025 .030
10	25 100	1.20 1.50	.05 .12	.050 .10

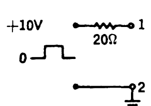
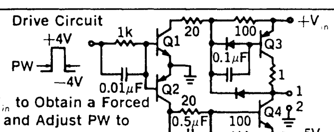
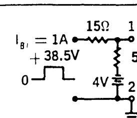
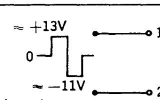
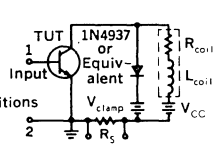
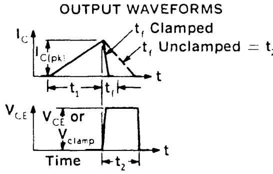
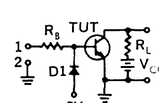
Resistive Turn-On Time



Resistive Turn-Off Time



TEST CONDITIONS FOR DYNAMIC PERFORMANCE

	$V_{CEO(SUS)}$	$V_{CEX(SUS)}$ AND INDUCTIVE SWITCHING	$E_{S/b}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain $I_C = 100mA$	 Set $+V_{in}$ to Obtain a Forced $h_{FE} = 5$ and Adjust PW to Attain Specified Peak I_C. Duty Cycle ≤ 3% f = 1kHz Q1 2N6408 Q3 2N5875 Q2 2N6406 Q4 2N5877 Diodes 1N4933	 PW Varied to Attain I_C	 $I_C = 10A$ PW ≤ 100μs t_r ≤ 5ns t_f ≤ 50ns Duty Cycle ≤ 2%
CIRCUIT VALUES	$L_{coil} = 80mH$ $V_{CC} = 10V$ $R_{coil} = 0.7Ω$ V_{clamp} (Unclamped)	$L_{coil} = 180μH$ $R_{coil} = 0.05Ω$ $V_{CC} = 20V$ $f_o = 500kHz$ V_{clamp} = Rated V_{CEX} Value	$L_{coil} = 40μH$ $V_{CC} = 10V$ $R_{coil} = 0.2Ω$ V_{clamp} (Unclamped)	$V_{CC} = 250V$ $R_L = 25Ω$ D1 = 1N5820 or Equiv. $R_B = 6Ω$
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT See Above For Detailed Conditions 	OUTPUT WAVEFORMS 	t_1 Adjusted to Obtain I_C $t_1 \approx \frac{L_{coil}(I_{Cpk})}{V_{CC}}$ $t_2 \approx \frac{L_{coil}(I_{Cpk})}{V_{clamp}}$ Test Equipment Tektronix Scope 475 or Equivalent	RESISTIVE TEST CIRCUIT 

POWER TRANSISTORS
8A, 400V, NPN Mesa

2N6671
2N6672
2N6673

FEATURES
- Collector Emitter Voltage: up to 650V
- Peak Collector Current: 10A
- Storage Time ≤ 2.5μs } at I_C = 5A
- Fall Time ≤ 0.4μs } at I_C = 5A

DESCRIPTION
These high voltage, multiple layer epitaxial, glass passivated power transistors combine fast switching, low saturation voltage and rugged second-breakdown capability. They are designed for use in off-line power supplies, high voltage inverters and switching regulators.

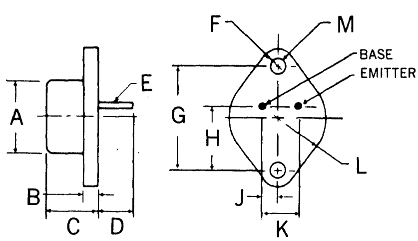
ABSOLUTE MAXIMUM RATINGS*

	2N6671	2N6672	2N6673
Collector Emitter Voltage, V_{CEV}	450V	550V	650V
Collector Emitter Voltage, V_{CEX}	350V	400V	450V
Collector Emitter Voltage, $V_{CEO\ (SUS)}$	300V	350V	400V
Emitter Base Voltage, V_{EBO}		8V	
Collector Current, I_C continuous		8A	
Collector Current, $I_{CM(peak)}$		12A	
Base Current, I_B continuous		4A	
Power Dissipation, up to 25°C		150W	
above 25°C, derate linearly		0.86W/°C	
Operating and Storage Temperature Range		−65°C to +200°C	

*JEDEC registered values.

MECHANICAL SPECIFICATIONS

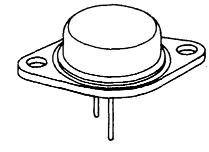
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



2N6671 2N6672 2N6673

	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.043 DIA.	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-.17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



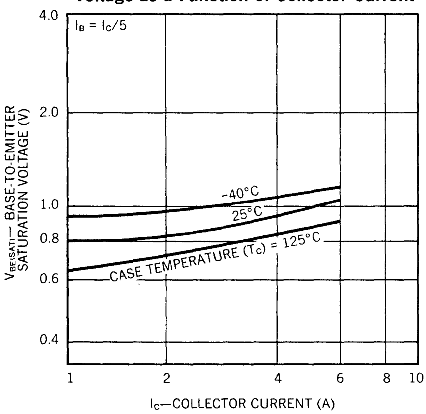
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

TEST	SYMBOL	2N6671		2N6672		2N6673		UNITS	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
Collector Cutoff Current	I_{CEV}	—	0.1	—	—	—	—	mA	V_{CE} = 450V, V_{BE} = −1.5V
		—	—	—	0.1	—	—	mA	V_{CE} = 550V, V_{BE} = −1.5V
		—	—	—	—	—	0.1	mA	V_{CE} = 650V, V_{BE} = −1.5V
Collector Cutoff Current T_C =125°C	I_{CEV}	—	1	—	—	—	—	mA	V_{CE} = 450V, V_{BE} = −1.5V
		—	—	—	1	—	—	mA	V_{CE} = 550V, V_{BE} = −1.5V
		—	—	—	—	—	1	mA	V_{CE} = 650V, V_{BE} = −1.5V
Emitter Base Cutoff Current	I_{EBO}	—	2	—	2	—	2	mA	V_{BE} = −8V, I_C = 0
Collector Emitter Sustaining Voltage (Notes 1 & 2)	$V_{CEO(sus)}$	300	—	350	—	400	—	V	I_C = 0.2A, I_B =0
DC Current Gain (Note 1)	h_{FE}	10	40	10	40	10	40		I_C = 5A, V_{CE} = 3V
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.6	—	1.6	—	1.6	V	I_C = 5A, I_B = 1A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1	—	1	—	1	V	I_C = 5A, I_B = 1A
Collector Saturation Voltage T_C = 125°C (Note 1)	$V_{CE(sat)}$	—	2	—	2	—	2	V	I_C = 5A, I_B = 1A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	2	—	2	—	2	V	I_C = 8A, I_B = 4A
Collector Emitter Voltage (Note 2)	V_{CEX}	350	—	400	—	450	—	V	L = 170μH, R_{BB} = 5Ω V_{BE} = −5V I_C = 5A, I_B = 1A
		200	—	250	—	300	—	V	L = 170μH, R_{BB} = 5Ω V_{BE} = −5V I_C = 8A, I_B = 3A
AC Current Gain	$\|h_{fe}\|$	3	12	3	12	3	12		I_C = 0.2A V_{CE} = 10V f =5MHz
Gain-Bandwidth Product	f_T	15	60	15	60	15	60	MHz	V_{CE} = 10V, I_C = 0.2A
Output Capacitance Common Base	C_{obo}	50	300	50	300	50	300	pF	V_{CB} = 10V, f = 0.1MHz
Switching Speeds									
Delay Time	t_d	—	0.1	—	0.1	—	0.1	μs	I_C = 5A, I_B = 1A V_{CC} = 125V t_p = 20μs
Rise Time	t_r	—	0.5	—	0.5	—	0.5		
Storage Time	t_s	—	2.5	—	2.5	—	2.5	μs	I_C = 5A, $-I_B$ = 1A V_{CC} = 125V t_p = 20μs
Fall Time	t_f	—	0.4	—	0.4	—	0.4		
Crossover Time	t_c	—	0.4	—	0.4	—	0.4	μs	I_C = 5A, I_{B2} = 1A V_{CC} = 125V L_C = 170μH, R_C = 25Ω Collector clamped to V_{CEX}
Switching Speeds T_C = 125°C									
Rise Time	t_r	—	0.8	—	0.8	—	0.8	μs	I_C = 5A, I_B = 1A V_{CC} = 125V t_p = 20μs
Storage Time	t_s	—	4	—	4	—	4	μs	I_C = 5A, $-I_B$ = 1A V_{CC} = 125V t_p = 20μs
Fall Time	t_f	—	0.8	—	0.8	—	0.8		
Crossover Time	t_c	—	0.8	—	0.8	—	0.8	μs	I_C = 5A, I_{B2} = 1A V_{CC} = 125V L = 170μH, R_C = 25Ω Collector clamped to V_{CEX}
Thermal Resistance, Junction to Case	$R_{\theta JC}$	—	1.17	—	1.17	—	1.17	°C/W	

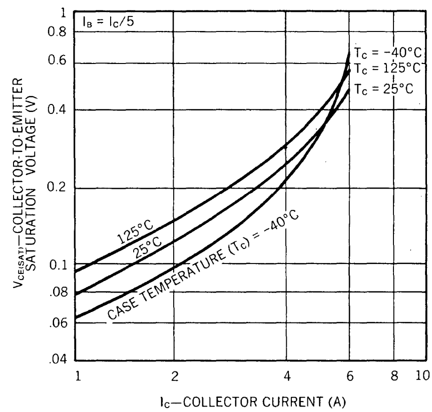
*JEDEC registered values.
Notes: 1. Pulse duration = 300μs; duty factor ≤ 2%
2. CAUTION: The sustaining voltage $V_{CEO(sus)}$ and V_{CEX} must not be measured on a curve tracer.

IV

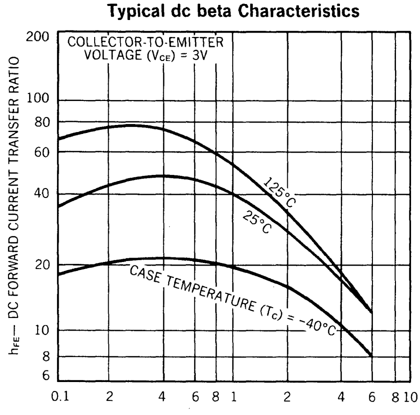
Typical Base-to-Emitter Saturation Voltage as a Function of Collector Current



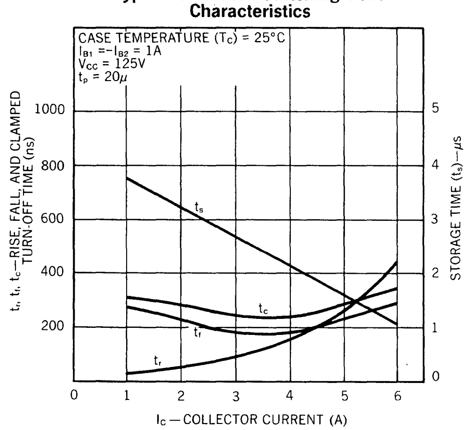
Typical Collector-to-Emitter Saturation Voltage as a Function of Collector Current



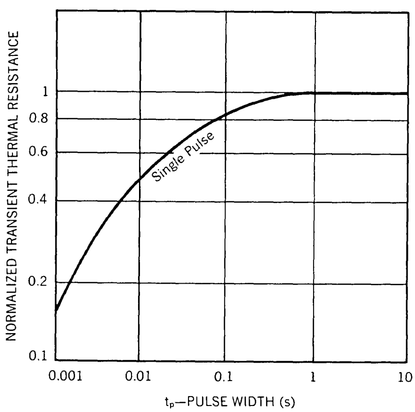
Typical dc beta Characteristics



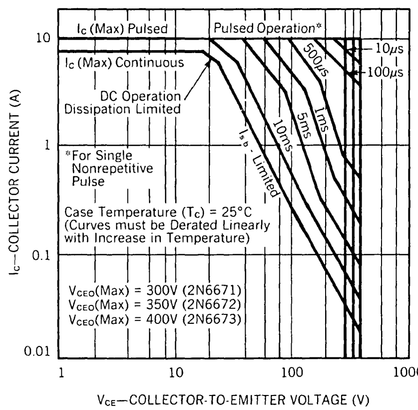
Typical Saturated-Switching-Time Characteristics



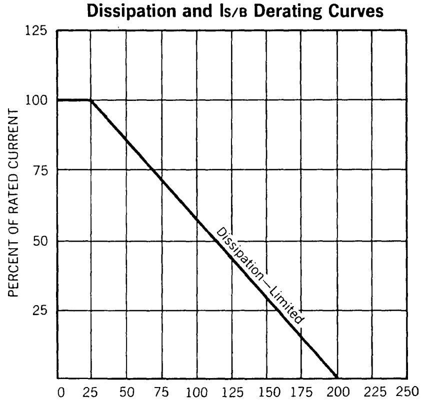
Typical Thermal-Response Characteristics (Normalized)



Maximum Operating Areas (Tc = 25°C)



Dissipation and Is/b Derating Curves



POWER TRANSISTORS
10A, 400V NPN Mesa

2N6674
2N6675

FEATURES
- Collector Emitter Voltage: up to 650V
- Peak Collector Current: 20A
- Storage Time ≤ 2.5μs } at I_C = 10A
- Fall Time ≤ 0.5μs }

DESCRIPTION
These high voltage, multiple layer epitaxial, glass passivated power transistors combine fast switching, low saturation voltage and rugged second-breakdown capability. They are designed for use in off-line power supplies, high voltage inverters and switching regulators.

ABSOLUTE MAXIMUM RATINGS*

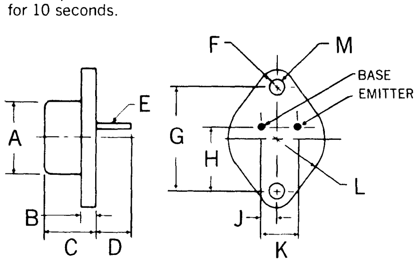
	2N6674	2N6675
Collector Emitter Voltage, V_{CEV}	450V	650V
Collector Emitter Voltage, V_{CEX}	350V	450V
Collector Emitter Voltage, $V_{CEO(sus)}$	300V	400V
Emitter Base Voltage, V_{EBO}	7V	
Collector Current, I_C continuous	15A	
Collector Current, $I_{CM(peak)}$	20A	
Base Current, I_B continuous	5A	
Power Dissipation, up to 25°C	175W	
above 25°C, derate linearly	1W/°C	
Operating and Storage Temperature Range	−65°C to +200°C	

*JEDEC registered values.

MECHANICAL SPECIFICATIONS

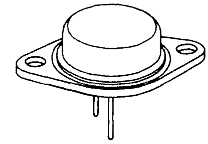
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

2N6674 2N6675



	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.043 DIA.	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-.17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

TEST	SYMBOL	2N6674 MIN.	2N6674 MAX.	2N6675 MIN.	2N6675 MAX.	UNITS	TEST CONDITIONS
Collector Cutoff Current	I_{CEV}	—	0.1			mA	V_{CE} = 450V, V_{BE} = −1.5V
				—	0.1	mA	V_{CE} = 650V, V_{BE} =−1.5V
Collector Cutoff Current T_C = 100°C	I_{CEV}	—	1	—	—	mA	V_{CE} = 450V, V_{BE} = −1.5V
		—	—	—	1	mA	V_{CE} = 650V, V_{BE} = −1.5V
Emitter Base Cutoff Current	I_{EBO}	—	2	—	2	mA	V_{BE} = −7V, I_C = 0
Collector Emitter Sustaining Voltage (Notes 1 & 2)	$V_{CEO(sus)}$	0	300	—	400	V	I_C = 0.2A, I_B =0
DC Current Gain (Note 1)	h_{FE}	8	20	8	20		I_C = 10A, V_{CE} = 2V
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.5	—	1.5	V	I_C = 10A, V_{CE} = 2A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1	—	1	V	I_C = 10A, I_B = 2A
Collector Saturation Voltage T_C = 100°C (Note 1)	$V_{CE(sat)}$	—	2	—	2	V	I_C = 10A, I_B = 2A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5	—	5	V	I_C = 15A, I_B = 5A
Collector Emitter Voltage (Note 2)	V_{CEX}	350	—	450	—	V	L = 50μH, R_{BB} = 2Ω V_{BE} = −4V, V_{CE} is clamped I_C = 10A, I_B = 2A
AC Current Gain	$\|h_{fe}\|$	3	10	3	10		I_C = 1A V_{CE} = 10V f =5MHz
Gain-Bandwidth Product	f_T	15	50	15	50	MHz	V_{CE} = 10V, I_C = 1A
Output Capacitance Common Base	C_{obo}	150	500	150	500	pF	V_{CB} = 10A, f = 0.1MHz
Switching Speeds Delay Time	t_d	—	0.1	—	0.1	μs	I_C = 10A, I_B = 2A V_{CC} = 125V, V_{BE} = −6V t_p = 20μs
Rise Time	t_r	—	0.6	—	0.6		
Storage Time	t_s	—	2.5	—	2.5	μs	I_C = 10A, $-I_B$ = 2A V_{CC} = 125V, V_{BE} = −6V t_p = 20μs
Fall Time	t_f	—	0.5	—	0.5		
Crossover Time	t_c	—	0.5	—	0.5	μs	I_C = 10A, I_{B2} = 2A V_{CC} = 135V, V_{BE} = −6V L_C = 50μH, $R_C \leq$ 13.5Ω Collector clamped to V_{CEX}
Switching Speeds T_C = 100°C Rise Time	t_r	—	1	—	1	μs	I_C = 10A, I_B = 2A V_{CC} = 125V, V_{BE} = −6V t_p = 20μs
Storage Time	t_s	—	4	—	4	μs	I_C = 10A, $-I_B$ = 2A V_{CC} = 125V, V_{BE} = −6V t_p = 20μs
Fall Time	t_f	—	1	—	1		
Crossover Time	t_c	—	0.8	—	0.8	μs	I_C = 10A, I_{B2} = 2A V_{CC} = 135V, V_{BE} = −6V L = 50μH, $R_C \leq$ 13.5Ω Collector clamped to V_{CEX}
Thermal Resistance, Junction to Case	$R_{\theta JC}$	—	1	—	1	°C/W	

*JEDEC registered values.

Notes: 1. Pulse duration = 300μs; duty factor $\leq$ 2%

2. CAUTION: The sustaining voltage $V_{CEO(sus)}$ and V_{CEX} must not be measured on a curve tracer.

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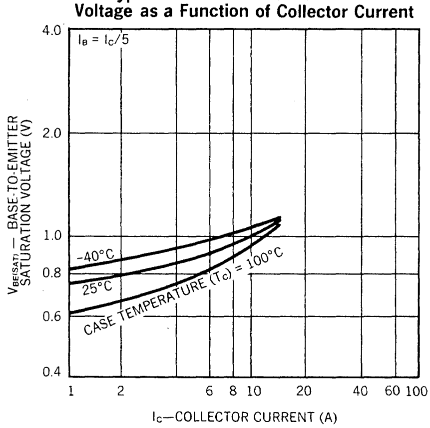
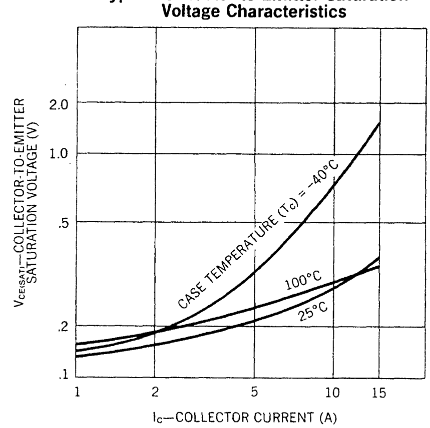
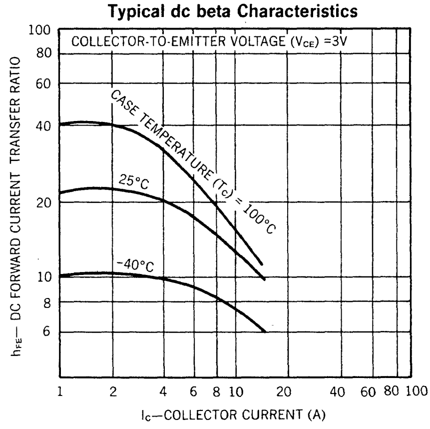
Typical Base-to-Emitter Saturation Voltage as a Function of Collector Current



Typical Collector-to-Emitter Saturation Voltage Characteristics



Typical dc beta Characteristics



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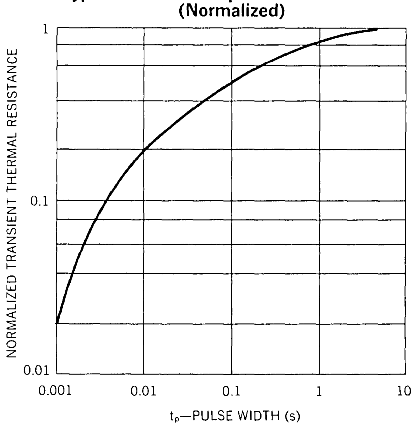
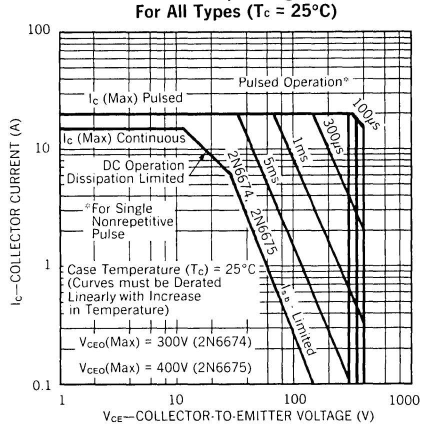
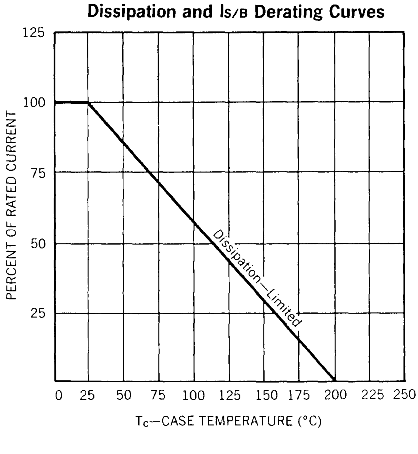
Typical Thermal-Response Characteristics (Normalized)



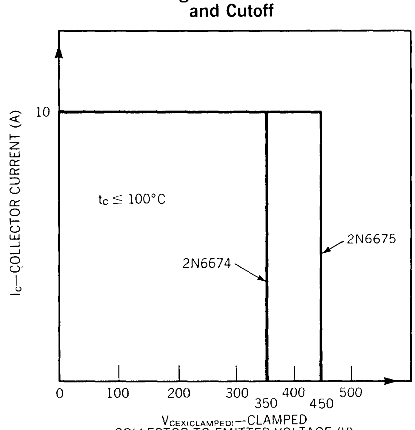
Maximum Operating Areas For All Types (Tc = 25°C)



Dissipation and Is/b Derating Curves



Maximum Operating Conditions for Switching Between Saturation and Cutoff



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POWER TRANSISTORS
15A, 400V NPN Mesa

2N6676
2N6677
2N6678

FEATURES
- Collector Emitter Voltage: up to 650V
- Peak Collector Current: 20A
- Storage Time ≤ 2.5μs } at I_C = 15A
- Fall Time ≤ 0.5μs } at I_C = 15A

DESCRIPTION
These high voltage, multiple layer epitaxial, glass passivated power transistors combine fast switching, low saturation voltage and rugged second-breakdown capability. They are designed for use in off-line power supplies, high voltage inverters and switching regulators.

ABSOLUTE MAXIMUM RATINGS*

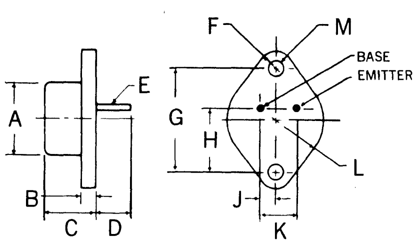
	2N6676	2N6677	2N6678
Collector Emitter Voltage, V_{CEV}	450V	550V	650V
Collector Emitter Voltage, V_{CEX}	350V	400V	450V
Collector Emitter Voltage, $V_{CEO(sus)}$	300V	350V	400V
Emitter Base Voltage, V_{EBO}		8V	
Collector Current, I_C continuous		15A	
Collector Current, $I_{CM(peak)}$		20A	
Base Current, I_B continuous		5A	
Power Dissipation, up to 25°C		175W	
above 25°C, derate linearly		1W/°C	
Operating and Storage Temperature Range		−65°C to +200°C	

*JEDEC registered values.

MECHANICAL SPECIFICATIONS

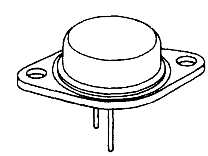
2N6676 2N6677 2N6678

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.043 DIA.	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-.17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)*

TEST	SYMBOL	2N6676 MIN.	2N6676 MAX.	2N6677 MIN.	2N6677 MAX.	2N6678 MIN.	2N6678 MAX.	UNITS	TEST CONDITIONS
Collector Cutoff Current	I_{CEV}	—	0.1	—	—	—	—	mA	V_{CE} = 450V, V_{BE} = −1.5V
		—	—	—	0.1	—	—	mA	V_{CE} = 550V, V_{BE} = −1.5V
		—	—	—	—	—	0.1	mA	V_{CE} = 650V, V_{BE} = −1.5V
Collector Cutoff Current T_C = 100°C	I_{CEV}	—	1	—	—	—	—	mA	V_{CE} = 450V, V_{BE} = −1.5V
		—	—	—	1	—	—	mA	V_{CE} = 550V, V_{BE} = −1.5V
		—	—	—	—	—	1	mA	V_{CE} = 650V, V_{BE} = −1.5V
Emitter Base Cutoff Current	I_{EBO}	—	2	—	2	—	2	mA	V_{BE} = −8V, I_C = 0
Collector Emitter Sustaining Voltage (Notes 1 & 2)	$V_{CEO(sus)}$	300	—	350	—	400	—	V	I_C = 0.2A, I_B = 0
DC Current Gain (Note 1)	h_{FE}	8	—	8	—	8	—		I_C = 15A, V_{CE} = 3V
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.5	—	1.5	—	1.5	V	I_C = 15A, I_B = 3A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1	—	1	—	1	V	I_C = 15A, I_B = 3A
Collector Saturation Voltage T_C = 100°C	$V_{CE(sat)}$	—	2	—	2	—	2	V	I_C = 15A, I_B = 3A
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.5	—	1.5	—	1.5	V	I_C = 15A, I_B = 3A
Collector Emitter Voltage (Note 2)	V_{CEX}	350	—	400	—	450	—	V	L = 50μH, R_{BB} = 2Ω V_{BE} = −6V, V_{CE} is clamped I_C = 15A, I_B = 3A
AC Current Gain	$\|h_{fe}\|$	3	10	3	10	3	10		I_C = 1A V_{CE} = 10V f = 5MHz
Gain-Bandwidth Product	f_T	15	50	15	50	15	50	MHz	V_{CE} = 10V, I_C = 1A
Output Capacitance Common Base	C_{obo}	150	500	150	500	150	500	pF	V_{CB} = 10V, f = 0.1MHz
Switching Speeds									
Delay Time	t_d	—	0.1	—	0.1	—	0.1	μs	I_C = 15A, I_B = 3A V_{CC} = 200V, $-V_{BE}$ = −6V t_p = 20μs
Rise Time	t_r	—	0.6	—	0.6	—	0.6		
Storage Time	t_s	—	2.5	—	2.5	—	2.5	μs	I_C = 15A, $-I_{B2}$ = 3A V_{CC} = 200V, $-V_{BE}$ = −6V t_p = 20μs
Fall Time	t_f	—	0.5	—	0.5	—	0.5		
Crossover Time	t_c	—	0.5	—	0.5	—	0.5	μs	I_C = 15A, I_B = 3A V_{CC} = 200V, V_{BE} = −6V L = 50μH, $R_C \leq$ 13.50Ω Collector clamped to V_{CEX}
Switching Speeds T_C = 100°C									
Rise Time	t_r	—	1	—	1	—	1	μs	I_C = 15A, I_B = 3A V_{CC} = 200V, V_{BE} = −6V L = 50μH, $R_C \leq$ 13.5Ω Collector Clamped to V_{CEX}
Storage Time	t_s	—	4	—	4	—	4	μs	I_C = 15A, $-I_{B2}$ = 3A V_{CC} = 200V, V_{BE} = −6V L = 50μH, $R_C \leq$ 13.5Ω Collector clamped to V_{CEX}
Fall Time	t_f	—	1	—	1	—	1		
Crossover Time	t_c	—	0.8	—	0.8	—	0.8	μs	I_C = 15A, I_B = 3A V_{CC} = 200V, V_{BE} = −6V L = 50μH, $R_C \leq$ 13.5Ω Collector clamped to V_{CEX}
Thermal Resistance, Junction to Case	$R_{\theta JC}$	—	1	—	1	—	1	°C/W	

*JEDEC registered values.

Notes: 1. Pulse duration = 300μs; duty factor $\leq$ 2%

2. CAUTION: The sustaining voltage $V_{CEO(sus)}$ and V_{CEX} must not be measured on a curve tracer.

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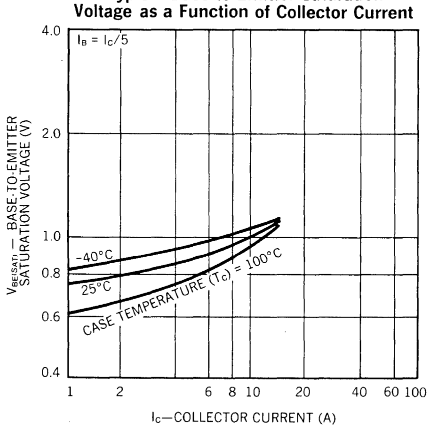
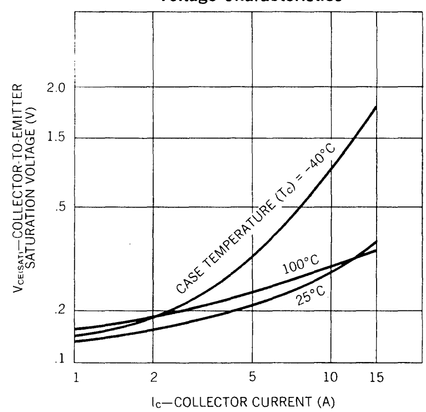
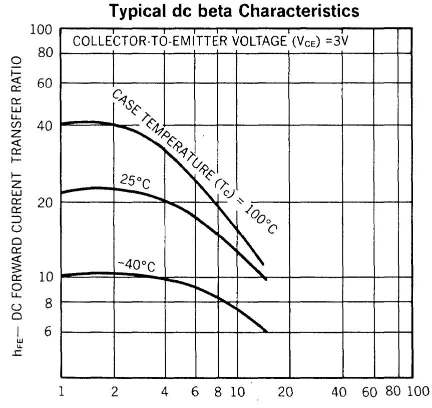
Typical Base-to-Emitter Saturation Voltage as a Function of Collector Current



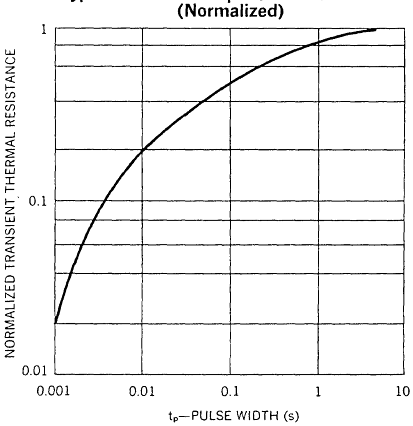
Typical Collector-to-Emitter Saturation Voltage Characteristics



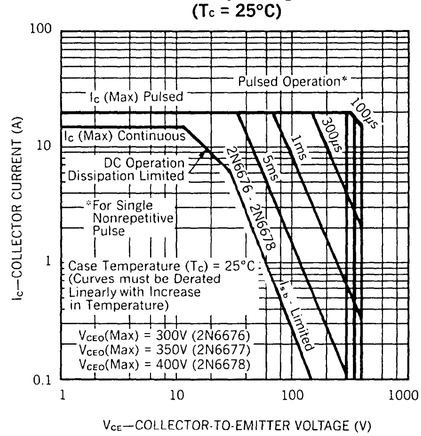
Typical dc beta Characteristics



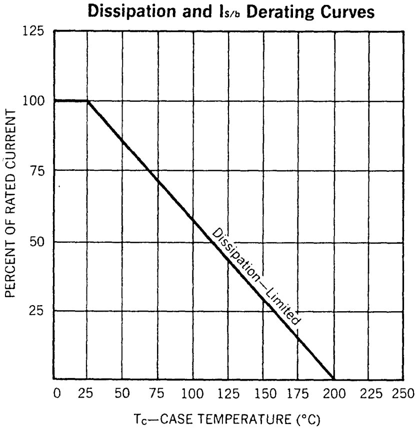
Typical Thermal-Response Characteristics (Normalized)



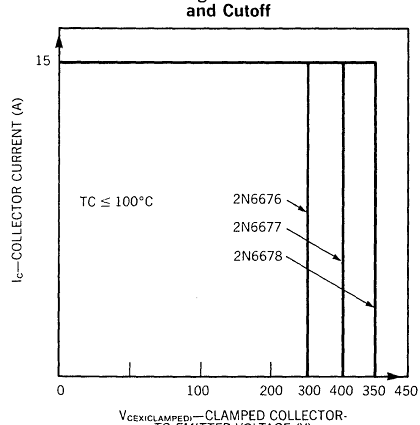
Maximum Operating Areas (T_C = 25°C)



Dissipation and $I_{S/b}$ Derating Curves



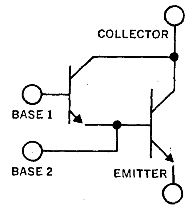
Maximum Operating Conditions For Switching Between Saturation and Cutoff



POWER DARLINGTONS

10 Amp, 150V, Planar NPN

U2T101
U2T105
U2T201
U2T205



FEATURES

- High Current Gain: up to 2000 min @ $I_C = 5A$
- Low Saturation Voltage: as low as 1.5V max @ $I_C = 5A$
- High Voltage: up to 150V min V_{CER}
- Monolithic Design Incorporating Multiple-Emitter Techniques
- Triple-Diffused Planar Construction

DESCRIPTION

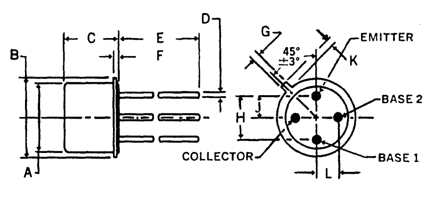
Unitrode NPN Darlingtons consist of a two transistor circuit on a single monolithic planar chip.

ABSOLUTE MAXIMUM RATINGS

	TO-33		3 PIN TO-66	
	U2T101	U2T105	U2T201	U2T205
Collector-Emitter Voltage	80V	150V	80V	150V
Emitter Base Voltages,				
V_{EB2}	6V	6V	6V	6V
V_{EB1}	12V	12V	12V	12V
D.C. Collector Current	5A	5A	5A	5A
Peak Collector Current	10A	10A	10A	10A
Base 1 Current	0.5A	0.5A	0.5A	0.5A
Power Dissipation				
25°C Ambient	1W	1W	2.5W	2.5W
100°C Case	5W	5W	25W	25W
Thermal Resistance, Junction to Case	20°C/W		4°C/W	
Operating and Storage Temperature Range	—65°C to 200°C		—65°C to 200°C	

MECHANICAL SPECIFICATIONS

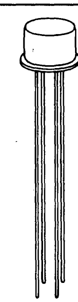
U2T101 U2T105



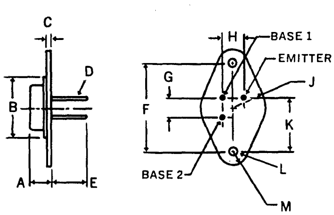
	ins.	mm
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.10-6 60
D	.017 ± .002/.001	.432 ± .051/.025
E	1.5 MIN.	38.10 MIN.
F	.018 MAX.	0.46 MAX.
G	031 ± .003	0.79 ± .08
H	.200	1.02
J	.100	2.54
K	.029-.045	0.74-1.14
L	.100	2.54

COLLECTOR CONNECTED TO CASE

TO-33



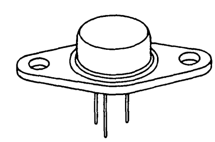
U2T201 U2T205



	ins	mm
A	.250-.340	6.35-8.64
B	.620 MAX.	15.75 MAX.
C	.050-.075	1.27-1.91
D	.028-.034	0.71-0.86
E	.360 MIN.	9.14 MIN.
F	.958-.962	24.33-24.43
G	.190-.210	4.83-5.33
H	.190-.210	4.83-5.33
J	.350 MAX. RAD.	8.89 MAX. RAD.
K	.570-.590	14.48-14.99
L	.142-.152	3.61-3.86
M	.145 MAX. RAD.	3.68 MAX. RAD.

COLLECTOR CONNECTED TO CASE

3 Pin TO-66



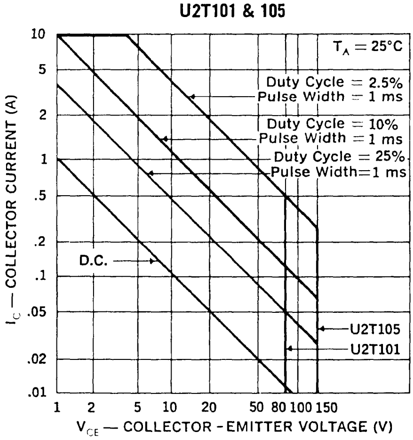
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

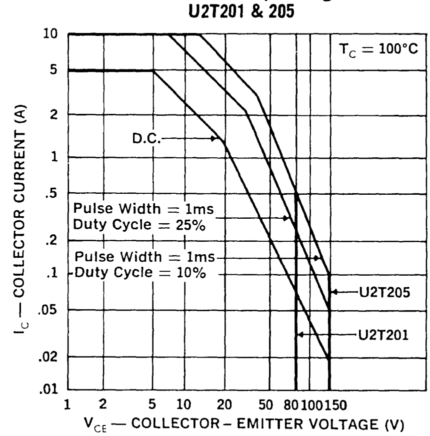
Test	Symbol	U2T101 & U2T201 Min.	U2T101 & U2T201 Max.	U2T105 & U2T205 Min.	U2T105 & U2T205 Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	2000	—	1000	—	—	$I_C = 1.0A$, $V_{CE} = 2V$, $R_{B2E} = 1K$
D.C. Current Gain (Note 1)	h_{FE}	2000	—	1000	—	—	$I_C = 5A$, $V_{CE} = 5V$, $R_{B2E} = 100$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.5	—	2.5	V	$I_C = 5A$, $R_{B2E} = 100$ U2T101, 201: $I_{B1} = 5mA$ U2T105, 205: $I_{B1} = 10mA$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}	80	—	150	—	V	$I_C = 25mA$, $R_{B1E} = 2.2K$, $R_{B2E} = 100$
Collector Cutoff Current	I_{CER}	—	1.0	—	1.0	μA	$R_{B1E} = 2.2K$, $R_{B2E} = 100$ U2T101, 201: $V_{CE} = 80V$ U2T105, 205: $V_{CE} = 150V$
Collector Cutoff Current	I_{CER}	—	1.0	—	1.0	mA	$R_{B1E} = 2.2K$, $R_{B2E} = 100$, $T = 150°C$ U2T101, 201: $V_{CE} = 80V$ U2T105, 205: $V_{CE} = 150V$
Collector Capacitance	C_{obo}	—	100	—	100	pf	$V_{CB1} = 10$, $I_E = 0$, $f = 1MHz$
A.C. Current Gain	h_{fe}	5	—	5	—	—	$I_C = 1.0A$, $V_{CE} = 10V$, $f = 10MHz$, $R_{B2E} = 100$
Switching Speeds — Delay Time	t_d	100 Typ.		100 Typ.		ns	$V_{CC} = 30V$,
Switching Speeds — Rise Time	t_r	300 Typ.		400 Typ.		ns	$I_C = 5A$,
Switching Speeds — Storage Time	t_s	600 Typ.		500 Typ.		ns	U2T101, 201: I_B (on) $= I_B$ (off) $= 5mA$, U2T105, 205: I_B (on) $= I_B$ (off) $= 10mA$,
Switching Speeds — Fall Time	t_f	500 Typ.		500 Typ.		ns	$R_{B2E} = 100$

Note: 1. Pulse width = 300 μs; duty cycle ⩽2%.

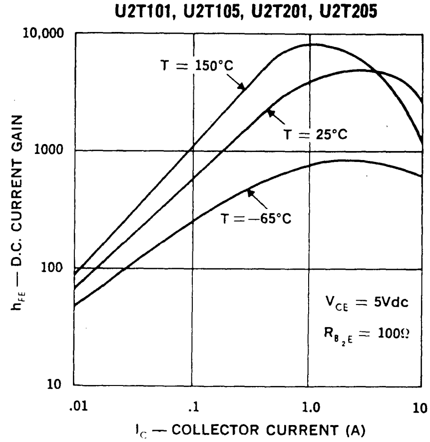
Maximum Safe Operating Area U2T101 & 105



Maximum Safe Operating Area U2T201 & 205



D.C. Current Gain vs. Collector Current U2T101, U2T105, U2T201, U2T205



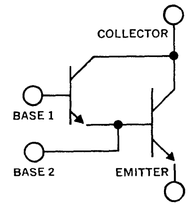
POWER DARLINGTONS

U2T301 U2T401
U2T305 U2T405

5 Amp, 150V, Planar NPN

FEATURES

- High Current Gain: 1000 min. @ $I_C = 2A$
- Low Saturation Voltage: as low as 1.5V max. @ $I_C = 2A$
- High Voltage: up to 150V min. V_{CER}
- Monolithic Design Incorporating Multiple-Emitter Techniques
- Triple-Diffused Planar Construction



DESCRIPTION

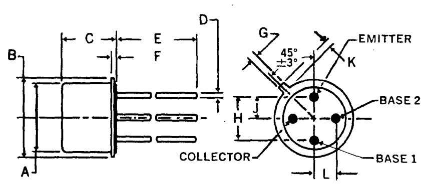
Unitrode NPN Darlingtons consist of a two transistor circuit on a single monolithic planar chip.

ABSOLUTE MAXIMUM RATINGS

	TO-33 U2T301	TO-33 U2T305	3 PIN TO-66 U2T401	3 PIN TO-66 U2T405
Collector-Emitter Voltage	60V	150V	60V	150V
Emitter Base Voltages,				
V_{EB2}	6V	6V	6V	6V
V_{EB1}	12V	12V	12V	12V
D.C. Collector Current	2A	2A	2A	2A
Peak Collector Current	5A	5A	5A	5A
Base 1 Current	0.5A	0.5A	0.5A	0.5A
Power Dissipation				
25°C Ambient	1W	1W	2W	2W
100°C Case	4W	4W	16W	16W
Thermal Resistance				
Junction to Case	25°C/W		6°C/W	
Operating and Storage Temperature Range	—65°C to 200°C		—65°C to 200°C	

MECHANICAL SPECIFICATIONS

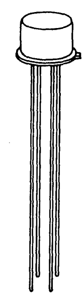
U2T301 U2T305



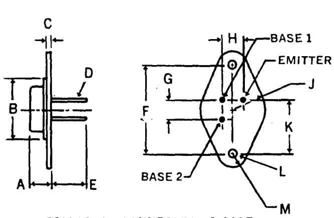
	ins.	mm
A	.305-3.35	7.75-8.51
B	.335-.370	8.51-9 40
C	.240-.260	6.10-6 60
D	.017 ± .002/.001	.432 ± .051/.025
E	1.5 MIN.	38.10 MIN.
F	.018 MAX.	0.46 MAX.
G	.031 ± .003	0.79 ± .08
H	.200	1.02
J	.100	2.54
K	.029-.045	0.74-1.14
L	.100	2.54

COLLECTOR CONNECTED TO CASE

TO-33



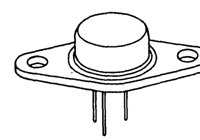
U2T401 U2T405



	ins	mm
A	.250-.340	6.35-8.64
B	.620 MAX.	15 75 MAX.
C	.050-.075	1.27-1.91
D	.028-.034	0.71-0.86
E	.360 MIN.	9.14 MIN.
F	.958-.962	24.33-24.43
G	.190-.210	4.83-5.33
H	.190-.210	4.83-5.33
J	.350 MAX. RAD.	8.89 MAX. RAD.
K	.570-.590	14.48-14.99
L	.142-.152	3.61-3.86
M	.145 MAX. RAD.	3.68 MAX. RAD.

COLLECTOR CONNECTED TO CASE

3 Pin TO-66



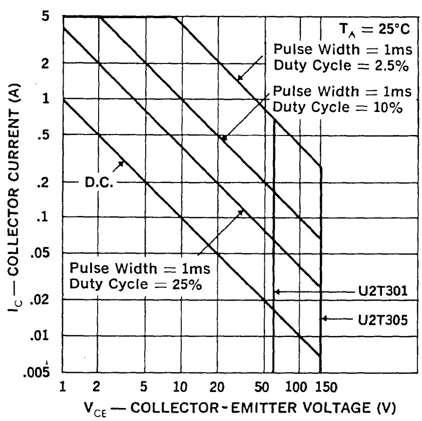
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

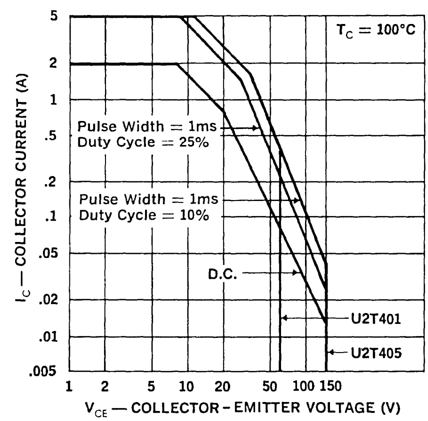
Test	Symbol	U2T301 & U2T401 Min.	U2T301 & U2T401 Max.	U2T305 & U2T405 Min.	U2T305 & U2T405 Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	1000	—	1000	—	—	$I_C = 1A$, $V_{CE} = 2V$, $R_{B2E} = 1K$
D.C. Current Gain (Note 1)	h_{FE}	1000	—	1000	—	—	$I_C = 2A$, $V_{CE} = 5V$, $R_{B2E} = 100$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.5	—	2.5	V	$I_C = 2A$, $R_{B2E} = 100$, $I_{B1} = 4mA$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}	60	—	150	—	V	$I_C = 25mA$, $R_{B1E} = 2.2K$, $R_{B2E} = 100$
Collector Cutoff Current	I_{CER}	—	1.0	—	1.0	μA	$R_{B1E} = 2.2K$, $R_{B2E} = 100$ U2T301, 401: $V_{CE} = 60V$ U2T305, 405: $V_{CE} = 150V$
Collector Cutoff Current	I_{CER}	—	1.0	—	1.0	mA	$R_{B1E} = 2.2K$, $R_{B2E} = 100$, $T = 150°C$ U2T301, 401: $V_{CE} = 60V$ U2T305, 405: $V_{CE} = 150V$
Collector Capacitance	C_{obo}	—	60	—	60	pf	$V_{CB1} = 10V$, $I_E = 0$, $f = 1MHz$
A.C. Current Gain	h_{fe}	5	—	5	—	—	$I_C = 0.5A$, $V_{CE} = 10V$, $f = 10MHz$, $R_{B2E} = 100$
Switching Speeds: Delay Time	t_d	100 Typ.		100 Typ.		ns	$V_{CC} = 30V$, $I_C = 2A$, I_B (on) $= I_B$ (off) $= 4mA$
Switching Speeds: Rise Time	t_r	200 Typ.		300 Typ.		ns	
Switching Speeds: Storage Time	t_s	800 Typ.		800 Typ.		ns	
Switching Speeds: Fall Time	t_f	300 Typ.		300 Typ.		ns	$R_{B2E} = 100$

Note: 1. Pulse width = 300 μs; duty cycle ≤2%.

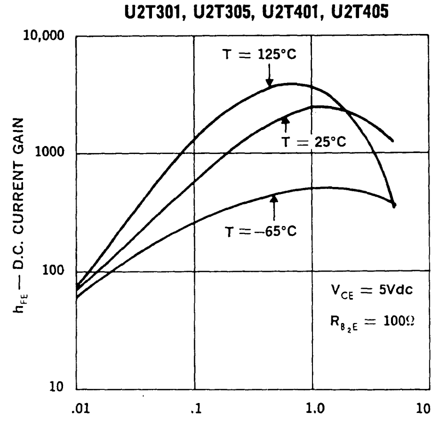
Maximum Safe Operating Area U2T301 & 305



Maximum Safe Operating Area U2T401 & 405



D.C. Current Gain vs. Collector Current U2T301, U2T305, U2T401, U2T405



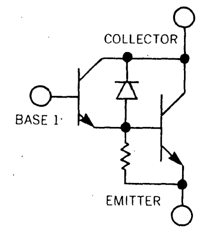
POWER DARLINGTONS

3 Amp, 100V, Planar NPN, Plastic

U2TA506
U2TA508
U2TA510

FEATURES

- High Current Gain: 500 min. @ $I_C = 3A$
- Low Saturation Voltage: as low as 1.5V max. @ $I_C = 3A$
- Economic Plastic Molded Construction



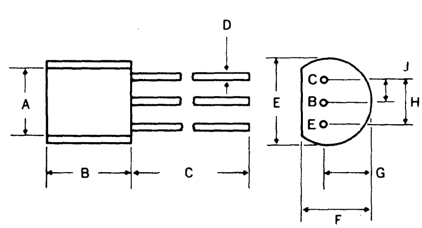
DESCRIPTION

Unitrode NPN Darlingtons consist of a two transistor circuit on a single monolithic planar chip, including integral bias resistance and protective diode. It is ideally suited for pulse power applications in power supplies, printers, solid state relays and displays.

ABSOLUTE MAXIMUM RATINGS

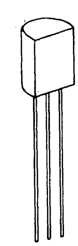
	U2TA506	U2TA508	U2TA510
Collector-Base Voltage, V_{CBO}	80V	100V	120V
Collector-Emitter Voltage, V_{CEO}	60V	80V	100V
Emitter-Base Voltage, V_{EBO}		5V	
D.C. Collector Current, I_C		.75A	
Peak Collector Current, I_C		5A	
Base Current, I_B		.6A	
Power Dissipation			
25°C Case		2.4W	
25°C Ambient		970mW	
Thermal Resistance, Θ_{J-C}		62.5°C/W	
Thermal Resistance, Θ_{J-A}		155°C/W	
Storage Temperature Range		−55 to +150°C	
Maximum Junction Temperature		+175°C	

U2TA506 U2TA508 U2TA510



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92

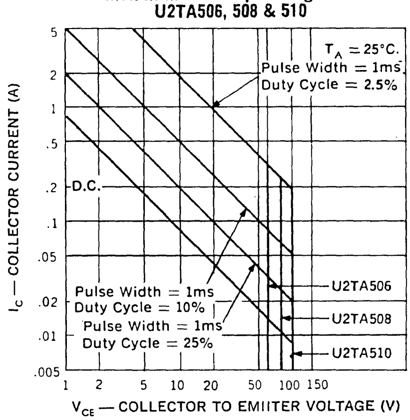


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

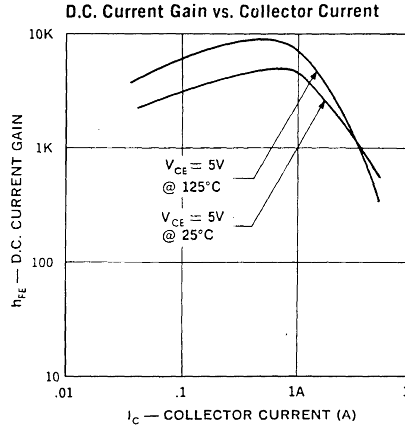
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	1000	—	—	$I_C = 1A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	500	—	—	$I_C = 3A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	300 Typ.		—	$I_C = 5A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.5	Vdc	$I_C = 3A$, $I_B = 30mA$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
U2TA506		60	—		
U2TA508		80	—		
U2TA510		100	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rating, R = 100Ω
Collector-Emitter Cutoff Current	I_{CER}	—	1	mAdc	V_{CE} = rating, R = 100Ω, T = 125°C
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	50	pf	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
A.C. Current Gain	h_{fe}	4.0 Typ.		—	$I_C = 1Adc$, $V_{CE} = 5Vdc$, f = 10MHz
Rise Time	t_r	600 Typ.		ns	$I_C = 2A$
Storage Time	t_s	1500 Typ.		ns	V_{CC} = rating, $I_{B(on)} = I_{B(off)} = 4mA$
Fall Time	t_f	800 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ≤ 2%.

Maximum Safe Operating Area U2TA506, 508 & 510



D.C. Current Gain vs. Collector Current



POWER TRANSISTORS

5A, 500V, Fast Switching, High $E_{S/b}$ Silicon NPN Mesa

UMT1006
UMT1007

FEATURES

- Rise Time: 0.4μS } $I_C = 3A$
- Fall Time: 0.4μS }
- High Second Breakdown Energy: 540μJ
- Collector Emitter Voltage: up to 500V
- Peak Collector Current: 10A
- Key Parameters characterized at 100°C

DESCRIPTION

These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

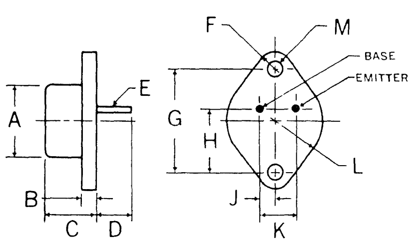
ABSOLUTE MAXIMUM RATINGS

	UMT1006	UMT1007
Collector Emitter Voltage, V_{CEV}	400V	500V
Collector Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	7V	7V
Collector Current, I_C continuous	5A	5A
Collector Current, I_C peak	10A	10A
Base Current, I_B continuous	5A	5A
Power Dissipation, 25°C Case	100W	100W
Derating Factor	.571W/°C	.571W/°C
Operating and Storage Temperature Range	–65 to 200°C	

MECHANICAL SPECIFICATIONS

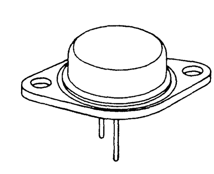
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

UMT1006 UMT1007



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



UNITRODE

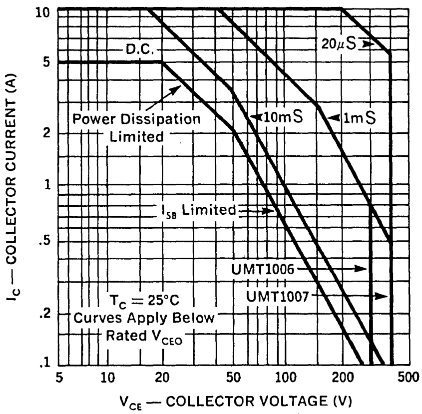
IV

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

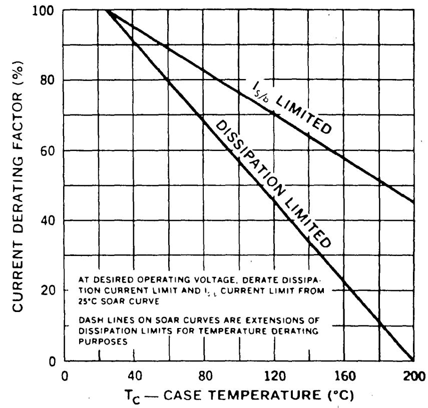
Test	Symbol	UMT1006		UMT1007		Units	Test Conditions
		MIN.	MAX.	MIN.	MAX.		
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 1.5A, V_{CE} = 2V$
D.C. Current Gain (Note 1)	h_{FE}	7	35	7	35		$I_C = 3.0A, V_{CE} = 2V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 3.0A, I_B = 0.6A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE(sat)}$	—	2.0	—	2.0	V	$I_C = 3.0A, I_B = 0.6A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5.0	—	5.0	V	$I_C = 5.0A, I_B = 1.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.4	—	1.4	V	$I_C = 3.0A, I_B = 0.6A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE(sat)}$	—	1.4	—	1.4	V	$I_C = 3.0A, I_B = 0.6A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 0.1A, I_B = 0$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX(sus)}$	350	—	450	—	V	$I_C = 3.0A, L = 180\mu H$ $I_{B1} = I_{B2} = 0.6A$ V_{CE} clamp = rated $V_{CEX(sus)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	— —	0.5 —	— —	— 0.5	mA	$V_{CE} = 400V, V_{BE} = -1.5V$ $V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	— —	2.5 —	— —	— 2.5	mA	$V_{CE} = 400V, V_{BE} = -1.5V$ $V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	— —	3.0 —	— —	— 3.0	mA	$V_{CE} = 400V, R_{BE} = 50\Omega$ $V_{CE} = 500V, R_{BE} = 50\Omega$
Output Capacitance, Common Base	C_{obo}	50	150	50	150	pF	$V_{CB} = 10V, f = 1 MHz$
Gain-Bandwidth Product	F_T	6	24	6	24	MHz	$V_{CE} = 10V, I_C = 0.2A, f = 1 MHz$
Energy Second Breakdown (unclamped)	$E_{S/b}$	540	—	540	—	μJ	$I_C = 3.0A, V_{BE(off)} = 4V$ $L = 120\mu H$ unclamped
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 .05 0.4 4.0 0.4	 — — — —	 .05 0.4 4.0 0.4	μS	$I_C = 3.0A$ $V_{CC} = 200V$ $I_{B1} = I_{B2} = 0.6A$ $V_{BE(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 4.0 0.4	 — —	 4.0 0.4	μS	$I_C = 3.0A, L = 180\mu H$ $I_{B1} = I_{B2} = 0.6A$ V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R\theta_{JC}$	—	1.75	—	1.75	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle $\leq$1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length $\cong$ 50μS; duty cycle $\leq$ 1%. Voltage clamped at maximum collector-emitter voltage.

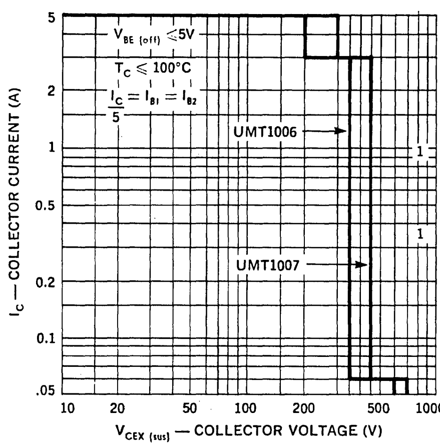
Forward Bias Safe Operating Area



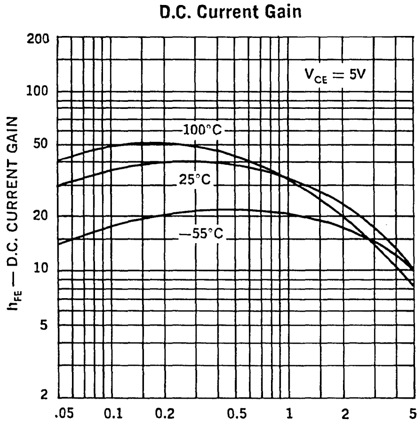
Power Derating



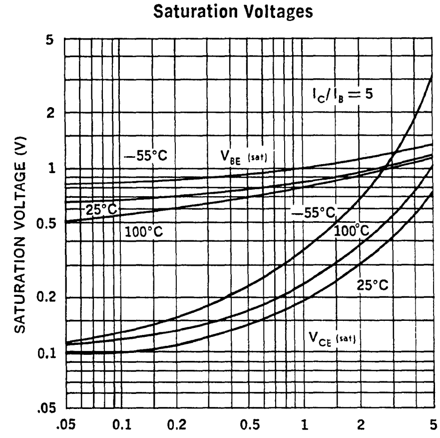
Reverse Biased Safe Operating Area



D.C. Current Gain



Saturation Voltages



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TWX (710) 326-6509 • TELEX 95-1064

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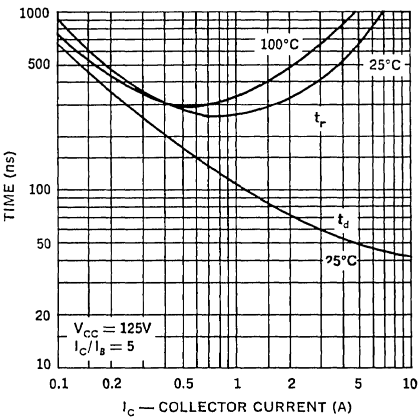
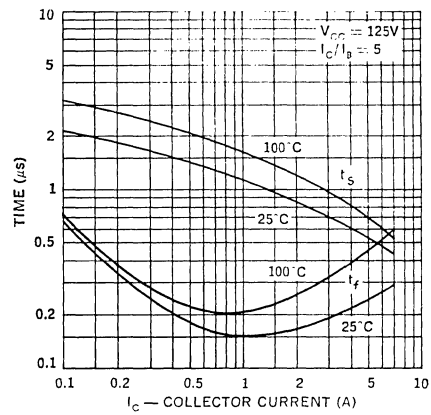
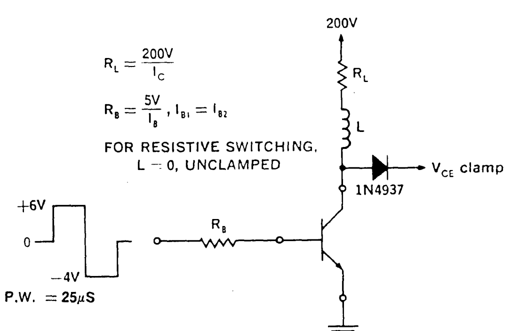
Resistive Turn-On Time



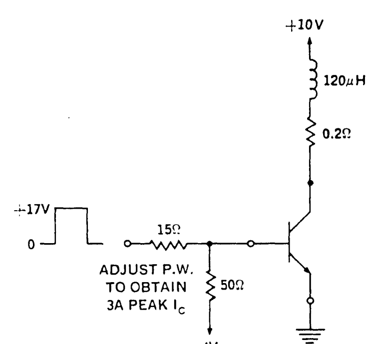
Resistive Turn-Off Time



Switching Time, $V_{CEX(sus)}$ Test Circuit



$E_{s/b}$ Test Circuit



POWER TRANSISTORS

UMT1008
UMT1009

8 Amp, 500V Fast Switching, High $E_{S/b}$ Silicon NPN Mesa

FEATURES

- Rise Time: 0.4μs } $I_C = 5A$
- Fall Time: 0.4μs }
- High Second Breakdown Energy: 1500μJ
- Collector Emitter Voltage: up to 500V
- Peak Collector Current: 16A
- Key Parameters characterized at 100°C

DESCRIPTION

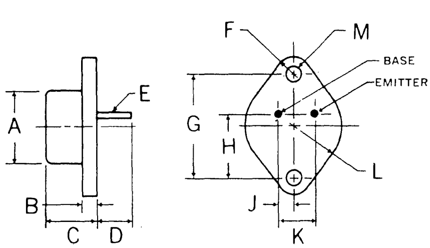
These high voltage triple diffused glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

ABSOLUTE MAXIMUM RATINGS

	UMT1008	UMT1009
Collector Emitter Voltage, V_{CEV}	400V	500V
Collector Emitter Voltage, $V_{CEO(SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	7V	7V
Collector Current, I_C continuous	8A	8A
Collector Current, I_C peak	16A	16A
Base Current, I_B continuous	8A	8A
Power Dissipation, 25°C Case	125W	125W
Derating Factor	.714W/°C	.714W/°C
Operating and Storage Temperature Range	—65 to 200°C	

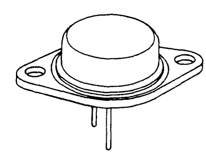
MECHANICAL SPECIFICATIONS

NOTE:
Loads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



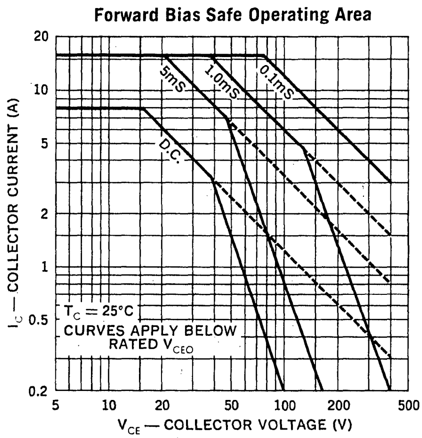
UNITRODE

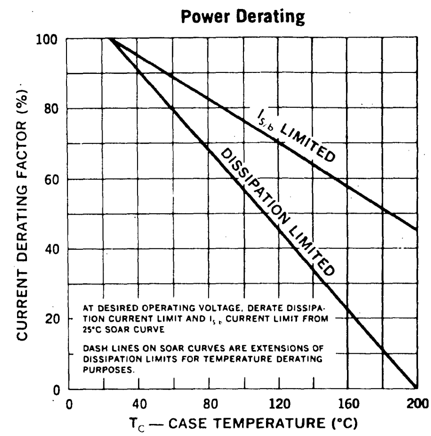
IV

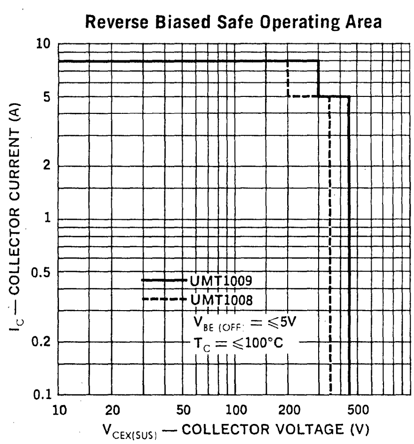
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

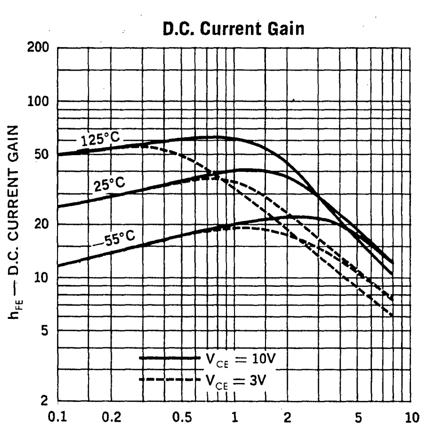
Test	Symbol	UMT1008 MIN.	UMT1008 MAX.	UMT1009 MIN.	UMT1009 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 2.5A, V_{CE} = 3V$
D.C. Current Gain (Note 1)	h_{FE}	7	35	7	35		$I_C = 5.0A, V_{CE} = 3V$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	1.5	—	1.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE\,(sat)}$	—	2.5	—	2.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	5.0	—	5.0	V	$I_C = 8.0A, I_B = 2.0A$
Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A, I_B = 1.0A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE\,(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A, I_B = 1.0A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	300	—	400	—	V	$I_C = 0.1A$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX\,(sus)}$	350	—	450	—	V	$I_C = 5.0A, L = 180\mu H$ $I_{B1} = I_{B2} = 1A$ V_{CE} clamp = rated $V_{CEX\,(SUS)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	0.5	—	—	mA	$V_{CE} = 400V, V_{BE} = -1.5V$
		—	—	—	0.5		$V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	2.5	—	—	mA	$V_{CE} = 400V, V_{BE} = -1.5V$
		—	—	—	2.5		$V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	—	3.0	—	—	mA	$V_{CE} = 400V, R_{BE} = 50\Omega$
		—	—	—	3.0		$V_{CE} = 500V, R_{BE} = 50\Omega$
Output Capacitance, Common Base	C_{obo}	100	200	100	200	pF	$V_{CB} = 10V, f = 1$ MHz
Gain-Bandwidth Product	F_T	6	30	6	30	MHz	$V_{CE} = 10V, I_C = 0.3A, f = 1$ MHz
Energy Second Breakdown (unclamped)	$E_{s/b}$	1500	—	1500	—	μJ	$I_C = 5.0A$ $I_{B1} = 1A$ $L = 120\mu H$ unclamped
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 0.1 0.4 4.0 0.4	 — — — —	 0.1 0.4 4.0 0.4	μs	$I_C = 5.0A$ $V_{CC} = 200V$ $I_{B1} = I_{B2} = 1.0A$ $V_{BE\,(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 4.0 0.4	 — —	 4.0 0.4	μs	$I_C = 5.0A, L = 180\mu H$ $I_{B1} = I_{B2} = 1A$ V_{CE} clamp = rated $V_{CEX\,(SUS)}$
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	—	1.4	—	1.4	°C/W	

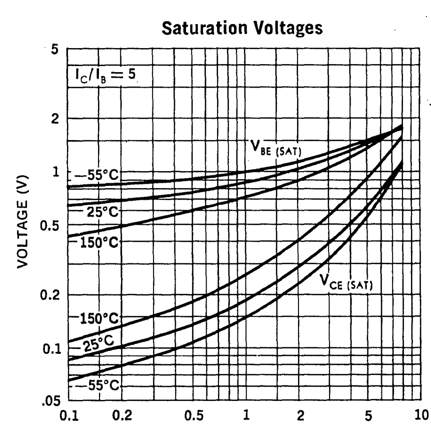
Notes:
1. Pulse width = $250\mu S$; duty cycle $\leq 1\%$.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length $\cong 50\mu S$; duty cycle $\leq 1\%$. Voltage clamped at maximum collector-emitter voltage.


Forward Bias Safe Operating Area
20
10
5
2
1
0.5
0.2
5 10 20 50 100 200 500
I_C — COLLECTOR CURRENT (A)
V_{CE} — COLLECTOR VOLTAGE (V)
5mS
1.0mS
0.1mS
D.C.
$T_C = 25°C$
CURVES APPLY BELOW
RATED V_{CEO}

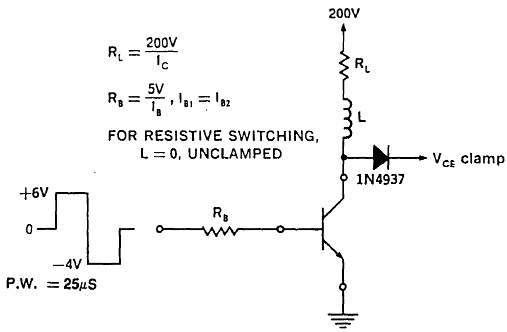

Power Derating
100
80
60
40
20
0
0 40 80 120 160 200
CURRENT DERATING FACTOR (%)
T_C — CASE TEMPERATURE (°C)
$I_{S/b}$ LIMITED
DISSIPATION LIMITED
AT DESIRED OPERATING VOLTAGE, DERATE DISSIPATION CURRENT LIMIT AND $I_{S/b}$ CURRENT LIMIT FROM 25°C SOAR CURVE
DASH LINES ON SOAR CURVES ARE EXTENSIONS OF DISSIPATION LIMITS FOR TEMPERATURE DERATING PURPOSES.


Reverse Biased Safe Operating Area
10
5
2
1
0.5
0.2
0.1
10 20 50 100 200 500
I_C — COLLECTOR CURRENT (A)
$V_{CEX(SUS)}$ — COLLECTOR VOLTAGE (V)
UMT1009
UMT1008
$V_{BE(OFF)} = \leq 5V$
$T_C = \leq 100°C$

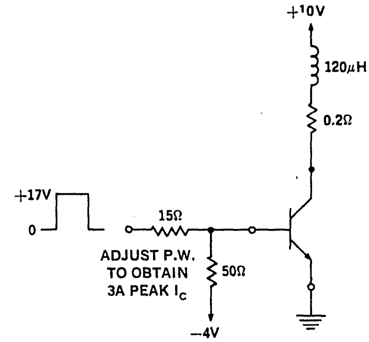

D.C. Current Gain
200
100
50
20
10
5
2
0.1 0.2 0.5 1 2 5 10
h_{FE} — D.C. CURRENT GAIN
I_C — COLLECTOR CURRENT (A)
125°C
25°C
−55°C
$V_{CE} = 10V$
$V_{CE} = 3V$


Saturation Voltages
5
2
1
0.5
0.2
0.1
.05
0.1 0.2 0.5 1 2 5 10
VOLTAGE (V)
I_C — COLLECTOR CURRENT (A)
$I_C/I_B = 5$
$V_{BE(SAT)}$
−55°C
25°C
150°C
$V_{CE(SAT)}$
150°C
25°C
−55°C

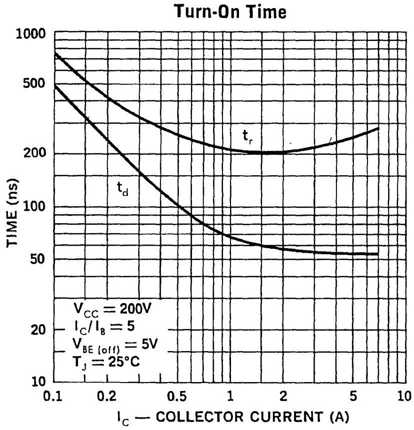
Switching Time, $V_{CEX\,(sus)}$ Test Circuit



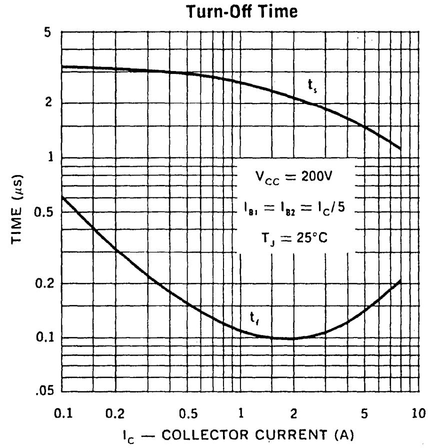
$E_{s/b}$ Test Circuit



Turn-On Time



Turn-Off Time



POWER TRANSISTORS

UMT1011
UMT1012

15A, 500V, Fast Switching, High $E_{S/b}$ Silicon NPN Mesa

FEATURES

- Rise Time: 0.4μS } $I_C = 10A$
- Fall Time: 0.4μS }
- High Second Breakdown Energy: 6000μJ
- Low Saturation Voltage
- Collector Emitter Voltage: up to 500V
- Peak Collector Current: 30A
- Key Parameters characterized at 100°C

DESCRIPTION

These high voltage glass passivated power transistors combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, ignition systems and deflection circuits.

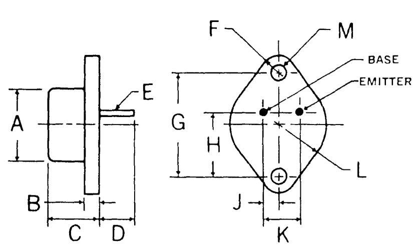
ABSOLUTE MAXIMUM RATINGS

	UMT1011	UMT1012
Collector Emitter Voltage, V_{CEV}	400V	500V
Collector Emitter Voltage, $V_{CEO\ (SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C continuous	15A	15A
Collector Current, I_C peak	30A	30A
Base Current, I_B continuous	10A	10A
Power Dissipation, 25°C Case	175W	175W
Derating Factor	1.0W/°C	1.0W/°C
Operating and Storage Temperature Range	—65 to 200°C	

MECHANICAL SPECIFICATIONS

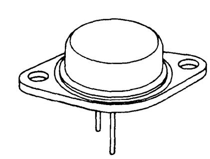
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

UMT1011 UMT1012



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



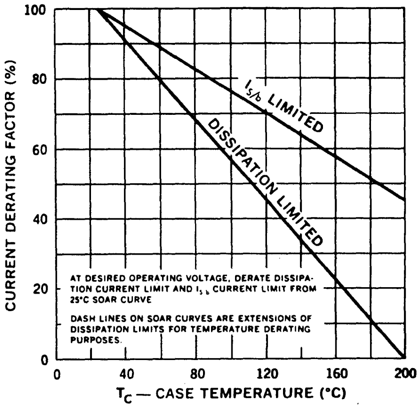
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

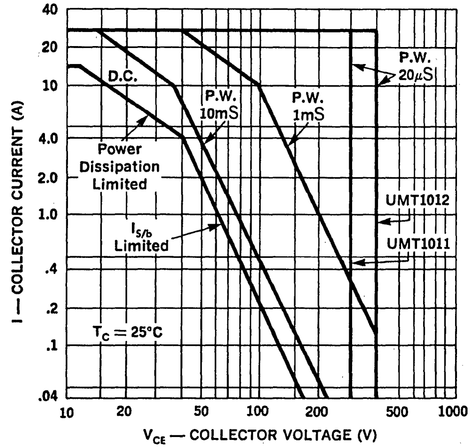
Test	Symbol	UMT1011 MIN.	UMT1011 MAX.	UMT1012 MIN.	UMT1012 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 5.0A, V_{CE} = 2.0V$
D.C. Current Gain (Note 1)	h_{FE}	6	30	6	30		$I_C = 10A, V_{CE} = 2.0V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 10A, I_B = 2.0A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE(sat)}$	—	2.0	—	2.0	V	$I_C = 10A, I_B = 2.0A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	5.0	—	5.0	V	$I_C = 15A, I_B = 3.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 10A, I_B = 2.0A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 10A, I_B = 2.0A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 0.1A, I_B = 0$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX(sus)}$	350	—	450	—	V	$I_C = 8.0A, L = 180\mu H$ $I_{B1} = I_{B2} = 2.0A$ V_{CE} clamp = rated $V_{CEX(sus)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	— —	1.0 —	— —	— 1.0	mA	$V_{CE} = 400V, V_{BE} = -1.5V$ $V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	— —	3.0 —	— —	— 3.0	mA	$V_{CE} = 400V, V_{BE} = -1.5V$ $V_{CE} = 500V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	— —	3.0 —	— —	— 3.0	mA	$V_{CE} = 400V, R_{BE} = 50\Omega$ $V_{CE} = 500V, R_{BE} = 50\Omega$
Output Capacitance, Common Base	C_{obo}	180	360	180	360	pF	$V_{CB} = 10V, f = 1$ MHz
Gain-Bandwidth Product	F_T	6	24	6	24	MHz	$V_{CE} = 10V, I_C = 0.5A, f = 1$ MHz
Energy Second Breakdown (unclamped)	$E_{s/b}$	6000	—	6000	—	μJ	$I_C = 10A, V_{BE(off)} = -4V$ $L = 120\mu H$ unclamped
Resistive Switching Speeds Delay Time Rise Time Storage Time Fall Time	 t_d t_r t_s t_f	 — — — —	 .05 0.4 4.0 0.4	 — — — —	 .05 0.4 4.0 0.4	μS	 $I_C = 10A$ $V_{CC} = 200V$ $I_{B1} = I_{B2} = 2.0A$ $V_{BE(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 4.0 0.4	 — —	 4.0 0.4	μS	$I_C = 10A, L = 180\mu H$ $I_{B1} = I_{B2} = 2.0A$ V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R_{\Theta JC}$	—	1.0	—	1.0	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

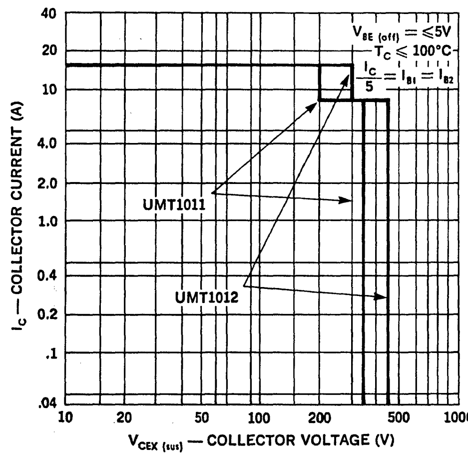
Power Derating



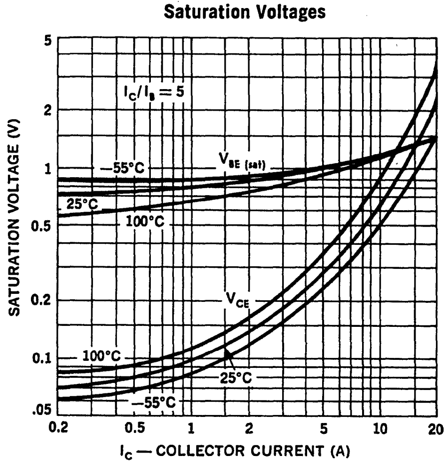
Forward Bias Safe Operating Area



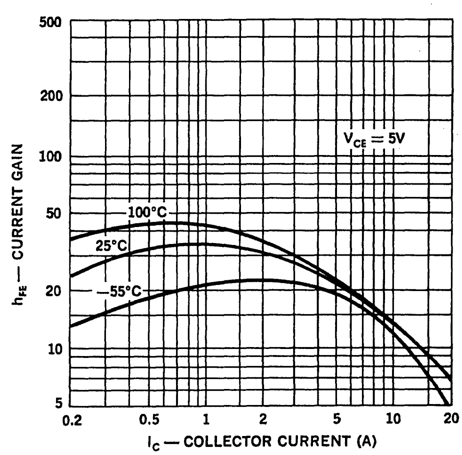
Reverse Biased Safe Operating Area



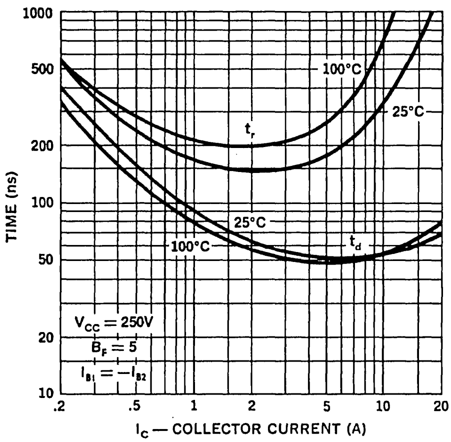
Saturation Voltages



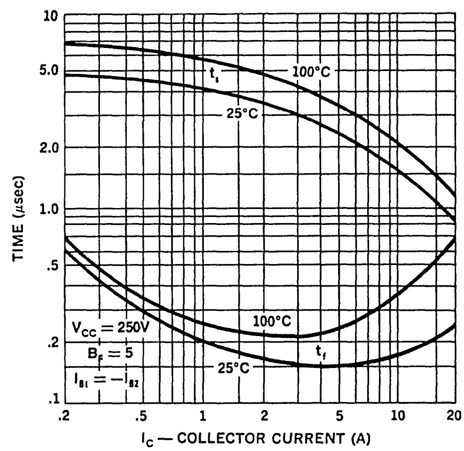
Current Gain



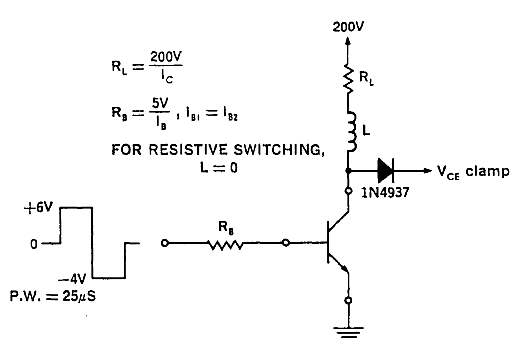
Resistive Turn-On Time



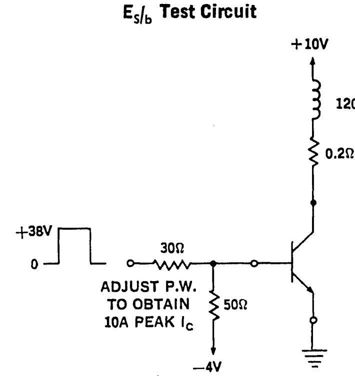
Resistive Turn-Off Time



Switching Time, $V_{CEX (sus)}$ Test Circuit



$E_s/_b$ Test Circuit



POWER TRANSISTORS

3 Amp, 500V, Fast Switching Silicon NPN Mesa

UMT1203
UMT1204

FEATURES

- Collector Emitter Voltage: up to 500V
- Peak Collector Current: 5A
- Rise Time: ⩽ 1.0μs } at I_C = 2A
- Fall Time: ⩽ 0.7μs } at I_C = 2A
- Key Parameters characterized at 100°C
- Economical Plastic Molded Construction

DESCRIPTION

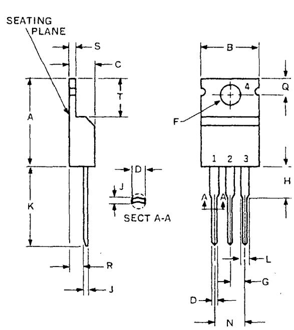
These high voltage triple diffused glass passivated power transistors, in a plastic TO-220AB package, combine fast switching, low saturation voltage and rugged $E_{s/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, deflection circuits, motor controls and solenoid/relay drivers.

ABSOLUTE MAXIMUM RATINGS

	UMT1203	UMT1204
Collector Emitter Voltage, V_{CEV}	400V	500V
Collector Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	7V	7V
Collector Current, I_C continuous	3A	3A
Collector Current, I_{CM} peak	5A	5A
Base Current, I_B continuous	1A	1A
Power Dissipation, 25°C Case	40W	40W
Derating Factor	0.32W/°C	0.32W/°C
Operating and Storage Temperature Range	—65 to 150°C	

MECHANICAL SPECIFICATIONS

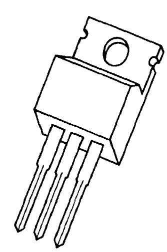
UMT1203, UMT1204



PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB



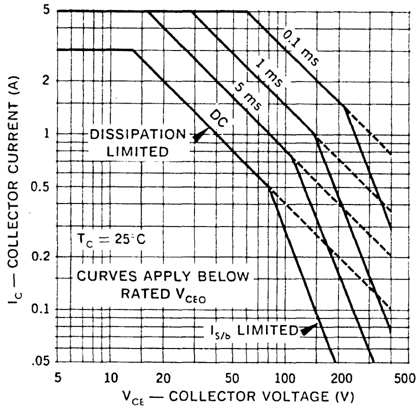
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

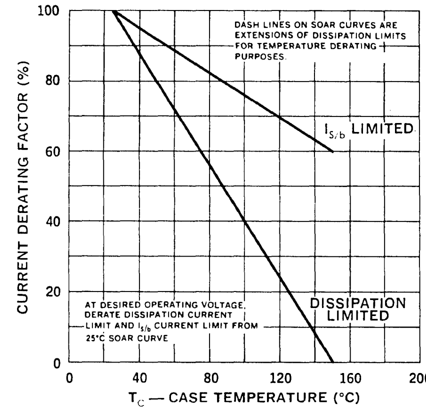
Test	Symbol	UMT1203 MIN.	UMT1203 MAX.	UMT1204 MIN.	UMT1204 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	12	60	12	60		$I_C = 1.0A$, $V_{CE} = 3V$
D.C. Current Gain (Note 1)	h_{FE}	7	35	7	35		$I_C = 2.0A$, $V_{CE} = 3V$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	1.2	—	1.2	V	$I_C = 2.0A$, $I_B = 0.4A$
Collector Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{CE\,(sat)}$	—	1.5	—	1.5	V	$I_C = 2.0A$, $I_B = 0.4A$
Collector Saturation Voltage (Note 1)	$V_{CE\,(sat)}$	—	3.0	—	3.0	V	$I_C = 3.0A$, $I_B = 0.75A$
Base Saturation Voltage (Note 1)	$V_{BE\,(sat)}$	—	1.3	—	1.3	V	$I_C = 2.0A$, $I_B = 0.4A$
Base Saturation Voltage, $T_C = 100°C$ (Note 1)	$V_{BE\,(sat)}$	—	1.5	—	1.5	V	$I_C = 2.0A$, $I_B = 0.4A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO\,(sus)}$	300	—	400	—	V	$I_C = 0.1A$
Collector-Emitter Sustaining Voltage $T_C = 100°C$ (Note 2)	$V_{CEX\,(sus)}$	350	—	450	—	V	$I_C = 2.0A$, $L = 500\mu H$; $I_{B1} = I_{B2} = 0.4A$; V_{CE} clamp = rated $V_{CEX\,(sus)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 7V$
Collector Cutoff Current	I_{CEV}	—	0.5	—	—	mA	$V_{CE} = 400V$, $V_{BE} = -1.5V$
		—	—	—	0.5	mA	$V_{CE} = 500V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	2.5	—	—	mA	$V_{CE} = 400V$, $V_{BE} = -1.5V$
		—	—	—	2.5	mA	$V_{CE} = 500V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CER}	—	3.0	—	—	mA	$V_{CE} = 400V$, $R = 50\Omega$
		—	—	—	3.0	mA	$V_{CE} = 500V$, $R = 50\Omega$
Output Capacitance, Common Base	C_{obo}	35	100	35	100	pF	$V_{CB} = 10V$, $f = 1$ MHz
Gain-Bandwidth Product	F_T	6	30	6	30	MHz	$V_{CE} = 10V$, $I_C = 0.3A$, $f = 1$ MHz
Energy Second Breakdown (unclamped)	$E_{S/b}$	80	—	80	—	μJ	$I_C = 2.0A$; $I_{B1} = 0.4A$; $L = 40\mu H$ unclamped
Resistive Switching Speeds							$I_C = 2.0A$; $V_{CC} = 200V$; $I_{B1} = I_{B2} = 0.4A$; $V_{BE\,(off)} = 5V$
Delay Time	t_d	—	0.1	—	0.1	μS	
Rise Time	t_r	—	1.0	—	1.0	μS	
Storage Time	t_s	—	4.0	—	4.0	μS	
Fall Time	t_f	—	0.7	—	0.7	μS	
Inductive Switching Speeds $T_C = 100°C$							$I_C = 2.0A$, $L = 500\mu H$; $I_{B1} = I_{B2} = 0.4A$; V_{CE} clamp = rated $V_{CEX\,(sus)}$
Storage Time	t_s	—	4.0	—	4.0	μS	
Fall Time	t_f	—	0.9	—	0.9	μS	
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	—	3.12	—	3.12	°C/W	

Notes:
1. Pulse width = $250\mu S$; duty cycle $\leq 1\%$.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length $\cong 50\mu S$; duty cycle $\leq 1\%$. Voltage clamped at maximum collector-emitter voltage.

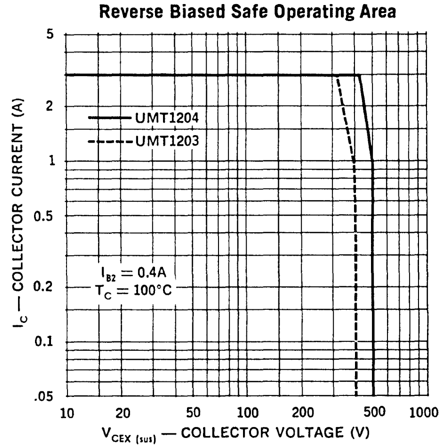
Forward Bias Safe Operating Area



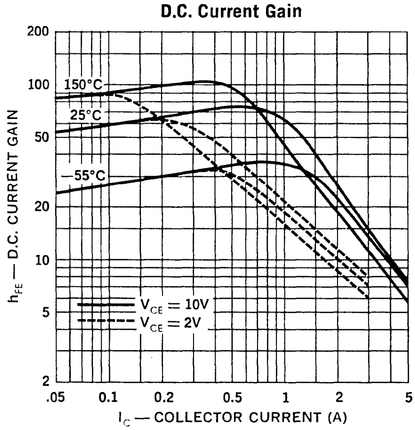
Power Derating



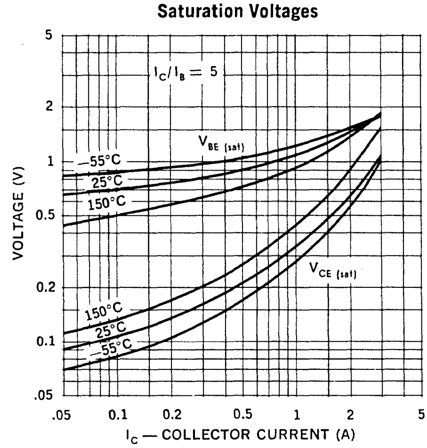
Reverse Biased Safe Operating Area



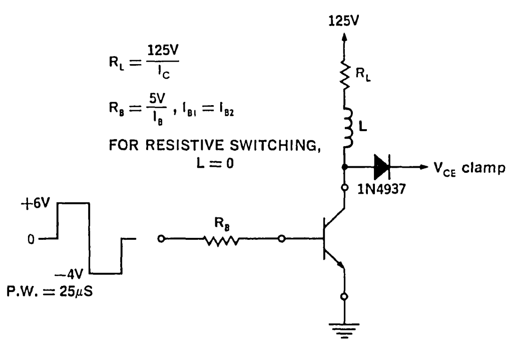
D.C. Current Gain



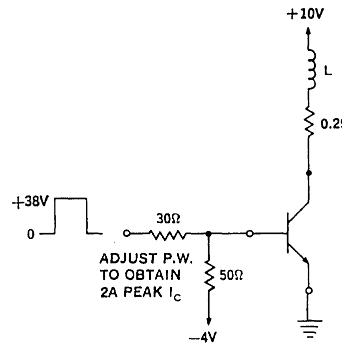
Saturation Voltages



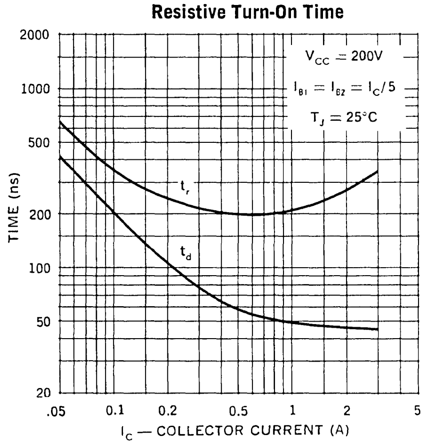
Switching Time Test Circuit



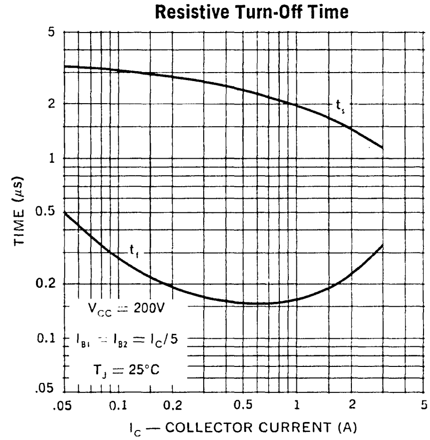
$E_{s/b}$ Test Circuit



Resistive Turn-On Time



Resistive Turn-Off Time



POWER TRANSISTORS

UMT2000

15A, 450V NPN Mesa

FEATURES

- Collector Emitter Voltage: 850V
- Peak Collector Current: 20A
- Storage Time ≤ 800ns } at I_C = 10A
- Fall Time ≤ 70ns } at I_C = 10A

DESCRIPTION

These high voltage, multiple layer epitaxial, glass passivated power transistors combine fast switching, low saturation voltage and rugged second-breakdown capability. They are designed for use in off-line power supplies, high voltage inverters and switching regulators.

ABSOLUTE MAXIMUM RATINGS

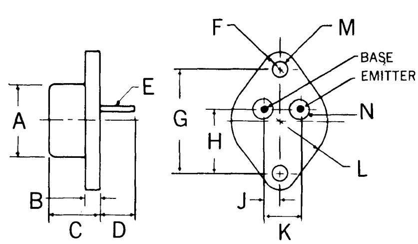
Collector Emitter Voltage, V_{CEV} 850V
Collector Emitter Voltage, $V_{CEO(sus)}$ 450V
Emitter Base Voltage, V_{EBO} 6V
Collector Current, I_C continuous 15A
Collector Current, I_{CM} peak (Note 1) 20A
Base Current, I_B continuous 10A
Base Current, I_{BM} peak 15A
Power Dissipation, 25°C Case 175W
100°C Case 100W
above 25°C, derate linearly .... 1W/°C
Operating and Storage Temperature Range .... −65°C to +200°C
Thermal Resistance, Junction to Case, $R_{\theta JC}$ .... 1°C/W

Note: 1. Pulse Test - Pulse Width = 5ms; Duty Cycle ≤ 10%

MECHANICAL SPECIFICATIONS

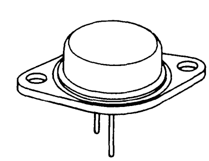
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

UMT2000



	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.043 DIA.	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-.17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.
N	.190-.210	4.83-5.33

TO-3



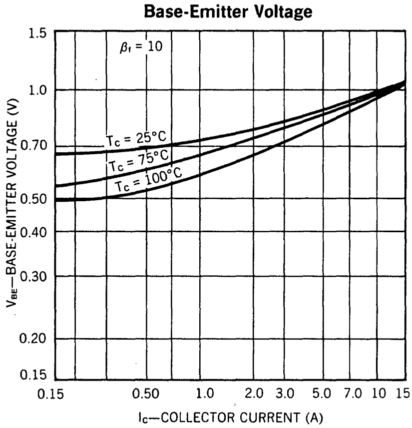
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

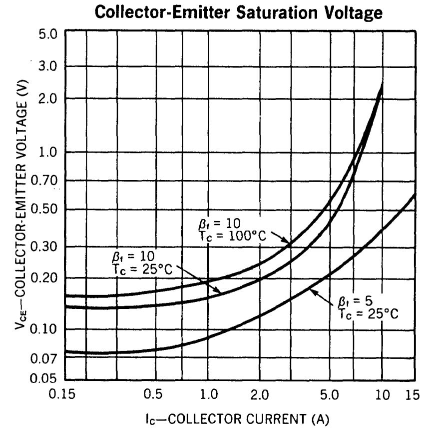
IV

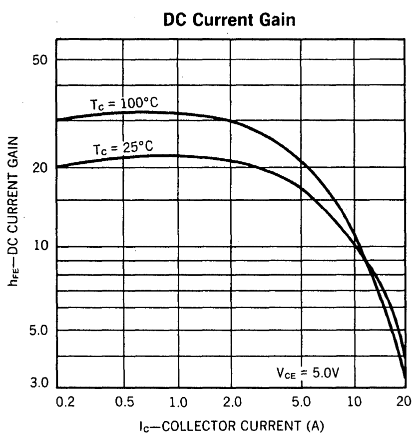
TEST	SYMBOL	MIN.	TYP.	MAX.	UNITS	TEST CONDITIONS
Off Characteristics						
Collector Emitter Sustaining Voltage	$V_{CEO(sus)}$	450	—	—	V	I_C = 100mA, I_B = 0, L = 10mH
Collector Cutoff Current	I_{CEV}	—	—	0.25	mA	V_{CEV} = 850V, $V_{BE(off)}$ = 1.5V
Collector Cutoff Current T_C = 100°C	I_{CEV}	—	—	2.5	mA	V_{CEV} = 850V, $V_{BE(off)}$ = 1.5V
Collector Cutoff Current T_C = 100°C	I_{CER}	—	—	1.5	mA	V_{CE} = 850V, R_{BE} = 50Ω
Emitter Cutoff Current	I_{EBO}	—	—	1.0	mA	V_{EB} = 6V, I_C = 0
On Characteristics (Note 1)						
Collector Emitter Saturation Voltage	$V_{CE(sat)}$	—	—	2.5	V	I_C = 5A, I_B = 0.5A
Collector Emitter Saturation Voltage	$V_{CE(sat)}$	—	—	3.0	V	I_C = 10A, I_B = 1A
Collector Emitter Saturation Voltage T_C = 100°C	$V_{CE(sat)}$	—	3.0	—	V	I_C = 10A, I_B = 1A
Base Emitter Saturation Voltage	$V_{BE(sat)}$	—	—	1.5	V	I_C = 10A, I_B = 1A
Base Emitter Saturation Voltage T_C = 100°C	$V_{BE(sat)}$	—	1.5	—	V	I_C = 10A, I_B = 1A
DC Current Gain	h_{FE}	5.0	—	—		I_C = 15A, V_{CE} = 5V
Dynamic Characteristics						
Output Capacitance	C_{obo}	—	—	400	pF	V_{CB} = 10V, I_E = 0, f test = 1.0kHz
Switching Characteristics						
Resistive Switching Speeds Turn on Time Storage Time (Note 2) Fall Time (Note 2)	 t_{on} t_s t_f	 — — —	 220 900 150	 — — —	 ns ns ns	I_C = 10A V_{CC} = 250V I_{B1} = 1A I_{B2} = 2A, R_B = 1.6Ω
Storage Time (Note 2) Fall Time (Note 2)	t_s t_f	— —	500 40	— —	ns ns	I_C = 10A V_{CC} = 250V I_{B1} = 1A I_{B2} = 2A, R_B = 1.6Ω $V_{BE(off)}$ = 5V
Inductive Switching Speeds T_C = 100°C Storage Time Fall Time Crossover Time	 t_{sv} t_{fi} t_c	 — — —	 650 30 50	 1500 150 200	 ns ns ns	I_C = 10A I_{B1} = 1A $V_{B-off)}$ = 5V $V_{CE(pk)}$ = 400V
T_C = 150°C Storage Time Fall Time Crossover Time	 t_{sv} t_{fi} t_c	 — — —	 850 30 70	 — — —	 ns ns ns	I_C = 10A I_{B1} = 1A $V_{BE(off)}$ = 5V $V_{CE(pk)}$ = 400V

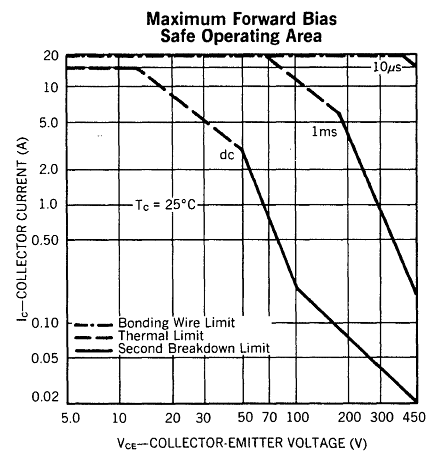
Notes: 1. Pulse Test — Pulse Width = 300μs, Duty Cycle ∢ 2%.
2. Pulse Test — Pulse Width = 30μs, Duty Cycle ∢ 2%.

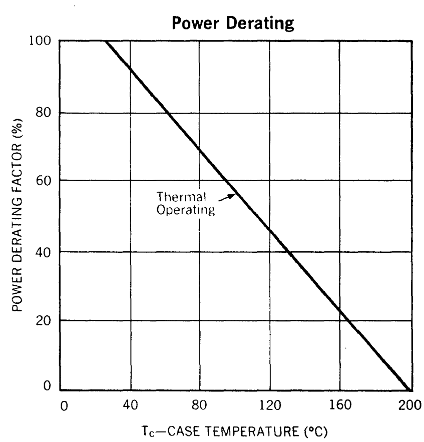
TYPICAL DYNAMIC CHARACTERISTICS



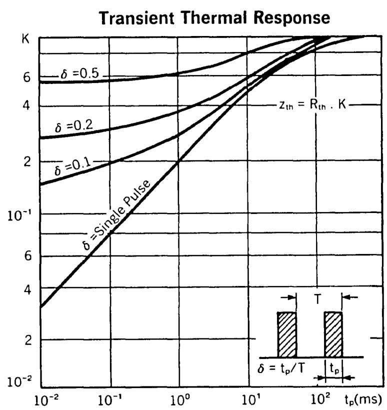


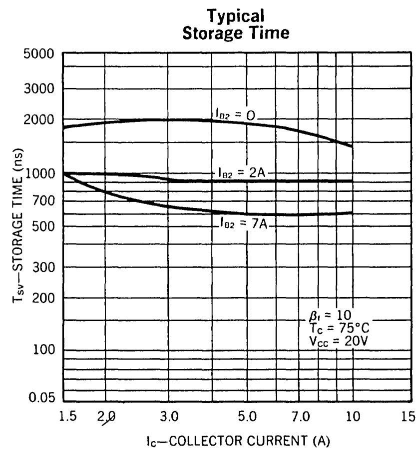


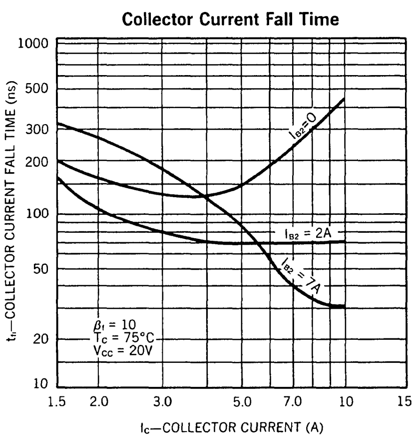


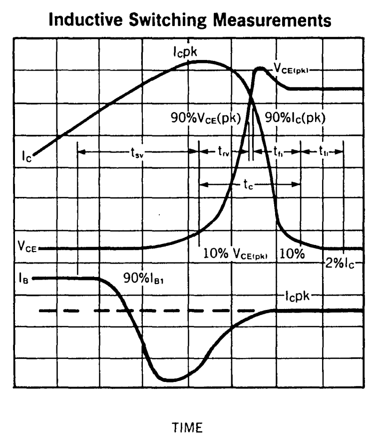


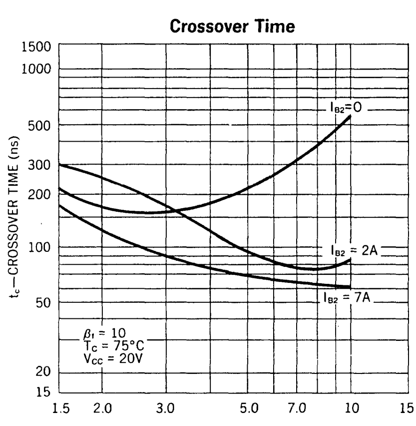
TYPICAL DYNAMIC CHARACTERISTICS











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POWER TRANSISTORS
30A, 400V, NPN Mesa

UMT2003

FEATURES
- Collector Emitter Voltage: 850V
- Peak Collector Current: 60A
- Storage Time ≤ 3μs } at I_C = 20A
- Fall Time ≤ 0.8μs } at I_C = 20A

DESCRIPTION
These high voltage, multiple layer epitaxial, glass passivated power transistors combine fast switching, low saturation voltage and rugged second-breakdown capability. They are designed for use in off-line power supplies, high voltage inverters and switching regulators.

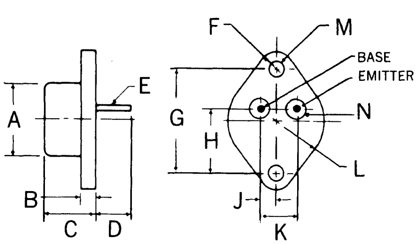
ABSOLUTE MAXIMUM RATINGS

Collector Emitter Voltage, V_{CEV}	850V
Collector Emitter Voltage, $V_{CEO(sus)}$	400V
Emitter Base Voltage, V_{EBO}	7V
Collector Current, I_C continuous	30A
Collector Current, I_{CM} peak	60A
Base Current, I_B continuous	8A
Base Current, I_{BM} peak	30A
Power Dissipation, 25°C Case	250W
Junction Temperature	+200°C
Thermal Resistance, Junction to Case, $R_{\theta JC}$	0.7°C/W

MECHANICAL SPECIFICATIONS

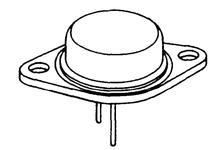
UMT2003

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	INCHES	MILLIMETERS
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.043 DIA.	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.057-.063	1.45-1.60 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.
N	.190-.210	4.83-5.33

TO-3 CASE



UNITRODE

IV

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

TEST	SYMBOL	MIN.	TYP.	MAX.	UNITS	TEST CONDITIONS
Off Characteristics						
Collector Emitter Sustaining Voltage	$V_{CEO(sus)}$	400	—	—	V	$I_C = 0.2A$, $I_B = 0$ L = 25mH
Emitter Base Voltage	V_{EBO}	7	—	30	V	$I_C = 0A$, $I_B = 0.1A$
Collector Cutoff Current $T_C = 25°C$	I_{CEX}	—	—	0.4	mA	$V_{CE} = V_{CEX}$ $V_{BE} = -2.5V$
Collector Cutoff Current $T_C = 125°C$	I_{CEX}	—	—	4	mA	$V_{CE} = V_{CEX}$ $V_{BE} = -2.5V$
Collector Cutoff Current $T_C = 25°C$	I_{CER}	—	—	1	mA	$V_{CE} = V_{CEX}$ $R_{BE} \leq 5\Omega$
Collector Cutoff Current $T_C = 125°C$	I_{CER}	—	—	8	mA	$V_{CE} = V_{CEX}$ $R_{BE} \leq 5\Omega$
Emitter Cutoff Current	I_{EBO}	—	—	2	mA	$V_{EB} = 5V$, $I_C = 0$
On Characteristics (Note 1)						
Collector Emitter Saturation Voltage	$V_{CE(sat)}$	—	—	1.5	V	$I_C = 20A$, $I_B = 4A$
Collector Emitter Saturation Voltage	$V_{CE(sat)}$	—	—	3.5	V	$I_C = 30A$, $I_B = 8A$
Base Emitter Saturation	$V_{BE(sat)}$	—	—	1.6	V	$I_C = 20A$, $I_B = 4A$
Dynamic Characteristics						
Gain-Bandwidth Product	f_T	—	5	—	MHz	$V_{CE} = 10V$, $I_C = 1A$ f = 1MHz
Output Capacitance	C_{obo}	—	500	—	pF	$V_{CE} = 10V$, f = 1MHz
Switching Characteristics						
Resistive Switching Speeds Turn On Time Storage Time Fall Time	 t_{on} t_s t_f	 — — —	 0.55 1.5 0.3	 1 3 0.8	 μs μs μs	 $I_C = 20A$ $V_{CC} = 150V$ $I_{B1} = -I_{B2} = 4A$
Inductive Switching Speeds $T_j = 25°C$ Storage Time Fall Time	 t_s t_f	 — —	 3.5 0.08	 — —	 μs μs	 $I_C = 20A$, $I_{B(end)} = 4A$ $L_B = 50\mu H$ $V_{CC} = 300V$, $-V_{BE} = 5V$
Inductive Switching Speeds $T_j = 100°C$ Storage Time Fall Time	 t_s t_f	 — —	 — —	 5 0.4	 μs μs	 $I_C = 20A$, $I_{B(end)} = 4A$ $L_B = 1.5\mu H$ $V_{CC} = 30V$, $-V_{BE} = 5V$

Note: 1. $t_p = 300\mu s$; duty cycle $\leq 2\%$.

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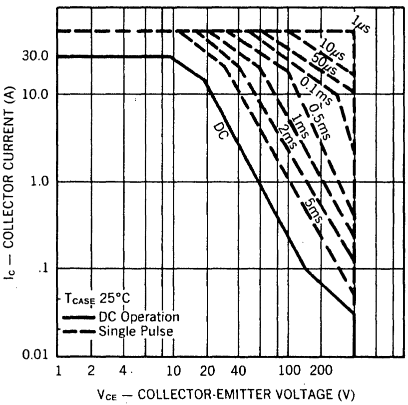
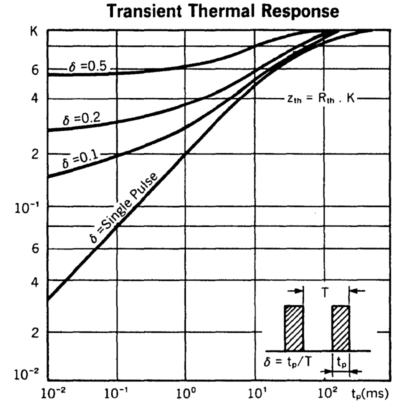
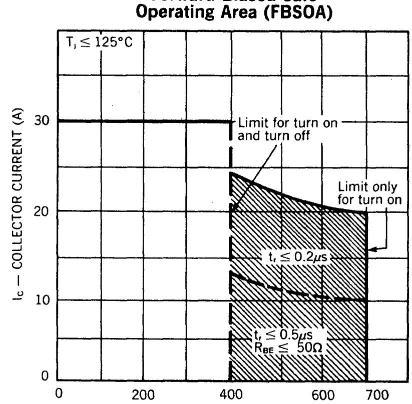






The shaded area can only be used for turn on.
V_{CE} — COLLECTOR-EMITTER VOLTAGE (V)

POWER TRANSISTORS

UMT3584
UMT3585

2 Amp, 500V, Fast Switching Silicon NPN Mesa

IV

FEATURES

- Collector Base Voltage: up to 500V
- Peak Collector Current: 5A
- Rise Time ⩽ 3μs } $I_C = 1A$
- Fall Time ⩽ 3μs }
- Economical Plastic Molded Construction

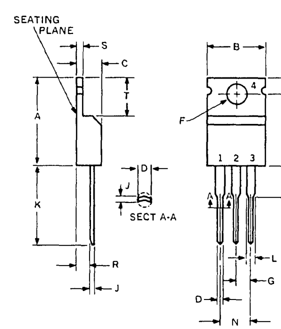
DESCRIPTION

These high voltage triple diffused glass passivated power transistors in a plastic TO-220AB package combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line switching regulators, converters, inverters and deflection circuitry.

ABSOLUTE MAXIMUM RATINGS

	UMT3584	UMT3585
Collector Base Voltage, V_{CBO}	375V	500V
Collector Emitter Voltage, $V_{CEO\,(sus)}$	250V	300V
Emitter Base Voltage, V_{EBO}	6V	6V
Collector Current, I_C continuous	2A	2A
I_{CM} peak	5A	5A
D.C. Base Current, continuous	1A	1A
Power Dissipation, P_T 25°C Case	35W	35W
Operating and Storage Temperature Range	−65 to +150°C	

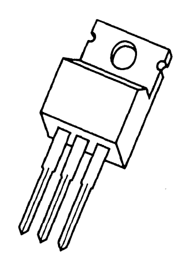
MECHANICAL SPECIFICATIONS



Pin 1. Gate
2. Drain
3. Source
4. Drain

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB

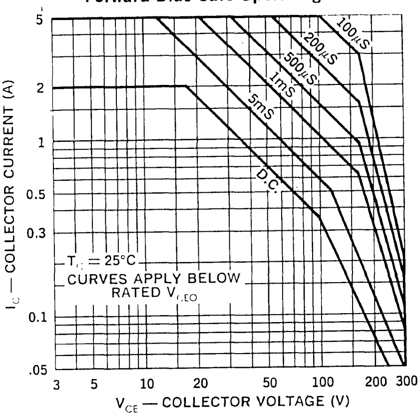


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

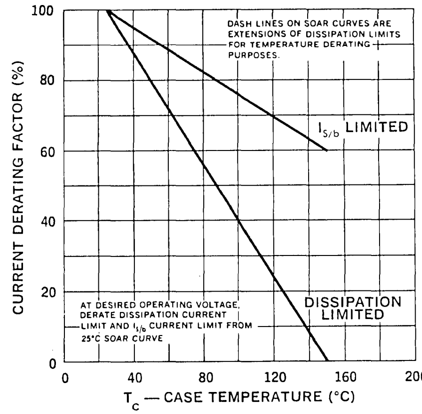
Test	Symbol	UMT3584 MIN.	UMT3584 MAX.	UMT3585 MIN.	UMT3585 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	40 8 25	— 80 100	40 8 25	— 80 100		$I_C = 100mA, V_{CE} = 10V$ $I_C = 1A, V_{CE} = 2V$ $I_C = 1A, V_{CE} = 10V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	0.75	—	0.75	V	$I_C = 1A, I_B = 125mA$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.4	—	1.4	V	$I_C = 1A, I_B = 100mA$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	250	—	300	—	V	$I_C = 200mA$
Collector-Emitter Sustaining Voltage (See Note 2)	$V_{CER(sus)}$	300	—	400	—	V	$I_C = 200mA$ $R_{BE} = 200\Omega$
Emitter Cutoff Current	I_{EBO}	—	0.5	—	0.5	mA	$V_{BE} = -6V$
Collector-Cutoff Current	I_{CEO}	—	5.0	—	5.0	mA	$V_{CE} = 150V$
Collector-Cutoff Current	I_{CEV}	— —	1.0 —	— —	— 1.0	mA	$V_{CE} = 340V, V_{BE} = -1.5V$ $V_{CE} = 450V, V_{BE} = -1.5V$
Collector Cutoff Current, 150°C	I_{CEV}	—	3.0	—	3.0	mA	$V_{CE} = 300V, V_{BE} = -1.5V$
Small Signal Forward Transfer Ratio	h_{fe}	3	—	3	—	—	$I_C = 200mA, V_{CE} = 10V$ $f = 5 MHz$
Collector Capacitance	C_{ob}	—	120	—	120	pF	$V_{CB} = 10V, f = 1 MHz$
Second Breakdown Collector Current	$I_{s/b}$	350	—	350	—	mA	$V_{CE} = 100V$
Second Breakdown Energy	$E_{s/b}$	200	—	200	—	μJ	$I_C = 2A$ $R_{BE} = 20\Omega$ $L = 100\mu H$
Switching Speeds Rise Time Storage Time Fall Time	 t_r t_s t_f	 — — —	 3.0 4.0 3.0	 — — —	 3.0 4.0 3.0	μs	$I_C = 1A$ $I_{B1} = I_{B2} = 100mA$ $V_{CC} = 200V$
Thermal Resistance: Junction-to-Case	$R_{\Theta JC}$	—	3.57	—	3.57	°C/W	
Junction-to-Ambient	$R_{\Theta JA}$	—	70	—	70	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

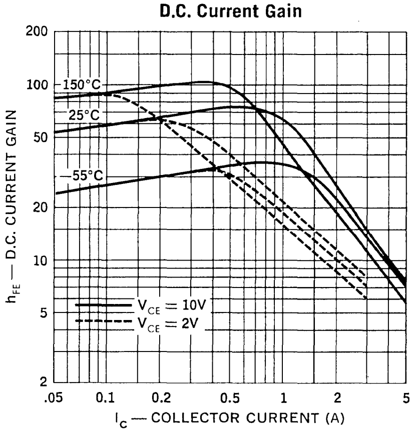
Forward Bias Safe Operating Area



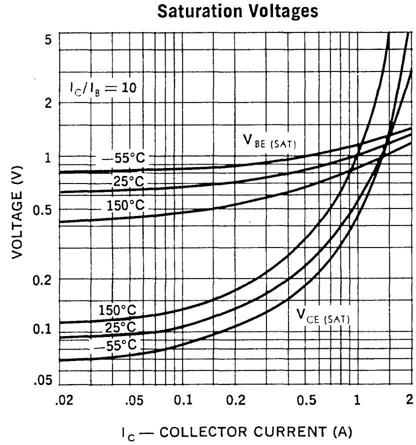
Power Derating



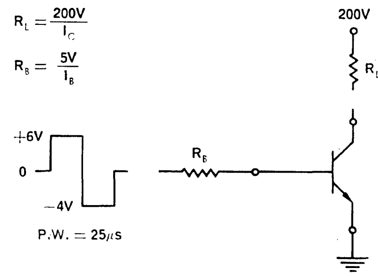
D.C. Current Gain



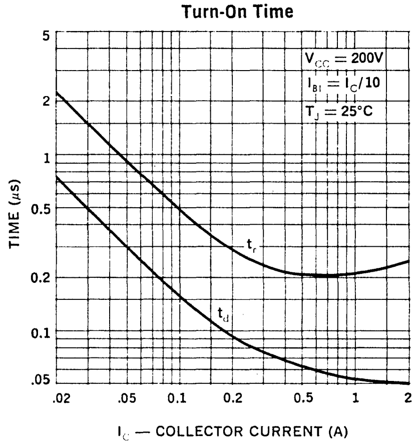
Saturation Voltages



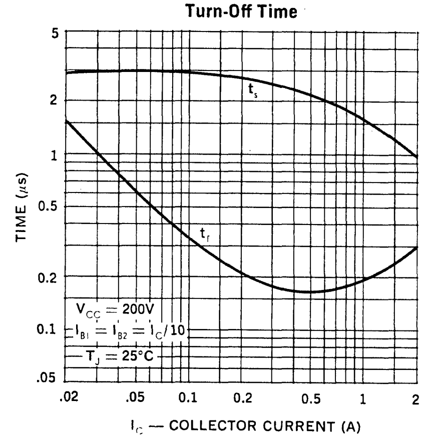
Switching Time Test Circuit



Turn-On Time



Turn-Off Time



POWER TRANSISTORS

4A, 700V, Fast Switching, Silicon NPN Mesa

UMT13004
UMT13005

IV

FEATURES

- Collector Emitter Voltage: up to 700V
- Peak Collector Current: 8A
- Rise Time: $\leqslant .7\mu S$ } at $I_C = 2A$
- Fall Time: $\leqslant 0.9\mu S$ } at $I_C = 2A$
- Key Parameters characterized at 100°C
- Economical Plastic Molded Construction

DESCRIPTION

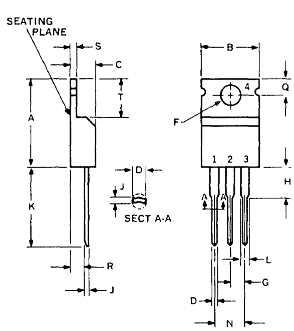
These high voltage glass passivated power transistors, in a plastic TO-220AB package, combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, deflection circuits, motor controls and solenoid/relay drivers.

ABSOLUTE MAXIMUM RATINGS

	UMT13004	UMT13005
Collector Emitter Voltage, V_{CEV}	600V	700V
Collector Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C continuous	4A	4A
Collector Current, I_{CM} peak	8A	8A
Base Current, I_B continuous	2A	2A
Power Dissipation, 25°C Case	75W	75W
Derating Factor	0.59W/°C	0.59W/°C
Operating and Storage Temperature Range	−65 to 150°C	

MECHANICAL SPECIFICATIONS

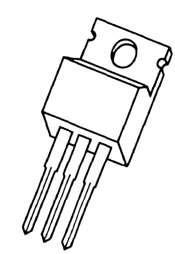
UMT13004, UMT13005



PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	UMT13004 MIN.	UMT13004 MAX.	UMT13005 MIN.	UMT13005 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	10	60	10	60		$I_C = 1.0A, V_{CE} = 5V$
D.C. Current Gain (Note 1)	h_{FE}	8	40	8	40		$I_C = 2.0A, V_{CE} = 5V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	.5	—	.5	V	$I_C = 1.0A, I_B = 0.2A$
Collector Saturation Voltage (Note 1) $T_C = 25°C$	$V_{CE(sat)}$	—	0.6	—	0.6	V	$I_C = 2.0A, I_B = 0.5A$
$T_C = 100°C$		—	1.0	—	1.0		
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 4.0A, I_B = 1.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.2	—	1.2	V	$I_C = 1.0A, I_B = 0.2A$
Base Saturation Voltage (Note 1) $T_C = 25°C$	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 2.0A, I_B = 0.5A$
$T_C = 100°C$		—	1.5	—	1.5		
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 1$ mA
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	1	—	—	mA	$V_{CE} = 600V, V_{BE} = -1.5V$
		—	—	—	1		$V_{CE} = 700V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	5	—	—	mA	$V_{CE} = 600V, V_{BE} = -1.5V$
		—	—	—	5		$V_{CE} = 700V, V_{BE} = -1.5V$
Output Capacitance, Common Base	C_{obo}	65 typ.		65 typ.		pF	$V_{CB} = 10V$, f = 1 MHz
Gain-Bandwidth Product	F_T	4	—	4	—	MHz	$V_{CE} = 10V, I_C = .5A$, f = 1 MHz
Resistive Switching Speeds							
Delay Time	t_d	—	0.1	—	0.1	μS	$I_C = 2.0A$
Rise Time	t_r	—	0.7	—	0.7	μS	$V_{CC} = 125V$
Storage Time	t_s	—	3.5	—	3.5	μS	$I_{B1} = I_{B2} = 0.4A$
Fall Time	t_f	—	0.9	—	0.9	μS	$V_{BE(off)} = 5V$, P.W. = $25\mu S$
Inductive Switching Speeds $T_C = 100°C$							$I_C = 2.0A, L = 500\mu H$
Storage Time	t_s	—	4.0	—	4.0	μS	$I_{B1} = 0.4A, V_{BE(off)} = 5V$
Fall Time ($t_{fi} + t_{fv}$)	t_f	—	0.9	—	0.9	μS	V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	—	1.67	—	1.67	°C/W	
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	—	62.5	—	62.5	°C/W	

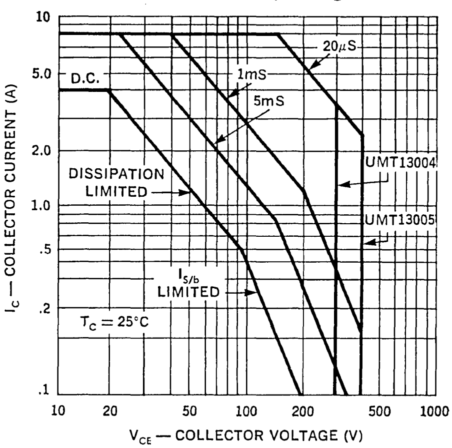
Notes:
1. Pulse width = $250\mu S$; duty cycle $\leq 1\%$.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length $\cong 50\mu S$; duty cycle $\leq 1\%$. Voltage clamped at maximum collector-emitter voltage.

Typical Inductive Load Switching Performance

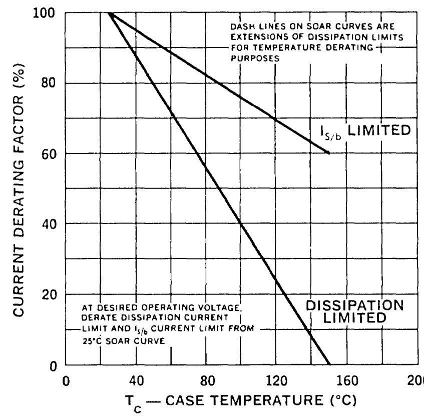
I_C Amps	T_J °C	t_s μS	t_{fv} nS	t_{fi} nS
0.5	25	1.8	180	20
	100	1.2	240	30
1.0	25	1.0	160	21
	100	1.5	220	30
2.0	25	1.2	180	25
	100	1.7	230	35

IV

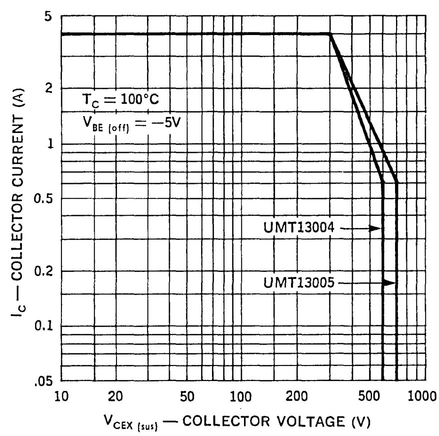
Forward Bias Safe Operating Area



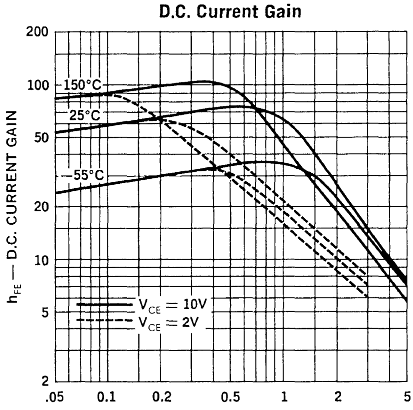
Power Derating



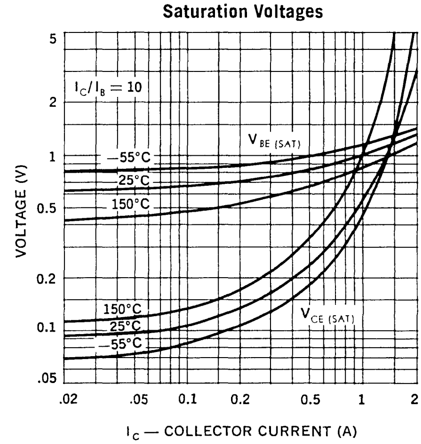
Reverse Biased Safe Operating Area



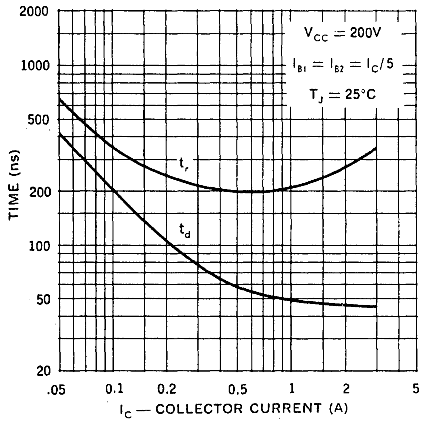
D.C. Current Gain



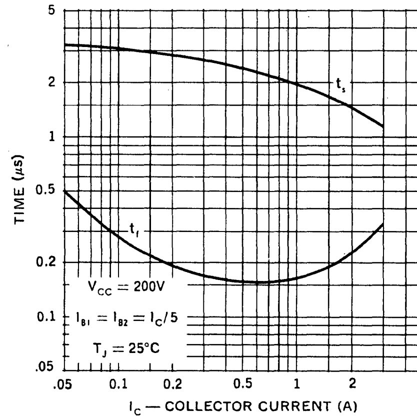
Saturation Voltages



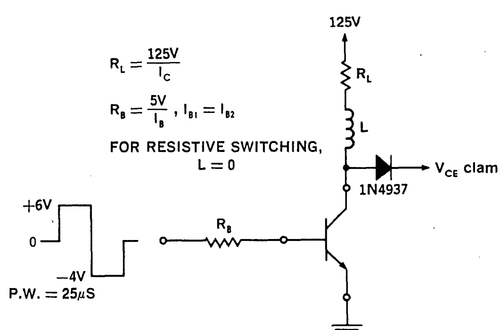
Resistive Turn-On Time



Resistive Turn-Off Time



Switching Time Test Circuit



POWER TRANSISTORS

8A, 700V, Fast Switching, Silicon NPN Mesa

UMT13006
UMT13007

IV

FEATURES

- Collector Emitter Voltage: up to 700V
- Peak Collector Current: 16A
- Rise Time: ≤ 1.0μS } at $I_C = 5A$
- Fall Time: ≤ 0.7μS } at $I_C = 5A$
- Key Parameters characterized at 100°C
- Economical Plastic Molded Construction

DESCRIPTION

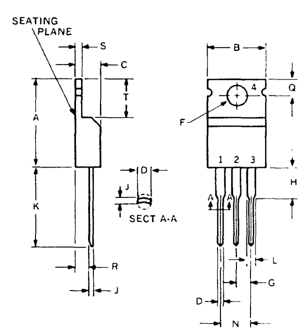
These high voltage glass passivated power transistors, in a plastic TO-220AB package, combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, deflection circuits, motor controls and solenoid/relay drivers

ABSOLUTE MAXIMUM RATINGS

	UMT13006	UMT13007
Collector Emitter Voltage, V_{CEV}	600V	700V
Collector Emitter Voltage, $V_{CEO\ (SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	8V	8V
Collector Current, I_C continuous	8A	8A
Collector Current, I_{CM} peak	16A	16A
Base Current, I_B continuous	4A	4A
Power Dissipation, 25°C Case	80W	80W
Derating Factor	0.641W/°C	0.641W/°C
Operating and Storage Temperature Range	—65 to 150°C	

MECHANICAL SPECIFICATIONS

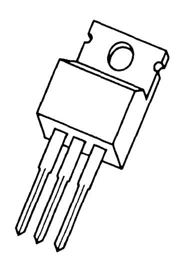
UMT13006, UMT13007



PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	UMT13006 MIN.	UMT13006 MAX.	UMT13007 MIN.	UMT13007 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	8	40	8	40		$I_C = 2.0A, V_{CE} = 5V$
D.C. Current Gain (Note 1)	h_{FE}	6	30	6	30		$I_C = 5.0A, V_{CE} = 5V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 2.0A, I_B = 0.4A$
Collector Saturation Voltage (Note 1) $T_C = 25°C$	$V_{CE(sat)}$	—	1.5	—	1.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage (Note 1) $T_C = 100°C$	$V_{CE(sat)}$	—	2.0	—	2.0	V	$I_C = 5.0A, I_B = 1.0A$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	3.0	—	3.0	V	$I_C = 8.0A, I_B = 2.0A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.2	—	1.2	V	$I_C = 2.0A, I_B = 0.4A$
Base Saturation Voltage (Note 1) $T_C = 25°C$	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A, I_B = 1.0A$
Base Saturation Voltage (Note 1) $T_C = 100°C$	$V_{BE(sat)}$	—	1.5	—	1.5	V	$I_C = 5.0A, I_B = 1.0A$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 10mA$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	1.0	—	—	mA	$V_{CE} = 600V, V_{BE} = -1.5V$
Collector Cutoff Current	I_{CEV}	—	—	—	1.0	mA	$V_{CE} = 700V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	5	—	—	mA	$V_{CE} = 600V, V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	—	—	5	mA	$V_{CE} = 700V, V_{BE} = -1.5V$
Output Capacitance, Common Base	C_{obo}	110 typ.		110 typ.		pF	$V_{CB} = 10V, f = 1 MHz$
Gain-Bandwidth Product	F_T	4	—	4	—	MHz	$V_{CE} = 10V, I_C = 0.5A, f = 1 MHz$
Resistive Switching Speeds							$I_C = 5.0A$, $V_{CC} = 125V$, $I_{B1} = I_{B2} = 1A$, $V_{BE(off)} = 5V$
Delay Time	t_d	—	0.1	—	0.1	μS	
Rise Time	t_r	—	1.0	—	1.0	μS	
Storage Time	t_s	—	3.0	—	3.0	μS	
Fall Time	t_f	—	0.7	—	0.7	μS	
Inductive Switching Speeds $T_C = 100°C$							$I_C = 5.0A, V_{BE(off)} = 5V$, $I_{B1} = 1A$, V_{CE} clamp = rated $V_{CEX(sus)}$
Storage Time	t_s	—	2.3	—	2.3	μS	
Fall Time ($t_{fi} + t_{fv}$)	t_f	—	0.7	—	0.7	μS	
Thermal Resistance, Junction-to-Case	$R_{\Theta JC}$	—	1.56	—	1.56	°C/W	
Thermal Resistance, Junction-to-Ambient	$R_{\Theta JA}$	—	62.5	—	62.5	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

Typical Inductive Load Switching Performance

Conditions:

$\frac{I_C}{I_{B1}} = 5$

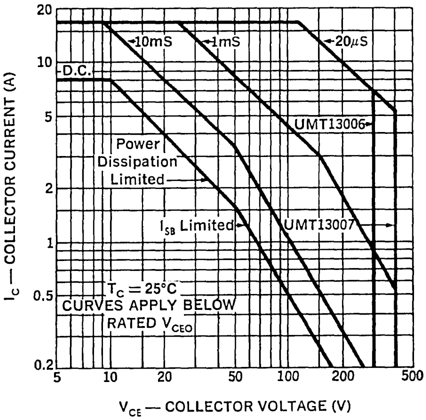
V clamp at rated $V_{CEX(sus)}$ (refer to RBSOA curve)

$V_{BE(off)} = -5V$

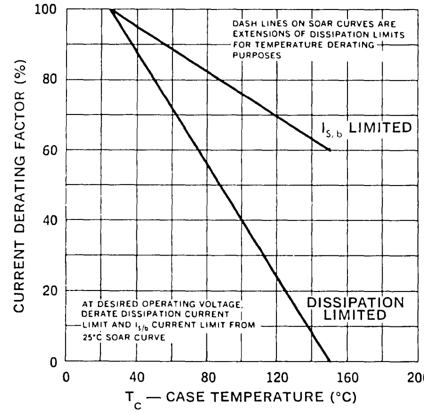
I_C Amps	T_J °C	t_s μS	t_{fv} nS	t_{fi} nS
3.0	25	.45	70	10
	100	.575	100	20
5.0	25	.475	25	4
	100	.60	45	10
8.0	25	.525	20	10
	100	.625	45	15

IV

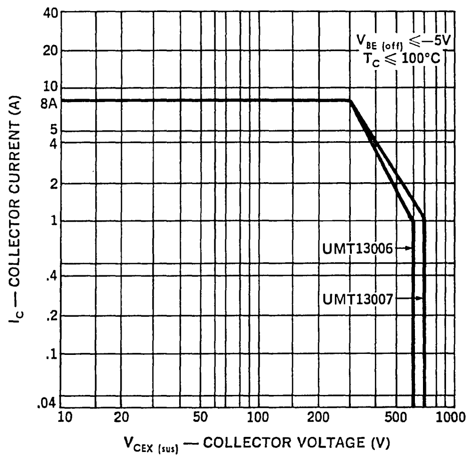
Forward Bias Safe Operating Area



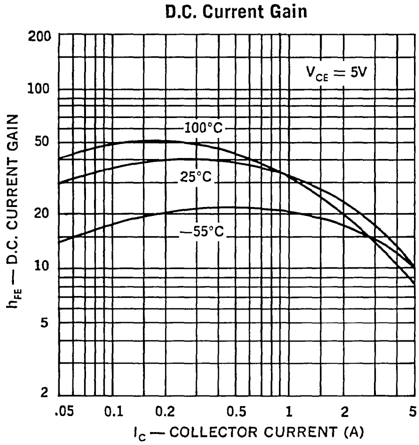
Power Derating



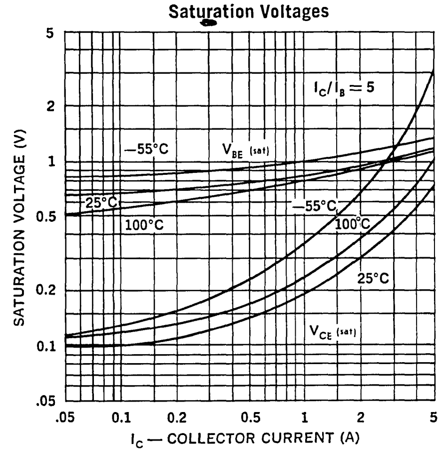
Reverse Biased Safe Operating Area



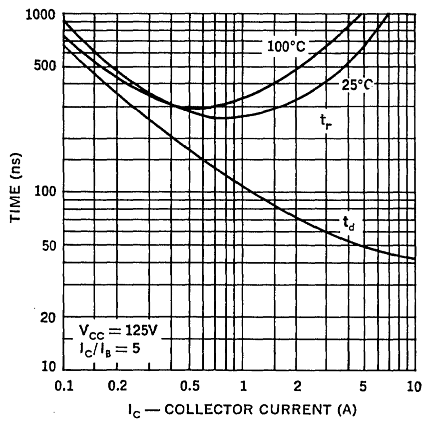
D.C. Current Gain



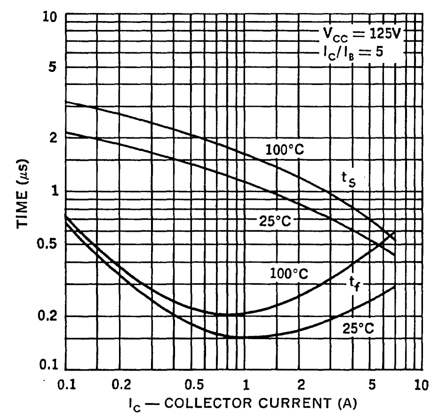
Saturation Voltages



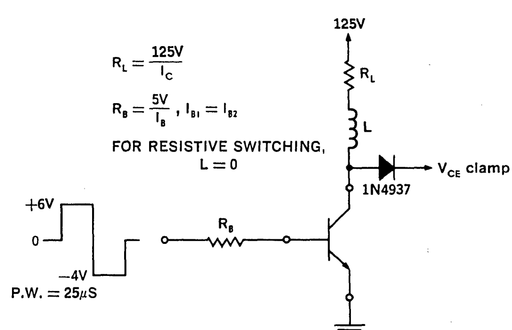
Resistive Turn-On Time



Resistive Turn-Off Time



Switching Time Test Circuit



POWER TRANSISTORS

12A, 700V, Fast Switching, Silicon NPN Mesa

UMT13008
UMT13009

IV

FEATURES

- Collector Emitter Voltage: up to 700V
- Peak Collector Current: 24A
- Rise Time: $\leqslant 1.0\mu S$ } at $I_C = 8A$
- Fall Time: $\leqslant 0.7\mu S$ } at $I_C = 8A$
- Key Parameters characterized at 100°C
- Economical Plastic Molded Construction

DESCRIPTION

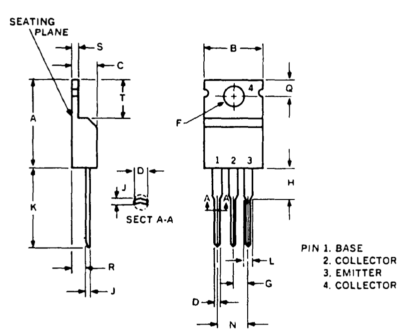
These high voltage glass passivated power transistors, in a plastic TO-220AB package, combine fast switching, low saturation voltage and rugged $E_{S/b}$ capability. They are designed for use in off-line power supplies, high voltage inverters, switching regulators, deflection circuits, motor controls and solenoid/relay drivers.

ABSOLUTE MAXIMUM RATINGS

	UMT13008	UMT13009
Collector Emitter Voltage, V_{CEV}	600V	700V
Collector Emitter Voltage, $V_{CEO\,(SUS)}$	300V	400V
Emitter Base Voltage, V_{EBO}	9V	9V
Collector Current, I_C continuous	12A	12A
Collector Current, I_{CM} peak	24A	24A
Base Current, I_B continuous	6A	6A
Power Dissipation, 25°C Case	100W	100W
Derating Factor	0.80W/°C	0.80W/°C
Operating and Storage Temperature Range	–65 to 150°C	

MECHANICAL SPECIFICATIONS

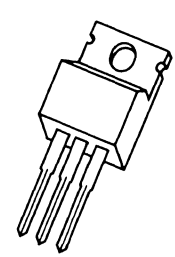
UMT13008 UMT13009



PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	UMT13008 MIN.	UMT13008 MAX.	UMT13009 MIN.	UMT13009 MAX.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	8	40	8	40		$I_C = 5.0A$, $V_{CE} = 5V$
D.C. Current Gain (Note 1)	h_{FE}	6	30	6	30		$I_C = 8.0A$, $V_{CE} = 5V$
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 5.0A$, $I_B = 1.0A$
Collector Saturation Voltage (Note 1) $T_C = 25°C$	$V_{CE(sat)}$	—	1.5	—	1.5	V	$I_C = 8.0A$, $I_B = 1.6A$
$T_C = 100°C$		—	2.0	—	2.0		
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	3.0	—	3.0	V	$I_C = 12.0A$, $I_B = 3A$
Base Saturation Voltage (Note 1)	$V_{BE(sat)}$	—	1.2	—	1.2	V	$I_C = 5.0A$, $I_B = 1.0A$
Base Saturation Voltage (Note 1) $T_C = 25°C$	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 8.0A$, $I_B = 1.6A$
$T_C = 100°C$		—	1.5	—	1.5		
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	300	—	400	—	V	$I_C = 10mA$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	1.0	—	—	mA	$V_{CE} = 600V$, $V_{BE} = -1.5V$
		—	—	—	1.0		$V_{CE} = 700V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	5.0	—	—	mA	$V_{CE} = 600V$, $V_{BE} = -1.5V$
		—	—	—	5.0		$V_{CE} = 700V$, $V_{BE} = -1.5V$
Output Capacitance, Common Base	C_{obo}	180 typ.		180 typ.		pF	$V_{CB} = 10V$, f = 1 MHz
Gain-Bandwidth Product	F_T	4	—	4	—	MHz	$V_{CE} = 10V$, $I_C = 0.5A$, f = 1 MHz
Resistive Switching Speeds						μS	$I_C = 8.0$
Delay Time	t_d	—	0.1	—	0.1		$V_{CC} = 125V$
Rise Time	t_r	—	1.0	—	1.0		$I_{B1} = I_{B2} = 1.6A$
Storage Time	t_s	—	3.0	—	3.0		$V_{BE(off)} = 5V$
Fall Time	t_f	—	0.7	—	0.7		
Inductive Switching Speeds $T_C = 100°C$						μS	$I_C = 8A$, $V_{BE(off)} = 5V$
Storage Time	t_s	—	2.3	—	2.3		$I_{B1} = 1.6A$
Fall Time ($t_{fi} + t_{fv}$)	t_f	—	0.7	—	0.7		V_{CE} clamp = rated $V_{CEX(sus)}$
Thermal Resistance, Junction-to-Case	$R_{\Theta JC}$	—	1.25	—	1.25	°C/W	
Thermal Resistance, Junction-to-Ambient	$R_{\Theta JA}$	—	62.5	—	62.5	°C/W	

Notes:
1. Pulse width = 250μS; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50μS; duty cycle ≤ 1%. Voltage clamped at maximum collector-emitter voltage.

Typical Inductive Load Switching Performance

Conditions:

$\frac{I_C}{I_{B1}} = 5$

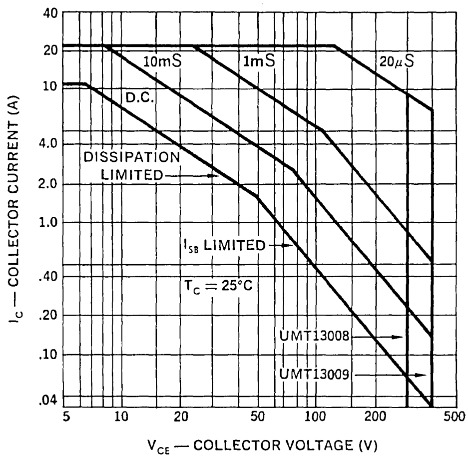
V clamp at rated $V_{CEX(sus)}$ (refer to RBSOA curve)

$V_{BE(off)} = -5V$

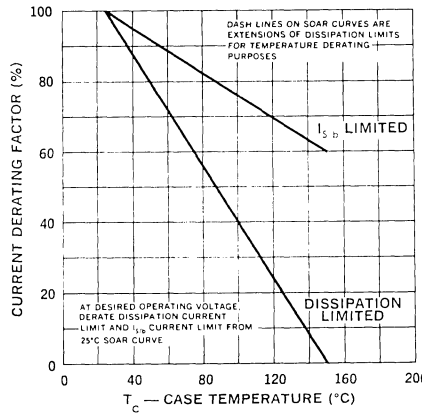
I_C Amps	T_J °C	t_s μS	t_{fv} nS	t_{fi} nS
3.0	25	0.5	100	10
	100	0.85	130	14
5.0	25	0.65	40	10
	100	0.90	50	12
8.0	25	0.72	60	12
	100	.092	65	28
12.0	25	.70	70	25
	100	.78	70	110

IV

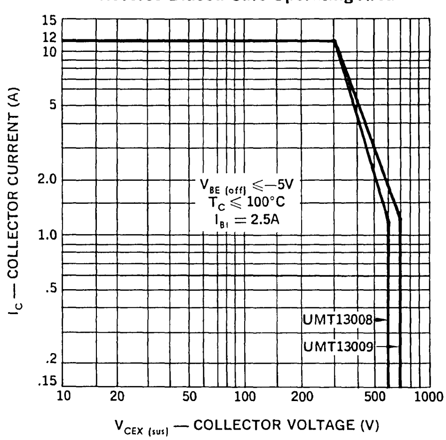
Forward Bias Safe Operating Area



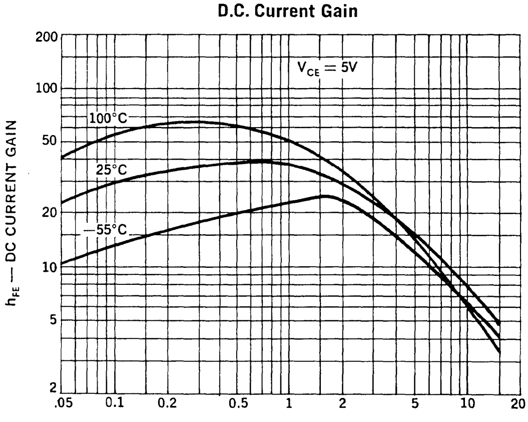
Power Derating



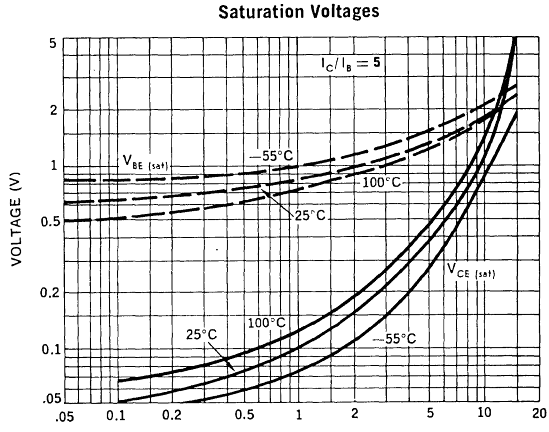
Reverse Biased Safe Operating Area



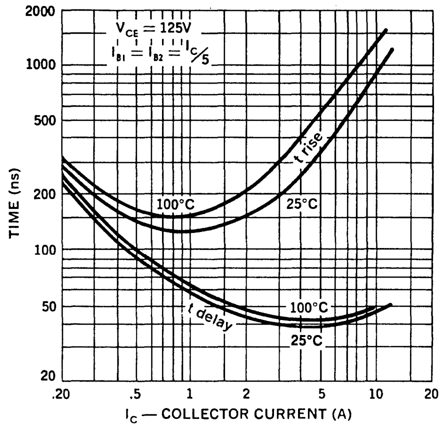
D.C. Current Gain



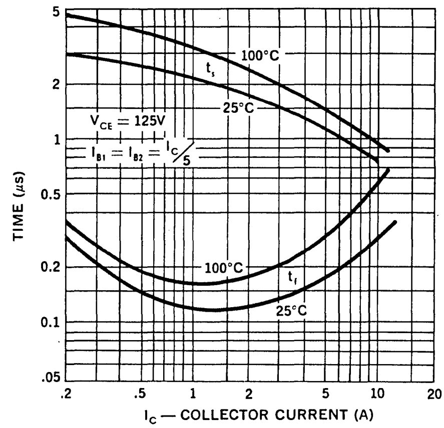
Saturation Voltages



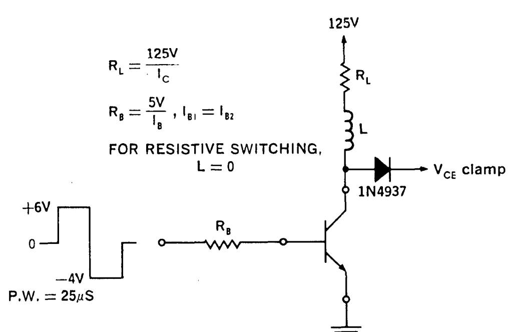
Resistive Turn-On Time



Resistive Turn-Off Time



Switching Time Test Circuit



POWER TRANSISTORS
1 Amp, 150V, Planar NPN

UPT111
UPT112
UPT113
UPT114
UPT115

IV

FEATURES
- Collector-Base Voltage: up to 150V
- Peak Collector Current: 2A
- Turn-on Time: 100ns
- Turn-off Time: 250ns

DESCRIPTION
Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

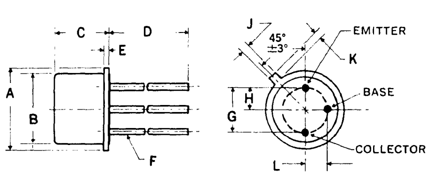
	UPT111	UPT112	UPT113	UPT114	UPT115
Collector-Base Voltage, V_{CBO}	60V	80V	100V	120V	150V
Collector-Emitter Voltage, V_{CEO}	40V	60V	80V	100V	100V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	1A	1A	1A	1A	1A
Peak Collector Current, I_C	2A	2A	2A	2A	2A
Base Current, I_B	0.5A	0.5A	0.5A	0.5A	0.5A

Power Dissipation
- 25°C Ambient .85W
- 100°C Case 4W

Thermal Resistance, Θ_{J-C} 25°C/W
Operating and Storage Temperature Range —65°C to 200°C

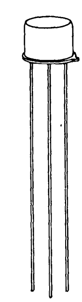
MECHANICAL SPECIFICATIONS

UPT111 UPT112 UPT113 UPT114 UPT115



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	0.254-0.762
F	.017 ± $^{.002}_{.001}$	.432 ± $^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



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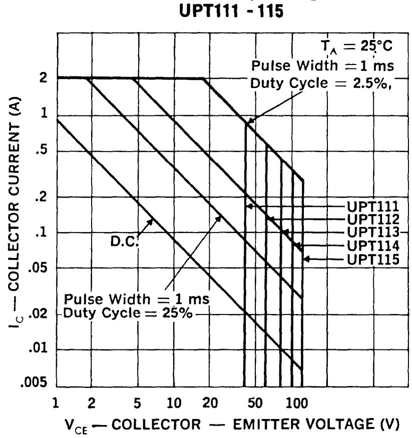
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

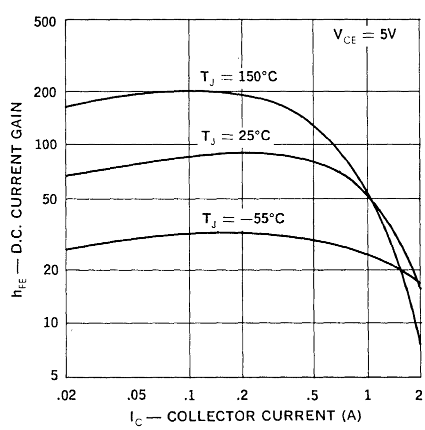
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	30	—	—	$I_C = 0.5A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	$I_C = 1A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	15 Typ.		—	$I_C = 2A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	$I_C = 1A$, $I_B = 0.1A$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.2	Vdc	$I_C = 1A$, $I_B = 0.1A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}			Vdc	$I_C = 10mAdc$; $R_{BE} = 100\Omega$
UPT111		60	—		
UPT112		80	—		
UPT113		100	—		
UPT114		120	—		
UPT115		150	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT111		40	—		
UPT112		60	—		
UPT113		80	—		
UPT114-5		100	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, T = 150°C
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	40	pf	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
Gain-Bandwidth Product	f_T	50 Typ.		MHz	$I_C = 0.1Adc$, $V_{CE} = 5Vdc$, f = 10MHz
Switching Speeds — Turn-on Time	t_{on}	100 Typ.		ns	$I_C = 1A$
Switching Speeds — Turn-off Time	t_{off}	250 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ≤2%.

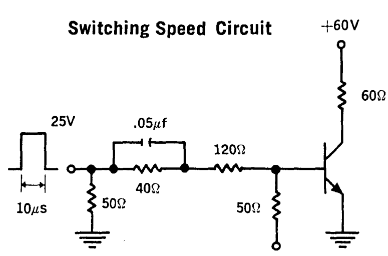
Maximum Safe Operating Area UPT111 - 115



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



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POWER TRANSISTORS

2 Amp, 150V, Planar NPN

UPT211
UPT212
UPT213
UPT214
UPT215

IV

FEATURES

- Collector-Base Voltage: up to 150V
- Peak Collector Current: 5A
- Turn-on Time: 130ns
- Turn-off Time: 300ns

DESCRIPTION

Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply, pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

	UPT211	UPT212	UPT213	UPT214	UPT215
Collector-Base Voltage, V_{CBO}	60V	80V	100V	120V	150V
Collector-Emitter Voltage, V_{CEO}	40V	60V	80V	100V	100V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	2A	2A	2A	2A	2A
Peak Collector Current, I_C	5A	5A	5A	5A	5A
Base Current, I_B	1A	1A	1A	1A	1A

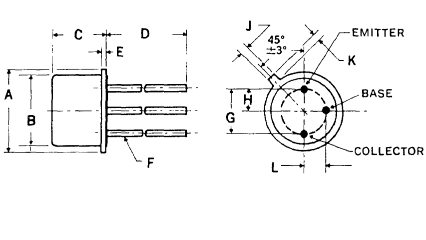
Power Dissipation
- 25°C Ambient .85W
- 100°C Case 4W

Thermal Resistance, θ_{J-C} 25°C/W

Operating and Storage Temperature Range —65°C to 200°C

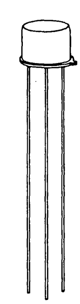
MECHANICAL SPECIFICATIONS

UPT211 UPT212 UPT213 UPT214 UPT215



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	0.254-0.762
F	.017 $\pm\,^{.002}_{.001}$	.432 $\pm\,^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



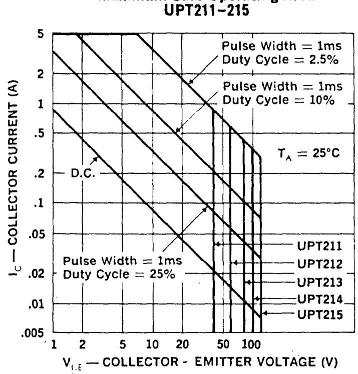
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

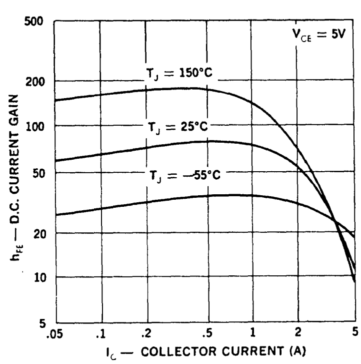
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	30	—	—	$I_C = 0.5A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	$I_C = 2A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10 Typ.		—	$I_C = 5A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	$I_C = 2A$, $I_B = 0.2A$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.2	Vdc	$I_C = 2A$, $I_B = 0.2A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}			Vdc	$I_C = 10mAdc$; $R_{BE} = 100\Omega$
UPT211		60	—		
UPT212		80	—		
UPT213		100	—		
UPT214		120	—		
UPT215		150	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT211		40	—		
UPT212		60	—		
UPT213		80	—		
UPT214-5		100	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, $T = 150°C$
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	40	pf	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Gain-Bandwidth Product	f_T	70 Typ.		MHz	$I_C = 0.1Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Switching Speeds — Turn-on Time	t_{on}	130 Typ.		ns	$I_C = 2A$
Switching Speeds — Turn-off Time	t_{off}	300 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ≤2%.

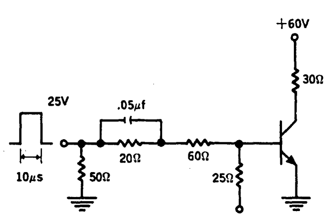
Maximum Safe Operating Area UPT211-215



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



POWER TRANSISTORS
2 Amp, 400V, Planar NPN

UPT311 UPT321
UPT312 UPT322
UPT313 UPT323
UPT314 UPT324
UPT315 UPT325

FEATURES
- Collector-Base Voltage: up to 400V
- Peak Collector Current: 3A
- Turn-on Time: 200 ns
- Turn-off Time: 800 ns

DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

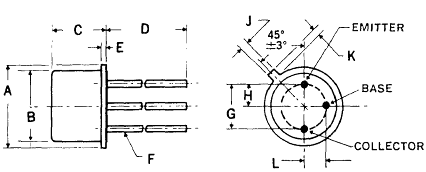
ABSOLUTE MAXIMUM RATINGS

	UPT311 UPT321	UPT312 UPT322	UPT313 UPT323	UPT314 UPT324	UPT315 UPT325
Collector-Base Voltage, V_{CBO}	200V	250V	300V	350V	400V
Collector-Emitter Voltage, V_{CEO}	150V	200V	250V	300V	300V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	2A	2A	2A	2A	2A
Peak Collector Current, I_C	3A	3A	3A	3A	3A
Base Current, I_B	1A	1A	1A	1A	1A

	UPT311-315	UPT321-325
Power Dissipation		
25°C Ambient	1W	2W
100°C Case	10W	16W
Thermal Resistance, Θ_{J-C}	10°C/W	6.7°C/W
Operating and Storage Temperature Range	—65°C to 200°C	—65°C to 200°C

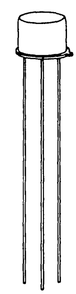
MECHANICAL SPECIFICATIONS

UPT311 UPT312 UPT313 UPT314 UPT315

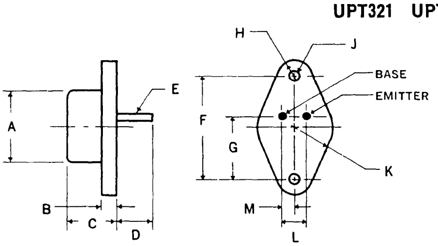


	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	0.254-0.762
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5

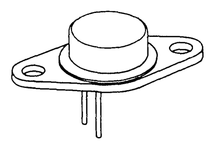


UPT321 UPT322 UPT323 UPT324 UPT325



	INCHES	MILLIMETERS
A	.620 MAX.	15.75 MAX.
B	.050 - .075	1.27 - 1.90
C	.250 - .340	6.35 - 8.63
D	.360 MIN.	9.14 MIN.
E	.028 - .034 DIA.	.711 - .863
F	.958 - .962	24.33 - 24.43
G	.570 - .590	14.47 - 14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142 - .152 DIA.	3.60 - 3.86 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190 - .210	4.82 - 5.33
M	.093 - .107	2.36 - 2.72

TO-66



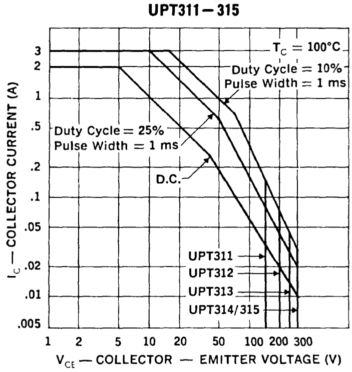
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

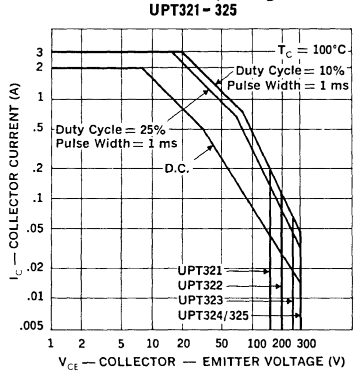
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	30	—	—	$I_C = 0.5A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	$I_C = 2A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10 Typ.		—	$I_C = 3A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	$I_C = 2A$, $I_B = 0.4A$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	$I_C = 2A$, $I_B = 0.4A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}			Vdc	$I_C = 10mAdc$; $R_{BE} = 100\Omega$
UPT311, UPT321		200	—		
UPT312, UPT322		250	—		
UPT313, UPT323		300	—		
UPT314, UPT324		350	—		
UPT315, UPT325		400	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT311, UPT321		150	—		
UPT312, UPT322		200	—		
UPT313, UPT323		250	—		
UPT314-5, UPT324-5		300	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, $T = 150°C$
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	50	pf	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Gain-Bandwidth Product	f_T	40 Typ.		MHz	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Switching Speeds — Turn-on Time	t_{on}	200 Typ.		ns	$I_C = 1A$
Switching Speeds — Turn-off Time	t_{off}	800 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ≤2%.

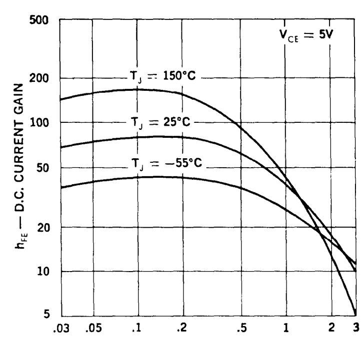
Maximum Safe Operating Area UPT311—315



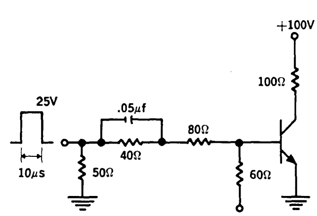
Maximum Safe Operating Area UPT321-325



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



POWER TRANSISTORS
3 Amp, 400V, Planar NPN

UPT521
UPT522
UPT523
UPT524
UPT525

IV

FEATURES
- Collector-Base Voltage: up to 400V
- Peak Collector Current: 5A
- Turn-on Time: 200ns
- Turn-off Time: 900ns

DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

ABSOLUTE MAXIMUM RATINGS

	UPT521	UPT522	UPT523	UPT524	UPT525
Collector-Base Voltage, V_{CBO}	200V	250V	300V	350V	400V
Collector-Emitter Voltage, V_{CEO}	150V	200V	250V	300V	300V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	3A	3A	3A	3A	3A
Peak Collector Current, I_C	5A	5A	5A	5A	5A
Base Current, I_B	2A	2A	2A	2A	2A

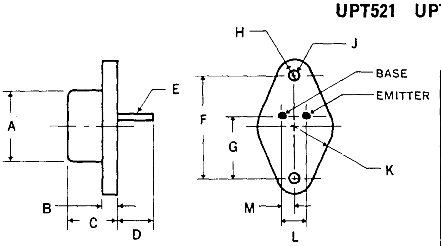
Power Dissipation
- 25°C Ambient 2W
- 100°C Case 25W

Thermal Resistance, Θ_{J-C} .... 4°C/W

Operating and Storage Temperature Range .... —65°C to 200°C

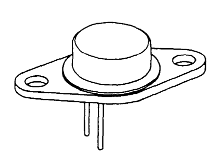
MECHANICAL SPECIFICATIONS

UPT521 UPT522 UPT523 UPT524 UPT525



	INCHES	MILLIMETERS
A	.620 MAX.	15.75 MAX.
B	.050 - .075	1.27 - 1.90
C	.250 - .340	6.35 - 8.63
D	.360 MIN.	9.14 MIN.
E	.028 - .034 DIA.	.711 - .863
F	.958 - .962	24.33 - 24.43
G	.570 - .590	14.47 - 14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142 - .152 DIA.	3.60 - 3.86 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190 - .210	4.82 - 5.33
M	.093 - .107	2.36 - 2.72

TO-66



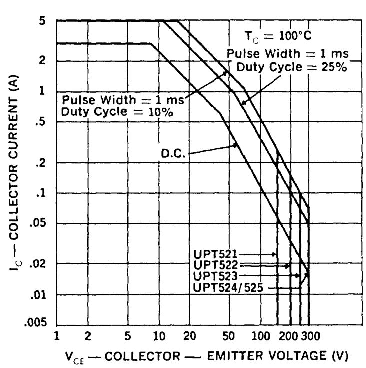
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

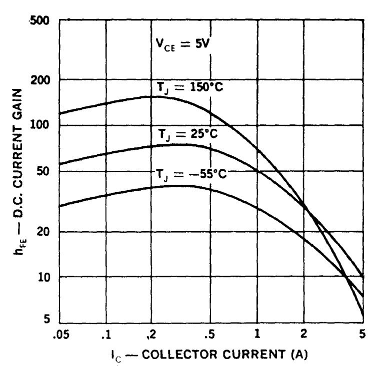
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	25	—	—	$I_C = 1.0A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	$I_C = 3A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10 Typ.		—	$I_C = 5A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	$I_C = 3A$, $I_B = 0.6A$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	$I_C = 3A$, $I_B = 0.6A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}			Vdc	$I_C = 10mAdc$; $R_{BE} = 100\Omega$
UPT521		200	—		
UPT522		250	—		
UPT523		300	—		
UPT524		350	—		
UPT525		400	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT521		150	—		
UPT522		200	—		
UPT523		250	—		
UPT524-5		300	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, $T = 150°C$
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	120	pf	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Gain-Bandwidth Product	f_T	30 Typ.		MHz	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Switching Speeds Turn-on Time	t_{on}	200 Typ.		ns	$I_C = 3A$
Switching Speeds Turn-off Time	t_{off}	900 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ⩽2%.

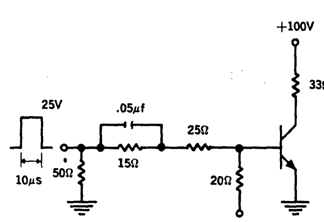
Maximum Safe Operating Area



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



POWER TRANSISTORS

5 Amp, 150V, Planar NPN

UPT611
UPT612
UPT613
UPT614
UPT615

IV

FEATURES

- Collector-Base Voltage: up to 150V
- Peak Collector Current: 10A
- Turn-on Time: 250ns
- Turn-off Time: 550ns

DESCRIPTION

Unitrode power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for power supply, pulse amplifier and similar high efficiency power switching applications.

ABSOLUTE MAXIMUM RATINGS

	UPT611	UPT612	UPT613	UPT614	UPT615
Collector-Base Voltage, V_{CBO}	60V	80V	100V	120V	150V
Collector-Emitter Voltage, V_{CEO}	40V	60V	80V	100V	100V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	5A	5A	5A	5A	5A
Peak Collector Current, I_C	10A	10A	10A	10A	10A
Base Current, I_B	2A	2A	2A	2A	2A

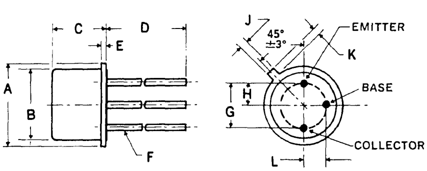
Power Dissipation
- 25°C Ambient 1W
- 100°C Case 5W

Thermal Resistance, θ_{J-C} .... 20°C/W

Operating and Storage Temperature Range .... —65°C to 200°C

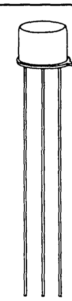
MECHANICAL SPECIFICATIONS

UPT611 UPT612 UPT613 UPT614 UPT615



	INCHES	MILLIMETERS
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	0.254-0.762
F	.017 $\pm ^{.002}_{.001}$	.432 $\pm ^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-5



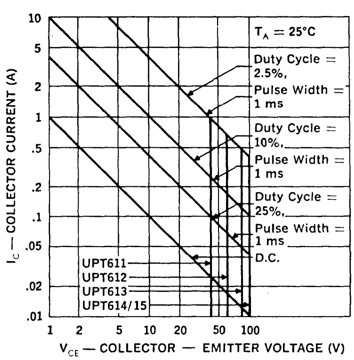
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

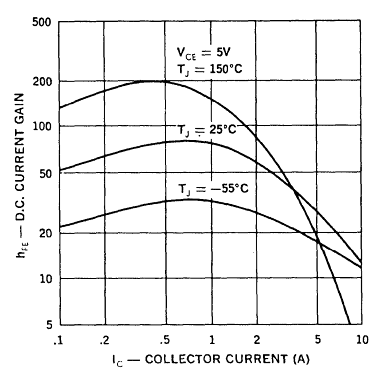
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	30	—	—	$I_C = 1A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	15	—	—	$I_C = 5A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	12 Typ.		—	$I_C = 10A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—			$I_C = 5A$, $I_B = 0.5A$
UPT611-3		—	1.0	Vdc	
UPT614-5		—	1.5	Vdc	
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—			$I_C = 5A$, $I_B = 0.5A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}		1.5	Vdc	$I_C = 10mAdc$; $R_{BE} = 100\Omega$
UPT611		60	—	Vdc	
UPT612		80	—		
UPT613		100	—		
UPT614		120	—		
UPT615		150	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT611		40	—		
UPT612		60	—		
UPT613		80	—		
UPT614-5		100	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, T = 150°C
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	120	pf	$V_{CB} = 10Vdc$, $I_E = 0$, f = 1MHz
Gain-Bandwidth Product	f_T	40 Typ.		MHz	$I_C = 0.5Adc$, $V_{CE} = 5Vdc$, f = 10MHz
Switching Speeds: Turn-on Time	t_{on}	250 Typ.		ns	$I_C = 5A$
Switching Speeds: Turn-off Time	t_{off}	500 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ⩽2%.

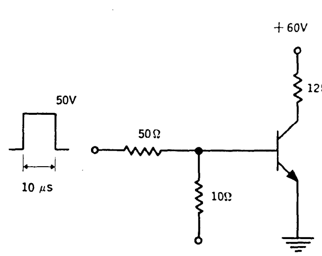
Maximum Safe Operating Area



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



POWER TRANSISTORS
5 Amp, 400V, Planar NPN

UPT721
UPT722
UPT723
UPT724
UPT725

IV

FEATURES
- Collector-Base Voltage: up to 400V
- Peak Collector Current: 10A
- Turn-on Time: 250ns
- Turn-off Time: 800ns

DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

ABSOLUTE MAXIMUM RATINGS

	UPT721	UPT722	UPT723	UPT724	UPT725
Collector-Base Voltage, V_{CBO}	200V	250V	300V	350V	400V
Collector-Emitter Voltage, V_{CEO}	150V	200V	250V	300V	300V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V	5V
D.C. Collector Current, I_C	5A	5A	5A	5A	5A
Peak Collector Current, I_C	10A	10A	10A	10A	10A
Base Current, I_B	3A	3A	3A	3A	3A

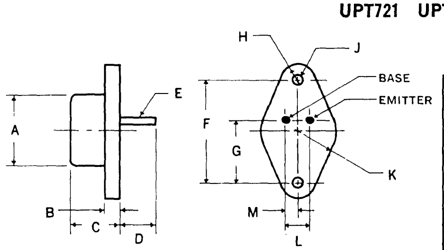
Power Dissipation
- 25°C Ambient 2W
- 100°C Case 25W

Thermal Resistance, Θ_{J-C} .... 4°C/W

Operating and Storage Temperature Range .... −65°C to 200°C

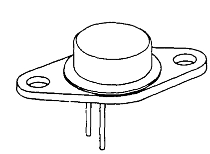
MECHANICAL SPECIFICATIONS

UPT721 UPT722 UPT723 UPT724 UPT725



	INCHES	MILLIMETERS
A	.620 MAX.	15.75 MAX.
B	.050 - .075	1.27 - 1.90
C	.250 - .340	6.35 - 8.63
D	.360 MIN.	9.14 MIN.
E	.028 - .034 DIA.	.711 - .863
F	.958 - .962	24.33 - 24.43
G	.570 - .590	14.47 - 14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142 - .152 DIA.	3.60 - 3.86 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190 - .210	4.82 - 5.33
M	.093 - .107	2.36 - 2.72

TO-66



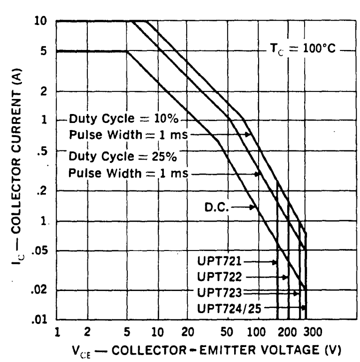
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

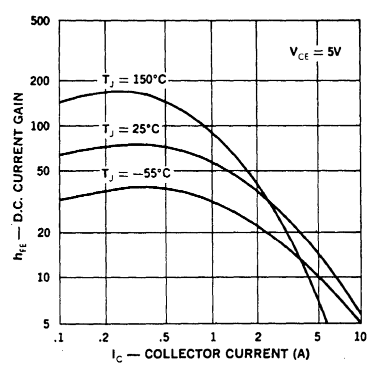
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	25	—	—	$I_C = 1A, V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	10	—	—	$I_C = 5A, V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	5 Typ.		—	$I_C = 10A, V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	$V_{CE}(sat)$	—	1.0	Vdc	$I_C = 5A, I_B = 1A$
Base Saturation Voltage (Note 1)	$V_{BE}(sat)$	—	1.8	Vdc	$I_C = 5A, I_B = 1A$
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CER}			Vdc	$I_C = 10mAdc; R_{BE} = 100\Omega$
UPT721		200	—		
UPT722		250	—		
UPT723		300	—		
UPT724		350	—		
UPT725		400	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPT721		150	—		
UPT722		200	—		
UPT723		250	—		
UPT724-5		300	—		
Collector-Emitter Cutoff Current	I_{CER}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$
Collector-Emitter Cutoff Current, 150°C	I_{CER}	—	1.0	mAdc	V_{CE} = rated BV_{CEO}, $R_{BE} = 100\Omega$, T = 150°C
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	120	pf	$V_{CB} = 10Vdc, I_E = 0, f = 1MHz$
Gain-Bandwidth Product	f_T	30 Typ.		MHz	$I_C = 0.5Adc, V_{CE} = 5Vdc, f = 10MHz$
Switching Speeds Turn-on Time	t_{on}	250 Typ.		ns	$I_C = 5A$
Switching Speeds Turn-off Time	t_{off}	800 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ⩽2%.

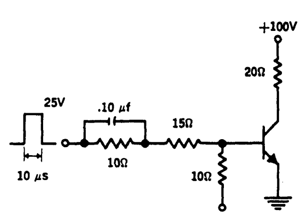
Maximum Safe Operating Area



D.C. Current Gain vs. Collector Current



Switching Speed Circuit



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POWER TRANSISTORS
0.5 Amp, 300V, Planar NPN, Plastic

UPTA510
UPTA520
UPTA530

IV

FEATURES
- Designed for High Speed Switching Applications
- Collector-Emitter Voltage: up to 300V
- Peak Collector Current: 1A
- Economical Plastic Molded Construction

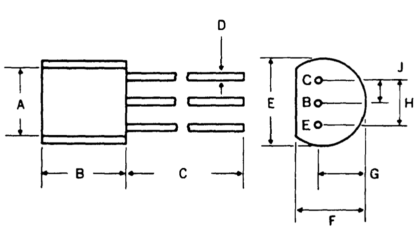
DESCRIPTION
Unitrode high voltage transistors provide a unique combination of low saturation voltage, fast switching, and excellent gain. They are ideally suited for off-line power supply designs and other applications where the increased voltage rating adds to system reliability.

ABSOLUTE MAXIMUM RATINGS

	UPTA510	UPTA520	UPTA530
Collector-Base Voltage, V_{CBO}	150V	250V	350V
Collector-Emitter Voltage, V_{CEO}	100V	200V	300V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V
D.C. Collector Current, I_C	.5A	.5A	.5A
Peak Collector Current, I_C	1A	1A	1A
Base Current, I_B	.5A	.5A	.5A
Power Dissipation			
25°C Case		2.4W	
25°C Ambient		750mW	
Thermal Resistance, θ_{J-C}		62.5°C/W	
Thermal Resistance, θ_{J-A}		200°C/W	
Storage Temperature Range		−55°C to +150°C	
Maximum Junction Temperature		+175°C	

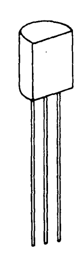
MECHANICAL SPECIFICATIONS

UPTA510 UPTA520 UPTA530



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92

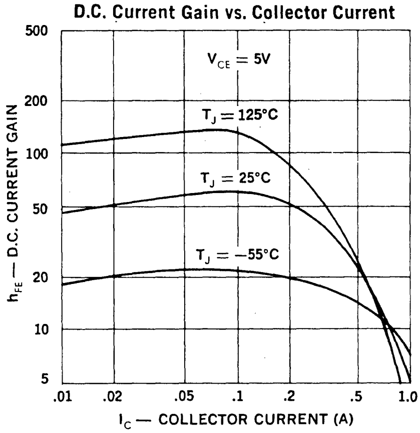


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

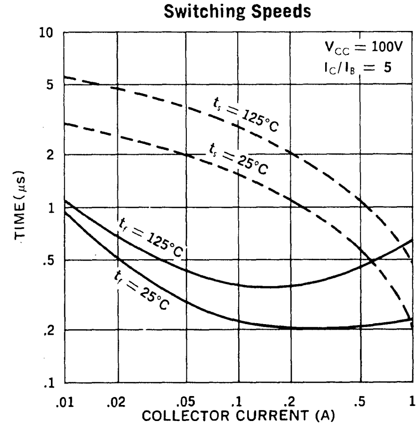
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	$I_C = .1A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	8	—	—	$I_C = .5A$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	5 Typ.		—	$I_C = 1A$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.0	Vdc	$I_C = .5A$, $I_B = .1A$
	V_{CE} (sat)		.5	Vdc	$I_C = .2A$, $I_B = .02A$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	$I_C = .5A$, $I_B = .1A$
Collector-Base Breakdown Voltage (Note 1)	BV_{CBO}			Vdc	$I_C = 10\mu Adc$
UPTA510		150	—		
UPTA520		250	—		
UPTA530		350	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 10mAdc$
UPTA510		100	—		
UPTA520		200	—		
UPTA530		300	—		
Collector-Emitter Cutoff Current	I_{CES}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $V_{BE} = 0$
Collector-Emitter Cutoff Current	I_{CES}	—	1	mAdc	V_{CE} = rated BV_{CEO}, $T = 125°C$, $V_{BE} = 0$
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	50	pf	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Gain-Bandwidth Product	f_T	15	—	MHz	$I_C = 1Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Rise Time	t_r	100 Typ.		ns	$I_C = .5A$
Delay Time	t_d	50 Typ.		ns	
Storage Time	t_s	500 Typ.		ns	
Fall Time	t_f	200 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ⩽ 2%.

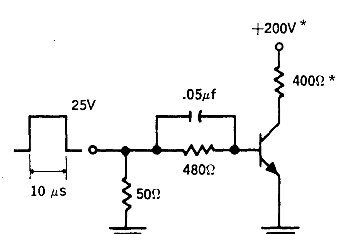
D.C. Current Gain vs. Collector Current



Switching Speeds



Switching Speed Circuit



*Note: For UPTA 410/510, V_{CC} = 100V, R_L = 200Ω

POWER TRANSISTORS
0.1 Amp, 500V, Planar NPN, Plastic

UPTB520
UPTB530
UPTB540
UPTB550

FEATURES
- Designed for High Speed Switching Applications
- Collector-Emitter Voltage: up to 500V
- Peak Collector Current: to .2A
- Economical Plastic Molded Construction

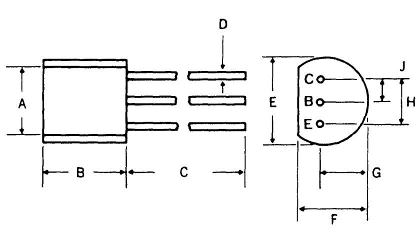
DESCRIPTION
Unitrode high voltage power transistors provide a unique combination of low saturation voltage, high gain and fast switching. They are ideally suited for pulse power applications in power supplies, thermal printers, solid state relays and pulse amplifiers.

ABSOLUTE MAXIMUM RATINGS

	UPTB520	UPTB530	UPTB540	UPTB550
Collector-Base Voltage, V_{CBO}	250V	350V	450V	550V
Collector-Emitter Voltage, V_{CEO}	200V	300V	400V	500V
Emitter-Base Voltage, V_{EBO}	5V	5V	5V	5V
D.C. Collector Current, I_C	.1A	.1A	.1A	.1A
Peak Collector Current, I_C	.2A	.2A	.2A	.2A
Base Current, I_B	.1A	.1A	.1A	.1A
Power Dissipation				
25°C Case	2.4W			
25°C Ambient	750mW			
Thermal Resistance, θ_{J-C}	62.5°C/W			
Thermal Resistance, θ_{J-A}	200°C/W			
Storage Temperature Range	−55°C to +150°C			
Maximum Junction Temperature	+175°C			

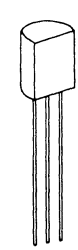
MECHANICAL SPECIFICATIONS

UPTB520 UPTB530 UPTB540 UPTB550



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92



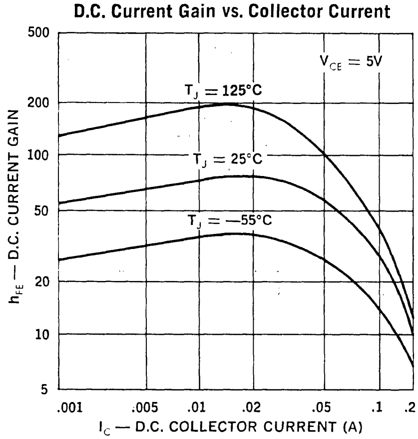
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

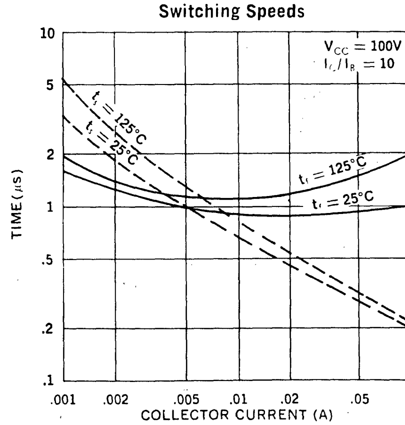
Test	Symbol	Min.	Max.	Units	Test Conditions
D.C. Current Gain (Note 1)	h_{FE}	20	—	—	$I_C = 25mA$, $V_{CE} = 5Vdc$
D.C. Current Gain (Note 1)	h_{FE}	5	—	—	$I_C = 100mA$, $V_{CE} = 5Vdc$
Collector Saturation Voltage (Note 1)	V_{CE} (sat)	—	1.2	Vdc	$I_C = 50mA$, $I_B = 10mA$
	V_{CE} (sat)		.5	Vdc	$I_C = 20mA$, $I_B = 2mA$
Base Saturation Voltage (Note 1)	V_{BE} (sat)	—	1.5	Vdc	$I_C = 50mA$, $I_B = 10mA$
Collector-Base Breakdown Voltage (Note 1)	BV_{CBO}			Vdc	$I_C = 10\mu Adc$
UPTB520		250	—		
UPTB530		350	—		
UPTB540		450	—		
UPTB550		550	—		
Collector-Emitter Breakdown Voltage (Note 1)	BV_{CEO}			Vdc	$I_C = 1mAdc$
UPTB520		200	—		
UPTB530		300	—		
UPTB540		400	—		
UPTB550		500	—		
Collector-Emitter Cutoff Current	I_{CES}	—	10	μAdc	V_{CE} = rated BV_{CEO}, $V_{BE} = 0$
Collector-Emitter Cutoff Current	I_{CES}	—	1	mAdc	V_{CE} = rated BV_{CEO}, $T = 125°C$, $V_{BE} = 0$
Emitter-Base Cutoff Current	I_{EBO}	—	50	μAdc	$V_{EB} = 5Vdc$
Output Capacitance	C_{ob}	—	50	pf	$V_{CB} = 10Vdc$, $I_E = 0$, $f = 1MHz$
Gain-Bandwidth Product	f_T	15	—	MHz	$I_C = 1Adc$, $V_{CE} = 5Vdc$, $f = 10MHz$
Rise Time	t_r	100 Typ.		ns	$I_C = 100mA$
Delay Time	t_d	50 Typ.		ns	
Storage Time	t_s	200 Typ.		ns	
Fall Time	t_f	1000 Typ.		ns	

Note: 1. Pulse width = 300 μs; duty cycle ⩽ 2%.

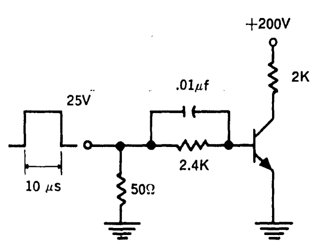
D.C. Current Gain vs. Collector Current



Switching Speeds



Switching Speed Circuit



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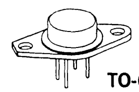
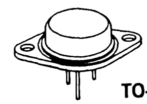
SWITCHING REGULATOR POWER CIRCUITS V

SWITCHING REGULATOR POWER CIRCUITS

The PIC600 through PIC672 series of devices consist of a driver transistor, a fast switching output transistor, a suitably matched fast recovery catch diode and thick film resistors in a hybrid circuit, designed, constructed and specified for use in high current switching regulator applications. Specific ratings for each type is summarized in this table.


TO-66


TO-3

Type	Output Current, Pk.	Input/Output Voltage	Polarity	Fall Time		On-State Voltage (V) @ (A)	Pkg.
				Volt. (ns)	Cur. (ns)		
PIC600		60	Pos.				
PIC601		80	Pos.				**4 PIN**
PIC602	5A	100	Pos.	75	150	1.5 @ 2	**TO-66**
PIC610		60	Neg.				**(Isolated)**
PIC611		80	Neg.				
PIC612		100	Neg.				
PIC660		60	Pos.				
PIC661		80	Pos.	150	250		**4 PIN**
PIC662	10A	100	Pos.			1.5 @ 5	**TO-66**
PIC670		60	Neg.				**(Isolated)**
PIC671		80	Neg.	250	250		
PIC672		100	Neg.				
PIC625		60	Pos.				
PIC626		80	Pos.	175	300		**4 PIN**
PIC627	15A	100	Pos.				**TO-66**
PIC635		60	Neg.			1.5 @ 7	**(Isolated)**
PIC636		80	Neg.	300	300		
PIC637		100	Neg.				
PIC645		60	Pos.				
PIC646		80	Pos.	150	300		
PIC647	20A	100	Pos.			1.5 @ 7	**3 PIN**
PIC655		60	Neg.				**TO-3**
PIC656		80	Neg.	300	300		
PIC657		100	Neg.				

The PIC730 and 740 series offer a Schottky diode in place of the fast recovery PN catch diode, to permit higher operating efficiencies in switching regulator designs.

PIC730 PIC740	30A	30 40	Pos. Pos.	350	300	1 @ 20	**3 PIN TO-3**

The PIC800 through 811 series are high voltage (up to 400V) versions of the PIC600 series. Applications include high voltage buck or flyback regulators, and, in combination, half bridge or full bridges, as well as deflection circuits and DC motor drives.

PIC800 PIC801	8A	350 400	Pos.	200	200	1.5 @ 5	**4 PIN TO-66 (Isolated)**
PIC810 PIC811	8A	350 400	Neg.	200	200	1.5 @ 5	**4 PIN TO-66 (Isolated)**

POWER INTEGRATED CIRCUIT

Switching Regulator 5 Amp Positive and Negative Power Output Stages

PIC600
PIC601
PIC602
PIC610
PIC611
PIC612

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI (See note 4.)
- High operating frequency (to > 100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency: Typical 2A circuit performance —
  Rise and Fall time <75ns
  Efficiency >85%
- No reverse recovery spike generated by commutating diode (See note 4. and Fig. 2.)
- Electrically isolated, 4-Pin, TO-66 hermetic case

DESCRIPTION

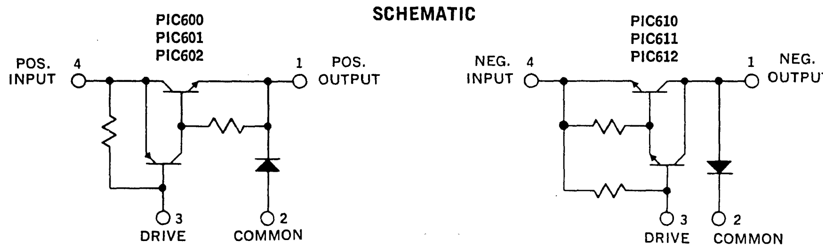
The Unitrode ESP Switching Regulator is a unique hybrid transistor circuit, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode, and empirically determining the optimum drive and bias conditions.

Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC600 series, the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC600 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; there is, in fact, no diode reverse recovery spike (see note 4.).

The PIC600 series switching regulators are designed and characterized to be driven with standard integrated circuit voltage regulators. They are completely characterized over their entire operating range of —55°C to +125°C. The devices are enclosed in a special 4-pin TO-66 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

Application Notes U-68 and U-76 provide a detailed description of the hybrid circuit and design guidance for specific circuit applications.

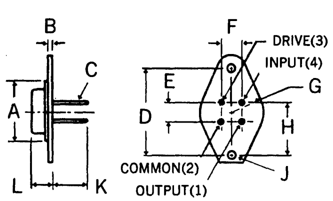
SCHEMATIC



MECHANICAL SPECIFICATIONS

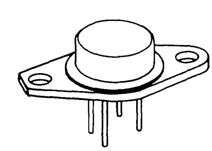
PIC600 PIC601 PIC602 PIC610 PIC611 PIC612

NOTES:
1. Case is electrically isolated.
2. Loads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm
A	.620 MAX.	15.75 MAX.
B	.050-.075	1.27-1.91
C	.028-.034	0.71-0.86
D	.958-.962	24.33-24.43
E	.190-.210	4.83-5.33
F	.190-.210	4.83-5.33
G	.350 MAX. RAD.	8.89 MAX. RAD.
H	.570-.590	14.48-14.99
J	.142-.152 DIA.	3.61-3.86 DIA.
K	.360 MIN.	9.14 MIN.
L	.250-.340	6.35-8.64

4-Pin TO-66



ABSOLUTE MAXIMUM RATINGS

	PIC600	PIC601	PIC602	PIC610	PIC611	PIC612
Input Voltage, V_{4-2}	60V	80V	100V	—60V	—80V	—100V
Output Voltage, V_{1-2}	60V	80V	100V	—60V	—80V	—100V
Drive-Input Reverse Voltage, V_{3-4}	5V	5V	5V	—5V	—5V	—5V
Output Current, I_1	5A	5A	5A	—5A	—5A	—5A
Drive Current, I_3	—0.2A	—0.2A	—0.2A	0.2A	0.2A	0.2A

Thermal Resistance
- Junction to Case, Θ_{J-C}
  - Power Switch .... 4.0°C/W
  - Commutating Diode .... 4.0°C/W
- Case to Ambient, Θ_{C-A} .... 60.0°C/W

Operating Temperature Range, T_C .... —55°C to +125°C
Maximum Junction Temperature, T_j .... +150°C
Storage Temperature Range .... —65°C to +150°C

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

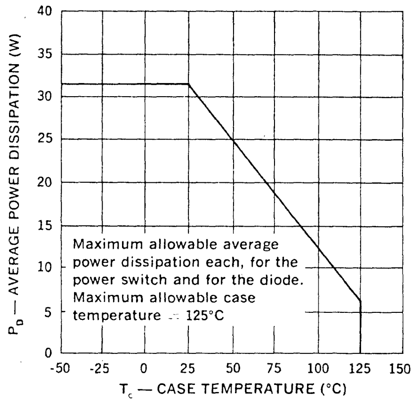
Test	Symbol	PIC600, 601, 602 Min.	Typ.	Max.	PIC610, 611, 612 Min.	Typ.	Max.	Units	Conditions
Current Delay Time	t_{di}	—	20	40	—	20	40	ns	V_{in} = 25V(—25V)
Current Rise Time	t_{ri}	—	50	75	—	50	75	ns	V_{out} = 5V(—5V)
Voltage Rise Time	t_{rv}	—	30	50	—	30	50	ns	I_{out} = 2A(—2A)
Voltage Storage Time	t_{sv}	—	700	—	—	700	—	ns	I_3 = —20mA(20mA)
Voltage Fall Time	t_{fv}	—	50	75	—	50	75	ns	See Figure 2.
Current Fall Time	t_{fi}	—	70	150	—	70	150	ns	See notes 1., 2., 4.
Efficiency (Notes 2. & 4.)	η	—	85	—	—	85	—	%	
On-State Voltage (Note 3.)	$V_{4-1(on)}$	—	1.0	1.5	—	—1.0	—1.5	V	I_4 = 2A(—2A), I_3 = —.02A(.02A)
On-State Voltage (Note 3.)	$V_{4-1(on)}$	—	2.5	3.5	—	—2.5	—3.5	V	I_4 = 5A(—5A), I_3 = —.02A(.02A)
Diode Forward Voltage (Note 3.)	$V_{2-1(on)}$	—	.8	1.0	—	—.8	—1.0	V	I_2 = 2A(—2A)
Diode Forward Voltage (Note 3.)	$V_{2-1(on)}$	—	1.0	1.5	—	—1.0	—1.5	V	I_2 = 5A(—5A)
Off-State Current	I_{4-1}	—	0.1	10	—	—0.1	—10	μA	V_4 = Rated input voltage
Off-State Current	I_{4-1}	—	10	—	—	—10	—	μA	V_4 = Rated input voltage, T_A = 100°C
Diode Reverse Current	I_{1-2}	—	1.0	10	—	—1.0	—10	μA	V_1 = Rated output voltage
Diode Reverse Current	I_{1-2}	—	500	—	—	500	—	μA	V_1 = Rated output voltage, T_A = 100°C

Notes:
1. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time (t_{DV}) ≅ t_{di} + t_{ri} and Current Storage Time (t_{si}) ≅ t_{sv} + t_{fv}.
2. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency is measured, is representative of typical operating conditions for the PIC600 series switching regulators.
3. Pulse test: Duration = 300μs, Duty Cycle ≤2%
4. As can be seen from the switching waveforms shown in Figure 2, no reverse or forward recovery spike is generated by the commutating diode during switching! This reduces self-generated noise, since no current spike is fed through the switching regulator. It also improves efficiency and reliability, since the power switch only carries current during turn-on.

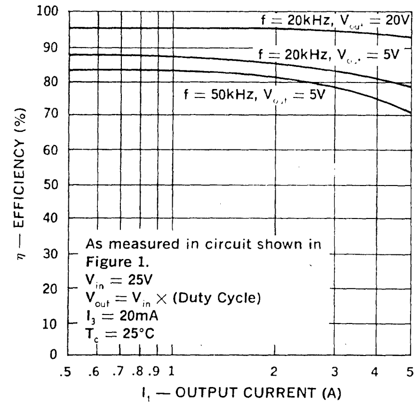
POWER DISSIPATION CONSIDERATIONS

The total power losses in the switching regulator is the sum of the switching losses, and the power switch and diode D.C. losses. Once total power dissipation has been determined, the Power Dissipation curve, or thermal resistance data may be used to determine the allowable case or ambient temperature for any operating condition.
The switching losses curve presents data for a frequency of 20KHz. To find losses at any other frequency, multiply by f/20KHz.
The D.C. losses curves present data for a duty cycle of .2. To find D.C. losses at any other duty cycle, multiply by D/.2 for the power switch and by (1-D)/.8 for the diode.
At frequencies much below 10KHz the above method for determining the allowable case or ambient temperature becomes invalid and a detailed transient thermal analysis must be performed. Please see design Note (DN-6) for further information.

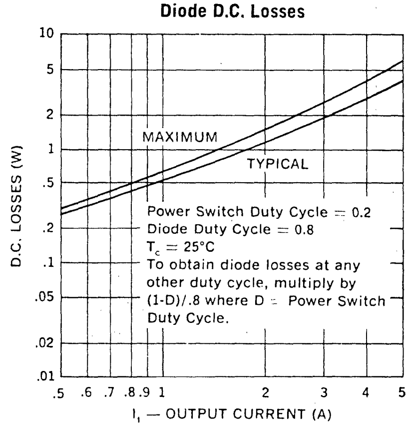
Power Dissipation



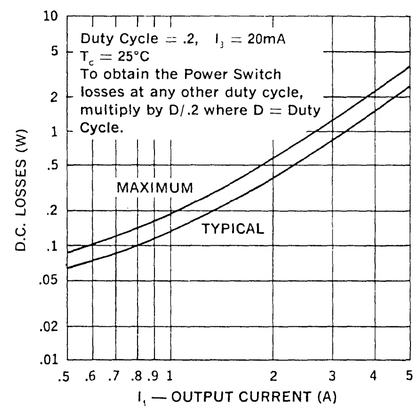
Efficiency



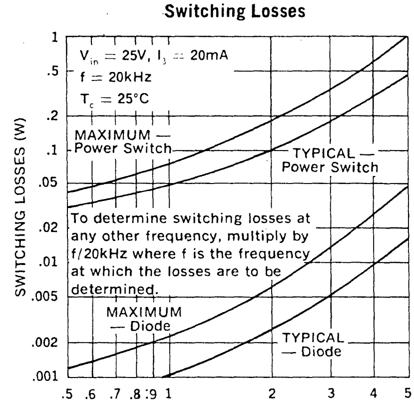
Diode D.C. Losses



Power Switch D.C. Losses



Switching Losses



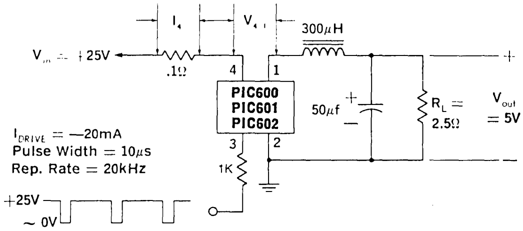


Figure 1. PIC600, 601, 602 Switching Speed Circuit

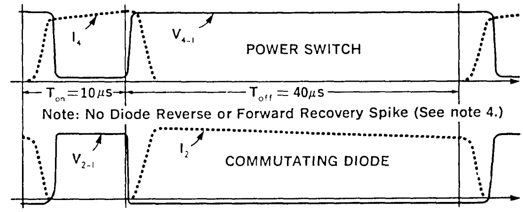
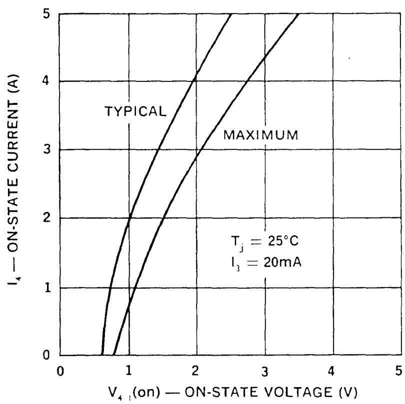


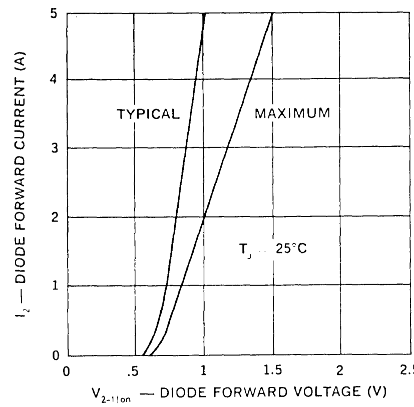
Figure 2. PIC600, PIC601, PIC602 Switching Waveforms

Note: PIC610, PIC611, PIC612 Test Circuit and waveforms are identical but of opposite polarity (V_{in} = —25V, V_{out} = —5V, I_{DRIVE} = +20mA).

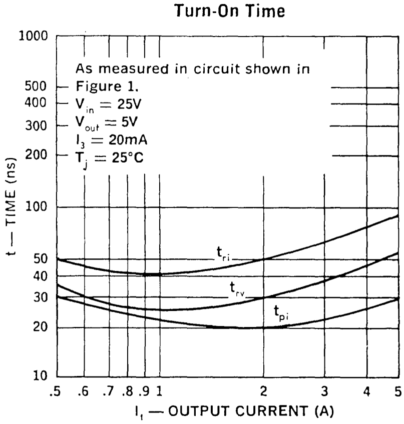
On-State Characteristics



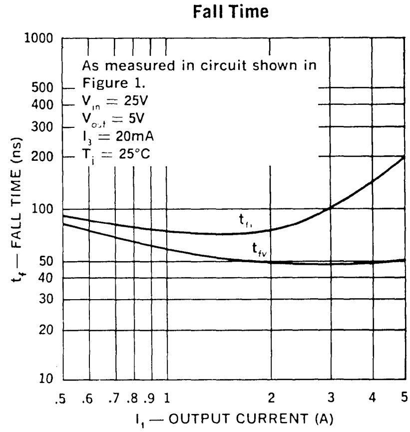
Diode Forward Characteristics



Turn-On Time



Fall Time



POWER INTEGRATED CIRCUIT

Switching Regulator 15 Amp Positive and Negative Power Output Stages

PIC625
PIC626
PIC627
PIC635
PIC636
PIC637

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI (See note 4.)
- High operating frequency (to >100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency: Typical 7A circuit performance —
  Rise and Fall time <300 ns
  Efficiency >85%
- No reverse recovery spike generated by commutating diode (See note 4. and Fig. 2.)
- Electrically isolated, 4-Pin, TO66 hermetic case

DESCRIPTION

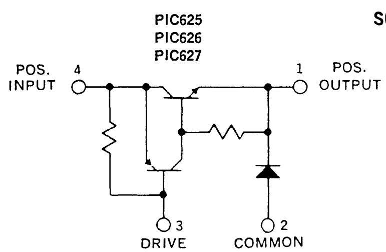
The Unitrode ESP Switching Regulator is a unique hybrid transistor circuit, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode, and empirically determining the optimum drive and bias conditions.

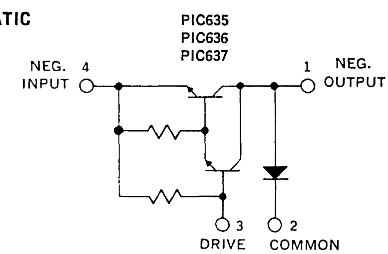
Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC600 series the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC600 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; there is, in fact, no diode reverse recovery spike (See note 4.).

The PIC600 series switching regulators are designed and characterized to be driven wih standard integrated circuit voltage regulators. They are completely characterized over their entire operating range of —55°C to +125°C. The devices are enclosed in a special 4-pin TO66 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

Application Notes U-68 and U-76 provide a detailed description of the hybrid circuit and design guidance for specific circuit applications.

SCHEMATIC



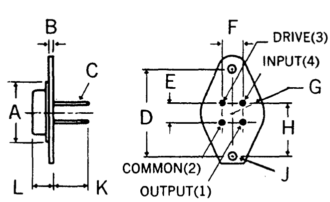


MECHANICAL SPECIFICATIONS

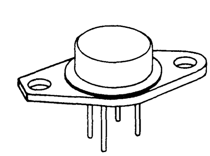
PIC625 PIC626 PIC627 PIC635 PIC636 PIC637

NOTES:
1. Case is electrically isolated.
2. Loads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

	ins.	mm
A	.620 MAX.	15 75 MAX.
B	.050-.075	1.27-1 91
C	.028-.034	0.71-0.86
D	958-.962	24.33-24 43
E	.190-.210	4.83-5.33
F	.190-.210	4.83-5.33
G	.350 MAX. RAD.	8 89 MAX. RAD.
H	.570-.590	14 48-14 99
J	.142-.152 DIA.	3 61-3.86 DIA.
K	.360 MIN	9 14 MIN
L	250- 340	6.35-8 64



4-Pin TO-66



UNITRODE

ABSOLUTE MAXIMUM RATINGS

	PIC625	PIC626	PIC627	PIC635	PIC636	PIC637
Input Voltage, V_{4-2}	60V	80V	100V	—60V	—80V	—100V
Output Voltage, V_{1-2}	60V	80V	100V	—60V	—80V	—100V
Drive-Input Reverse Voltage, V_{3-4}	5V	5V	5V	—5V	—5V	—5A
Output Current, I_1	15A	15A	15A	—15A	—15A	—15A
Drive Current, I_3	—0.4A	—0.4A	—0.4A	0.4A	0.4A	0.4A

Thermal Resistance

Junction to Case, θ_{J-C}

Power Switch .... 4.0°C/W

Commutating Diode .... 4.0°C/W

Case to Ambient, θ_{C-A} .... 60.0°C/W

Operating Temperature Range, T_C .... —55°C to +125°C

Maximum Junction Temperature, T_j .... +150°C

Storage Temperature Range .... —65°C to +150°C

V

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	PIC625/626/627 Min.	Typ.	Max.	PIC635/636/637 Min.	Typ.	Max.	Units	Conditions
Current Delay Time	t_{di}	—	35	60	—	35	60	ns	V_{in} = 25V(—25V)
Current Rise Time	t_{ri}	—	65	150	—	65	175	ns	V_{out} = 5V(—5V)
Voltage Rise Time	t_{rv}	—	40	60	—	40	60	ns	I_{out} = 7A(—7A)
Voltage Storage Time	t_{sv}	—	900	—	—	900	—	ns	I_3 = —30mA(30mA)
Voltage Fall Time	t_{fv}	—	70	175	—	100	300	ns	See Figure 2
Current Fall Time	t_{fi}	—	175	300	—	175	300	ns	See notes 1, 2, 4
Efficiency (Notes 2 and 4)	η	—	85	—	—	85	—	%	
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	1.0	1.5	—	—1.0	—1.5	V	I_4 = 7A(—7A), I_3 = —.03A(.03A)
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	2.5	3.5	—	—2.5	—3.5	V	I_4 = 15A(—15A), I_3 = —.03A(.03A)
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.85	1.25	—	—.85	—1.25	V	I_2 = 7A(—7A)
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.95	1.75	—	—.95	—1.75	V	I_2 = 15A(—15A)
Off-State Current	I_{4-1}	—	0.1	10	—	—0.1	—10	μA	V_4 = Rated input voltage
Off-State Current	I_{4-1}	—	10	—	—	—10	—	μA	V_4 = Rated input voltage, T_A = 100°C
Diode Reverse Current	I_{1-2}	—	1.0	10	—	—1.0	—10	μA	V_1 = Rated output voltage
Diode Reverse Current	I_{1-2}	—	500	—	—	500	—	μA	V_1 = Rated output voltage, T_A = 100°C

Notes:

1. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2.). Therefore, Voltage Delay Time (t_{DV}) ≅ t_{di} + t_{ri} and Current Storage Time (t_{si}) ≅ t_{sv} + t_{fv}.
2. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1., in which the efficiency is measured, is representative of typical operating conditions for the PIC600 series switching regulators.
3. Pulse test: Duration = 300μs, Duty Cycle ≤2%.
4. As can be seen from the switching waveforms shown in Figure 2., no reverse or forward recovery spike is generated by the commutating diode during switching! This reduces self-generated noise, since no current spike is fed through the switching regulator. It also improves efficiency and reliability, since the power switch only carries current during turn-on.

POWER DISSIPATION CONSIDERATIONS

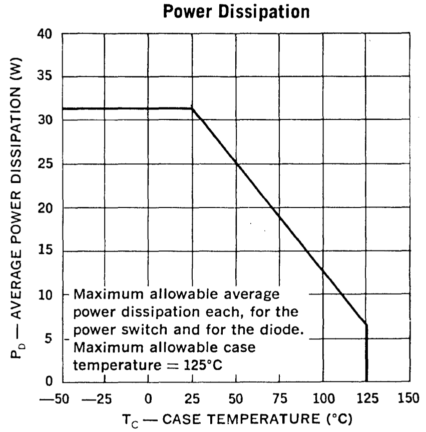
The total power losses in the switching regulator is the sum of the switching losses, and the power switch and diode D.C. losses. Once total power dissipation has been determined, the Power Dissipation curve, or thermal resistance data may be used to determine the allowable case or ambient temperature for any operating condition.

The switching losses curve presents data for a frequency of 20KHz. To find losses at any other frequency, multiply by f/20KHz.

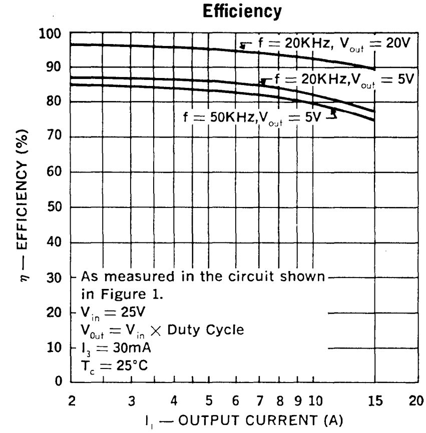
The D.C. losses curves present data for a duty cycle of .2. To find D.C. losses at any other duty cycle, multiply by D/.2 for the power switch and by (1-D)/.8 for the diode.

At frequencies much below 10KHz the above method for determining the allowable case or ambient temperature becomes invalid and a detailed transient thermal analysis must be performed. Please see Design Note 6 (DN-6) for further information.

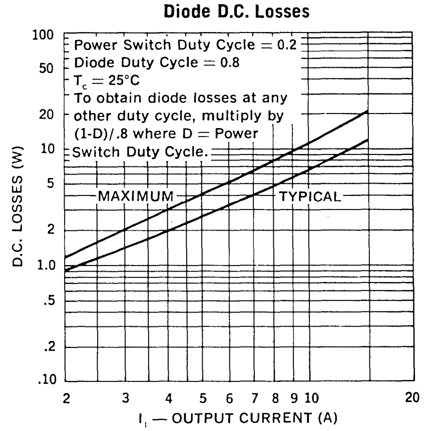
Power Dissipation



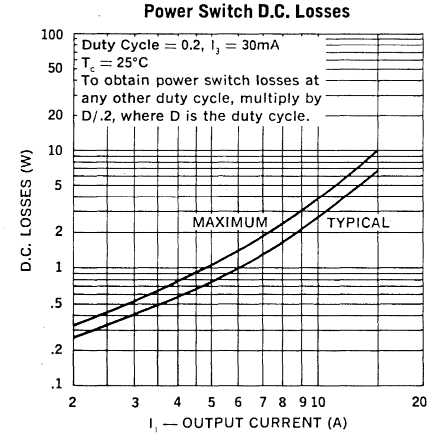
Efficiency



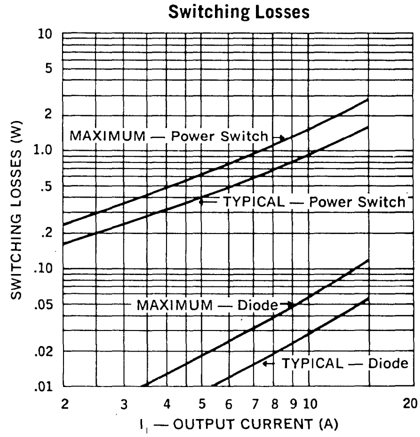
Diode D.C. Losses



Power Switch D.C. Losses



Switching Losses



V_{in} = 25V, I_3 = 30mA
f = 20KHz
T_C = 25°C
To determine switching losses at any other frequency, multiply by f/20KHz where f is the frequency at which the losses are to be determined.

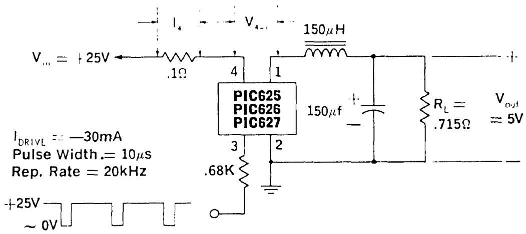


Figure 1. PIC625, 626, 627 Switching Speed Circuit

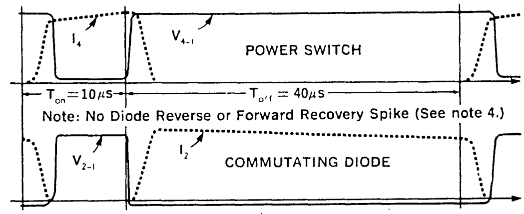
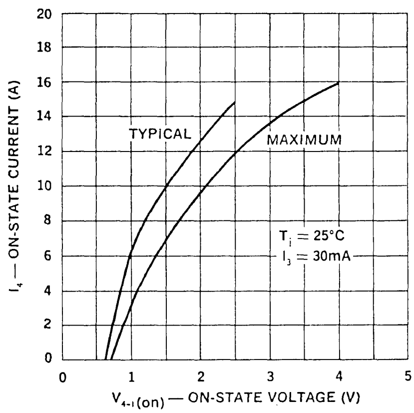


Figure 2. PIC625, 626, 627 Switching Waveforms

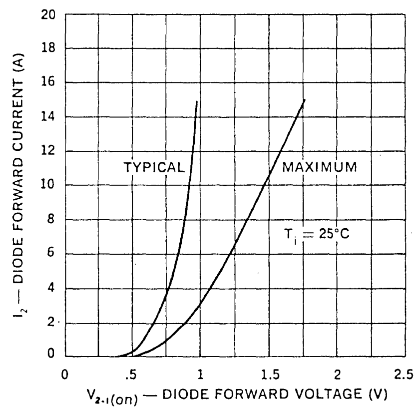
Note: PIC635, PIC636, PIC637 Circuit and waveforms are identical but of opposite polarity (V_{in} = −25V, V_{out} = −5V, I_{DRIVE} = +30mA.)

V

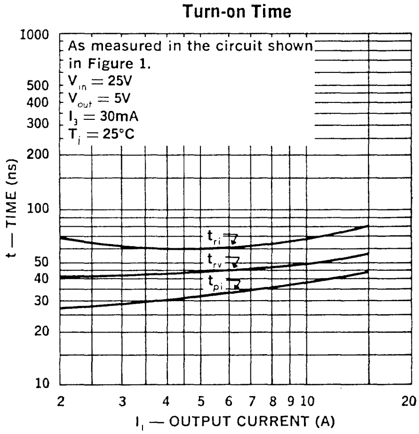
On-State Characteristics



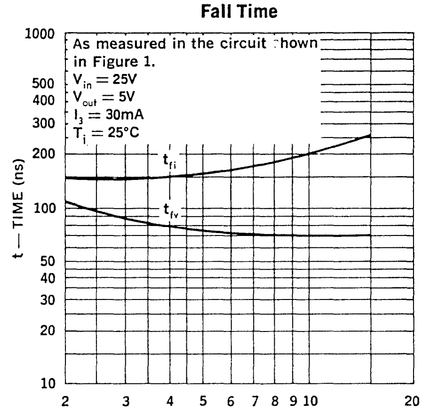
Diode Forward Characteristics



Turn-on Time



Fall Time



POWER INTEGRATED CIRCUIT

Switching Regulator 15 Amp Positive and Negative Power Output Stages

PIC645
PIC646
PIC647
PIC655
PIC656
PIC657

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI (See note 4.)
- High operating frequency (to >100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency: Typical 7A circuit performance —
  Rise and Fall time <300 ns
  Efficiency >85%
- No reverse recovery spike generated by commutating diode (See note 4. and Fig. 2.)

DESCRIPTION

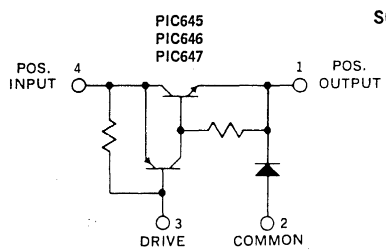
The Unitrode ESP Switching Regulator is a unique hybrid transistor circuit, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode, and empirically determining the optimum drive and bias conditions.

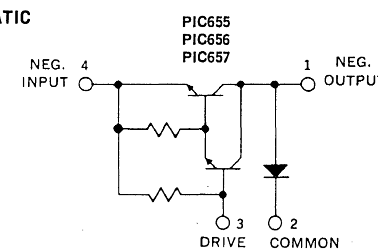
Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC600 series the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC600 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; there is, in fact, no diode reverse recovery spike (See note 4.).

The PIC600 series switching regulators are designed and characterized to be driven with standard integrated circuit voltage regulators. They are completely characterized over their entire operating range of $-55°C$ to $+125°C$. The devices are enclosed in a special 3 pin TO-3 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

Application Notes U-68 and U-76 provide a detailed description of the hybrid circuit and design guidance for specific circuit applications.

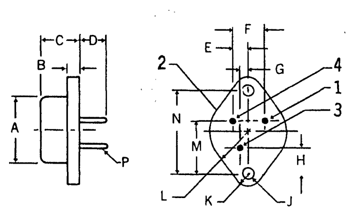
SCHEMATIC





MECHANICAL SPECIFICATIONS

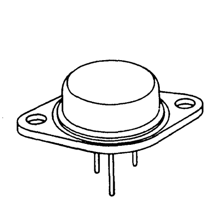
PIC645 PIC646 PIC647 PIC655 PIC656 PIC657



NOTE:
Loads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

	ins.	mm
A	.875 MAX.	22.23 MAX.
B	.135	3.43
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.205-.225	5.21-5.72
F	.420-.440	10.67-11.18
G	.145-.165	3.68-4.19
H	.395-.405	10.03-10.29
J	.151-.161 DIA.	3.84-4.09 DIA.
K	.188 MAX. RAD.	4.78 MAX. RAD.
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.708-.728	17.98-18.49
N	1.177-1.197	29.90-30.40
P	.038-.043 DIA.	.97-1.09 DIA.

3 Pin TO-3



ABSOLUTE MAXIMUM RATINGS

	PIC645	PIC646	PIC647	PIC655	PIC656	PIC657
Input Voltage, V_{4-2}	60V	80V	100V	—60V	—80V	—100V
Output Voltage, V_{1-2}	60V	80V	100V	—60V	—80V	—100V
Drive-Input Reverse Voltage, V_{3-4}	5V	5V	5V	—5V	—5V	—5V
Continuous Output Current, I_1	15A	15A	15A	—15A	—15A	—15A
Peak Output Current	20A	20A	20A	—20A	—20A	—20A
Drive Current, I_3	—0.4A	—0.4A	—0.4A	0.4A	0.4A	0.4A

Thermal Resistance
- Junction to Case, θ_{J-C}
  - Power Switch .... 2°C/W
  - Commutating Diode .... 2°C/W
- Case to Ambient, θ_{C-A} .... 30.0°C/W

Operating Temperature Range, T_C .... —55°C to +125°C
Maximum Junction Temperature, T_J .... +150°C
Storage Temperature Range .... —65°C to +150°C

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	PIC645/646/647 Min.	Typ.	Max.	PIC655/656/657 Min.	Typ.	Max.	Units	Conditions
Current Delay Time	t_{di}	—	35	60	—	35	60	ns	$V_{in} = 25V(-25V)$
Current Rise Time	t_{ri}	—	65	150	—	65	175	ns	$V_{out} = 5V(-5V)$
Voltage Rise Time	t_{rv}	—	40	60	—	40	60	ns	$I_{out} = 7A(-7A)$
Voltage Storage Time	t_{sv}	—	900	—	—	900	—	ns	$I_3 = -30mA(30mA)$
Voltage Fall Time	t_{fv}	—	70	175	—	100	300	ns	See Figure 2
Current Fall Time	t_{fi}	—	175	300	—	175	300	ns	See notes 1, 2, 4
Efficiency (Notes 2 and 4)	η	—	85	—	—	85	—	%	
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	1.0	1.5	—	—1.0	—1.5	V	$I_4 = 7A(-7A), I_3 = -.03A(.03A)$
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	2.5	3.5	—	—2.5	—3.5	V	$I_4 = 15A(-15A), I_3 = -.03A(.03A)$
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.85	1.25	—	—.85	—1.25	V	$I_2 = 7A(-7A)$
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.95	1.75	—	—.95	—1.75	V	$I_2 = 15A(-15A)$
Off-State Current	I_{4-1}	—	0.1	10	—	—0.1	—10	μA	V_4 = Rated input voltage
Off-State Current	I_{4-1}	—	10	—	—	—10	—	μA	V_4 = Rated input voltage, $T_A = 100°C$
Diode Reverse Current	I_{1-2}	—	1.0	10	—	—1.0	—10	μA	V_1 = Rated output voltage
Diode Reverse Current	I_{1-2}	—	500	—	—	500	—	μA	V_1 = Rated output voltage, $T_A = 100°C$

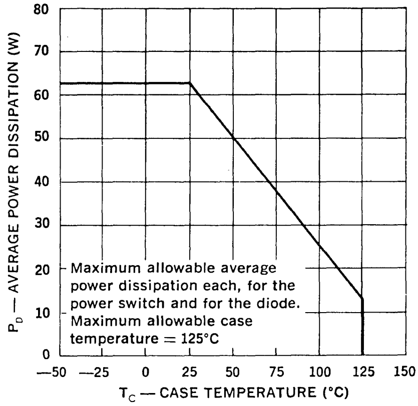
Notes:
1. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2.). Therefore, Voltage Delay Time (t_{DV}) ≅ $t_{di} + t_{ri}$ and Current Storage Time (t_{si}) ≅ $t_{sv} + t_{fv}$.
2. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1., in which the efficiency is measured, is representative of typical operating conditions for the PIC600 series switching regulators.
3. Pulse test: Duration = 300μs, Duty Cycle ≤2%
4. As can be seen from the switching waveforms shown in Figure 2., no reverse or forward recovery spike is generated by the commutating diode during switching! This reduces self-generated noise, since no current spike is fed through the switching regulator. It also improves efficiency and reliability, since the power switch only carries current during turn-on.

POWER DISSIPATION CONSIDERATIONS

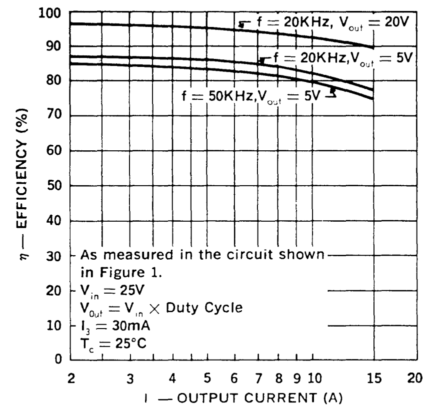
The total power losses in the switching regulator is the sum of the switching losses, and the power switch and diode D.C. losses. Once total power dissipation has been determined, the Power Dissipation curve, or thermal resistance data may be used to determine the allowable case or ambient temperature for any operating condition.
The switching losses curve presents data for a frequency of 20KHz. To find losses at any other frequency, multiply by f/20KHz.
The D.C. losses curves present data for a duty cycle of .2. To find D.C. losses at any other duty cycle, multiply by D/.2 for the power switch and by (1-D)/.8 for the diode.
At frequencies much below 10KHz the above method for determining the allowable case or ambient temperature becomes invalid and a detailed transient thermal analysis must be performed. Please see design Note (DN-6) for further information.

V

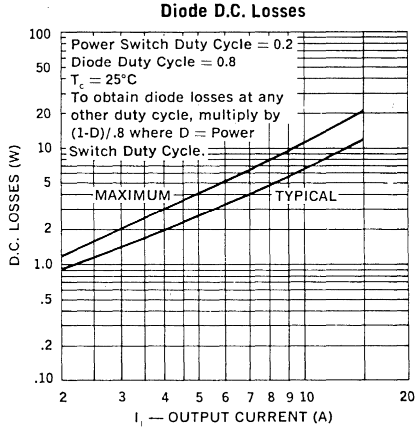
Power Dissipation



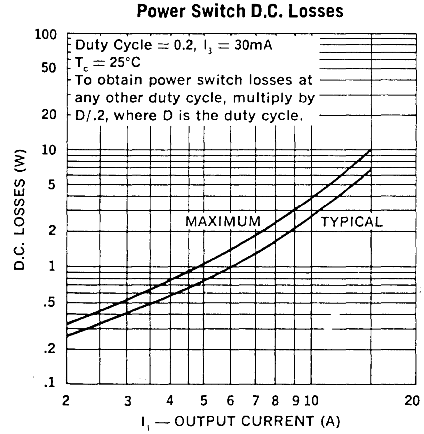
Efficiency



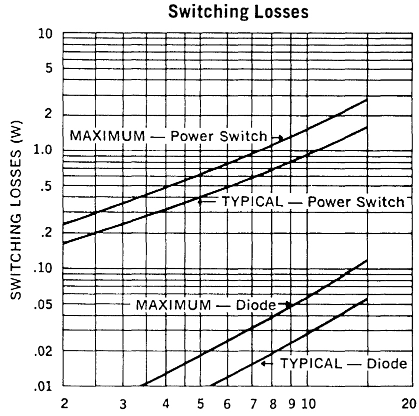
Diode D.C. Losses



Power Switch D.C. Losses



Switching Losses



V_{in} = 25V, I_3 = 30mA
f = 20KHz
T_C = 25°C
To determine switching losses at any other frequency, multiply by f/20KHz where f is the frequency at which the losses are to be determined.

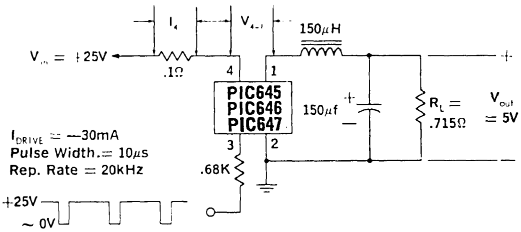


Figure 1. PIC645, 646, 647 Switching Speed Circuit

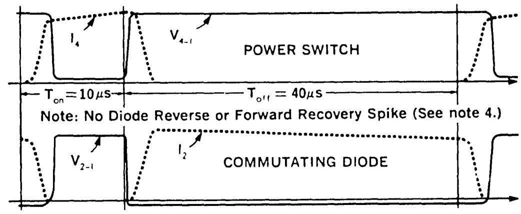
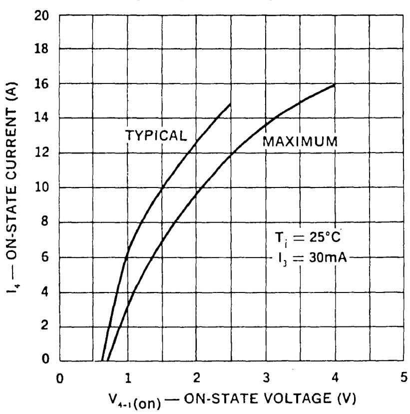


Figure 2. PIC645, 646, 647 Switching Waveforms

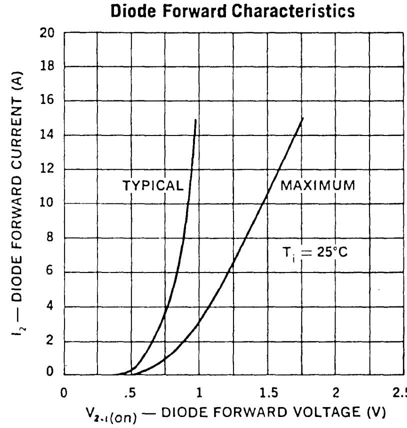
Note: PIC655, PIC656, PIC657 Circuit and waveforms are identical but of opposite polarity (V_{in} = −25V, V_{out} = −5V, I_{DRIVE} = +30mA.)

V

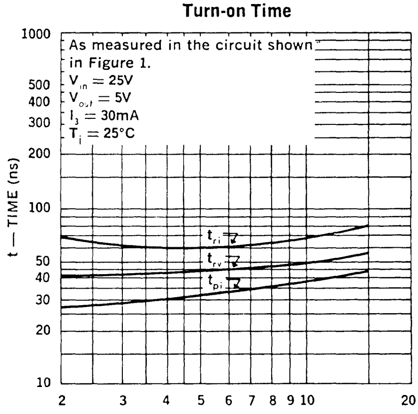
On-State Characteristics



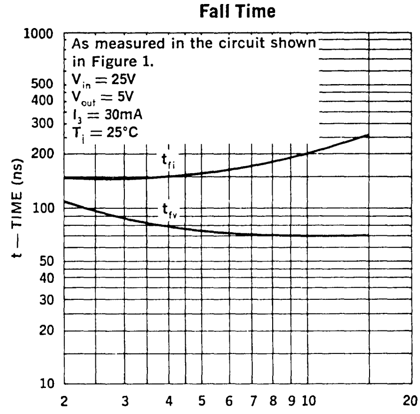
Diode Forward Characteristics



Turn-on Time



Fall Time



POWER INTEGRATED CIRCUIT

Switching Regulator 10 Amp Positive and Negative Power Output Stages

PIC660
PIC661
PIC662
PIC670
PIC671
PIC672

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI (See note 4.)
- High operating frequency (to >100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency: Typical 5A circuit performance —
  Rise and Fall time <300ns
  Efficiency >85%
- No reverse recovery spike generated by commutating diode (See note 4. and Fig. 2.)
- Electrically isolated, 4-Pin, TO-66 hermetic case

DESCRIPTION

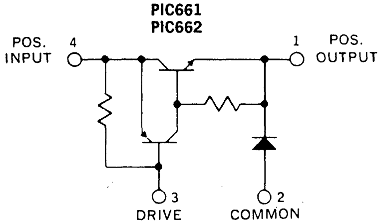
The Unitrode Switching Regulator is a unique hybrid transistor circuit, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode, and empirically determining the optimum drive and bias conditions.

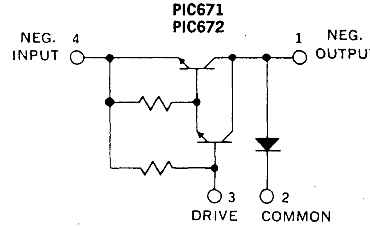
Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC600 series the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC600 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; there is, in fact, no diode reverse recovery spike (See note 4.).

The PIC600 series switching regulators are designed and characterized to be driven wih standard integrated circuit voltage regulators. They are completely characterized over their entire operating range of −55°C to +125°C. The devices are enclosed in a special 4-Pin TO-66 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

Application Notes U-68 and U-76 provide a detailed description of the hybrid circuit and design guidance for specific circuit applications.

SCHEMATIC

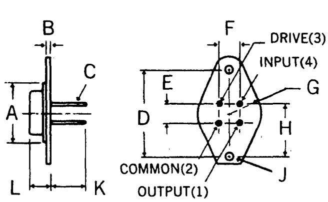




MECHANICAL SPECIFICATIONS

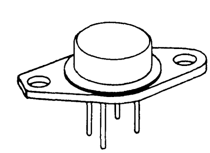
PIC660 PIC661 PIC662 PIC670 PIC671 PIC672

NOTES:
1. Case is electrically isolated.
2. Loads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm
A	620 MAX	15 75 MAX
B	050- 075	1 27-1 91
C	028- 034	0 71-0 86
D	958- 962	24 33-24 43
E	190- 210	4 83-5 33
F	190- 210	4 83-5 33
G	350 MAX RAD	8 89 MAX RAD
H	570- 590	14 48-14 99
J	142- 152 DIA	3 61-3 86 DIA
K	360 MIN	9 14 MIN
L	250- 340	6 35-8 64

4-Pin TO-66



ABSOLUTE MAXIMUM RATINGS

	PIC660	PIC661	PIC662	PIC670	PIC671	PIC672
Input Voltage, V_{4-2}	60V	80V	100V	−60V	−80V	−100V
Output Voltage, V_{1-2}	60V	80V	100V	−60V	−80V	−100V
Drive-Input Reverse Voltage, V_{3-4}	5V	5V	5V	−5V	−5V	−5V
Output Current, I_1	10A	10A	10A	−10A	−10A	−10A
Drive Current, I_3	−0.4A	−0.4A	−0.4A	0.4A	0.4A	0.4A

Thermal Resistance
Junction to Case, θ_{J-C}
Power Switch .... 4.0°C/W
Commutating Diode .... 4.0°C/W
Case to Ambient, θ_{C-A} .... 60.0°C/W
Operating Temperature Range, T_C .... −55°C to +125°C
Maximum Junction Temerature, T_j .... +150°C
Storage Temperature Range .... −65°C to +150°C

V

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	PIC660/661/662 Min.	Typ.	Max.	PIC670/671/672 Min.	Typ.	Max.	Units	Conditions
Current Delay Time	t_{di}	—	35	60	—	35	60	ns	$V_{in} = 25V(-25V)$
Current Rise Time	t_{ri}	—	65	150	—	65	175	ns	$V_{out} = 5V(-5V)$
Voltage Rise Time	t_{rv}	—	40	60	—	40	60	ns	$I_{out} = 5A(-5A)$
Voltage Storage Time	t_{sv}	—	900	—	—	900	—	ns	$I_3 = -30mA(30mA)$
Voltage Fall Time	t_{fv}	—	70	175	—	100	300	ns	See Figure 2
Current Fall Time	t_{fi}	—	175	300	—	175	300	ns	See notes 1, 2, 4
Efficiency (Notes 2 and 4)	η	—	85	—	—	85	—	%	
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	1.0	1.5	—	−1.0	−1.5	V	$I_4 = 5A(-5A)$, $I_3 = -.03A(.03A)$
On-State Voltage (Note 3)	$V_{4-1(on)}$	—	2.5	3.5	—	−2.5	−3.5	V	$I_4 = 10A(-10A)$, $I_3 = -.03A(.03A)$
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.85	1.25	—	−.85	−1.25	V	$I_2 = 5A(-5A)$
Diode Fwd. Voltage (Note 3)	$V_{2-1(on)}$	—	.95	1.75	—	−.95	−1.75	V	$I_2 = 10A(-10A)$
Off-State Current	I_{4-1}	—	0.1	10	—	−0.1	−10	μA	V_4 = Rated input voltage
Off-State Current	I_{4-1}	—	10	—	—	−10	—	μA	V_4 = Rated input voltage, $T_A = 100°C$
Diode Reverse Current	I_{1-2}	—	1.0	10	—	−1.0	−10	μA	V_1 = Rated output voltage
Diode Reverse Current	I_{1-2}	—	500	—	—	500	—	μA	V_1 = Rated output voltage, $T_A = 100°C$

Notes:
1. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2.). Therefore, Voltage Delay Time (t_{DV}) ≅ t_{di} + t_{ri} and Current Storage Time (t_{si}) ≅ t_{sv} + t_{fv}.
2. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1., in which the efficiency is measured, is representative of typical operating conditions for the PIC600 series switching regulators.
3. Pulse test: Duration = 300μs, Duty Cycle ⩽2%.
4. As can be seen from the switching waveforms shown in Figure 2., no reverse or forward recovery spike is generated by the commutating diode during switching! This reduces self-generated noise, since no current spike is fed through the switching regulator. It also improves efficiency and reliability, since the power switch only carries current during turn-on.

POWER DISSIPATION CONSIDERATIONS

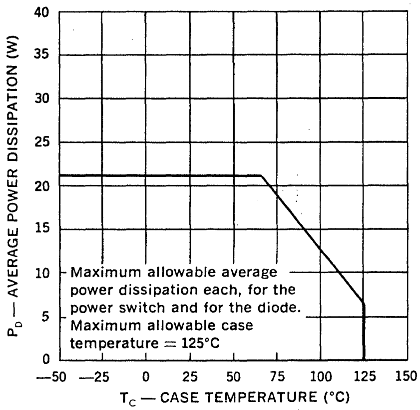
The total power losses in the switching regulator is the sum of the switching losses, and the power switch and diode D.C. losses. Once total power dissipation has been determined, the Power Dissipation curve, or thermal resistance data may be used to determine the allowable case or ambient temperature for any operating condition.

The switching losses curve presents data for a frequency of 20KHz. To find losses at any other frequency, multiply by f/20KHz.

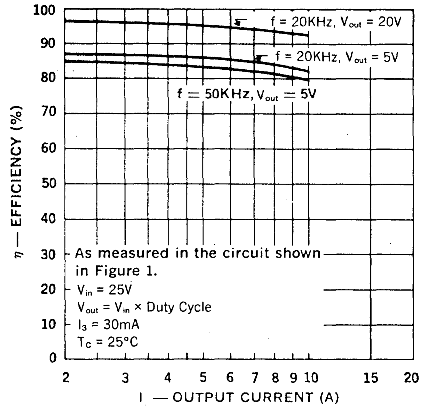
The D.C. losses curves present data for a duty cycle of .2. To find D.C. losses at any other duty cycle, multiply by D/.2 for the power switch and by (1-D)/.8 for the diode.

At frequencies much below 10KHz the above method for determining the allowable case or ambient temperature becomes invalid and a detailed transient thermal analysis must be performed. Please see Design Note 6 (DN-6) for further information.

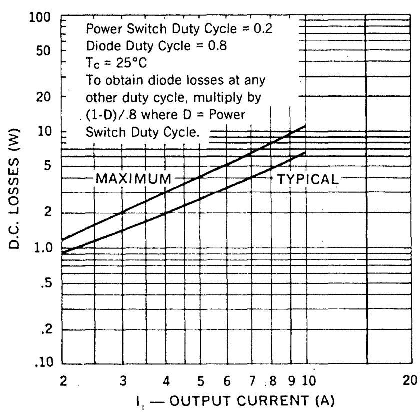
Power Dissipation



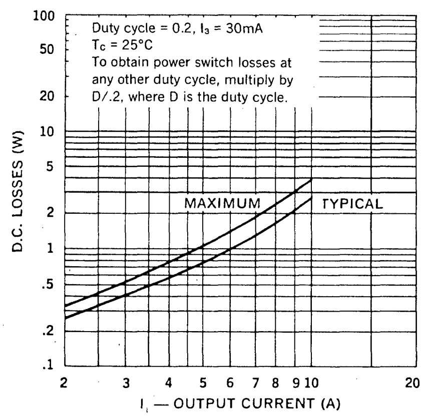
Efficiency



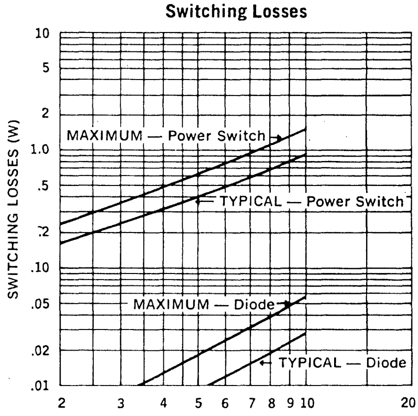
Diode D.C. Losses



Power Switch D.C. Losses



Switching Losses



V_{in} = 25, V, I_3 = 30mA
f = 20KHz
T_C = 25°C
To determine switching losses at any other frequency, multiply by f/20KHz where f is the frequency at which the losses are to be determined.

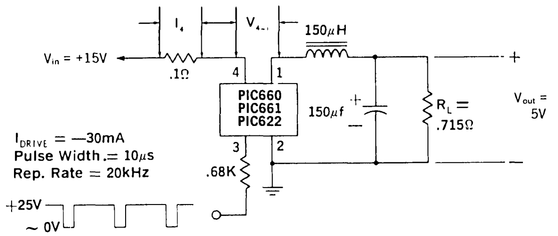


Figure 1. PIC660, 661, 662 Switching Speed Circuit

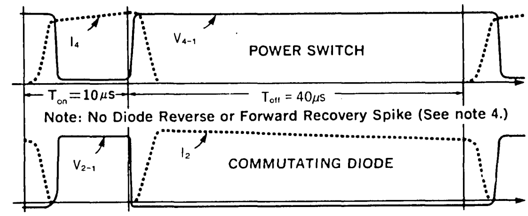
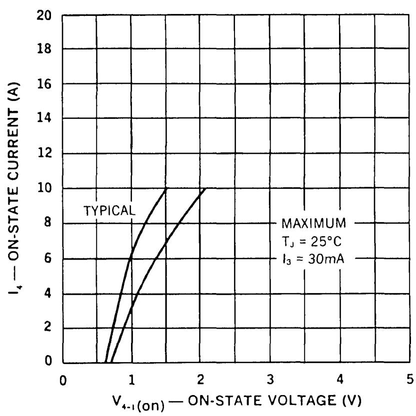


Figure 2. PIC660, 661, 662 Switching Waveforms

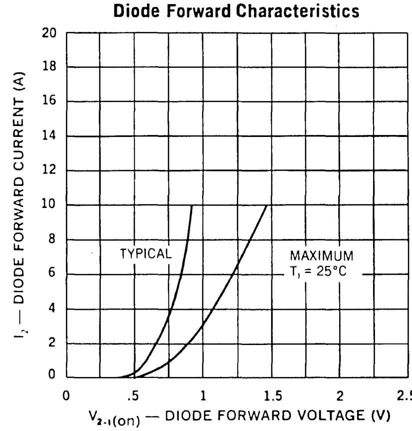
Note: PIC670, PIC671, PIC672 Circuit and waveforms are identical but of opposite polarity (V_{in} = −15V, V_{out} = −5V, I_{DRIVE} = +30mA.)

V

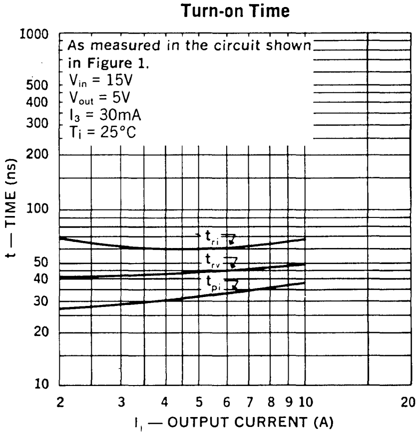
On-State Characteristics



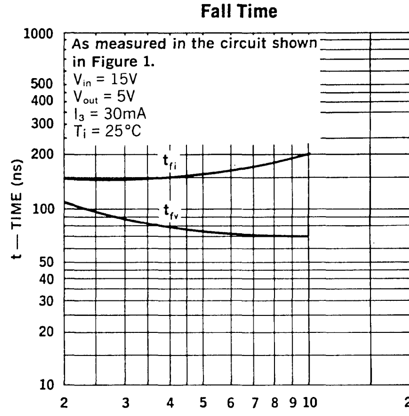
Diode Forward Characteristics



Turn-on Time



Fall Time



POWER INTEGRATED CIRCUIT

Schottky Switching Regulator 30A, 40V Power Output Stages

PIC730
PIC740

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI
- High operating frequency (to 100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- Low forward drop of Schottky Rectifier: $V_F = .6V$ at 20 A
- High Efficiency: 90% typ. @ 15A (see last page)

APPLICATIONS:

High efficiency and high current Buck or Flyback type switching regulator.

DESCRIPTION

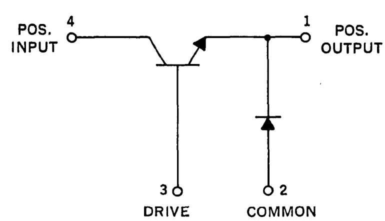
The Unitrode PIC700 series are unique hybrid circuits, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode.

Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC700 series the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC700 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time.

The PIC700 series switching regulators are completely characterized over their entire operating range of −55°C to +125°C. The devices are enclosed in a special 3 pin TO-3 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

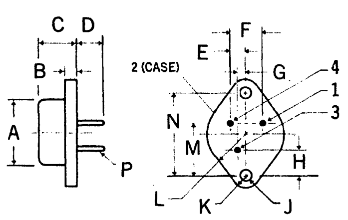
SCHEMATIC

PIC730
PIC740



MECHANICAL SPECIFICATIONS

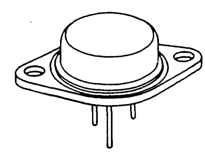
NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.



PIC730 PIC740

	ins.	mm
A	.875 MAX.	22.23 MAX.
B	.135	3.43
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.205-.225	5.21-5.72
F	.420-440	10.67-11.18
G	.145-.165	3.68-4.19
H	.395-.405	10.03-10.29
J	.151-.161 DIA.	3.84-4.09 DIA.
K	.188 MAX. RAD.	4.78 MAX. RAD.
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.708-.728	17.98-18.49
N	1.177-1.197	29.90-30.40
P	.038-.043 DIA.	.97-1.09 DIA.

3 Pin TO-3



ABSOLUTE MAXIMUM RATINGS

	PIC730	PIC740
Input Voltage	30V	40V
Output Voltage	30V	40V
Drive-Input Reverse Voltage	8V	8V
Continuous Output Current	20A	20A
Peak Output Current	30A	30A
Drive Current	5A	5A

Thermal Resistance
- Junction to Case, $\theta_{J\text{-}C}$
  - Power Switch .... 1.0°C/W
  - Commutating Diode .... 2.0°C/W
- Case to Ambient, $\theta_{C\text{-}A}$ .... 30°C/W

Operating Temperature Range, T_C .... —55°C to +125°C

Maximum Junction Temperature, T_J .... +150°C

Storage Temperature Range .... —65°C to +150°C

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

SCHOTTKY RECTIFIER

Test	Symbol	PIC730 Min.	PIC730 Max.	PIC740 Min.	PIC740 Max.	Unit	Test Conditions
Maximum Instantaneous Reverse Current	i_R	—	50	—	50	mA	V_R = rated, T_C = 125°C, Pulse Width = 300μs, Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	V_F	—	0.6	—	0.6	V	i_F = 20A, T_C = 125°C,

TRANSISTOR

Test		Symbol	PIC730 Min.	PIC730 Max.	PIC740 Min.	PIC740 Max.	Unit	Test Conditions
Collector Saturation Voltage (Note 1)		$V_{CE(sat)}$	—	1.0	—	1.0	V	I_C = 20A I_B = 2.5A
Base Saturation Voltage (Note 1)		$V_{BE(sat)}$	—	1.5	—	1.5	V	I_C = 20A I_B = 2.5A
Collector-Emitter Sustaining Voltage (Note 2)		$V_{CEO(sus)}$	30	—	40	—	V	I_C = 100mA
Collector Cut-off Current		I_{CEO}	—	10	—	10	mA	V_{CE} = 40V, P.W. = 300μs
Emitter Cut-off Current		I_{EBO}	—	10	—	10	mA	V_{EB} = 8V, P.W. = 300μs
Resistive Switching Speed	Rise Storage Fall	t_r t_s t_f	—	500 1.5 250	—	500 1.5 250	nS μS nS	V_{CC} = 30V, I_C = 20A, $I_{B1} = I_{B2}$ = 2.5A, $V_{BE(off)}$ = —4V
Inductive Switching Speed	Current Fall	t_{fi}	—	300	—	300	nS	T_J = 100°C, V_{CC} = 30V I_C = 20A, V clamp = 40V L = 175μH, $I_{B1} = I_{B2}$ = 2.5A
	Voltage Fall	t_{fv}	—	350	—	350	nS	

Notes
1. Pulse length=250 μs; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50 μs; duty cycle ≤1%. Voltage clamped at maximum collector-emitter voltage.

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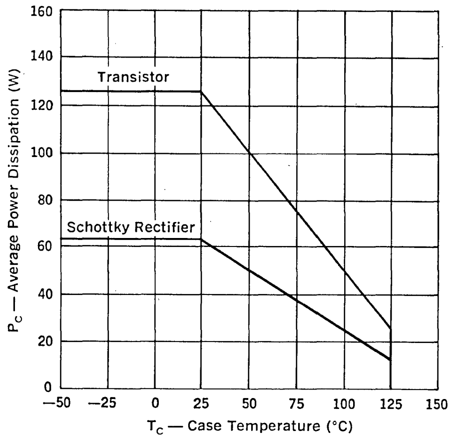
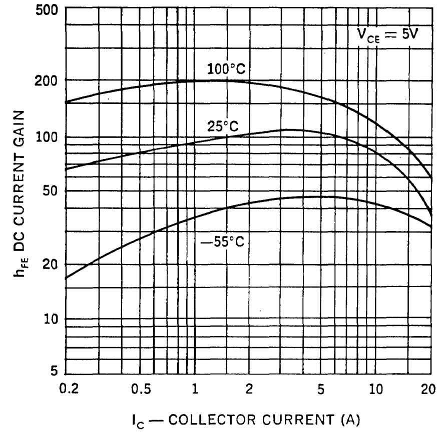
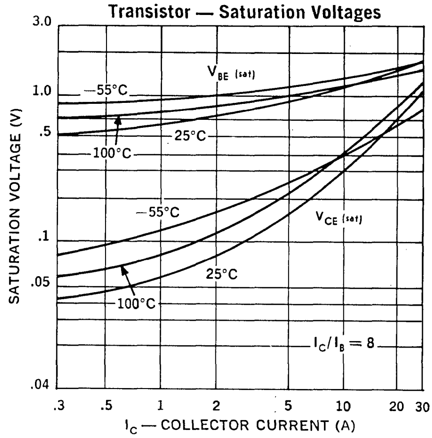
Power Dissipation



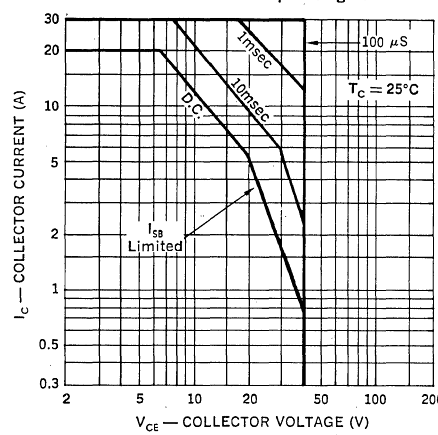
DC Current Gain



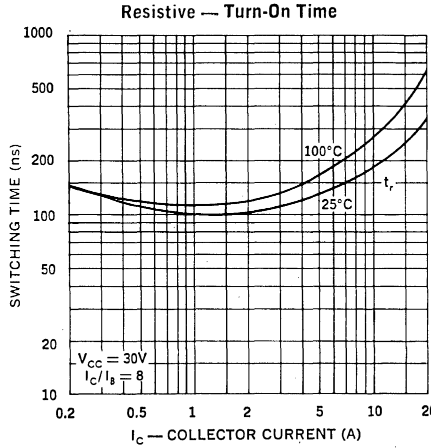
Transistor — Saturation Voltages



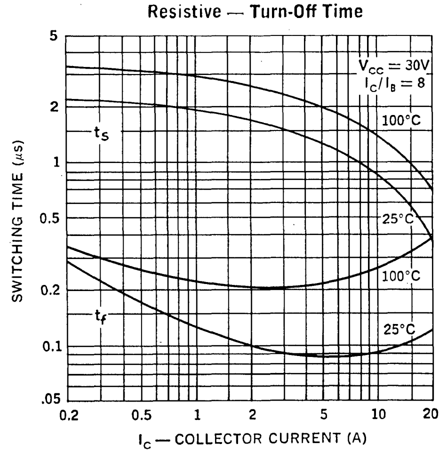
Forward Bias Safe Operating Area



Resistive — Turn-On Time



Resistive — Turn-Off Time



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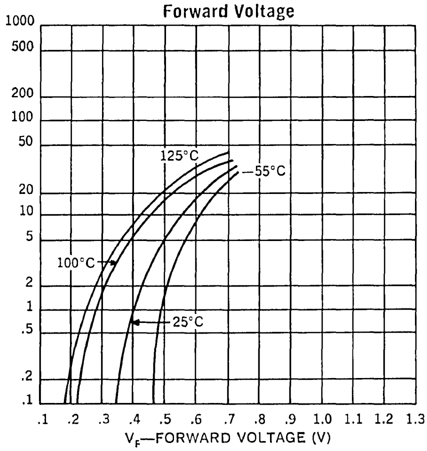
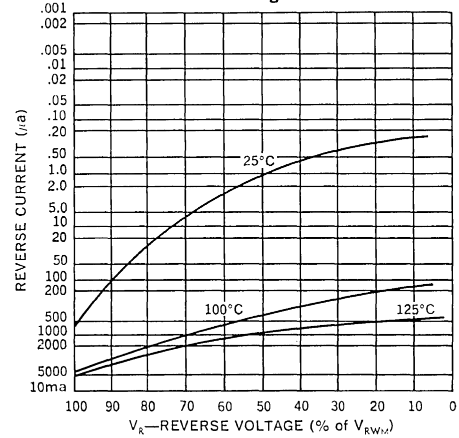
V

Rectifier — Forward Current vs Forward Voltage



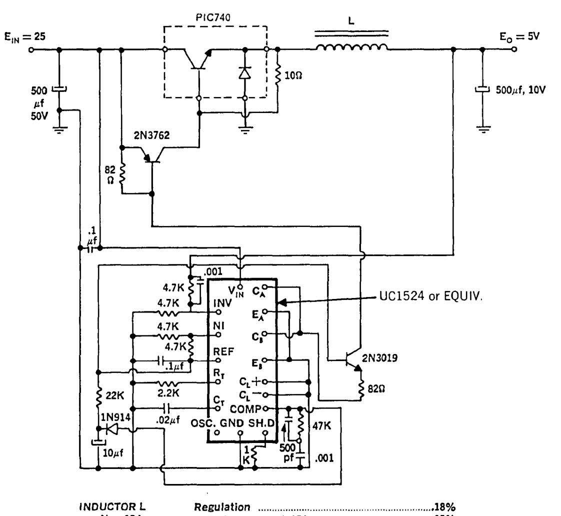
Rectifier — Typical Reverse Current vs Reverse Voltage



Possible Circuit Configurations

15 AMP SWITCHING REGULATOR

Pass Transistor — Unsaturated-Mode

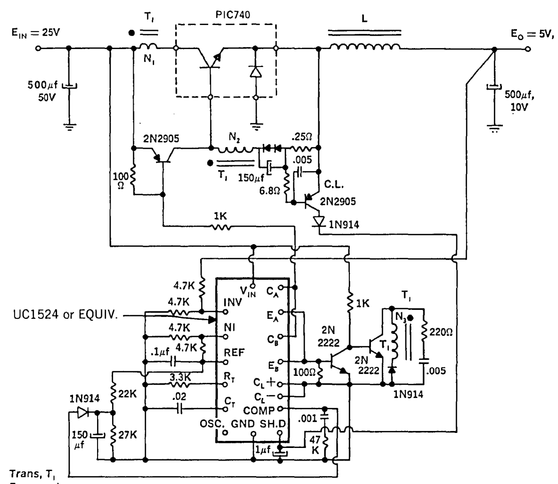


INDUCTOR L
N = 35 turns
Wire size #18
Arnold A4-17172

Regulation 18%
Typ. Efficiency at 15A 85%

15 AMP SWITCHING REGULATOR

Pass Transistor — Saturated-Mode



Trans. T_1
Ferroxcube core, 2616P-3B7
N_1 = 2.
N_2 = 16.
N_3 = 40.

Inductor L
N = 35 turns.
Wire size #18
Arnold A4-17172

Regulation 18%
Typ. Efficiency at 15A 90%

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POWER INTEGRATED CIRCUIT

Switching Regulator 8A, 400V Power Output Stages

PIC800
PIC801
PIC810
PIC811

FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI
- High operating frequency (to 100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency
- Electrically isolated, 4 PIN, TO-66 hermetic case
- Fast reverse recovery time of commutating diode
- Low capacitance between active components and case (≈ 10pf)

APPLICATIONS:

PIC800/801 – High voltage Buck or Flyback regulator.
PIC810/811 – Single ended half bridge (2 required), Full bridge (4 required), Deflection circuits, DC motor drive.

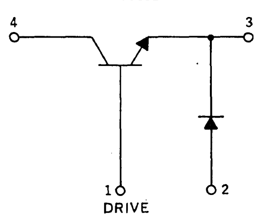
DESCRIPTION

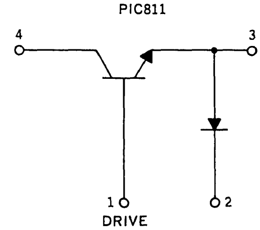
The Unitrode PIC800 series are power hybrid circuits, specifically designed, constructed and specified for use in high voltage switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode.

Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight, and internal power losses and a major decrease in overall cost. Using the Unitrode PIC800 series the designer can achieve further improvements in size, weight, efficiency, and costs. At the same time, because of the PIC800 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; the reverse recovery time of the commutating diode is less than 50 nanoseconds. The capacitance between the active components and the package is about 10 picofarads.

PIC800 series are completely characterized over their entire operating range of −55°C to +125°C. The devices are enclosed in a special 4-pin TO-66 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.
Suggested circuit applications are listed on fourth page of this sheet.

SCHEMATIC

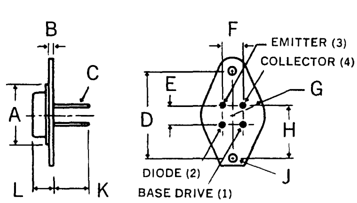




MECHANICAL SPECIFICATIONS

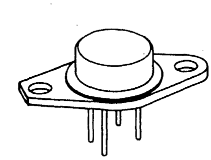
PIC800 PIC801 PIC810 PIC811

NOTES:
1. Case is electrically isolated.
2. Leads may be soldered to within 1/16″ of base provided temperature-time exposure is less than 260°C for 10 seconds.



	ins.	mm
A	.620 MAX.	15.75 MAX.
B	.050-.075	1.27-1.91
C	.028-.034	0.71-0.86
D	.958-.962	24.33-24.43
E	.190-.210	4.83-5.33
F	.190-.210	4.83-5.33
G	.350 MAX. RAD.	8.89 MAX. RAD.
H	.570-.590	14.48-14.99
J	.142-.152 DIA.	3.61-3.86 DIA.
K	.360 MIN.	9.14 MIN.
L	.250-.340	6.35-8.64

4-Pin TO-66



UNITRODE

ABSOLUTE MAXIMUM RATINGS

	PIC800-PIC810	PIC801-PIC811
Input Voltage	350V	400V
Output Voltage	350V	400V
Drive-Input Reverse Voltage	5V	5V
Peak Output Current	8A	8A
Continuous Output Current	5A	5A
Drive Current	2A	2A

Thermal Resistance
Junction to Case, Θ_{J-C}
Power Switch .... 2°C/W
Commutating Diode .... 3°C/W
Case to Ambient, Θ_{C-A} .... 60.0°C/W
Operating Temperature Range, T_C .... −55°C to +125°C
Maximum Junction Temperature, T_J .... +150°C
Storage Temperature Range .... −65°C to +150°C

V

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

RECTIFIER

Test	Symbol	PIC800-PIC810 Min.	PIC800-PIC810 Max.	PIC801-PIC811 Min.	PIC801-PIC811 Max.	Unit	Test Conditions
Maximum Inst. Reverse Current $T_J = 25°C$	i_R	—	20	—	20	μA	V_R = rated, Pulse Width = 300μs, Duty Cycle = 1 percent
Maximum Inst. Reverse Current $T_J = 100°C$	i_R	—	500	—	500	μA	
Maximum Forward Voltage $T_J = 25°C$	V_F	—	1.25	—	1.25	V	$i_F = 3A$
Maximum Forward Voltage $T_J = 100°C$	V_F	—	1.15	—	1.15	V	
DC Blocking Voltage	V_R	350	—	400	—	V	Pulse Width = 300μs, $I_R = 20\mu A$
Maximum Reverse Recovery Time	t_{rr}	—	50	—	50	nS	$I_F = ½A$, $I_R = 1A$, $I_{REC} = .25A$

TRANSISTOR

Test	Symbol	PIC800-PIC810 Min.	PIC800-PIC810 Max.	PIC801-PIC811 Min.	PIC801-PIC811 Max.	Unit	Test Conditions
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	1.0	—	1.0	V	$I_C = 2.0A$, $I_B = 0.4A$
Collector Saturation Voltage (Note 1) $T_C = 25°C$	$V_{CE(sat)}$	—	1.5	—	1.5	V	$I_C = 5.0A$, $I_B = 1.0A$
Collector Saturation Voltage (Note 1) $T_C = 100°C$	$V_{CE(sat)}$	—	2.0	—	2.0	V	
Collector Saturation Voltage (Note 1)	$V_{CE(sat)}$	—	3.0	—	3.0	V	$I_C = 8.0A$, $I_B = 2.0A$
Base Saturation Voltage	$V_{BE(sat)}$	—	1.2	—	1.2	V	$I_C = 2.0A$, $I_B = 0.4A$
Base Saturation Voltage (Note 1) $T_C = 100°C$	$V_{BE(sat)}$	—	1.6	—	1.6	V	$I_C = 5.0A$, $I_B = 1.0A$
Base Saturation Voltage (Note 1) $T_C = 25°C$	$V_{BE(sat)}$	—	1.5	—	1.5	V	
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEO(sus)}$	350	—	400	—	V	$I_C = 10mA$
Collector-Emitter Sustaining Voltage (Note 2)	$V_{CEX(sus)}$	350	—	400	—	V	$I_C = 3.0A$, $L = 180\mu H$, $I_{B1} = I_{B2} = 0.6A$, V_{CE} clamp = rated $V_{CEX(sus)}$
Emitter-Base Cutoff Current	I_{EBO}	—	1	—	1	mA	$V_{EB} = 9V$
Collector Cutoff Current	I_{CEV}	—	1.0	—	—	mA	$V_{CE} = 350V$, $V_{BE} = -1.5V$
		—	—	—	1.0		$V_{CE} = 400V$, $V_{BE} = -1.5V$
Collector Cutoff Current, $T_C = 100°C$	I_{CEV}	—	5	—	—	mA	$V_{CE} = 350V$, $V_{BE} = -1.5V$
		—	—	—	5		$V_{CE} = 400V$, $V_{BE} = -1.5V$
Output Capacitance, Common Base	C_{obo}	110	Typ	110	Typ	pF	$V_{CB} = 10V$, f = 1 MHz
Gain-Bandwidth Product	F_T	4	—	4	—	MHz	$V_{CE} = 10V$, $I_C = 0.5A$, f = 1 MHz
Energy Second Breakdown (unclamped)	$E_{s/b}$	180	—	180	—	μJ	$I_C = 3.0A$, $V_{BE(off)} = 4V$, $I_{B1} = 0.6A$, $L = 40\mu H$ unclamped
Resistive Switching Speeds Delay Time	t_d	—	0.1	—	0.1	μs	$I_C = 5.0A$
Rise Time	t_r	—	0.8	—	0.8	μs	$V_{CC} = 125V$
Storage Time	t_s	—	2.0	—	2.0	μs	$I_{B1} = I_{B2} = 1A$
Fall Time	t_f	—	0.4	—	0.4	μs	$V_{BE(off)} = 5V$
Inductive Switching Speeds $T_C = 100°C$ Storage Time	t_s	—	2.3	—	2.3	μs	$I_C = 5.0A$, $V_{BE(off)} = 5V$, $I_{B1} = I_{B2} = 1A$
Fall Time	t_f	—	0.4	—	0.4	μs	V_{CE} clamp = rated $V_{CEX(sus)}$

Notes
1. Pulse length=250 μs; duty cycle ≤1%.
2. Sustaining Voltage. Measured at a high current point where collector-emitter voltage is lowest. Current pulse length ≅ 50 μs; duty cycle ≤1%. Voltage clamped at maximum collector-emitter voltage.

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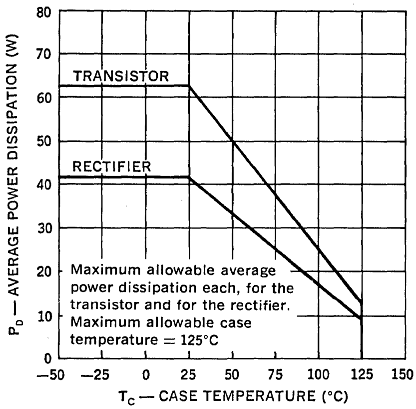
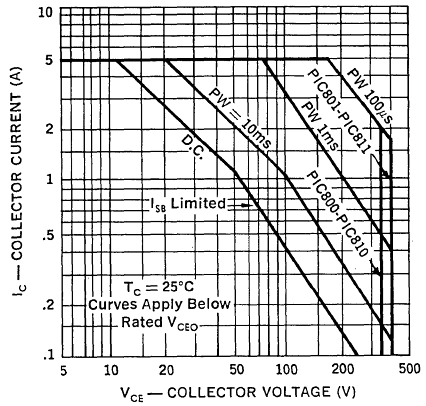
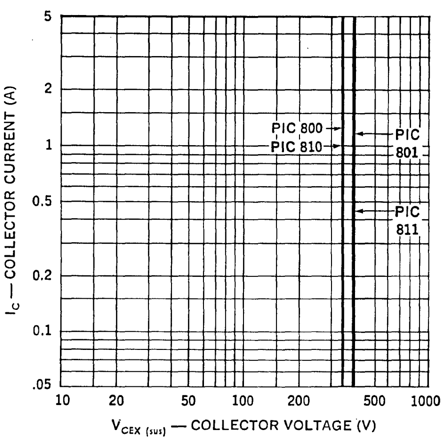
Power Dissipation



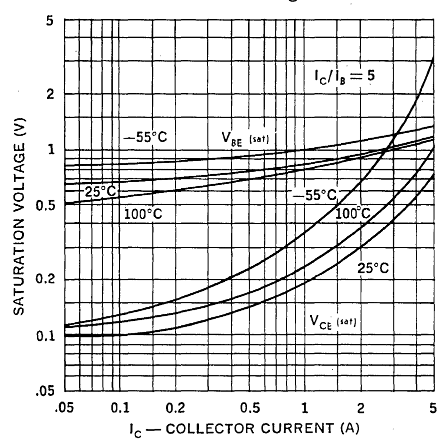
Forward Bias Safe Operating Area



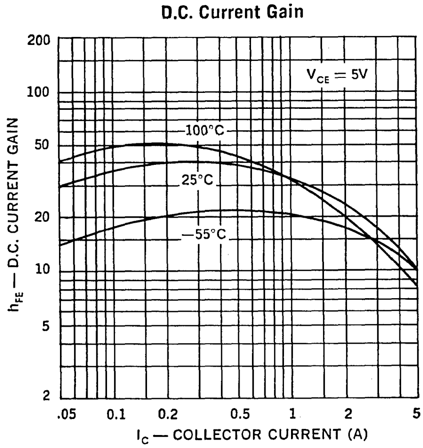
Reverse Biased Safe Operating Area



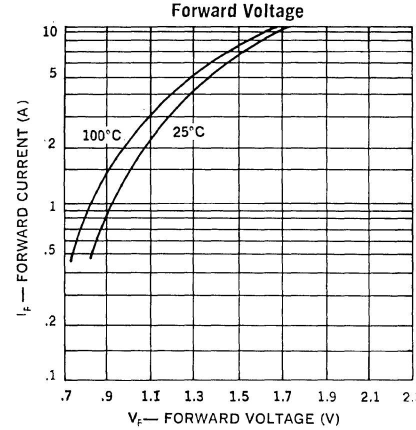
Saturation Voltages



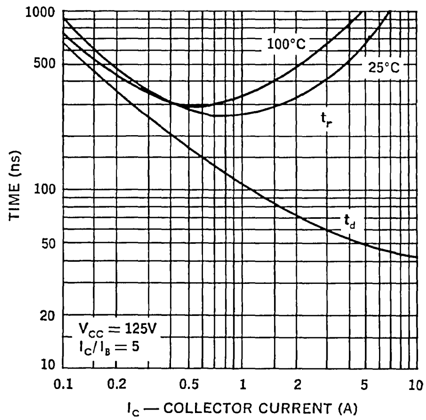
D.C. Current Gain



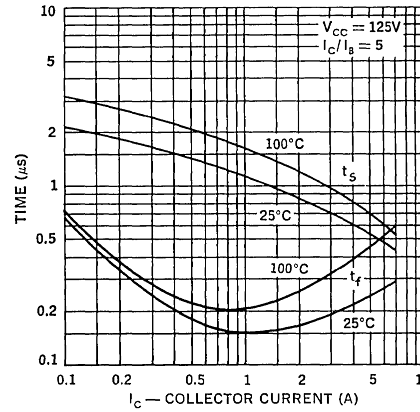
Rectifier — Forward Current vs Forward Voltage



Resistive — Turn-On Time



Resistive — Turn-Off Time



Typical Inductive Switching Times

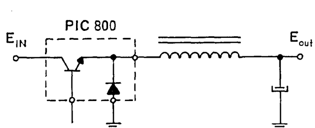
$$\frac{I_C}{5} = I_{B1} = -I_{B2},\ V(clamp) = 350V$$

$$V_{CC} = 125V$$

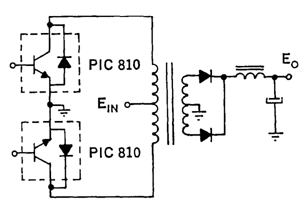
Current	Temp.	t_s µS	t_{fv} nS	t_{fi} nS
$I_C = 1A$	25°C	1.2	120	160
	100°C	1.76	140	185
$I_C = 3A$	25°C	.8	100	100
	100°C	1.1	170	130
$I_C = 5A$	25°C	.9	80	100
	100°C	1.0	190	140

APPLICATIONS:

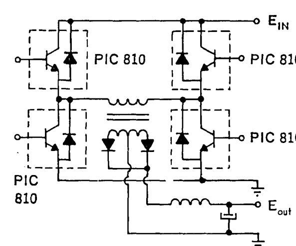
BUCK REGULATOR



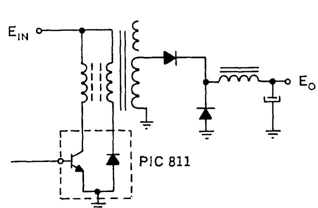
PUSH-PULL



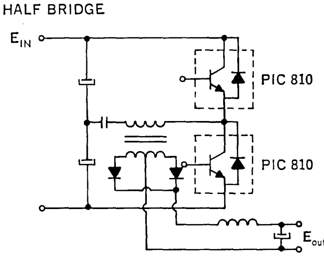
FULL BRIDGE



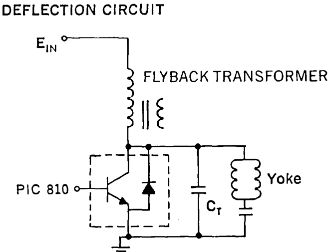
SINGLE ENDED



HALF BRIDGE

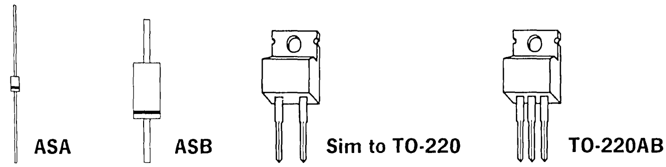


DEFLECTION CIRCUIT

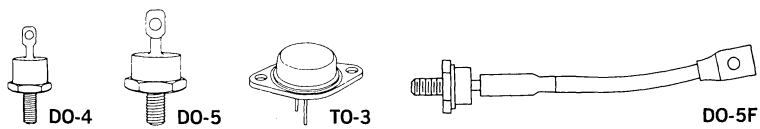


RECTIFIERS VI

VI



Average D.C. Output Current		1A	3A	6A	8A	12A Center-Tap	12A	16A Center-Tap
Package Style		**ASA**	**ASB**	**Sim to TO-220**	**Sim to TO-220**	**TO-220AB**	**Sim to TO-220**	**TO-220AB**
PEAK INVERSE VOLTAGE	20V	1N5817	1N5820	USD620	USD720	USD620C	USD820	USD720C
	30V	1N5818	1N5821					
	35V			USD635	USD735	USD635C	USD835	USD735C
	40V	1N5819	1N5822	USD640	USD740	USD640C	USD840	USD740C
	45V			USD645	USD745	USD645C	USD845	USD745C



Average D.C. Output Current		16A	25A	30A	50A	60A Center-Tap	60A	75A
Package Style		**Sim to TO-220**	**DO-4**	**DO-4**	**DO-5**	**TO-3**	**DO-5 DO-5F**	**DO-5 DO-5F**
PEAK INVERSE VOLTAGE	20V	USD920		USD420		USD320C		USD520
	30V		1N6095		1N6097			
	35V	USD935		USD435		USD335C		USD535
	40V	USD940	1N6096		1N6098			
	45V	USD945		USD445 SD41[1]		USD345C SD241[1]	SD51[1]	USD545[2]

(1) V_R @ 25°C is 45V, V_R @ 150°C is 35V,
(2) Hi-Rel devices available, add HR2 sufix to part number.

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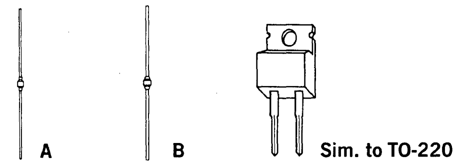
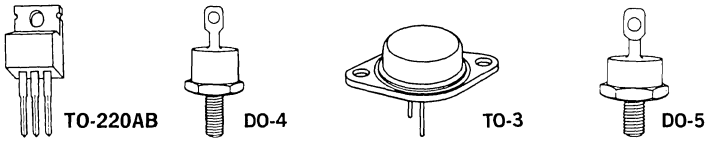


ULTRA-FAST RECOVERY (t_{rr} — 25 to 50ns)

Average D.C. Output Current		1A	2A	2.5A	5A	6A	8A
Package Style		**A**	**A**	**A**	**B**	**B**	**Sim to TO-220**
Peak Inverse Voltage 50V	V_F t_{rr}	UES1001 .895 @ 1A 25ns		1N5802* UES1101 .895 @ 2A 25ns		1N5807* UES1301 .850 @ 6A 30ns	UES1401 .895 @ 8A 35ns
75V	V_F t_{rr}			1N5803 .895 @ 1A 25ns		1N5808 .850 @ 6A 30ns	
100V	V_F t_{rr}	UES1002 .895 @ 1A 25ns		1N5804* UES1102 .895 @ 2A 25ns		1N5809* UES1302 .850 @ 6A 30ns	UES1402 .895 @ 8A 35ns
125V	V_F t_{rr}			1N5805 .895 @ 1A 25ns		1N5810 .850 @ 6A 30ns	
150V	V_F t_{rr}	UES1003 .895 @ 1A 25ns		1N5806* UES1103 .895 @ 2A 25ns		1N5811* UES1303 .850 @ 6A 30ns	UES1403 .895 @ 8A 35ns
200V	V_F t_{rr}		UES1104 1.15 @ 1A 50ns		UES1304 1.15 @ 3A 50ns		
300V	V_F t_{rr}		UES1105 1.15 @ 1A 50ns		UES1305 1.15 @ 3A 50ns		
400V	V_F t_{rr}		UES1106 1.15 @ 1A 50ns		UES1306 1.15 @ 3A 50ns		

*Available as JAN, JANTX, JANTXV

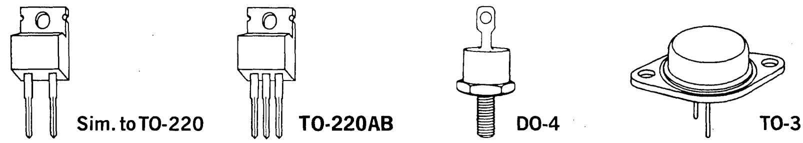


ULTRA-FAST RECOVERY (t_{rr} — 25 to 50ns)

Average D.C. Output Current		16A Center-Tap	20A	25A	30A Center-Tap	50A	70A
Package Style		**TO-220AB**	**DO-4**	**DO-4**	**TO-3**	**DO-5**	**DO-5**
Peak Inverse Voltage 50V		UES2401		1N5812* UES701	UES2601		1N6304 UES801
	V_F	.895 @ 8A		.825 @ 25A	.825 @ 15A		.84 @ 70A
	t_{rr}	35ns		35ns	35ns		50ns
75V				1N5813			
	V_F			.825 @ 25A			
	t_{rr}			35ns			
100V		UES2402		1N5814* UES702	UES2602		1N6305 UES802
	V_F	.895 @ 8A		.825 @ 25A	.825 @ 15A		.84 @ 70A
	t_{rr}	35ns		35ns	35ns		50ns
125V				1N5815			
	V_F			.825 @ 25A			
	t_{rr}			35ns			
150V		UES2403		1N5816* UES703	UES2603		1N6306 UES803
	V_F	.895 @ 8A		.825 @ 25A	.825 @ 15A		.84 @ 70A
	t_{rr}	35ns		35ns	35ns		50ns
200V			UES704		UES2604	UES804	
	V_F		1.15 @ 20A		1.15 @ 15A	1.15 @ 50A	
	t_{rr}		50ns		50ns	50ns	
300V			UES705		UES2605	UES805	
	V_F		1.15 @ 20A		1.15 @ 15A	1.15 @ 50A	
	t_{rr}		50ns		50ns	50ns	
400V			UES706		UES2606	UES806	
	V_F		1.15 @ 20A		1.15 @ 15A	1.15 @ 50A	
	t_{rr}		50ns		50ns	50ns	

*Available as JAN, JANTX, JANTXV

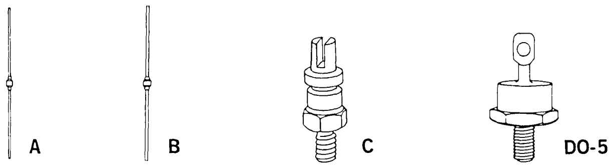
RECTIFIERS



SUPER-FAST RECOVERY (t_{rr} - 75 to 100ns)

Average D.C. Output Current			1A	2A	2A	3A	4A
Package Style			**A**	**A**	**A**	**B**	**B**
Peak Inverse Voltage	50V	V_F t_{rr}	UTX105 1.00 @ .5A 75ns	UTX205 1.0V @ 1A 75ns	SES5001 .975 @ 1A 100ns	UTX3105 1V @ 2A 100ns	UTX4105 1V @ 3A 100ns
	100V	V_F t_{rr}	UTX110 1.0V @ .5A 75ns	UTX210 1.0V @ 1A 75ns	SES5002 .975 @ 1A 100ns	UTX3110 1.0V @ 2A 100ns	UTX4110 1.0V @ 3A 100ns
	150V	V_F t_{rr}	UTX115 1.00 @ .5A 75ns	UTX215 1.0V @ 1A 75ns	SES5003 .975 @ 1A 100ns	UTX3115 1.0V @ 2A 100ns	UTX4115 1.0V @ 3A 100ns
	200V	V_F t_{rr}	UTX120 1.00 @ 1A 75ns	UTX220 1.0V @ 1A 75ns		UTX3120 1.0V @ 2A 100ns	UTX4120 1.0V @ 3A 100ns
	250V	V_F t_{rr}	UTX125 1.00 @ .5A 75ns	UTX225 1.0V @ 1A 75ns			

Average D.C. Output Current			5A	8A	16A Center-Tap	20A	25A Center-Tap	60A
Package Style			**B**	**Sim to TO-220**	**TO-220AB**	**DO-4**	**TO-3**	**DO-5**
Peak Inverse Voltage	50V	V_F t_{rr}	SES5301 .975 @ 5A 100ns	SES5401 1.025 @ 8A 100ns	SES5401C 1.025 @ 8A 100ns	SES5701 .83 @ 20A 100ns	SES5601C .83 @ 12.5A 100ns	SES5801 .85 @ 60A 100ns
	100V	V_F t_{rr}	SES5302 .975 @ 5A 100ns	SES5402 1.025 @ 8A 100ns	SES5402C 1.025 @ 8A 100ns	SES5702 .83 @ 20A 100ns	SES5602C .83 @ 12.5A 100ns	SES5802 .85 @ 60A 100ns
	150V	V_F t_{rr}	SES5303 .975 @ 5A 100ns	SES5403 1.025 @ 8A 100ns	SES5403C 1.025 @ 8A 100ns	SES5703 .83 @ 20A 100ns	SES5603C .83 @ 12.5A 100ns	SES5803 .85 @ 60A 100ns



VI

ST RECOVERY (t_{rr} — 150 to 500ns)

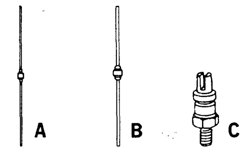
Average D.C. Output Current		1A	1A	2A	3A	3A	4A	6-9A	30A
Package Style		**A**	**A**	**A**	**B**	**B**	**B**	**C**	**DO-5**
Peak Inverse Voltage 50V	V_F t_{rr}	UTR01 1.1V @ .5A 250ns		UTR02 1.1V @ 1A 250ns	UTR3305 1.1V @ 3A 250ns	1N5415* 1.5V @ 9A 150ns	UTR4305 1.1V @ 4A 250ns	UTR4405 UTR5405 UTR6405 1.1V @ 6A 300ns	1N3909** 1.4V @ 95A 200ns
100V	V_F t_{rr}	UTR11 1.1V @ .5A 250ns		UTR12 1.1V @ 1A 250ns	UTR3310 1.1V @ 3A 250ns	1N5416* 1N5186** 1.5V @ 9A 150ns	UTR4310 1.1V @ 4A 250ns	UTR4410 UTR5410 UTR6410 1.1V @ 6A 300ns	1N3910** 1.4V @ 95A 200ns
200V	V_F t_{rr}	UTR21 1.1V @ .5A 250ns	1N4942* 1N5615* 1.3V @ 1A 150ns	UTR22 1.1V @ 1A 250ns	UTR3320 1.1V @ 3A 250ns	1N5417* 1N5187** 1.5V @ 9A 150ns	UTR4320 1.1V @ 4A 250ns	UTR4420 UTR5420 UTR6420 1.1V @ 6A 400ns	1N3911** 1.4V @ 95A 300ns
300V	V_F t_{rr}	UTR31 1.1V @ .5A 300ns		UTR32 1.1V @ 1A 300ns					1N3912** 1.4V @ 95A 200ns
400V	V_F t_{rr}	UTR41 1.1V @ .5A 350ns	1N4944* 1N5617* 1.3V @ 1A 150ns	UTR42 1.1V @ 1A 350ns	UTR3340 1.1V @ 3A 300ns	1N5418* 1N5188** 1.5V @ 9A 150ns	UTR4340 1.1V @ 4A 400ns	UTR4440 UTR5400 UTR6440 1.1V @ 6A 500ns	1N3913* 1.4V @ 95A 200ns
500V	V_F t_{rr}	UTR51 1.1V @ .5A 400ns		UTR52 1.1V @ 1A 400ns	UTR3350 1.1V @ 3A 350ns	1N5419* 1.5V @ 9A 250ns	UTR4350 1.1V @ 4A 400ns		
600V	V_F t_{rr}	UTR61 1.1V @ .5A 400ns	1N4946* 1N5619* 1.3V @ 1A 250ns	UTR62 1.1V @ 1A 400ns	UTR3360 1.1V @ 3A 400ns	1N5420* 1N5190** 1.5V @ 9A 400ns	UTR4360 1.1V @ 4A 400ns		

vailable as JAN, JANTX, JANTXV
vailable as JAN, JANTX

Semtech
General Instr.

Semtech
General Inst

415-494-0113



STANDARD RECOVERY

Average D.C. Output Current	1A	2A	3A	4A	7.5A	9A	12A
Package Style	**A**	**A**	**B**	**B**	**C**	**C**	**C**
Peak Inverse Voltage 50V	UR105†	UR205	UT3005	UT4005	UT5105	UT6105	UT8105
100V	UT236 UR110†	UT261 UR210†	UT3010	UT4010	UT5110	UT6110	UT8110
150V	UR115†	UR215†					
200V	UT234 UR120† 1N4245* 1N5614*	UT262 UR220† 1N3611**	UT3020	UT4020 1N5550*	UT5120	UT6120	UT8120
250V	UR125†	UR225†					
400V	UT235 1N4246* 1N5616*	UT264 1N3612**	UT3040	UT4040 1N5551*	UT5140	UT6140	UT8140
600V	UT238 1N4247* 1N5618*	UT267 1N3613**	UT3060	UT4060 1N5552*	UT5160	UT6160	UT8160
800V	UT361 1N4248* 1N5620*	UT268 1N3614**		1N5553*			
1000V	UT347 1N4249*	UT364					

*Available as JAN, JANTX, JANTXV.
**Available as JAN, JANTX.
†Radiation Tolerant

RECTIFIERS

Military Approved, 1 Amp, General Purpose

JAN & JANTX 1N3611-1N3614

FEATURES

- Qualified to MIL-S-19500/228
- Continuous Rating: 1A
- Surge Rating: 30A
- PIV: to 800V

DESCRIPTION

This series of MIL approved JAN and JANTX general purpose 1 amp rectifiers are useful in many high rel applications.

ABSOLUTE MAXIMUM RATINGS

Peak Reverse Voltage Min.	Reverse Working Voltage	Type
240V	200V	JAN & JANTX 1N3611
480V	400V	JAN & JANTX 1N3612
720V	600V	JAN & JANTX 1N3613
920V	800V	JAN & JANTX 1N3614

Maximum Average D.C. Output Current

@ $T_A = 100°C$ 1.0A

@ $T_A = 150°C$ 0.3A

Non-Repetitive Sinusoidal Surge Current (8.3ms) 30A

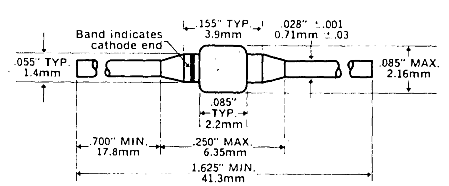
Operating Temperature Range .... —65°C to +175°C

Storage Temperature Range .... —65°C to +200°C

Thermal Resistance .... See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

JAN & JANTX 1N3611-1N3614



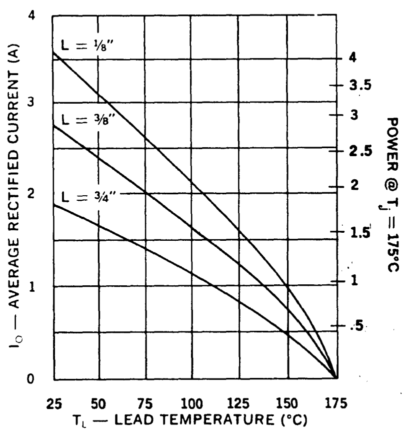
BODY A

UNITRODE

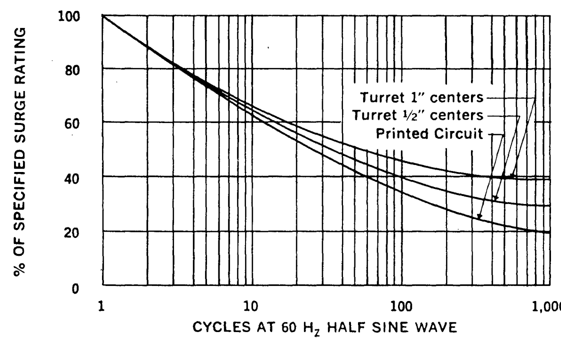
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Peak Reverse D.C. Voltage	Minimum Reverse Breakdown Voltage @ 100μA	Peak Forward Voltage Min.	Peak Forward Voltage Max.	Maximum D.C. Reverse Current at D.C. Voltage 25°C	Maximum D.C. Reverse Current at D.C. Voltage 150°C
JAN & JANTX 1N3611	200V	240V	0.6V	1.1V(pk) @ 1.0A	1μA	300μA
JAN & JANTX 1N3612	400V	480V				
JAN & JANTX 1N3613	600V	720V				
JAN & JANTX 1N3614	800V	920V				

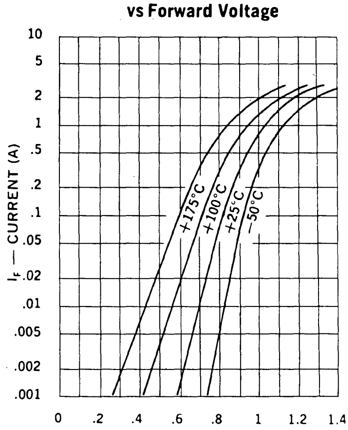
Maximum Current vs Lead Temperature



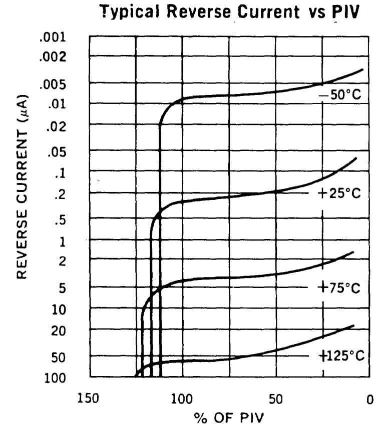
Allowable Forward Surge vs Number of Cycles



Typical Forward Current vs Forward Voltage



Typical Reverse Current vs PIV



RECTIFIERS
Military Approved, Fast Recovery, 30A

JAN, JANTX 1N3909
JAN, JANTX 1N3910
JAN, JANTX 1N3911
JAN, JANTX 1N3912
JAN, JANTX 1N3913

FEATURES
- Qualified to MIL-S-19500/308
- High Mechanical Integrity
- Low Thermal Resistance
- JAN and JANTX Available

DESCRIPTION
These devices feature unique mechanical ruggedness combined with fast switching electrical characteristics. Devices may be used in many power switching circuits.

VI

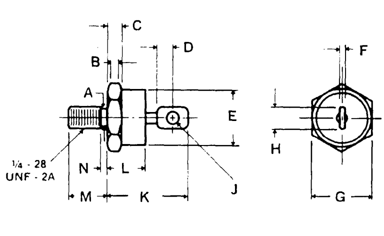
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
50V	JAN, JANTX 1N3909
100V	JAN, JANTX 1N3910
200V	JAN, JANTX 1N3911
300V	JAN, JANTX 1N3912
400V	JAN, JANTX 1N3913

Maximum Average D.C. Output Current
@ $T_C = 100°C$ 30A
Non Repetitive Sinusoidal Surge Current
@ $T_C = 100°C$ 300A
Thermal Resistance, Junction-to-Case .... 1.2°C/W
Operating Temperature .... $T_C = -65°C$ to $+150°C$
Storage Temperature .... $T_C = -65°C$ to $+175°C$

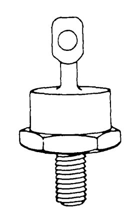
MECHANICAL SPECIFICATIONS

JAN, JANTX 1N3909, 1N3910, 1N3911, 1N3912, 1N3913



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



Notes:
1. Polarity is cathode-to-stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds.
4. Angular orientation of terminal is undefined.

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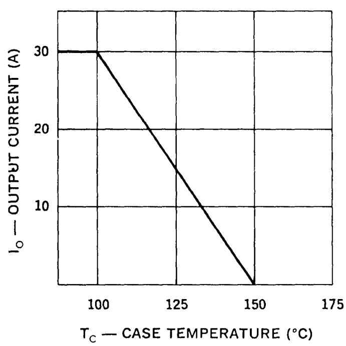
UNITRODE

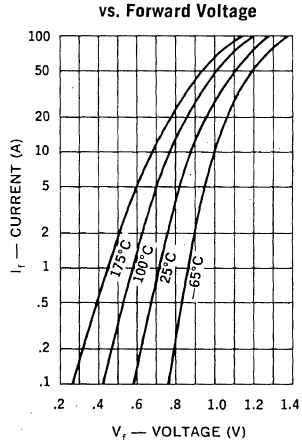
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Type	Peak Inverse Voltage	Maximum Forward Voltage	Maximum Leakage Current @ PIV		Maximum Reverse Recovery Time $I_F = 1A, V_R = 30V$
			25°C	100°C	
J, JTX 1N3909 J, JTX 1N3910 J, JTX 1N3911 J, JTX 1N3912 J, JTX 1N3913	50V 100V 200V 300V 400V	1.4V(pk) @ $I_f = 95Apk$ $t_p \leqslant 8.3ms$ $d_C \leqslant 2\%$	80μA	10mA	200 nsec

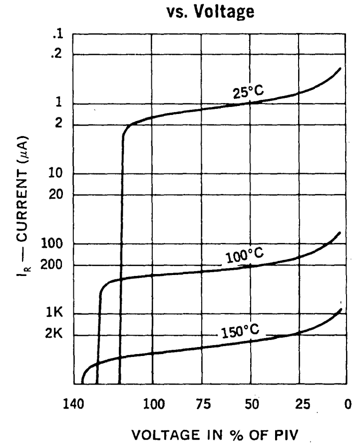
Output Current vs. Case Temperature



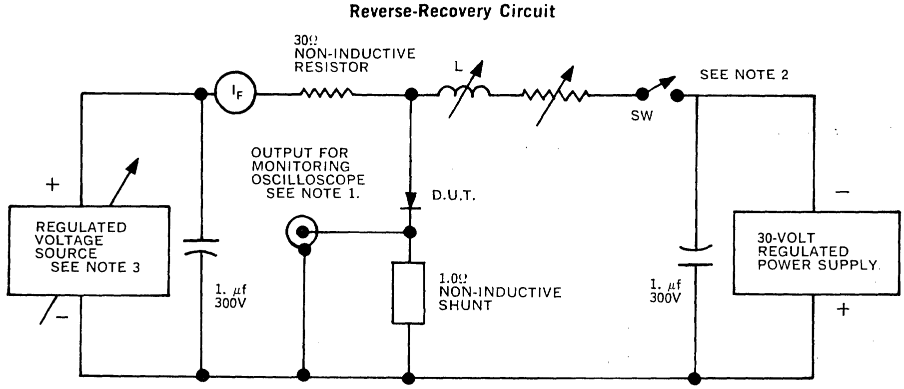
Typical Forward Current vs. Forward Voltage



Typical Reverse Current vs. Voltage



Reverse-Recovery Circuit



NOTES:

1. Monitoring oscilloscope requirements: $t_r \leqslant 14$ nsec, $R_{in} \geqslant 9M\Omega$, $C_{in} \leqslant 12$ pF, L_{in} (series) $\leqslant 0.5$ μH.
2. SW characteristics: Mercury-wetted make-before-break relay switches at a 60 Hz rate. The relay should conduct for approximately 640 μsec and be open for approximately 7.7 msec. (C.P. Clare HGP 1004 or equivalent).
3. Voltage source characteristics: Output impedance $\leqslant 0.5\Omega$ from 0 to 2 Hz.

RECTIFIERS

Military Approved, 1 Amp, General Purpose

1N4245-1N4249
JAN, JANTX & JANTXV

VI

FEATURES
- Qualified to MIL-S-19500/286
- Surge Rating: 25A
- PIV: to 1000 V
- Controlled Avalanche
- No Plastic, Epoxy, Silicone, Oxides, Gases or Solder are used

DESCRIPTION
This series of general purpose power rectifiers are available as JAN, JANTX or JANTXV for many power supply applicatons.

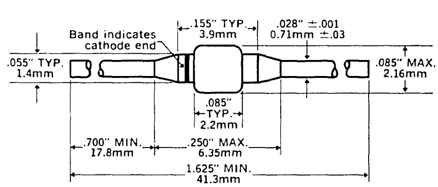
ABSOLUTE MAXIMUM RATINGS

Maximum Reverse Voltage	Type
200V	JAN, JANTX, JANTXV 1N4245
400V	JAN, JANTX, JANTXV 1N4246
600V	JAN, JANTX, JANTXV 1N4247
800V	JAN, JANTX, JANTXV 1N4248
1000V	JAN, JANTX, JANTXV 1N4249

Maximum Average D.C. Output Current
@ T_A = 100°C 1.0A
@ T_A = 150°C 0.333A
Non-Repetitive Sinusoidal
Surge Current 25A
Operating Temperature Range .... —65°C to +175°C
Storage Temperature Range .... —65°C to +175°C
Thermal Resistance .... See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N4245-1N4249



BODY A

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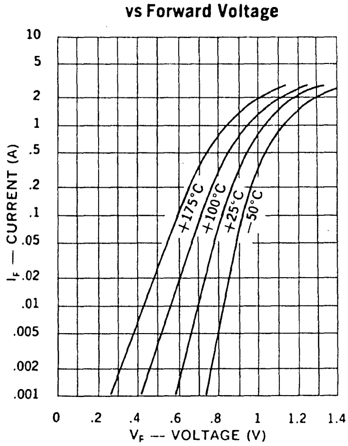
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

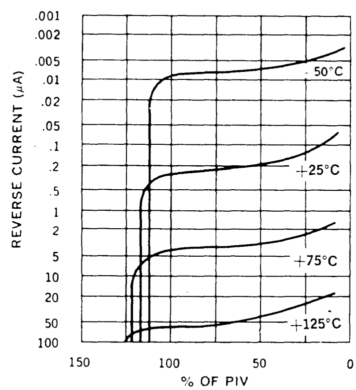
Type	PIV	Minimum Reverse Breakdown Voltage @ 100μA	Forward Voltage Min.	Forward Voltage Max.	Maximum Reverse Current 25°C	Maximum Reverse Current 150°C	Maximum Reverse Recovery Time*
J, JTX, JTXV 1N4245	200V	240V	0.6V	1.3V(pk) @ 3.0A(pk)	1.0μA	150μA	5.0μs
J, JTX, JTXV 1N4246	400V	480V					
J, JTX, JTXV 1N4247	600V	720V					
J, JTX, JTXV 1N4248	800V	960V					
J, JTX, JTXV 1N4249	1000V	1150V					

*Measured in circuit $I_F = ½A$, $I_R = 1.0A$, $I_{REC} = ¼A$

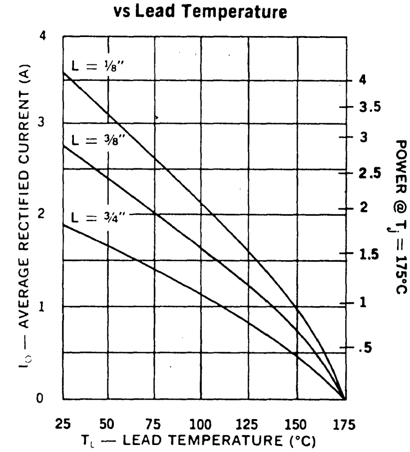
Typical Forward Current vs Forward Voltage



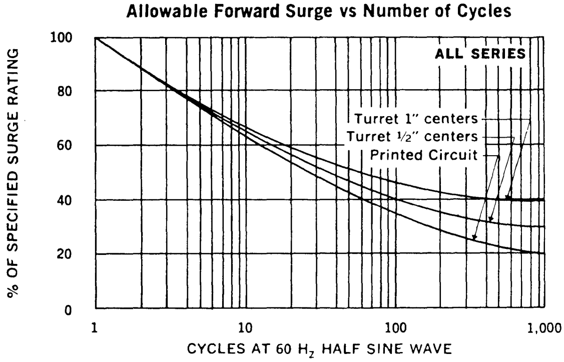
Typical Reverse Current vs PIV



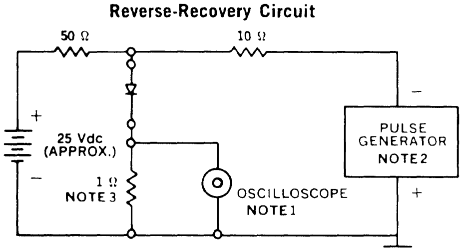
Maximum Current vs Lead Temperature



Allowable Forward Surge vs Number of Cycles



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

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RECTIFIERS

Military Approved, 1 Amp, Fast Recovery

JAN, JANTX, & JANTXV 1N4942
JAN, JANTX, & JANTXV 1N4944
JAN, JANTX, & JANTXV 1N4946

FEATURES
- Qualified to MIL-S-19500/359
- Surge Rating: 15A
- PIV: to 600V
- Controlled Avalanche

DESCRIPTION
These fast recovery rectifiers are suitable for use as power devices for many applications. Devices are available as JAN, JANTX or JANTXV.

1N4942
1k
.66

VI

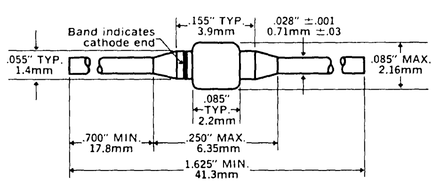
ABSOLUTE MAXIMUM RATINGS

Maximum Reverse Voltage	Type
200V	JAN, JANTX, & JANTXV 1N4942
400V	JAN, JANTX, & JANTXV 1N4944
600V	JAN, JANTX, & JANTXV 1N4946

Maximum Average D.C. Output Current
@ $T_A = 55°C$ 1.0A
@ $T_A = 100°C$ 0.75A
Non-Repetitive Sinusoidal
Surge Current (8.3ms) 15A
Operating Temperature Range .... —65°C to +175°C
Storage Temperature Range .... —65°C to +175°C
Thermal Resistance .... See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

JAN, JANTX, & JANTXV 1N4942, 1N4944, 1N4946



BODY A

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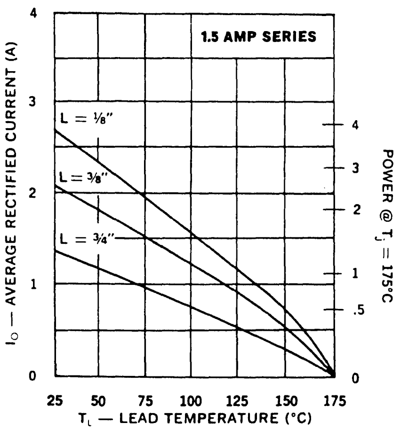
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

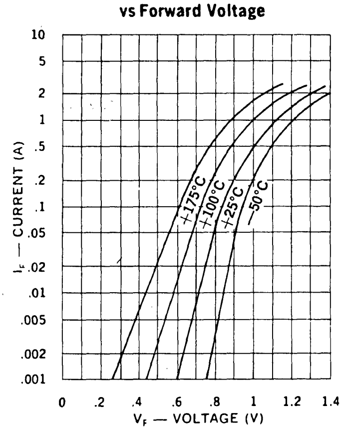
Type	Peak Inverse Voltage	Minimum Reverse Breakdown Voltage @ 50µA	Forward Voltage Min.	Forward Voltage Max.	Maximum Reverse Current 25°C	Maximum Reverse Current 150°C	Maximum Reverse Recovery Time*	Capacitance @ $V_R = 12V$ f = 1MHz
J, JTX, JTXV 1N4942	200V	220V	0.6V	1.3Vdc @ 1 Adc	1.0µA	200µA	150ns	45pf
J, JTX, JTXV 1N4944	400V	440V					150ns	35pf
J, JTX, JTXV 1N4946	600V	660V					250ns	25pf

*Measured in circuit $I_F = ½A$, $I_R = 1.0A$, $I_{REC} = ¼A$

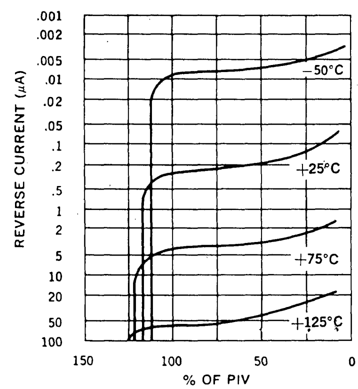
Maximum Current vs Lead Temperature



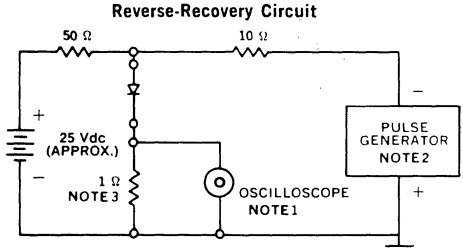
Typical Forward Current vs Forward Voltage



Typical Reverse Current vs PIV

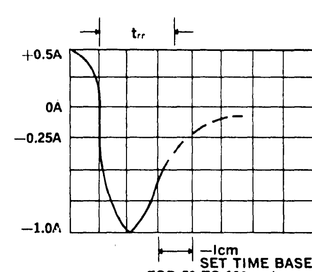


Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Characteristic Waveform.



RECTIFIERS

Military Approved, 3 Amp, Fast Recovery

1N5186-1N5190
JAN & JANTX

FEATURES

- Continuous Rating: 3A
- Qualified to MIL-S-19500/424
- PIV : to 600V
- Recovery Time: 150ns
- Miniature Size
- Controlled Avalanche

DESCRIPTION

These miniature fast recovery rectifiers permit operation at full power at frequencies as high as 100kHz sine wave.
They are qualified to military specification and available as JAN, JANTX or JANTXV.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
100V	JAN & JANTX 1N5186
200V	JAN & JANTX 1N5187
400V	JAN & JANTX 1N5188
600V	JAN & JANTX 1N5190

Maximum Average D.C. Output Current

@ $T_A = 25°C$ 3.0A
@ $T_A = 150°C$ 0.7A

Non-Repetitive Sinusoidal
Surge Current (8.3ms) 80A

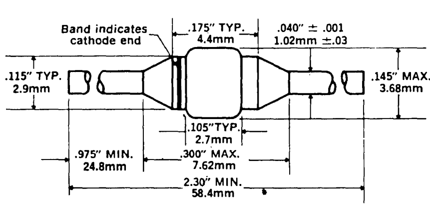
Operating Temperature Range .... —65°C to +175°C

Storage Temperature Range .... —65°C to +200°C

Thermal Resistance .... See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

JAN & JANTX 1N5186-1N5190



BODY B

UNITRODE

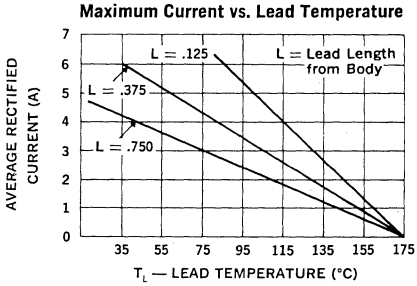
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Peak Inverse Voltage	Minimum Reverse Breakdown Voltage @ 100μA	Peak Forward Voltage Min.	Peak Forward Voltage Max.	Maximum Reverse D.C. Current @ PIV 25°C	Maximum Reverse D.C. Current @ PIV 100°C
J, JTX 1N5186	100V	120V	0.9V	1.5V	2μA	100μA
J, JTX 1N5187	200V	240V	@ 9A(pk)			
J, JTX 1N5188	400V	480V	(8.3ms)			
J, JTX 1N5190	600V	660V				

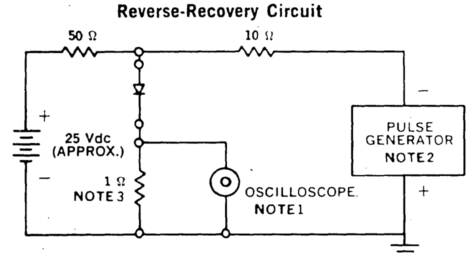
Type	Reverse Recovery Time*	Capacitance @ V_R = 0V f = 1MHz	Capacitance @ V_R = 4V f = 1MHz
J, JTX 1N5186	150ns	300pf	200pf
J, JTX 1N5187	200ns	300pf	170pf
J, JTX 1N5188	250ns	230pf	120pf
J, JTX 1N5190	400ns	180pf	90pf

*Recovery time measured from I_F = 0.5A to I_R = 1.0A, I_{REC} = 0.25A

Maximum Current vs. Lead Temperature

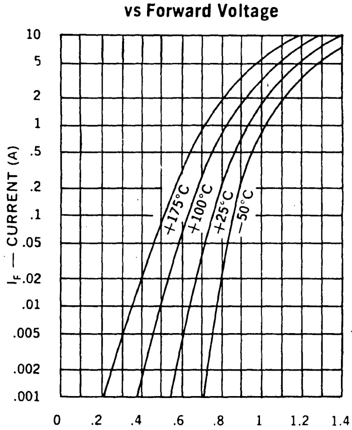


Reverse-Recovery Circuit

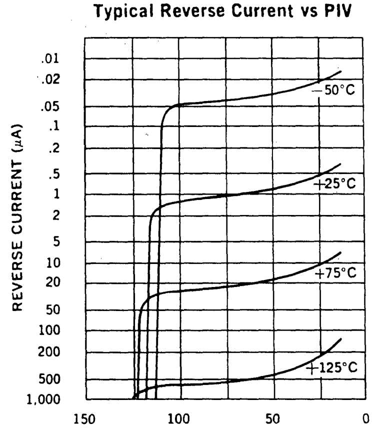


NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Typical Forward Current vs Forward Voltage



Typical Reverse Current vs PIV



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RECTIFIERS
Military Approved, Fast Recovery, 3 Amp

1N5415-1N5420
JAN, JANTX & JANTXV

FEATURES
- Qualified to MIL-S-19500/411
- PIV: to 600V
- Controlled Avalanche

DESCRIPTION
This series of devices as designed to meet the need for high speed, power rectifiers in military high-rel power supplies.

VI

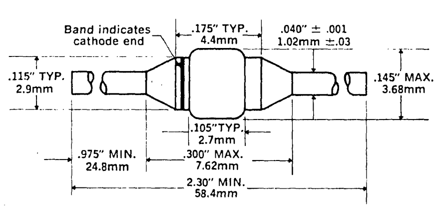
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
50V	JAN, JANTX, JANTXV 1N5415
100V	JAN, JANTX, JANTXV 1N5416
200V	JAN, JANTX, JANTXV 1N5417
400V	JAN, JANTX, JANTXV 1N5418
500V	JAN, JANTX, JANTXV 1N5419
600V	JAN, JANTX, JANTXV 1N5420

Maximum Average D.C. Output Current
@ $T_A = 55°C$ 3.0A
@ $T_A = 100°C$ 2.0A
Non-Repetitive Sinusoidal
Surge Current (8.3ms) 80A
Operating Temperature Range .... —65°C to +175°C
Storage Temperature Range .... —65°C to +200°C
Thermal Resistance θ_{JL} @ L = 3/8" .... 20°C/W
See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N5415-1N5420



Dimensions in inches.

BODY B

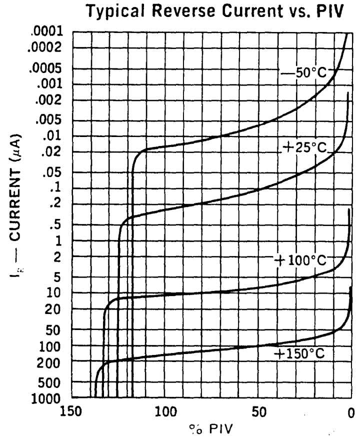
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

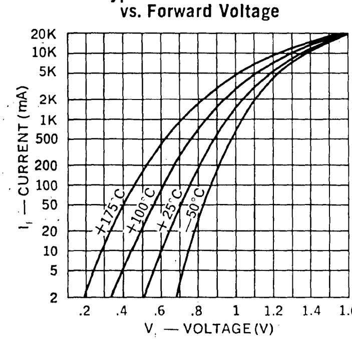
Type	PIV	Minimum Reverse Breakdown Voltage @ 50μA	Forward Voltage Min.	Forward Voltage Max.	Maximum Reverse Current 25°C	Maximum Reverse Current 100°C	Maximum Reverse Recovery Time*
J, JTX, JTXV 1N5415	50V	55V	0.6V	1.5V(pk)	1.0μA	20μA	150
J, JTX, JTXV 1N5416	100V	110V	@ 9Adc				150
J, JTX, JTXV 1N5417	200V	220V	tp = 300μs				150
J, JTX, JTXV 1N5418	400V	440V					150
J, JTX, JTXV 1N5419	500V	550V					250
J, JTX, JTXV 1N5420	600V	660V					400

*Measured in circuit $I_F = 0.5$ A, $I_R = 1$A, $I_{REC} = 0.25$ A.

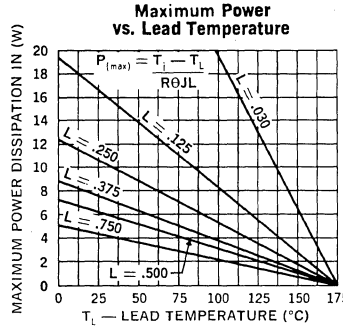
Typical Reverse Current vs. PIV



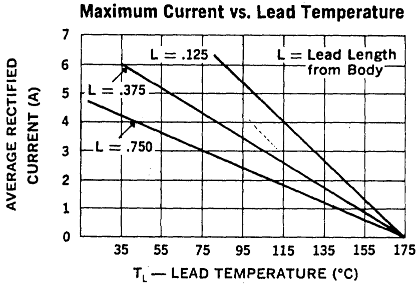
Typical Forward Current vs. Forward Voltage



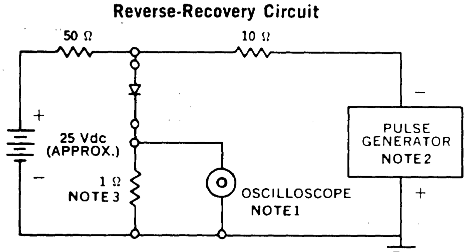
Maximum Power vs. Lead Temperature



Maximum Current vs. Lead Temperature



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

Military Approved, 5 Amp, General Purpose

1N5550-1N5553 JAN, JANTX & JANTXV

FEATURES

- Qualified to MIL-S-19500/420A
- Continuous Rating: 5A
- PIV: to 800V
- TX Parts 100% Screened
- Miniature Size
- Controlled Avalanche

DESCRIPTION

This series of military approved rectifiers is useful in many military applications. The 100% screening requirements in the "TX" version combined with the unique Unitrode construction assures the highest degree of reliability.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
200V	JAN, JANTX & JANTXV 1N5550
400V	JAN, JANTX & JANTXV 1N5551
600V	JAN, JANTX & JANTXV 1N5552
800V	JAN, JANTX & JANTXV 1N5553

Maximum Average D.C. Output Current
- @ $T_A = 55°C$ 3.0A
- @ $T_L = 55°C$ 5.0A

Non-Repetitive Sinusoidal Surge Current (8.3ms) 100A

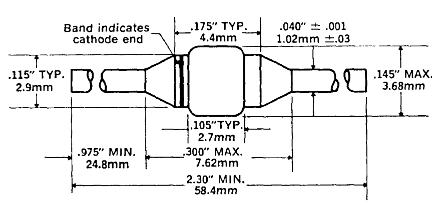
Operating Temperature Range .... —65°C to +175°C

Storage Temperature Range .... —65°C to +200°C

Thermal Resistance .... See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N5550-1N5553



BODY B

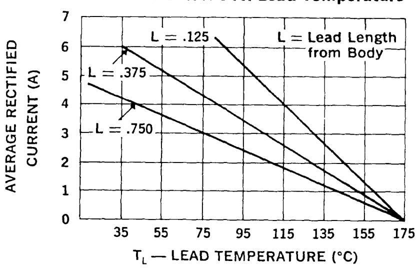
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

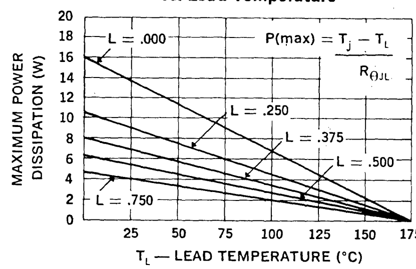
Type	Peak Inverse Voltage	Minimum Reverse Breakdown Voltage @ 50μA	Peak Forward Voltage Min.	Peak Forward Voltage Max.	Maximum Leakage Current @ PIV 25°C	Maximum Leakage Current @ PIV 100°C	Maximum Reverse Recovery Time*
J, JTX, JTXV 1N5550	200V	240V	0.6V	1.2V	1.0μA	75μA	2.0μs
J, JTX, JTXV 1N5551	400V	460V	@ I_F = 9A(pk) (8.3ms)				
J, JTX, JTXV 1N5552	600V	660V					
J, JTX, JTXV 1N5553	800V	880V					

*Measured in a test circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

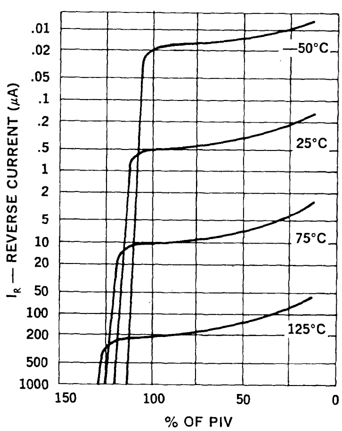
Maximum Current vs. Lead Temperature



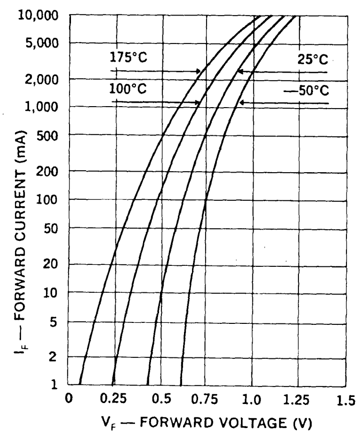
Maximum Power Dissipation vs. Lead Temperature



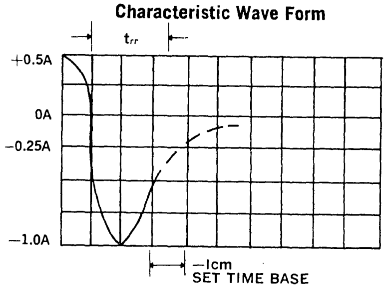
Typical Reverse Current vs. PIV



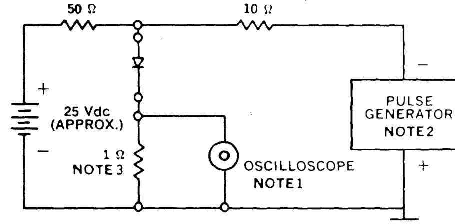
Typical Forward Current vs. Forward Voltage



Characteristic Wave Form



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

Standard Recovery, 1 Amp
Military Approved

1N5614, 1N5616, 1N5618,
1N5620,
JAN, JANTX & JANTXV

FEATURES
- Qualified to MIL-S-19500/427
- PIV: to 800V
- Controlled Avalanche

DESCRIPTION
This series of medium power general purpose rectifiers can be used in the most demanding military supplies. Rugged mechanical integrity and tight electrical parameters make them particularly useful.

1k 10k 100k
.033

VI

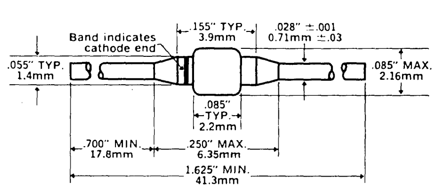
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
200V	JAN, JANTX & JANTXV 1N5614
400V	JAN, JANTX & JANTXV 1N5616
600V	JAN, JANTX & JANTXV 1N5618
800V	JAN, JANTX & JANTXV 1N5620

Maximum Average D.C. Output Current
@ $T_A = 55°C$ 1.0A
@ $T_A = 100°C$ 0.75A
Non-Repetitive Sinusoidal
Surge Current (8.3ms) 30A
Operating Temperature Range .... −65°C to +175°C
Storage Temperature Range .... −65°C to +200°C
Thermal Resistance θ_{JL} @ L = 3/8" .... 38°C/W
See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N5614, 1N5616, 1N5618, 1N5620



BODY A

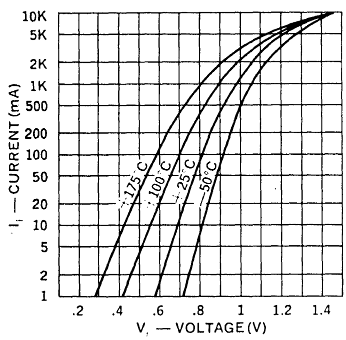
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

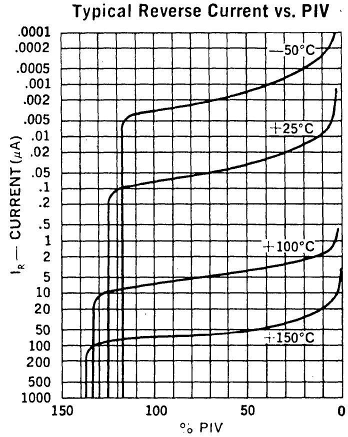
Type	PIV	Minimum Reverse Breakdown Voltage @ 50μA	Forward Voltage		Maximum Reverse Current		Maximum Reverse Recovery Time*
			Min.	Max.	25°C	100°C	
J, JTX, JTXV 1N5614	200V	220V	0.8	1.3V(pk) @ 3.0A tp = 300μs	0.5μA	25μA	2.0μs
J, JTX, JTXV 1N5616	400V	440V					
J, JTX, JTXV 1N5618	600V	660V					
J, JTX, JTXV 1N5620	800V	880V					

*Measured in Circuit $I_F = ½A$, $I_R = 1.0A$, $I_{REC} = ¼A$

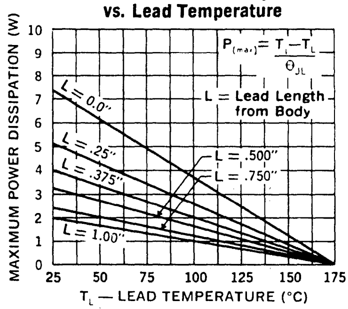
Typical Forward Voltage vs. Forward Current



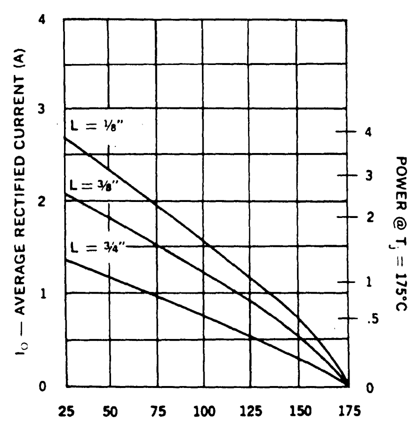
Typical Reverse Current vs. PIV



Maximum Power Dissipation vs. Lead Temperature



Maximum Current vs Lead Temperature



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RECTIFIERS
Military Approved, Fast Recovery, 1 Amp

1N5615, 1N5617, 1N5619
JAN, JANTX & JANTXV

FEATURES
- Qualified to MIL-S-19500/429
- PIV: to 600V
- Controlled Avalanche

DESCRIPTION
This series of military approved rectifiers is useful in many military applications where fast recovery and medium power are required. The 100% screening requirements in the "TX" version combined with the unique Unitrode construction assures the highest degree of reliability.

VI

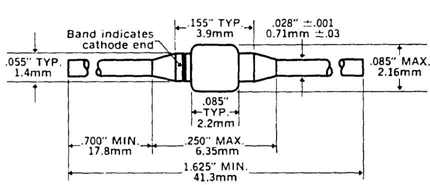
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
200V	JAN, JANTX, JANTXV 1N5615
400V	JAN, JANTX, JANTXV 1N5617
600V	JAN, JANTX, JANTXV 1N5619

Maximum Average D.C. Output Current
@ $T_A = 55°C$ 1.0A
@ $T_A = 100°C$ 0.75A
Non-Repetitive Sinusoidal
Surge Current (8.3ms) 25A
Operating Temperature Range .... −65°C to +175°C
Storage Temperature Range .... −65°C to +200°C
Thermal Resistance θ_{JL} .... 38°C/W
See Lead Temperature Derating Curve

MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N5615, 1N5617, 1N5619



BODY A

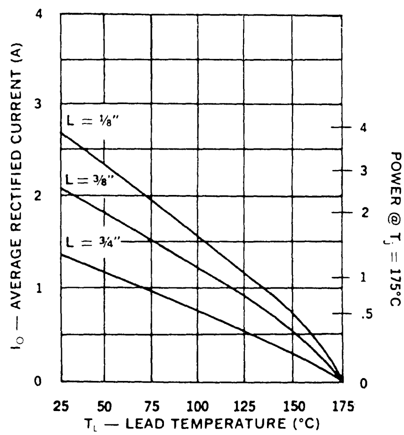
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

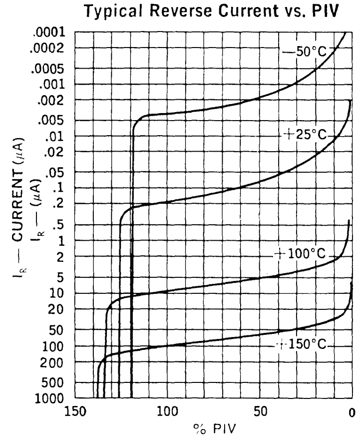
Type	PIV	Minimum Reverse Breakdown Voltage @ 50μA	Forward Voltage Min.	Forward Voltage Max.	Maximum Reverse Current 25°C	Maximum Reverse Current 100°C	Maximum Reverse Recovery Time*	Capacitance @ $V_R = 12V$ f = 1MHz
J, JTX, JTXV 1N5615	200V	220V	0.8V	1.6V (pk) @ 3.0 Adc tp = 300μs	0.5μA	25μA	150ns	45pf
J, JTX, JTXV 1N5617	400V	440V					150ns	35pf
J, JTX, JTXV 1N5619	600V	660V					250ns	25pf

*Measured in Circuit $I_F = ½A$, $I_R = 1A$, $I_{REC} = ¼A$

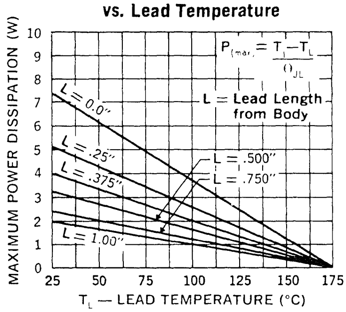
Maximum Current vs Lead Temperature



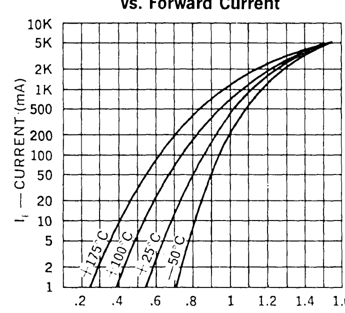
Typical Reverse Current vs. PIV



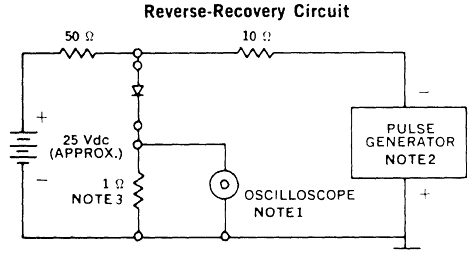
Maximum Power vs. Lead Temperature



Typical Forward Voltage vs. Forward Current



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, ESP, 2.5 Amp to 20 Amp

1N5802-1N5806
1N5807-1N5811
1N5812-1N5816

FEATURES
- Exceptional Efficiency
- Low Forward Voltage
- Extremely Fast Reverse Recovery Time
- Extremely Fast Forward Recovery Time
- High Surge
- Small Size
- Rugged, High Current Termination
- Radiation Tolerant

DESCRIPTION
This series of High Efficiency Power Rectifiers allows circuit designers to design high current, high frequency supplies to 500 kHz with very low diode losses. The high forward surge capability makes these devices useful in protective circuits.

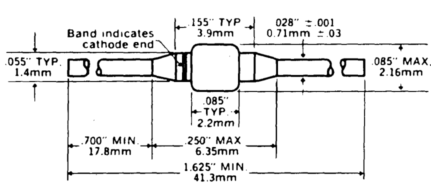
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	2.5 Amp Series	6 Amp Series	20 Amp Series
50V	1N5802	1N5807	1N5812
75V	1N5803	1N5808	1N5813
100V	1N5804	1N5809	1N5814
125V	1N5805	1N5810	1N5815
150V	1N5806	1N5811	1N5816

	2.5 AMP SERIES	6.0 AMP SERIES	20 AMP SERIES
Maximum Average D.C. Output Current			
@ $T_L = 75°C$, $L = 3/8''$	2.5A	6.0A	—
@ $T_C = 100°C$			20.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	35A	125A	250A
Operating and Storage Temperature Range	−65°C to +175°C		
Thermal Resistance 2.5A and 6A Series	See Lead Temperature Derating Curve		
20A Series			3.0°C/W

MECHANICAL SPECIFICATIONS

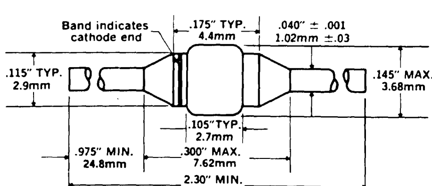
1N5802-1N5806



Typical Weight — 0.22 grams

BODY A

1N5807-1N5811



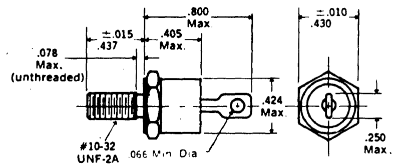
Typical Weight — 0.75 grams

BODY B

UNITRODE

MECHANICAL SPECIFICATIONS

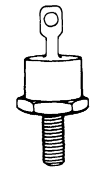
1N5812-1N5816



Part Identification: Type number printed on metal case.
Polarity: Cathode to stud end
Max. Weight: 7.0 Grams
Installation Precautions: Maximum unlubricated stud torque: 10 inch pounds
Thermal Resistance: 3.0°C/W

Dimensions in inches.

DO-4

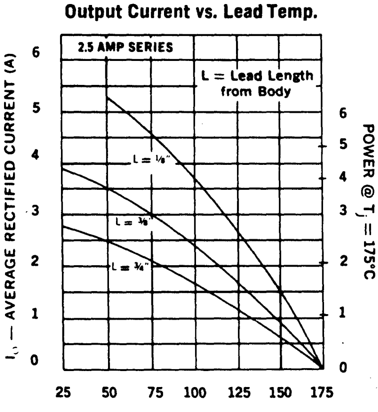


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

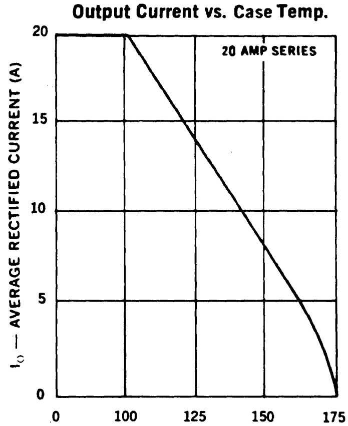
Type	PIV	Maximum Forward Voltage Drop*	Leakage Current @ PIV		Maximum Reverse Recovery Time I_F, I_R, I_{REC}	Typical Forward Recovery Time @ 1A Recover to 1V	Typical Forward Recovery Voltage @ 1A tr = 8ns	Typical Junction Capacitance @ —10V
			25°C	100°C				
1N5802 1N5803 1N5804 1N5805 1N5806	50V 75V 100V 125V 150V	.875 @ 1A	1μA	50μA	25ns, 0.5A-0.5A-0.05A	15ns	1.5V	15pf
1N5807 1N5808 1N5809 1N5810 1N5811	50V 75V 100V 125V 150V	.875 @ 4A	5μA	150μA	30ns, 1.0-1.0-0.1A	15ns	1.5V	45pf
1N5812 1N5813 1N5814 1N5815 1N5816	50V 75V 100V 125V 150V	.900 @ 10A	10μA	750μA	35ns, 1.0-1.0-0.1A	15ns	1.5V	200pf

*Pulse width = 250ms

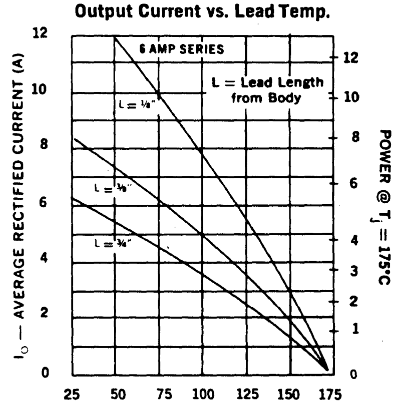
Output Current vs. Lead Temp.



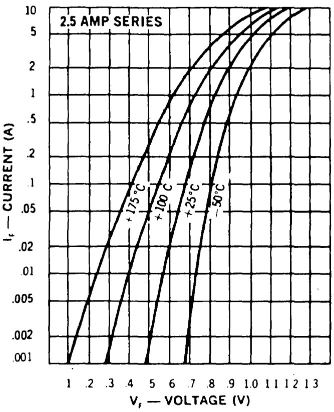
Output Current vs. Case Temp.



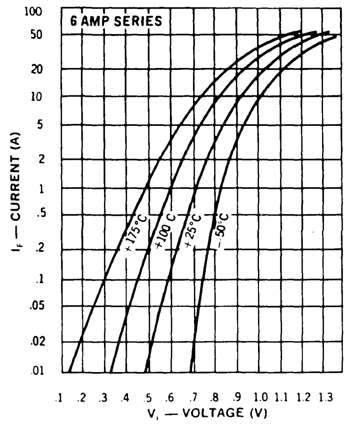
Output Current vs. Lead Temp.



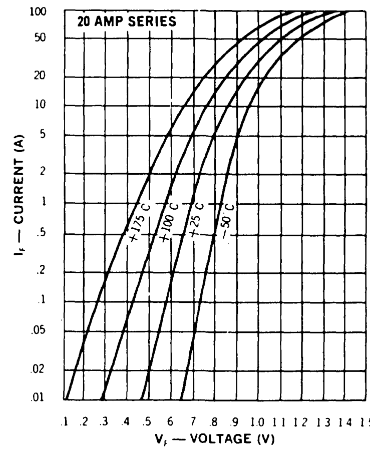
Typical Forward Current vs. Forward Voltage



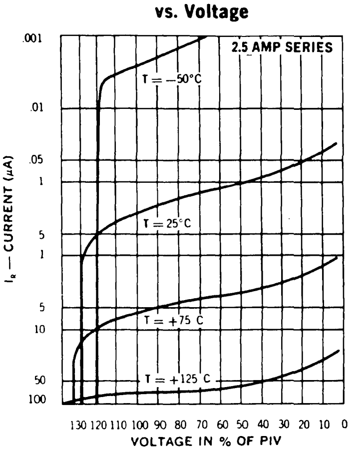
Typical Forward Current vs. Forward Voltage



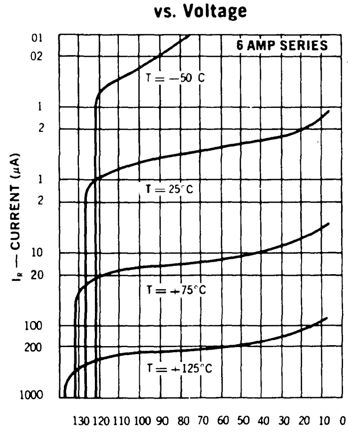
Typical Forward Current vs. Forward Voltage



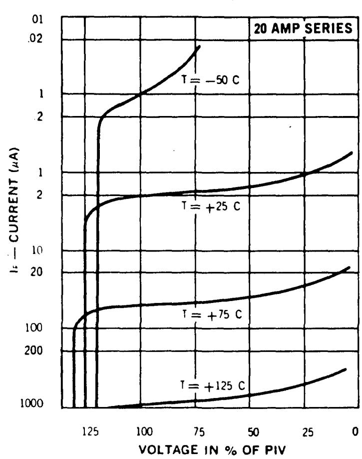
Typical Reverse Current vs. Voltage



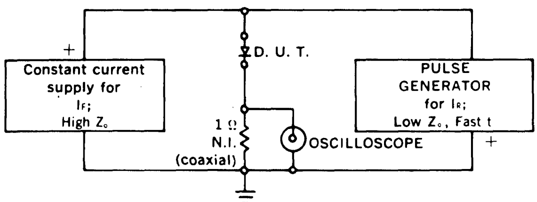
Typical Reverse Current vs. Voltage



Typical Reverse Current vs. Voltage

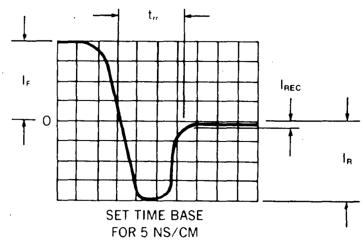


Reverse-Recovery Time Circuit

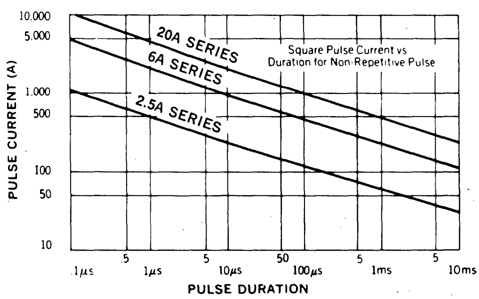


NOTES:
1. Oscilloscope: Rise time ⩽ 3 ns; input impedance = 50 Ω.
2. Pulse Generator: Rise time ⩽ 8 ns; source impedance 10 Ω.

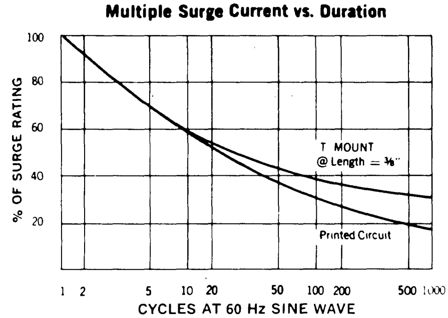
Characteristic Waveform



Forward Pulse Current vs. Duration



Multiple Surge Current vs. Duration



RECTIFIERS
Military Approved, High Efficiency, 2.5 Amp and 6.0 Amp

1N5802, 1N5804, 1N5806, 1N5807, 1N5809, 1N5811 JAN, JANTX & JANTXV

VI

FEATURES
- Qualified to MIL-S-19500/477
- PIV: to 150V
- Low Forward Voltage

DESCRIPTION
This series of high efficiency power rectifiers are particularly applicable to switching regulator power supplies where extremely fast switching and low forward losses are most important.

ABSOLUTE MAXIMUM RATINGS

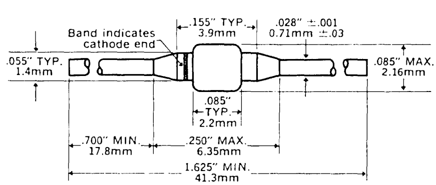
Peak Inverse Voltage	2.5A Series	6.A Series
50V	JAN, JANTX & JANTXV 1N5802	JAN, JANTX & JANTXV 1N5807
100V	JAN, JANTX & JANTXV 1N5804	JAN, JANTX & JANTXV 1N5809
150V	JAN, JANTX & JANTXV 1N5806	JAN, JANTX & JANTXV 1N5811

	2.5A SERIES	6A SERIES
Maximum Average D.C. Output Current		
@ $T_L = 75°C$, $L = 3/8''$	2.5A	6.0A
@ $T_A = 55°C$	1.0A	3.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	35A	125A
Operating Temperature Range	−65°C to +175°C	
Storage Temperature Range	−65°C to +200°C	
Thermal Resistance, θ_{JL} @ $L = 3/4''$	59°C/W	35.5°C/W

See lead temperature derating curve

MECHANICAL SPECIFICATIONS

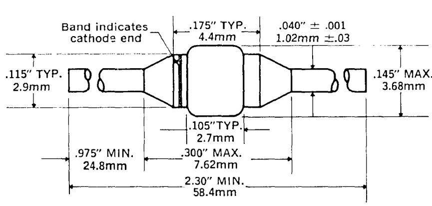
J, JTX, JTXV 1N5802-1N5806



Dimensions in inches.

BODY A

J, JTX, JTXV 1N5807-1N5811



Dimensions in inches.

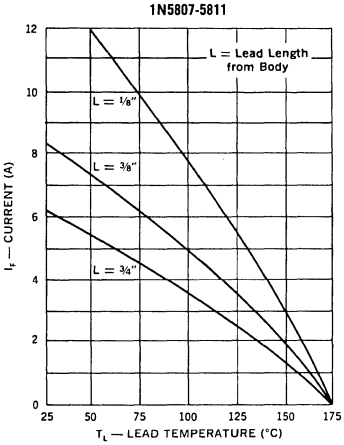
BODY B

UNITRODE

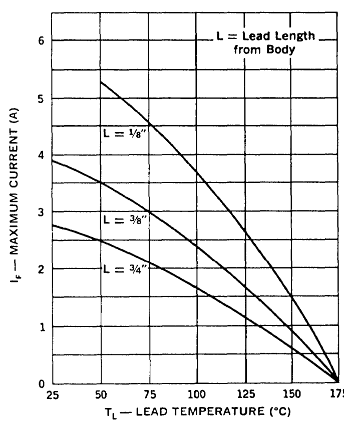
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

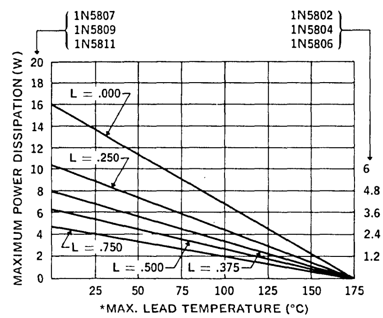
Type	PIV	Minimum Breakdown Voltage @ 100μA	Forward Voltage @ 25°C	Forward Voltage @ 100°C	Maximum Reverse Current @ PIV 25°C	Maximum Reverse Current @ PIV 100°C	Maximum Reverse Recovery Time
J, JTX, JTXV 1N5807 J, JTX, JTXV 1N5809 J, JTX, JTXV 1N5811	50V 100V 150V	60V 110V 160V	.875V Max. @ 4A (pk) .925V Max. @ 6A (pk)	.8V Max. @ 4A (pk)	5μA	150μA	30ns $I_F = I_R = 1.0A$ $I_{REC} = 0.1A$ di/dt = 100A/μs min.
J, JTX, JTXV 1N5802 J, JTX, JTXV 1N5804 J, JTX, JTXV 1N5806	50V 100V 150V	60V 110V 160V	.875V Max. @ 1A (pk) .975V Max. @ 2.5A (pk)	.8V Max. @ 1A (pk)	1μA	50μA	25ns $I_F = I_R = 0.5A$ $I_{REC} = 0.05A$ di/dt = 65A/μs min.

Output Current vs. Lead Temperature
1N5807-5811



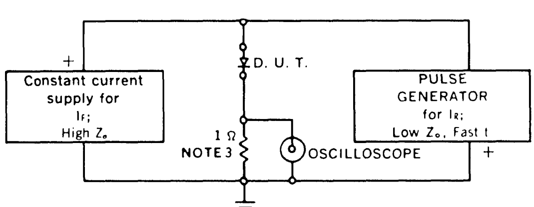
Output Current vs. Lead Temperature
1N5802-5806



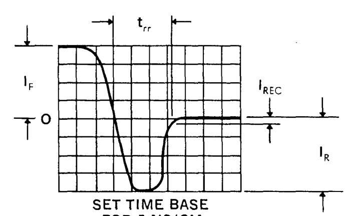


*Maximum lead temperature in °C (T_L) at point "L" from body. (For maximum operating junction temperature of 175°C with equal two-lead conditions.)

Reverse-Recovery Circuit

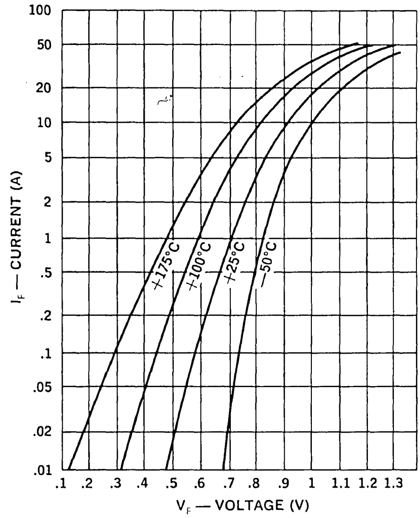


Characteristic Waveform

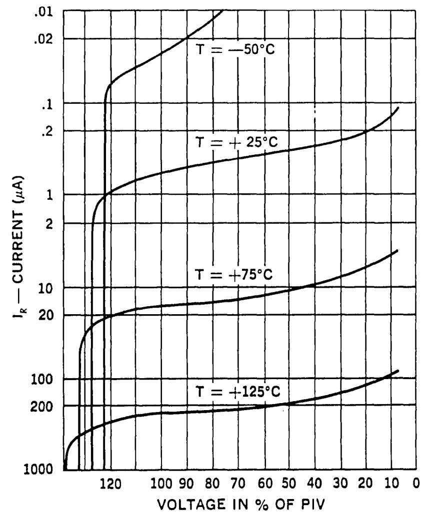


NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

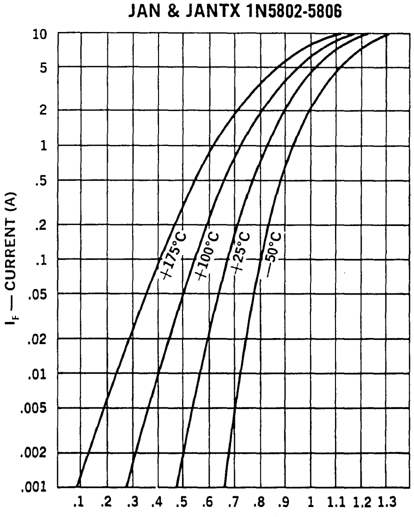
Typical Forward Current vs. Forward Voltage
JAN & JANTX 1N5807-5811



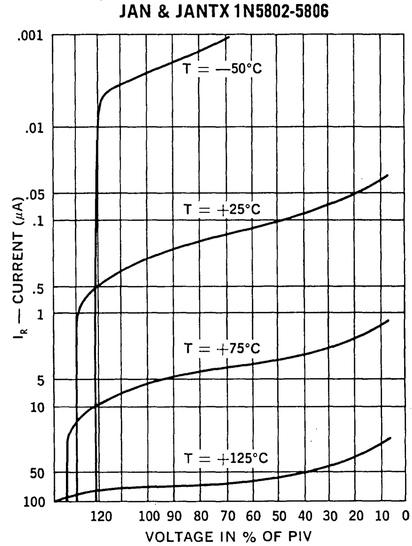
Typical Reverse Current vs. Voltage
JAN & JANTX 1N5807-5811



Typical Forward Current vs. Forward Voltage
JAN & JANTX 1N5802-5806



Typical Reverse Current vs. Voltage
JAN & JANTX 1N5802-5806



RECTIFIERS
Military Approved
High Efficiency, 20 Amp

1N5812, 1N5814, 1N5816
JAN, JANTX & JANTXV

FEATURES
- Qualified to MIL-S-19500/478
- Exceptional Efficiency
- Mechanically Rugged
- Low Thermal Resistance
- JAN, JANTX and JANTXV Available

DESCRIPTION
This series is suited for use as a power rectifier in switching regulator and high frequency inverter/converter and other appropriate equipment circuits where low voltage drop and fast recovery times are important.

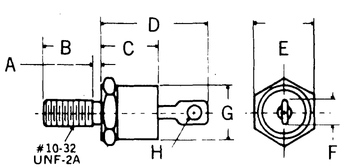
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
50V	JAN, JANTX, JANTXV 1N5812
100V	JAN, JANTX, JANTXV, 1N5814
150V	JAN, JANTX, JANTXV 1N5816

Maximum Average D.C. Output Current
@ $T_C = 100°C$ 20A
@ $T_A = 55°C$ 5A
Non-Repetitive Sinusoidal
Surge Current @ 8.3mSec 400A
Thermal Resistance, Junction to Case .... 1.5°C/W
Operating Junction Temperature .... −65°C to +175°C
Storage Ambient Temperature .... −65°C to +200°C

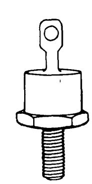
MECHANICAL SPECIFICATIONS

J, JTX, JTXV 1N5812, 1N5814, 1N5816



	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4



Notes:
1. Polarity is cathode-to-stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 15 inch pounds.
4. Angular orientation of terminal is undefined.

UNITRODE

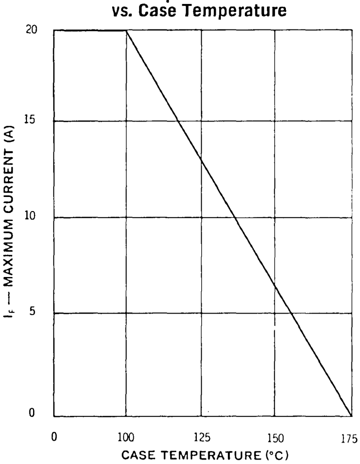
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Peak Inverse Voltage	Minimum Reverse Breakdown Voltage @ 100μA	Peak Forward Voltage @ 10Apk	Peak Forward Voltage @ 20Apk	Maximum Leakage Current @ PIV 25°C	Maximum Leakage Current @ PIV 100°C
J, JTX, JTXV 1N5812	50V	60V	.86V MAX.	.95V MAX.	10μA	750μA
J, JTX, JTXV 1N5814	100V	110V				
J, JTX, JTXV 1N5816	150V	160V				

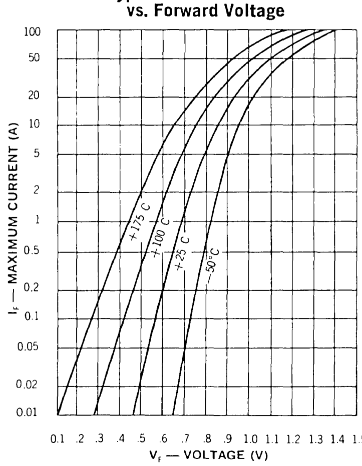
Maximum Reverse Recovery Time @ I_F, I_R, I_{REC}	Maximum Forward Recovery Time @ 1A Recovery to 1V	Maximum Forward Recovery Voltage @ 1A tr = 8nsec	Maximum Junction Capacitance @ —10V
35nsec 1.0A —1.0A —0.1A	15nsec	2.2V	300pf

VI

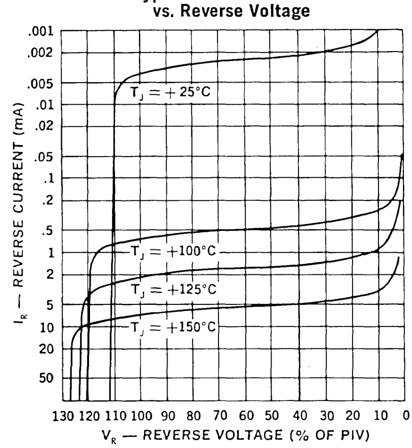
Output Current vs. Case Temperature



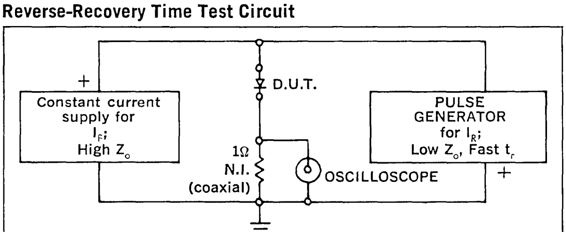
Typical Forward Current vs. Forward Voltage



Typical Reverse Current vs. Reverse Voltage

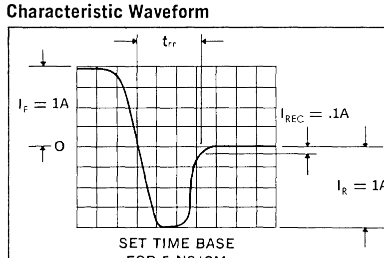


Reverse-Recovery Time Test Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3 ns; input impedance = 50 Ω.
2. Pulse Generator: Rise time ≤ 8 ns; source impedance 10 Ω.

Characteristic Waveform



POWER SCHOTTKY RECTIFIERS
1A, Up to 40V

1N5817
1N5818
1N5819

FEATURES

- Very Low Forward Voltage (0.45V max @ 1A for the 1N5817)
- Low Stored Charge, Majority Carrier Conduction
- Economical, Convenient Plastic Package
- Small Size

DESCRIPTION

The 1N5817, 1N5818 and 1N5819 series of Schottky barrier rectifiers are ideally suited for use as rectifiers in low voltage, high frequency inverters, as free wheeling diodes and as polarity protection diodes.

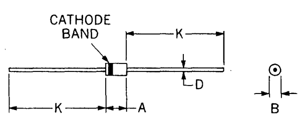
ABSOLUTE MAXIMUM RATINGS*

	1N5817	1N5818	1N5819
Peak Repetitive Reverse Voltage, V_{RRM}	20V	30V	40V
Working Peak Reverse Voltage, V_{RWM}	20V	30V	40V
DC Blocking Voltage, V_R	20V	30V	40V
Non-Repetitive Peak Reverse Voltage, V_{RSM}	24V	36V	48V
RMS Reverse Voltage, $V_{R(RMS)}$	14V	21V	28V
Average Rectified Forward Current, I_O ($V_{R(equiv)} \leq 0.2\ V_R(DC)$, $T_L = 90°C$, $R_{\theta JA} = 80°C/W$, PC Board Mounting, see Note 1, $T_A = 55°C$)		1.0A	
Ambient Temperature, T_A (Rated $V_R(DC)$, $P_{F(AV)} = 0$, $R_{\theta JA} = 80°C/W$)	85°C	80°C	75°C
Non-Repetitive Peak Surge Current, I_{FSM} (Surge applied at rated load conditions, half-wave, single phase 60Hz, $T_L = 70°C$)		25A (for one cycle)	
Operating and Storage Junction Temperature Range, (Reverse Voltage Applied)		−65°C to +125°C	
Peak Operating Junction Temperature, $T_{j(pk)}$ (Forward Current Applied)		150°C	
Thermal Resistance, Junction to Ambient (Note 1), $R_{\theta JA}$		80°C/W Max.	

* JEDEC registered values.
Note 1: Lead Temperature reference is cathode lead 1/32" from case.

MECHANICAL SPECIFICATION

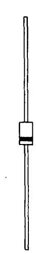
1N5817 1N5818 1N5819



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.160	0.260	4.06	6.60
B	0.110	0.120	2.79	3.05
D	0.030	0.034	0.76	0.86
K	1.100	—	27.94	—

Soldering 220°C, 1/16" from case for ten seconds.

ASA



UNITRODE

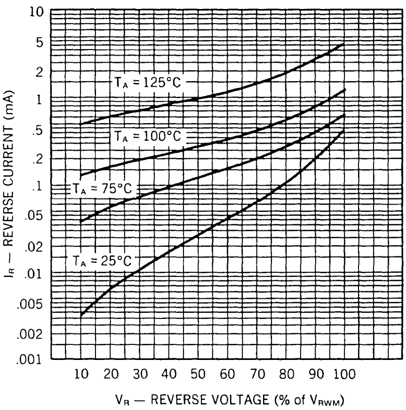
ELECTRICAL CHARACTERISTICS (T_L = 25°C unless noted)*

CHARACTERISTIC	SYMBOL	1N5817	1N5818	1N5819	UNITS	CONDITIONS
Maximum Instantaneous Forward Voltage (Note 2)	V_F	0.450	0.550	0.600	V	i_F = 1.0A
		0.750	0.875	0.900	V	i_F = 3.0A
Maximum Instantaneous Reverse Current @ Rated DC Voltage (Note 2)	i_R	1.0	1.0	1.0	mA	T_L = 25°C
		10	10	10	mA	T_L = 100°C

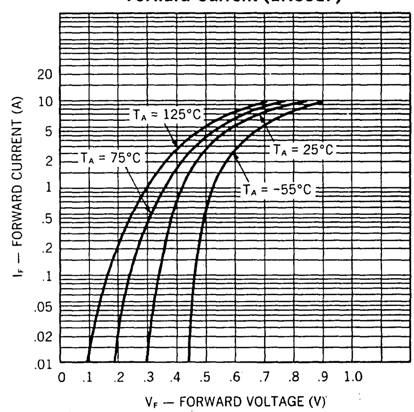
* JEDEC registered values.
Note 2: Pulse width = 300μs; duty cycle = 2%.

VI

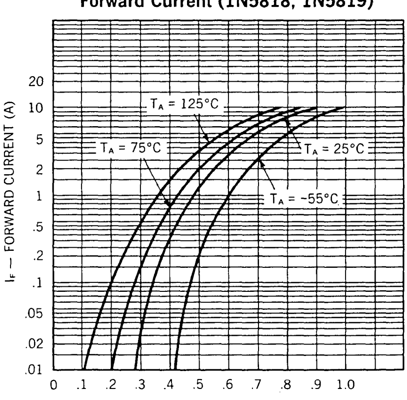
Typical Reverse Current vs Reverse Voltage



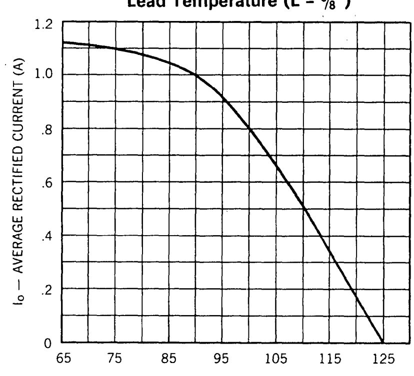
Typical Forward Voltage vs Forward Current (1N5817)



Typical Forward Voltage vs Forward Current (1N5818, 1N5819)



Output Current vs Lead Temperature (L = 3/8")



POWER SCHOTTKY RECTIFIERS
3A, Up to 40V

1N5820
1N5821
1N5822

FEATURES
- Very Low Forward Voltage (0.475V max @ 3A for the 1N5820)
- Low Stored Charge, Majority Carrier Conduction
- Economical, Convenient Plastic Package
- Small Size

DESCRIPTION
The 1N5820, 1N5821 and 1N5822 series of Schottky barrier rectifiers are ideally suited for use as rectifiers in low voltage, high frequency inverters, as free wheeling diodes and as polarity protection diodes.

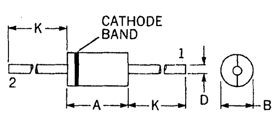
ABSOLUTE MAXIMUM RATINGS*

	1N5820	1N5821	1N5822
Peak Repetitive Reverse Voltage, V_{RRM}	20V	30V	40V
Working Peak Reverse Voltage, V_{RWM}	20V	30V	40V
DC Blocking Voltage, V_R	20V	30V	40V
Non-Repetitive Peak Reverse Voltage, V_{RSM}	24V	36V	48V
RMS Reverse Voltage, $V_{R(RMS)}$	14V	21V	28V
Average Rectified Forward Current, I_O ($V_{R(equiv)} \leq 0.2\ V_R(DC)$, $T_L = 95°C$, $R_{\theta JA} = 28°C/W$, PC Board Mounting, see Note 1, $T_A = 55°C$)		3.0A	
Ambient Temperature, T_A (Rated $V_R(DC)$, $P_{F(AV)} = 0$, $R_{\theta JA} = 28°C/W$)	90°C	85°C	80°C
Non-Repetitive Peak Surge Current, I_{FSM} (Surge applied at rated load conditions, half-wave, single phase 60Hz, $T_L = 75°C$)		80A (for one cycle)	
Operating and Storage Junction Temperature Range, (Reverse Voltage Applied)		−65°C to +125°C	
Peak Operating Junction Temperature, $T_{j(pk)}$ (Forward Current Applied)		150°C	
Thermal Resistance, Junction to Ambient (Note 1), $R_{\theta JA}$		28°C/W Max.	

* JEDEC registered values.
Note 1: Lead Temperature reference is cathode lead 1/32" from case.

MECHANICAL SPECIFICATIONS

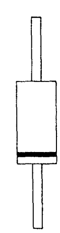
1N5820 1N5821 1N5822



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.370	0.380	9.40	9.65
B	0.190	0.210	4.83	5.33
D	0.048	0.052	1.22	1.32
K	1.062	1.072	26.97	27.23

Soldering: 220°C, 1/16" from case for ten seconds.

ASB



UNITRODE

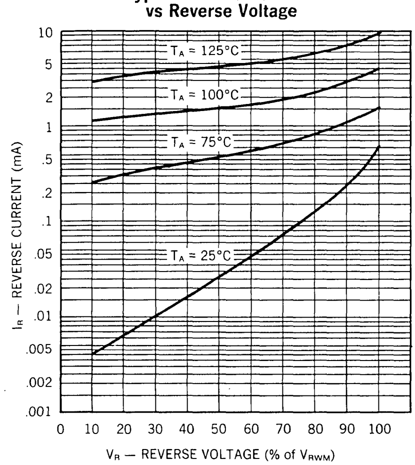
ELECTRICAL CHARACTERISTICS (T_L = 25°C unless noted)*

CHARACTERISTIC	SYMBOL	1N5820	1N5821	1N5822	UNITS	CONDITIONS
Maximum Instantaneous Forward Voltage (Note 2)	v_F	0.370	0.380	0.390	V	i_F = 1.0A
		0.475	0.500	0.525	V	i_F = 3.0A
		0.850	0.900	0.950	V	i_F = 9.4A
Maximum Instantaneous Reverse Current @ Rated DC Voltage (Note 2)	i_R	2.0	2.0	2.0	mA	T_L = 25°C
		20	20	20	mA	T_L = 100°C

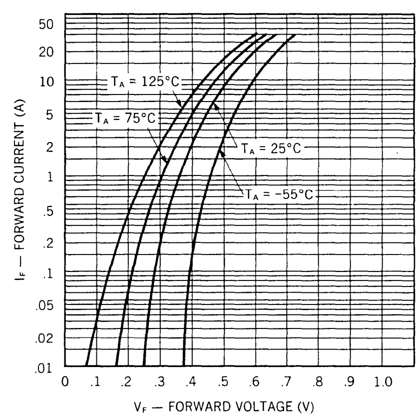
* JEDEC registered values.
Note 2: Pulse width = 300μs; duty cycle = 2%

VI

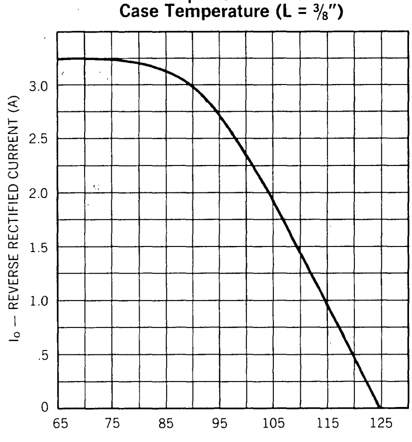
Typical Reverse Current vs Reverse Voltage



Typical Forward Voltage vs Forward Current



Output Current vs Case Temperature (L = 3/8")



POWER SCHOTTKY RECTIFIERS

25A, 30 and 40V

1N6095
1N6096

FEATURES

- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (DO-4)
- High Efficiency for Low Voltage Supplies
- Reverse Energy Tested (2A pk)

DESCRIPTION

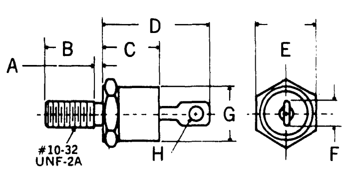
Unitrode's series of Schottky barrier power rectifiers is ideally suited for output rectifiers and catch diodes in low voltage power supplies. The Unitrode high conductivity design, using a heavy copper top post and 4 point crimp, ensures cool thermal operation and low dynamic impedance. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

ABSOLUTE MAXIMUM RATINGS (T_{CASE} = 25°C)

	1N6095	1N6096
Working Peak Reverse Voltage, V_{RWM}	30V	40V
DC Blocking Voltage, V_R	30V	40V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	40V
Non-repetitive Peak Reverse Voltage, V_{RSM}	36V	48V
Average Rectified Forward Current, I_O	25A (T_c = 70°C) 10A (T_c = 105°C)	
Non-repetitive Peak Surge Current (8.3 mS), I_{FSM}	400A	
Storage Temperature Range, T_{stg}	-65 to +125°C	
Peak Operating Junction Temperature, $T_{j(pk)}$	+150°C	
Thermal Resistance Junction to Case, $R_{\theta JC}$	2°C/W Max.	

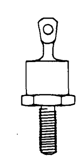
MECHANICAL SPECIFICATIONS

1N6095, 1N6096



	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4



Notes:

1. Cathode is stud.
2. Maximum unlubricated stud torque: 10 inch pounds.
3. Angular Orientation of terminal is undefined.

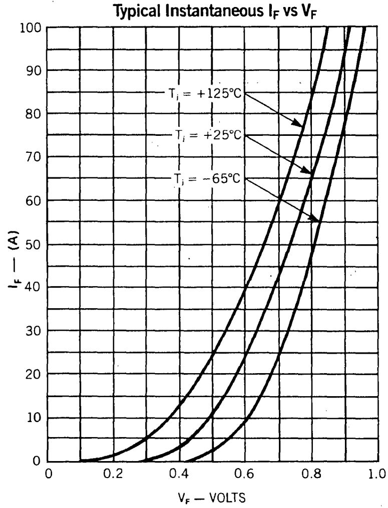
ELECTRICAL CHARACTERISTICS (T_{CASE}=25°C)

Characteristic	Symbol	Both Types	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	250	mA	V_{RWM} = Rated T_C = 125°C Pulse Width = 300μS Duty Cycle ≤ 2 percent
Maximum Reverse Current	I_R	250	mA	V_R = Rated, T_C = 105°C
Maximum Instantaneous Forward Voltage	V_{FM}	0.86	V	I_F = 25A[1] T_C = 70°C
	V_{FM}	0.60	V	I_F = 5A Pulse Width 300μS Duty Cycle ≤ 2 percent
Capacitance	C_t	6000	pF	V_R = 1.0V

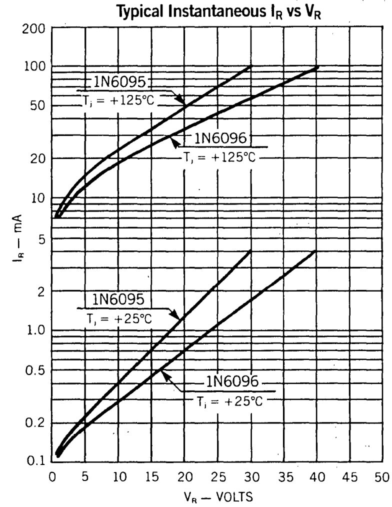
[1] I_{FM} = 78.5A

VI

Typical Instantaneous I_F vs V_F



Typical Instantaneous I_R vs V_R



POWER SCHOTTKY RECTIFIERS

1N6097
1N6098

50 Amp, 30 and 40 Volts

FEATURES

- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (DO-5)
- Low Thermal Resistance
- High Surge Current
- Reverse Energy Tested (2A pk)

DESCRIPTION

Unitrode's series of Schottky barrier power rectifiers is ideally suited for output rectifiers and catch diodes in low voltage power supplies. The Unitrode high conductivity design, using a heavy copper top post and 4 point crimp, ensures cool thermal operation and low dynamic impedance. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

ABSOLUTE MAXIMUM RATINGS

	1N6097	1N6098
Working Peak Reverse Voltage, V_{RWM}	30V	40V
DC Blocking Voltage, V_R	30V	40V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	40V
Non-repetitive Peak Reverse Voltage, V_{RSM}	36V	48V
Average Rectified Forward Current, I_O	50A ($T_C = 70°C$) 20A ($T_C = 105°C$)	
Non-repetitive Peak Surge Current (8.3 mS), I_{FSM}	800A	
Storage Temperature Range, T_{stg}	−65 to +125°C	
Peak Operating Junction Temperature, $T_{j(pk)}$	+150°C	
Thermal Resistance Junction to Case, $R_{\Theta JC}$	1°C/WMax.	

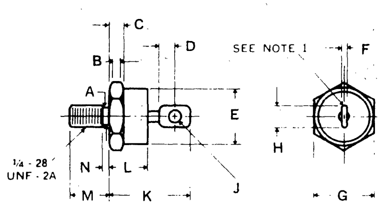
ELECTRICAL CHARACTERISTICS ($T_{CASE} = 25°C$)

Characteristic	Symbol	Both Types	Units	Conditions
Maximum Instantaneous Reverse Current	I_{RRM}	250	mA	V_{RWM} = Rated, $T_C = 125°C$ Pulse Width = 300μs, Duty Cycle ≤ 2 percent
Maximum Reverse Current	I_R	250	mA	V_R = Rated, T_C = 115°C
Maximum Instantaneous Forward Voltage	V_{FM}	0.86	V	I_O = 50A* T_C = 70°C
	V_{FM}	0.60	V	I_F = 10A Pulse Width 300μs Duty Cycle ≤ 2 percent
Capacitance	C_t	7000	pF	$V_R = 1.0V$

*I_{FM} = 157A

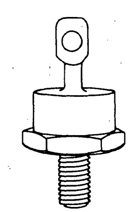
MECHANICAL SPECIFICATIONS

1N6097, 1N6098



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

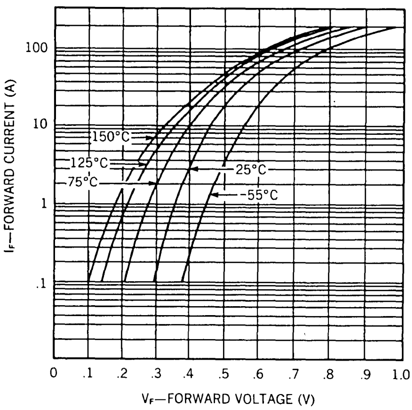
DO-5



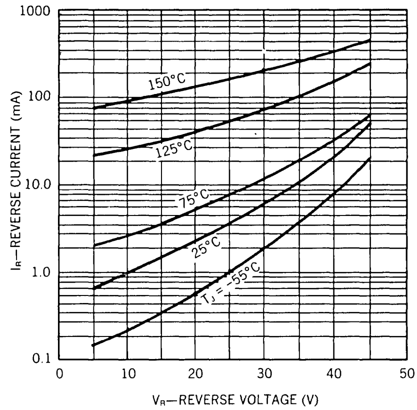
Notes:

1. Cathode is stud.
2. Maximum unlubricated stud torque: 30 inch pounds.
3. Angular orientation of terminal is undefined.
4. Maximum tension (90°) anode terminal 15 pounds for 30 seconds.

Typical Forward Current vs Forward Voltage



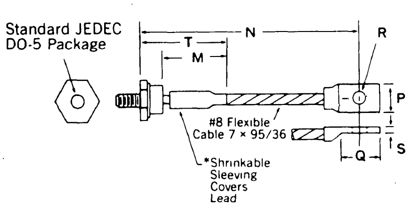
Typical Reverse Current vs Reverse Voltage



VI

MECHANICAL SPECIFICATIONS

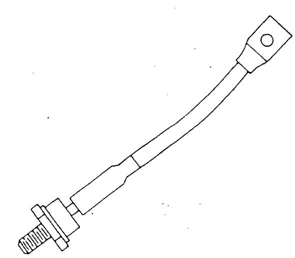
FLEXIBLE TOP LEAD (OPTIONAL) **1N6097, 1N6098**
Add an "F" Suffix to Part Number.



	INCHES	MILLIMETERS
M	.718 MAX.	18.24 MAX.
N	4.50 ± .250	114.3 ± 6.35
P	.525 MAX.	13.23 MAX.
Q	.675 ± .035	17.15 ± 0.89
R	.205 ± .005	5.21 ± 0.13
S	.075 ± .010	1.91 ± 0.25
T	1.125 MAX.	28.58 MAX.

*To 125°C (Ambient)

DO-5 with Flexible Lead



Note: Consult Factory for Non-standard Lead Lengths.

RECTIFIERS
High Efficiency, 70A

1N6304—1N6306
JAN, JANTX, JANTXV

FEATURES
- High Continuous Current Rating
- Very Low Forward Voltage
- Very Fast Switching Speeds
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available
- Qualified to MIL-S-19500/550

DESCRIPTION

The 1N6304 Series is specifically designed for operation in power switching circuits operating at frequencies of at least 20KHz. The very low forward voltage and very fast recovery time make them particularly suited for switching type power supplies.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, 1N6304	50V
Peak Inverse Voltage, 1N6305	100V
Peak Inverse Voltage, 1N6306	150V
Maximum Average D.C. Output Current at T_C = 100°C	70A
Non-Repetitive Sinusodal Surge Current 8.3ms	800A
Thermal Resistance, Junction to Case	0.8°C/W
Operating and Storage Temperature Range	−65°C to +175°C
Operating and Storage Temperature Range (JEDEC types)	−55°C to +175°C

POWER CYCLING

These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

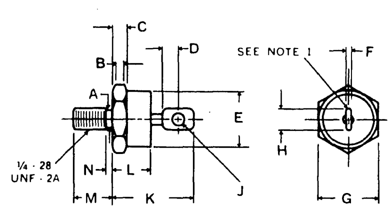
In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS

The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

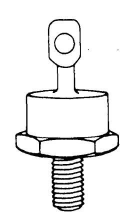
MECHANICAL SPECIFICATIONS

1N6304-1N6306



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-203AB (DO-5)



Notes:
1. Standard polarity is cathode-to-stud. For reverse polarity (anode-to-stud) add suffix "R", ie. 1N6304R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 20 inch pounds (20 kg. cm).
4. Angular orientation of terminal is undefined.

ELECTRICAL SPECIFICATIONS

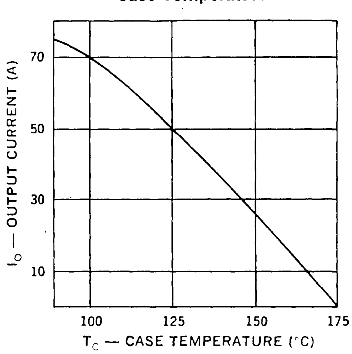
Type	V_R	Maximum Forward Voltage V_F		Maximum Reverse Current I_R		Maximum Reverse Recovery Time t_{rr}
		T_C = 25°C	T_C = 150°C	T_C = 25°C	T_C = 150°C	
1N6304 1N6305 1N6306	50V 100V 150V	.975V @ 70A t_P = 300μS	.840V @ 70A t_P = 300μS	25μA	30mA	50ns 1A-1A-0.1A
J, JTX, JTXV 1N6304 J, JTX, JTXV 1N6305 J, JTX, JTXV 1N6306	50V 100V 150V	.975V @ 70A t_P = 300μs	.840V @ 70A t_P = 300μs	25μA	30mA	50ns(1)
		1.18V @ 150A t_P = 300μs				60ns(2)

(1) I_F = 0.5A, I_R = 1A, I_{REC} = 0.25A, di/dt = 85A/μs (min.).
(2) I_{FM} = 70A, di/dt = 130A/μs.

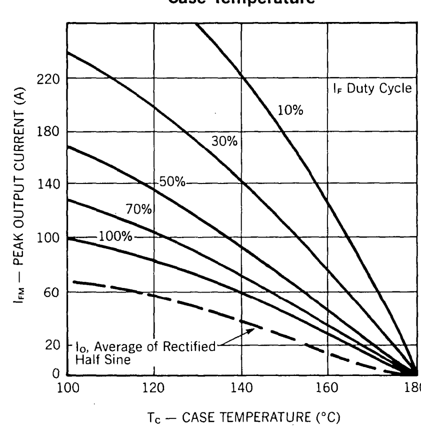
Type	V_R	Maximum Forward Recovery Time	Maximum Forward Voltage	Maximum Junction Capacitance
J, JTX, JTXV 1N6304 J, JTX, JTXV 1N6305 J, JTX, JTXV 1N6306	50V 100V 150V	15ns I_{FM} = 1A, t_r = 8ns	2.2V I_{FM} = 1A, t_r = 8ns	@ −10V 600pF

VI

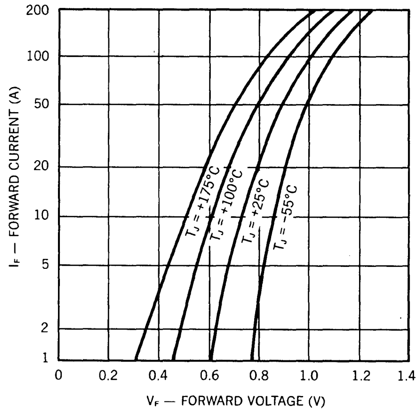
Output Current vs. Case Temperature



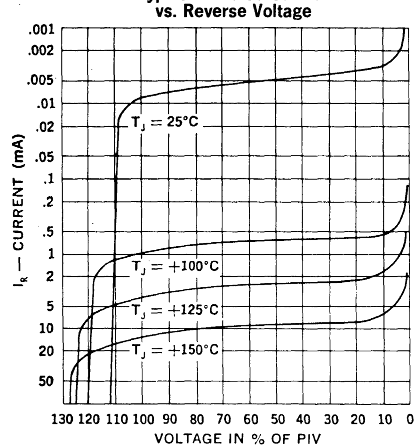
Peak Output Current vs. Case Temperature



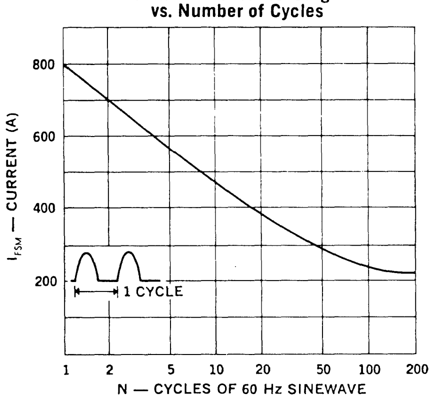
Forward Current vs. Forward Voltage



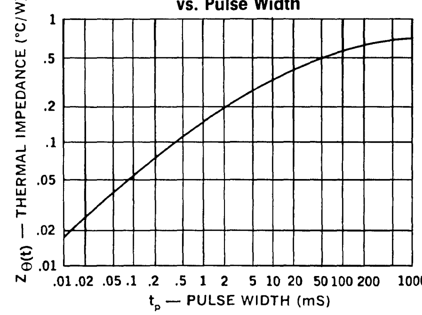
Typical Reverse Current vs. Reverse Voltage



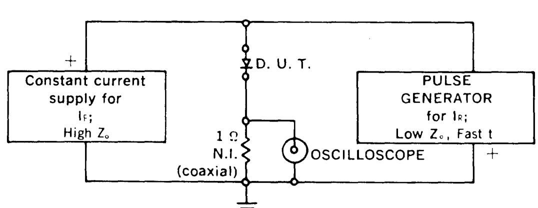
Maximum Forward Surge vs. Number of Cycles



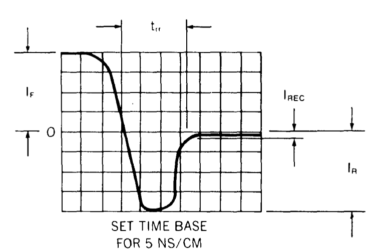
Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



Characteristic Waveform



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance = 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

POWER SCHOTTKY RECTIFIERS

SD41

60A Pk, 45V

FEATURES
- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (DO-4)
- High Efficiency for Low Voltage Supplies

DESCRIPTION
The SD41 has a Schottky barrier junction and is ideally suited for output rectifiers and catch diodes in low voltage power supplies. The Unitrode high conductivity design, using a heavy copper top post and a 4 point crimp, ensures cool terminal operation and low dynamic impedance. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

VI

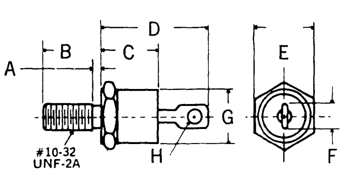
ABSOLUTE MAXIMUM RATINGS (T_{CASE} = 25°C)

Peak Repetitive Reverse Voltage, V_{RRM} 45V*
Working Peak Reverse Voltage V_{RWM} 35V*
Average Rectified Forward Current, I_O 30A
Peak Repetitive Forward
Current (Rated V_R, Square Wave, 20 KHz,
50 percent Duty cycle), I_{FRM} 60A
Non-repetitive Peak
Surge current (8.3 mS), I_{FSM} .... 600 A
Peak Reverse Transient Current, I_{RM} 2A
Storage Temperature Range, T_{stg} .... −55°C to +165°C
Junction Operating Temperature Range, T_j .... −55°C to +150°C
Thermal Resistance, Junction to Case, $R\theta_{JC}$ .... 2.0°C/W

*See curve of V_{RRM} Rating vs Case Temperature

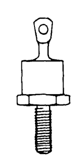
MECHANICAL SPECIFICATIONS

SD41



	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4

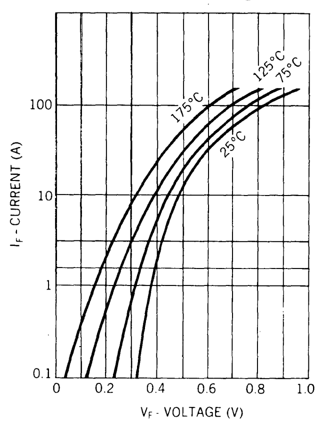


Notes:
1. Cathode is stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 10 inch pounds.
4. Angular orientation of terminal is undefined.

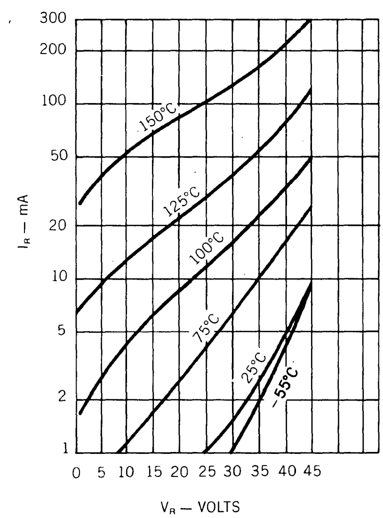
ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	25 125	mA mA	T_C = 25°C, V_R = 35V T_c = 125°C Pulse Width = 400μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	V_F	0.55	V	i_F = 30A T_c = 125°C Pulse Width = 300μS Duty Cycle = 1 percent
Capacitance	C_t	2000	pF	V_R = 5.0V
Voltage Rate of Change	dv/dt	700	v/μS	v_R = 35V

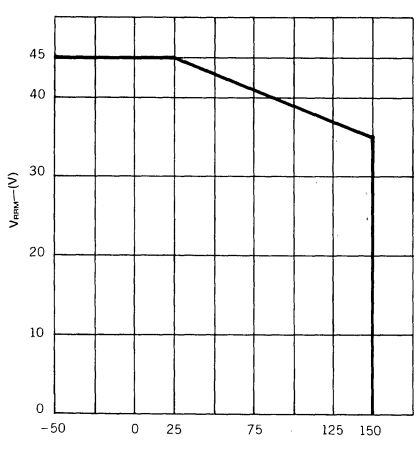
Typical Forward Current vs. Forward Voltage



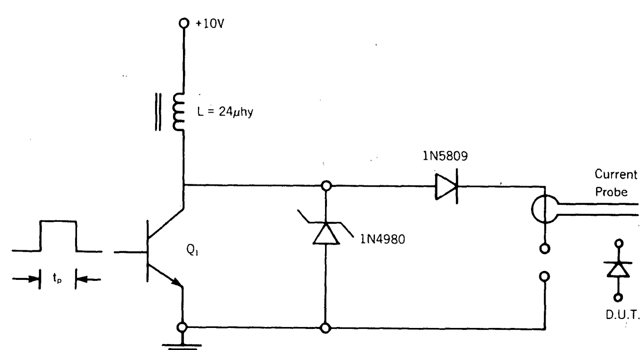
Typical Reverse Characteristics @ Various T_j



V_{RRM} Rating vs Case Temperature



Reverse Energy Circuit



t_p, adjust for desired peak current in D.U.T. when Q turns off.
Q_1, must have fall time t_f of 100nS max.

POWER SCHOTTKY RECTIFIERS

SD51

120 Amp Pk, 45V

FEATURES

- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (DO-5)
- High Efficiency for Low Voltage Supplies
- Available with Flexible Top Lead

DESCRIPTION

The SD51 has a Schottky barrier junction and is ideally suited for output rectifiers and catch diodes in low voltage power supplies. The Unitrode high conductivity design, using a heavy copper top post and a 4 point crimp, ensures cool terminal operation and low dynamic impedance. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

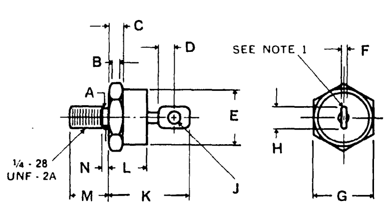
ABSOLUTE MAXIMUM RATINGS ($T_{CASE} = 25°C$)

Peak Repetitive Reverse Voltage, V_{RRM} 45V*
Working Peak Reverse Voltage, V_{RWM} 35V*
Peak Repetitive Forward
Current (Rated V_R, Square Wave, 20 KHz,
50 percent Duty Cycle), I_{FRM} 120A
Non-repetitive Peak
Surge Current (8.3 mS), I_{FSM} 800A
Peak Reverse Transient Current, I_{RM} 2A
Storage Temperature Range, T_{stg} .... −55°C to +165°C
Junction Operating Temperature Range, T_j .... −55°C to +150°C
Thermal Resistance, Junction-to-Case, $R_{\Theta JC}$ .... 1.0°C/W

*See curve of V_{RRM} Rating vs Case Temperature

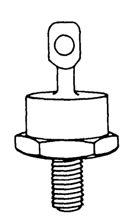
MECHANICAL SPECIFICATIONS

SD51



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5

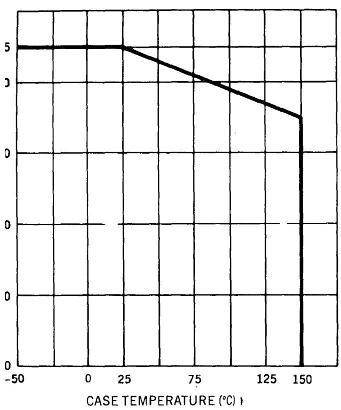


Notes:
1. Cathode is stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds (35 kg. cm).
4. Angular orientation of terminal is undefined.

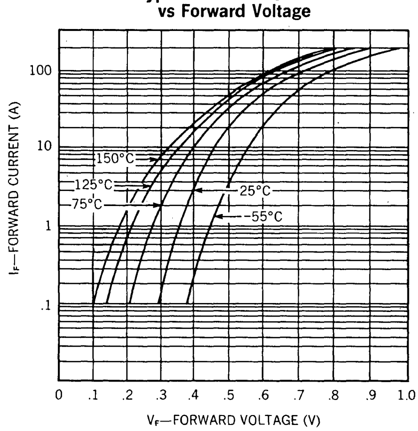
ELECTRICAL CHARACTERISTICS ($T_{CASE} = 25°C$)

Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	50 200	mA mA	$T_C = 25°C$, $V_R = 35V$ $T_C = 125°C$ Pulse Width = 400μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	V_F	0.60	V	$i_F = 60A$ $T_c = 125°C$ Pulse Width = 300μS Duty Cycle = 1 percent
Flexible Top Lead Option	V_F	0.65	V	
Maximum Capacitance	C_t	4000	pF	$V_R = 5.0V$
Maximum Voltage Rate of Change	dv/dt	700	V/μS	$V_R = 35V$

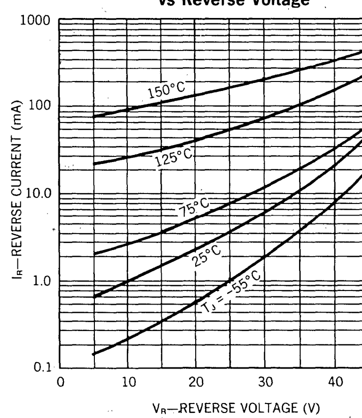
V_{RRM} Rating vs Case Temperature



Typical Forward Current vs Forward Voltage

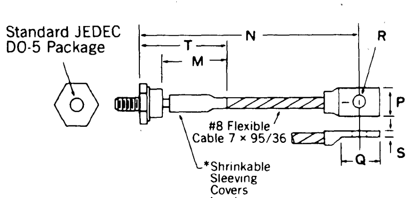


Typical Reverse Current vs Reverse Voltage



MECHANICAL SPECIFICATIONS

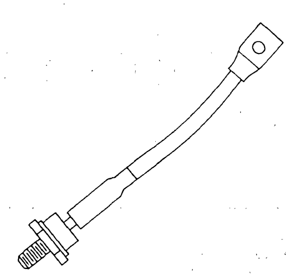
FLEXIBLE TOP LEAD (OPTIONAL) **SD51F**
Add an "F" Suffix to Part Number.



	INCHES	MILLIMETERS
M	.718 MAX.	18.24 MAX.
N	4.50 ± .250	114.3 ± 6.35
P	.525 MAX.	13.23 MAX.
Q	.675 ± .035	17.15 ± 0.89
R	.205 ± .005	5.21 ± 0.13
S	.075 ± .010	1.91 ± 0.25
T	1.125 MAX.	28.58 MAX.

*To 125°C (Ambient)

DO-5 with Flexible Lead



Note: Consult Factory for Non-standard Lead Lengths.

UNITRODE CORPORATION • 5 FORBES ROAD
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TWX (710) 326-6509 • TELEX 95-1064

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DUAL POWER SCHOTTKY RECTIFIERS

SD241

30 Amp Pk per diode, 45V

FEATURES
- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Packaged Design (TO-3)
- High Efficiency for Low Voltage Supplies
- Dual Schottky Rectifiers in a Single Package

DESCRIPTION
The SD241 has two Schottky barrier junctions arranged in a common cathode configuration and is ideally suited for output rectifiers and catch diodes in low voltage supplies.

VI

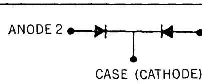
ABSOLUTE MAXIMUM RATINGS (T_{CASE} = 25°C) Per Diode

Peak Repetitive Reverse Voltage, V_{RRM} 45V*
Working Peak Reverse Voltage, V_{RWM} 35V
Average Rectified Forward Current, I_O 30A
Non-repetitive Peak
  Surge current (8.3 mS), I_{FSM} 400A
Peak Reverse Transient Current, I_{RM} 2A
Storage Temperature Range, T_{stg} .... −55°C to +175°C
Junction Operating Temperature Range, T_j .... −55°C to +150°C
Package Thermal Resistance, Junction to Case, $R_{\theta JC}$ .... 1.4°C/W

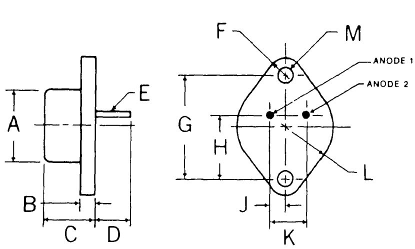
* See curve of V_{RRM} Rating vs Case Temperature.

MECHANICAL SPECIFICATIONS

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

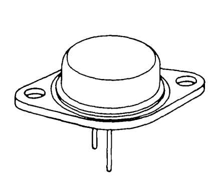


SD241



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



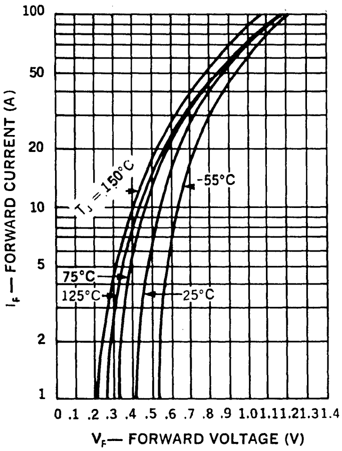
Notes: All metal surfaces tin plated.

UNITRODE

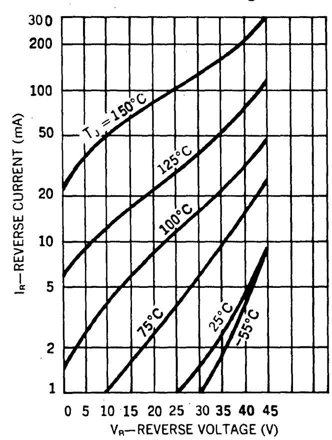
ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C) Per Diode

Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	25 100	mA mA	T_C = 25°C, V_R = 35V T_C = 125°C Pulse Width = 400μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	v_F	.47	V	i_F = 10A Pulse Width = 300μS Duty Cycle = 1 percent T_c = 125°C
		.60	V	i_F = 20A Pulse Width = 300μS Duty Cycle = 1 percent T_c = 125°C
Maximum Capacitance	C_t	2000	pF	V_R = 5.0V
Maximum Voltage Rate of Change	dv/dt	1000	v/μS	v_R = 35V

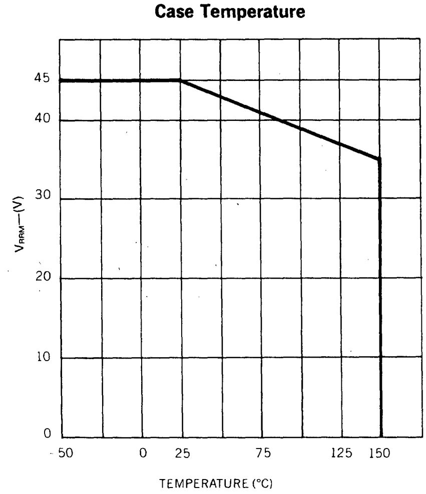
Typical Forward Current vs Forward Voltage



Typical Reverse Current vs Reverse Voltage



V_{RRM} Rating vs Case Temperature



RECTIFIERS
High Efficiency, 2A

SES5001-SES5003

FEATURES
- Fast Recovery Times
- Low Forward Voltage
- Small Size
- Convenient Package

DESCRIPTION
An axial leaded power rectifier useful in many switching applications. Particularly suited where very fast recovery and low forward voltage are required.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5001 .... 50V
Peak Inverse Voltage, SES5002 .... 100V
Peak Inverse Voltage, SES5003 .... 150V
Maximum Average D.C. Output Current at T_L = 75°C, L = 3/8″ 2A
Non-Repetitive Surge Current at 8.3mS 35A
Thermal Resistance, @ L = 3/8″ .... 38°C/W
Operating and Storage Temperature Range .... −55°C +175°C

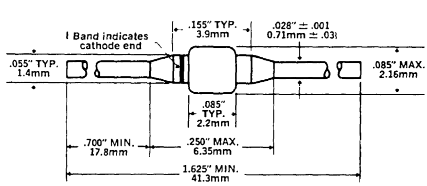
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		T_J = 25°C	T_J = 100°C	@ T_J = 25°C	@ T_J = 100°C	
SES5001 SES5002 SES5003	50V 100V 150V	.975V @ 1A	.895V @ 1A	2μA	50μA	100nS

*Measured in circuit I_F = .5A, I_R = 1.0A, I_{REC} = .25A

MECHANICAL SPECIFICATIONS

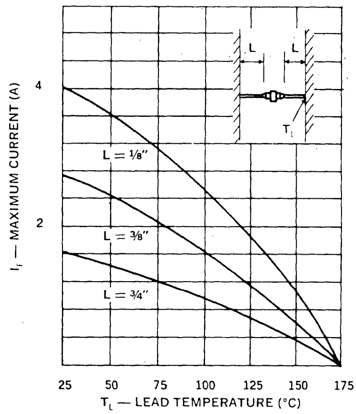
SES5001-SES5003



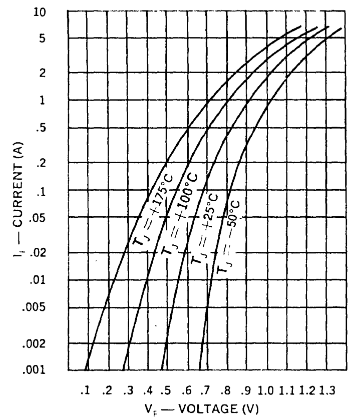
BODY A

UNITRODE

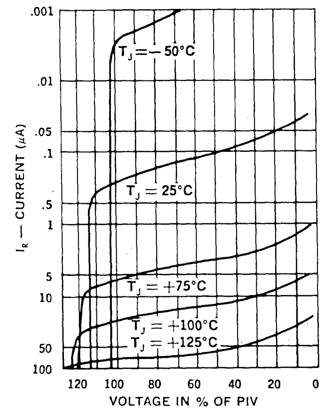
Output Current vs. Lead Temperature



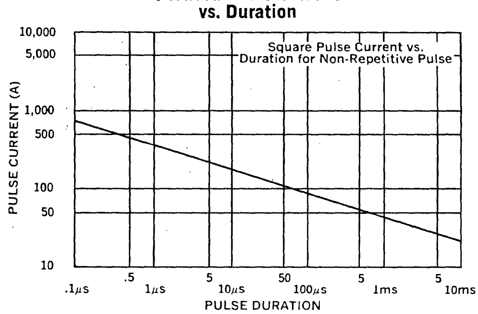
Typical Forward Current vs. Forward Voltage



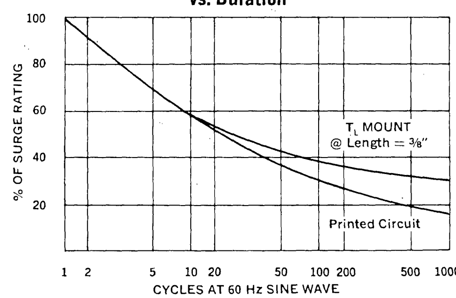
Typical Reverse Current vs. Voltage



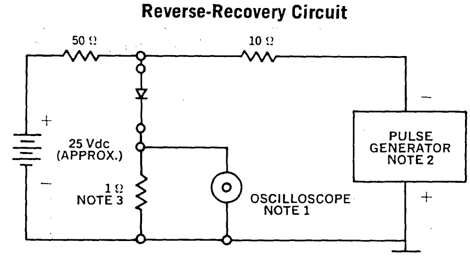
Forward Pulse Current vs. Duration



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time≤3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time≤8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 5A

SES5301-SES5303

FEATURES
- Low Forward Voltage
- Fast Recovery Times
- Small Size
- High Surge

DESCRIPTION
An axial leaded power rectifier useful in many switching applications. Particularly suited where very fast recovery and low forward voltage are required.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5301 .... 50V
Peak Inverse Voltage, SES5302 .... 100V
Peak Inverse Voltage, SES5303 .... 150V
Maximum Average D.C. Output Current at $T_L = 75\,°C$, L = 3/8″ 5A
Non-Repetitive Sinusoidal Surge Current at 8.3mS 110A
Thermal Resistance at L = 3/8″ .... 20 °C/W
Operating and Storage Temperature Range .... −55 °C to +170 °C

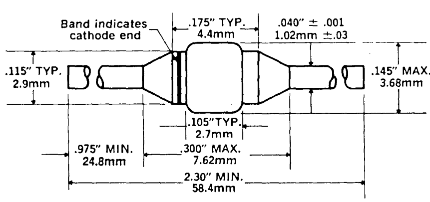
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		$T_J = 25\,°C$	$T_J = 100\,°C$	@$T_J = 25\,°C$	@$T_J = 100\,°C$	
SES5301 SES5302 SES5303	50V 100V 150V	0.975V @ 5A	0.895V @ 5A	5μA	150μA	100 ns

*Measured in circuit $I_F = 0.5A$, $I_R = 1.0A$, $I_{REC} = 0.25A$

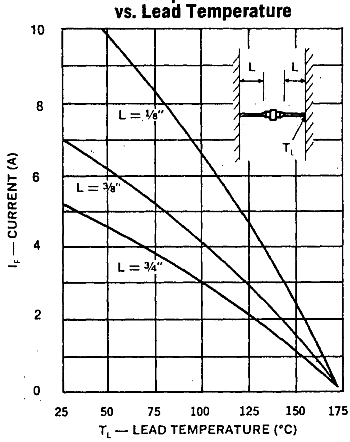
MECHANICAL SPECIFICATIONS

SES5301-SES5303

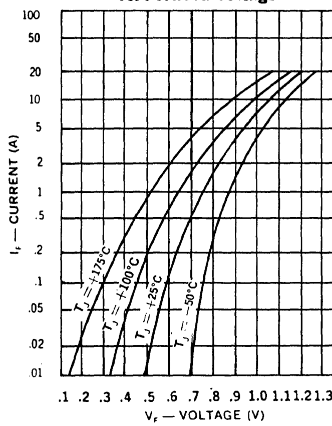


BODY B

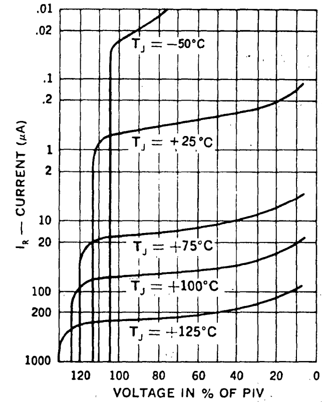
Output Current vs. Lead Temperature



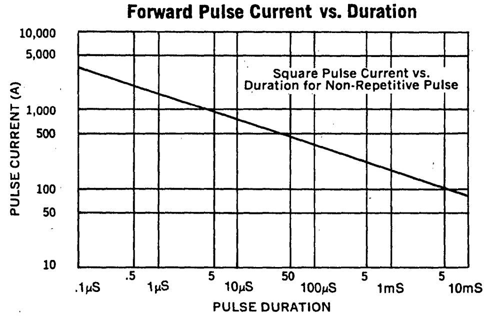
Typical Forward Current vs. Forward Voltage



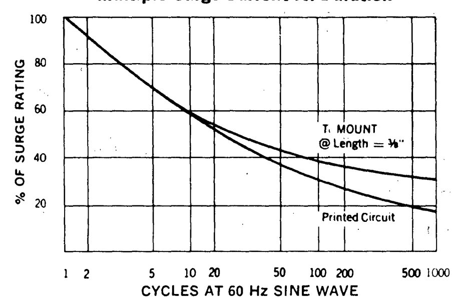
Typical Reverse Current vs. Voltage



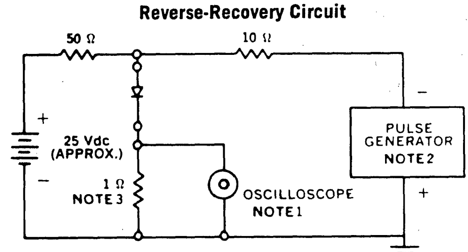
Forward Pulse Current vs. Duration



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 8A

SES5401-SES5403

VI

FEATURES

- Low Forward Voltage
- Fast Recovery Times
- Economical, Convenient TO-220 Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION

The SES5401 Series, in the economical, convenient TO-220 package, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The very low forward voltage and very fast recovery time make them particularly suited for switching type power supplies.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5401 .... 50V
Peak Inverse Voltage, SES5402 .... 100V
Peak Inverse Voltage, SES5403 .... 150V
Maximum Average D.C. Output Current
@ T_C = 125°C 8.0A
@ T_A = 25°C 3.0A
@ T_A = 25°C (Note 1) 8.0A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 70A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 2.5°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

NOTE 1. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

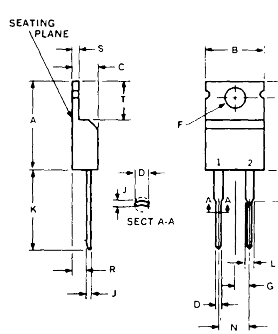
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @1A t_r=8nS
		T_J = 25°C	T_J = 100°C	@ T_J = 25°C	@ T_J = 100°C		
SES5401 SES5402 SES5403	50V 100V 150V	1.025V @ 8A	0.945V @ 8A	5μA	150μA	100nS	1.4V

*Measured in circuit I_F = 0.50A, I_R = 1.0A, I_{REC} = 0.25A

MECHANICAL SPECIFICATIONS

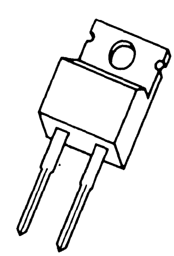
SES5401-SES5403



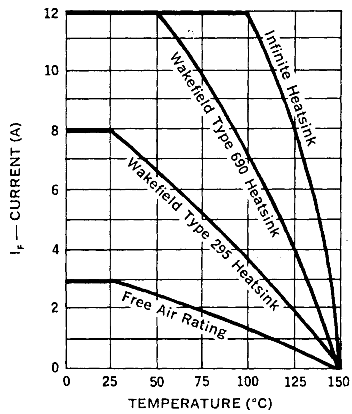
PIN 1. Cathode
2. Anode
Tab is connected to Cathode.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

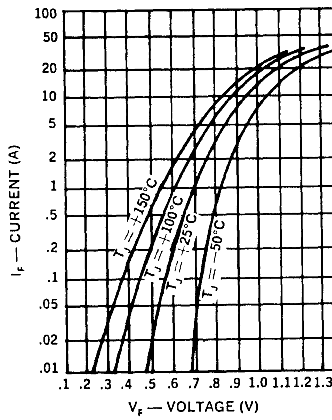
SIMILAR TO TO-220



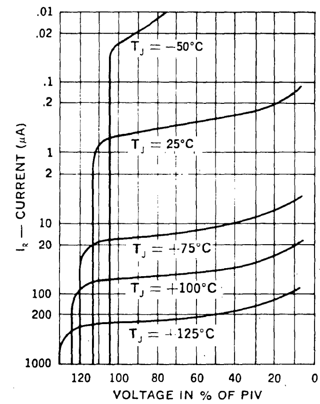
Output Current vs. Temperature



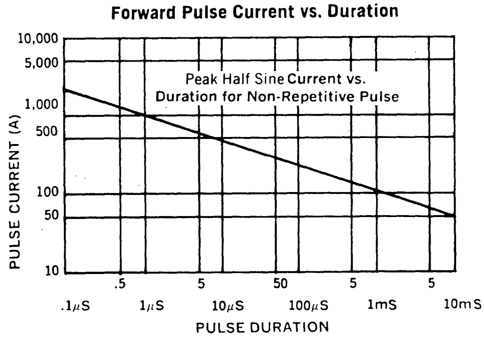
Typical Forward Current vs. Forward Voltage



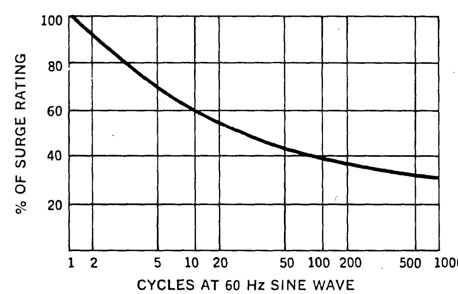
Typical Reverse Current vs. Voltage



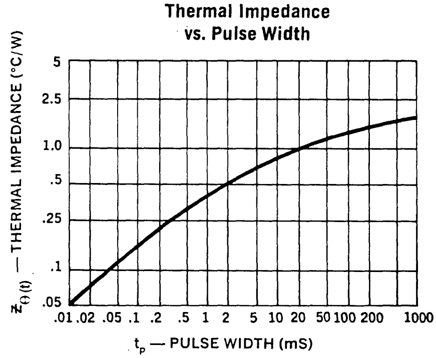
Forward Pulse Current vs. Duration



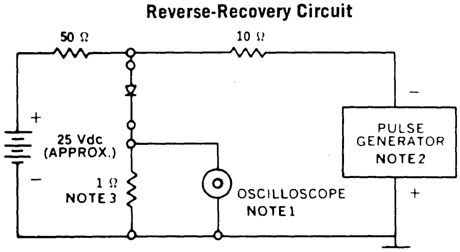
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

SES5401C-SES5403C

High Efficiency, 16A Center-Tap

FEATURES

- Low Forward Voltage
- Fast Recovery Times
- Economical, Convenient TO-220AB Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION

The SES5401C Series in the economical, convenient TO-220AB package, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The series combines two high efficiency devices into one package, simplifying installation, reducing heatsink requirements and the need to purchase matched components.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5401C 50V
Peak Inverse Voltage, SES5402C 100V
Peak Inverse Voltage, SES5403C 150V
Maximum Average D.C. Output Current
@ T_C = 125°C 16A
@ T_A = 25°C 3A
@ T_A = 25°C (Note 1) 10A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 70A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 1.75°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

NOTE 1. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

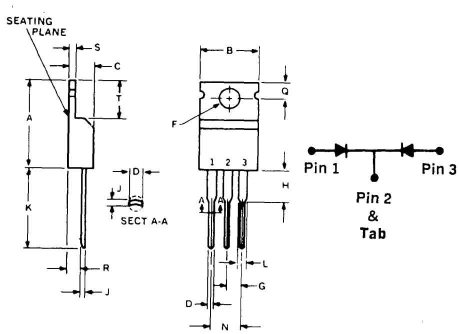
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @1A t_r = 8nS
		T_J = 25°C	T_J = 100°C	@ T_J = 25°C	@ T_J = 100°C		
SES5401C SES5402C SES5403C	50V 100V 150V	1.025V @ 8A	0.945V @ 8A	5μA	150μA	100nS	1.4V

*Measured in circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

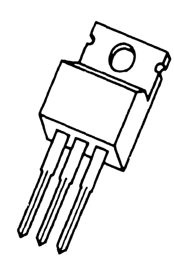
MECHANICAL SPECIFICATIONS

SES5401C-SES5403C

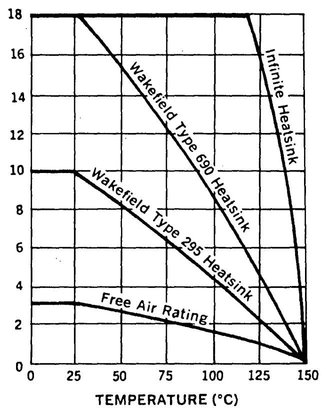


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

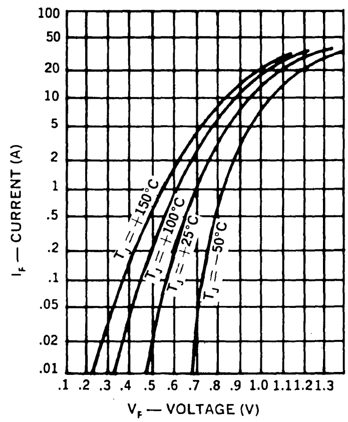
TO-220AB



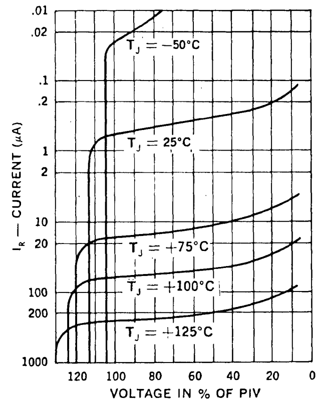
Output Current vs. Temperature



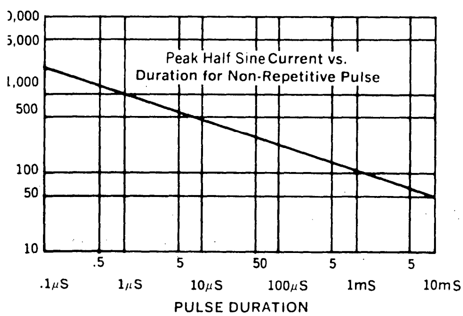
Typical Forward Current vs. Forward Voltage



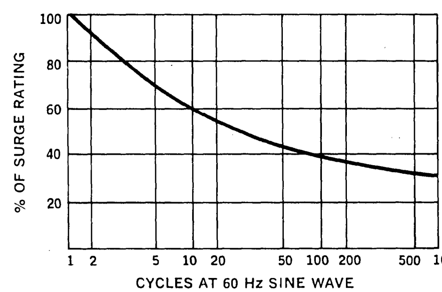
Typical Reverse Current vs. Voltage



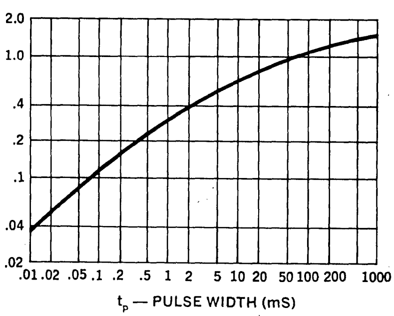
Forward Pulse Current vs. Duration



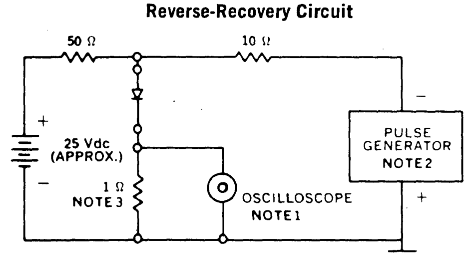
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 25A Center-Tap

SES5601C
SES5602C
SES5603C

FEATURES
- Low Forward Voltage
- Fast Switching Speed
- Convenient Package
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged TO-3 Package
- Available as Positive or Negative Center-Tap

DESCRIPTION
The SES, super-fast recovery, rectifiers are specifically designed for operation in power switching circuits. Their super-fast recovery time and very low forward voltage make them particularly efficient in most switching applications.

VI

ABSOLUTE MAXIMUM RATINGS

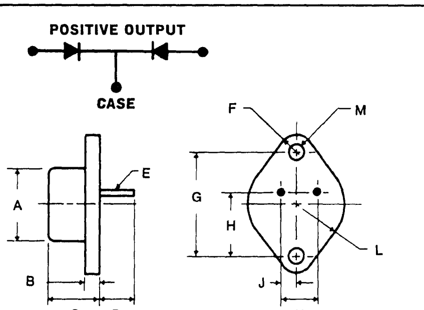
Peak Inverse Voltage, SES5601C 50V
Peak Inverse Voltage, SES5602C 100V
Peak Inverse Voltage, SES5603C 150V
Maximum Average D.C. Output Current at $T_c = 100°C$ 25A
Non-Repetitive Sinusoidal Surge Current 8.3 mS 400A
Thermal Resistance, Junction to Case .... 1 °C/W
Operating and Storage Temperature Range .... −55 °C to +175 °C

ELECTRICAL SPECIFICATIONS PER DIODE

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	@$T_C = 25°C$	@$T_C = 125°C$	
SES5601C SES5602C SES5603C	50V 100V 150V	0.990V @ 12.5A $t_p = 300\mu S$	0.830V @ 12.5A $t_p = 300\mu S$	20μA	4mA	100nS

*Measured in circuit $I_F = 0.5A$, $I_R = 1.0A$, $I_{REC} = 0.25A$

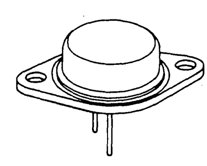
MECHANICAL SPECIFICATIONS



SES5601C-SES5603C

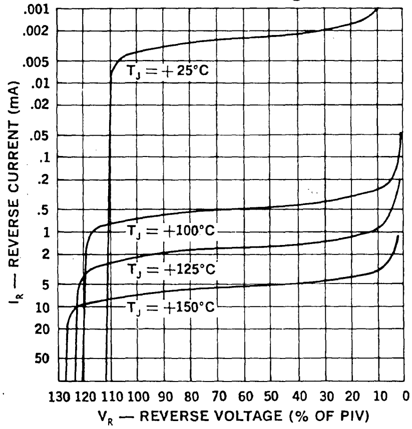
	Ins.	mm
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.00-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA	3.84-4.09 DIA.

TO-3

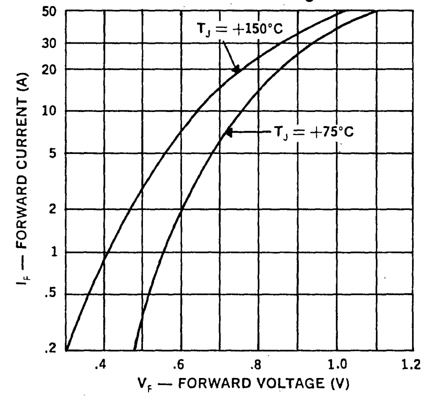


NOTES:
1. Standard polarity is positive output.
   For reverse polarity (negative output) add suffix "R", ie, SES5601CR.
2. All metal surfaces tin plated.

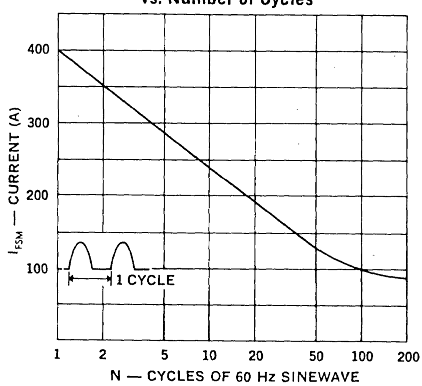
Typical Reverse Current vs. Reverse Voltage



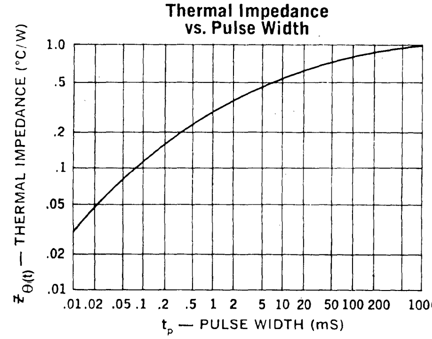
Typical Forward Current vs. Forward Voltage



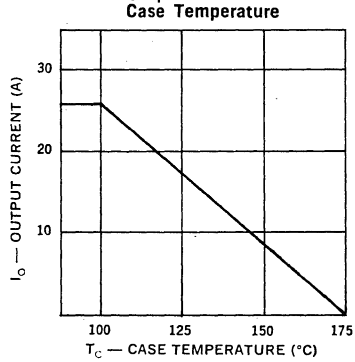
Maximum Forward Surge vs. Number of Cycles



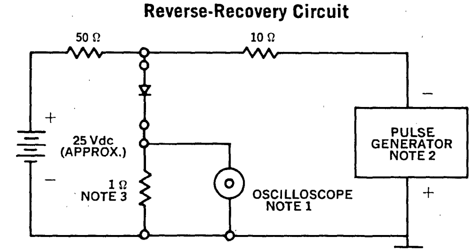
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time $\leqslant$ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time $\leqslant$ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 20A

SES5701
SES5702
SES5703

VI

FEATURES
- Low Forward Voltage
- Fast Switching
- Low Thermal Resistance
- High Surge Capability
- Mechanically Rugged DO-4 Package
- Reverse Polarity Available

DESCRIPTION

The SES, super-fast recovery, rectifiers are specifically designed for operation in power switching circuits. Their super-fast recovery time and very low forward voltage drop make them particularly efficient in most switching applications.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5701 .... 50V
Peak Inverse Voltage, SES5702 .... 100V
Peak Inverse Voltage, SES5703 .... 150V
Maximum Average D.C. Output Current at $T_c = 100°C$ 20A
Non-Repetitive Sinusoidal Surge Current 8.3 mS 400A
Thermal Resistance, Junction to Case .... 1.5°C/W
Operating and Storage Temperature Range .... −55°C to +175°C

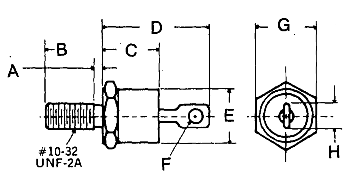
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	@ $T_C = 25°C$	@$T_C = 125°C$	
SES5701 SES5702 SES5703	50V 100V 150V	.990V @ 20A $t_p = 300\mu S$	.830 @ 20A $t_p = 300\mu S$	20μA	4mA	100nS

*Measured in circuit I_F = .5A, I_R = 1.0A, I_{REC} = .25A

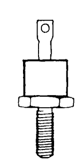
MECHANICAL SPECIFICATIONS

SES5701-SES5703



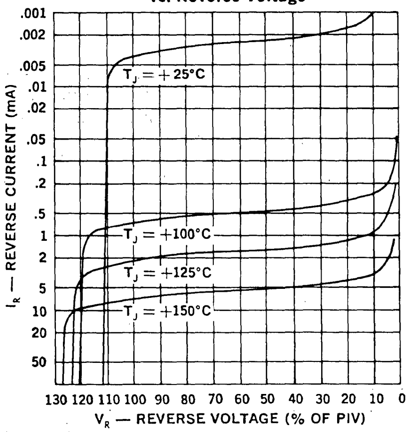
	ins.	mm
A	.078 MAX.	1.98 MAX.
B	±.437 ±.015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.424 MAX.	10.77 MAX.
F	.066 MIN. DIA.	1.68 MIN. DIA.
G	.430 ±.010	10.92 ±0.25
H	.250 MAX.	6.35 MAX.

DO-4

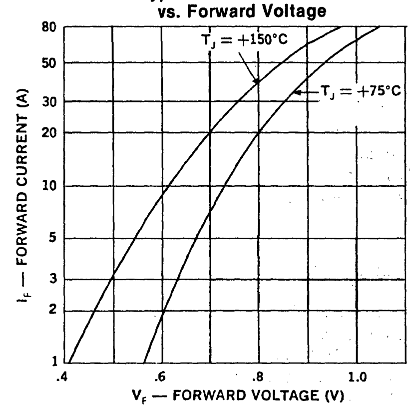


NOTES:
1. Standard polarity is cathode-to-stud.
   For reverse Polarity (anode-to-stud) add suffix "R", ie. SES5701R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 10 inch pounds.
4. Angular orientation of terminal is undefined.

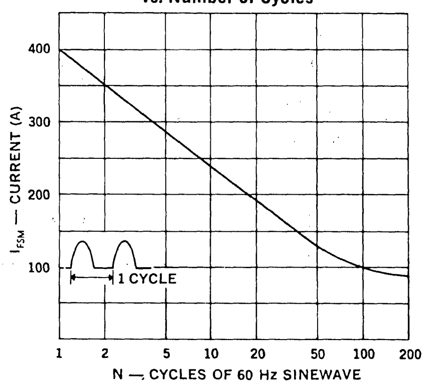
Typical Reverse Current vs. Reverse Voltage



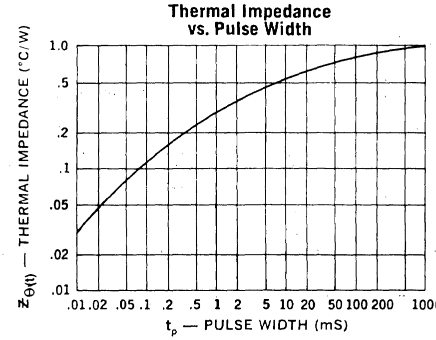
Typical Forward Current vs. Forward Voltage



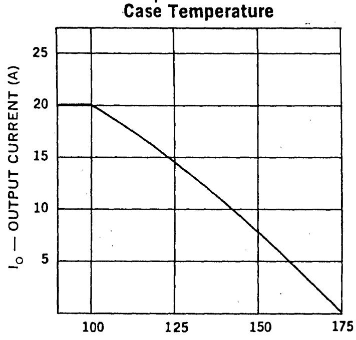
Maximum Forward Surge vs. Number of Cycles



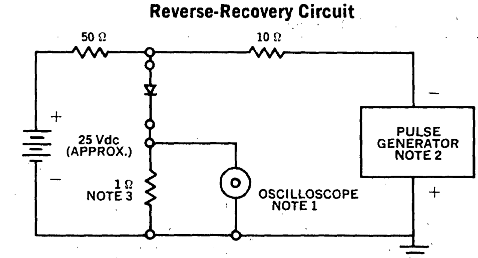
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 60A

SES5801
SES5802
SES5803

FEATURES
- Low Forward Voltage
- Fast Switching Speeds
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged DO-5 Package
- Reverse Polarity Available

DESCRIPTION
The SES, super-fast recovery, rectifiers are specifically designed for operation in power switching circuits. Their super-fast recovery time and very low forward voltage drop make them particularly efficient in most switching applications.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5801 .... 50V
Peak Inverse Voltage, SES5802 .... 100V
Peak Inverse Voltage, SES5803 .... 150V
Maximum Average D.C. Output Current at $T_c = 100°C$ 60A
Non-Repetitive Sinusoidal Surge Current 8.3 mS 800A
Thermal Resistance, Junction to Case .... 0.8 °C/W
Operating and Storage Temperature Range .... −55 °C to +175 °C

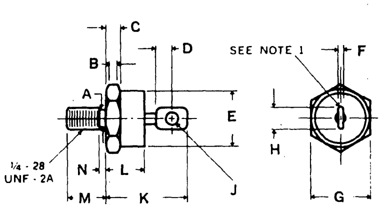
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 150°C$	@$T_C = 25°C$	@$T_C = 150°C$	
SES5801 SES5802 SES5803	50V 100V 150V	0.990V @ 60A $t_p = 300\mu S$	0.850V @ 60A $t_p = 300\mu S$	25μA	30mA	100nS

*Measured in circuit $I_F = 0.5A$, $I_R = 1.0A$, $I_{REC} = 0.25A$

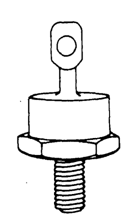
MECHANICAL SPECIFICATIONS

SES5801-SES5803



	Ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.667 ± .010	16.94 ± 0.25
H	.375	9.53
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ±.015	11.13 ± 0.38
N	.078 MAX	1.98 MAX.

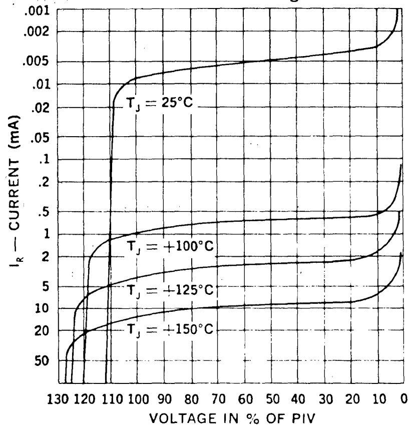
DO-5



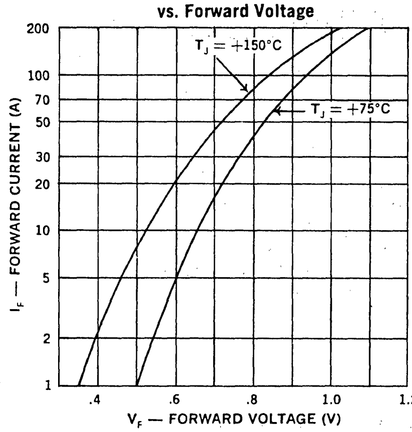
Notes:
1. Standard polarity is cathode-to-stud.
   For reverse polarity (anode-to-stud) add suffix "R", ie. SES5801R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 20 inch pounds.
4. An angular orientation of terminal is undefined.

UNITRODE

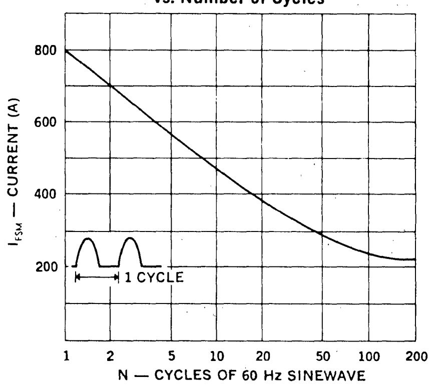
Typical Reverse Current vs. Reverse Voltage



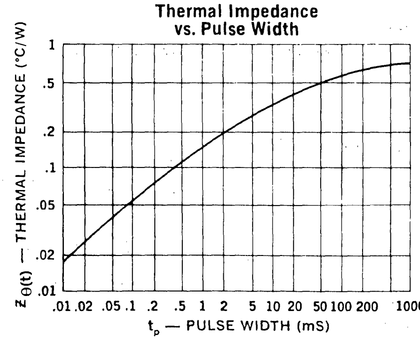
Forward Current vs. Forward Voltage



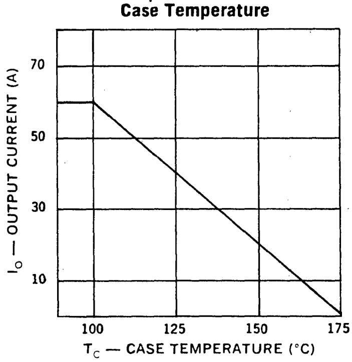
Maximum Forward Surge vs. Number of Cycles



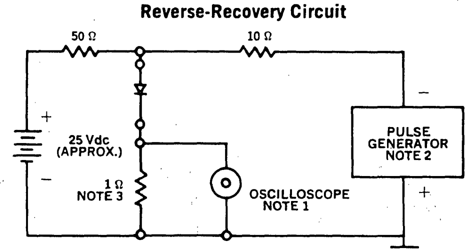
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3nS ; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 50 Amp

UES501-UES505

FEATURES

- 50A Continuous Rating at Case Temperature of 125°C
- Exceptional Efficiency
- Low Forward Voltage
- Extremely Fast Reverse Recovery Time
- Extremely Fast Forward Recovery Time
- High Surge
- Radiation Tolerant
- Rugged, High Current Termination

DESCRIPTION:

This series of High Efficiency Power Rectifiers allows circuit designers to design high current, high frequency supplies with very low diode losses. Reverse recovery time is typically 1/10 - 1/100th of equivalent power rectifiers, with even lower forward voltage.

VI

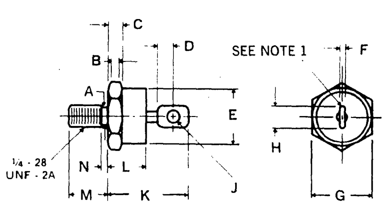
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	Type
50V	UES501
75V	UES502
100V	UES503
125V	UES504
150V	UES505

Maximum Average D.C. Output Current
@ $T_C = 125$°C 50A
Non-Repetitive Sinusoidal
Surge Current (8.3ms) 600A
Operating Temperature Range .... −65°C to +175°C
Storage Temperature Range .... −65°C to +175°C
Thermal Resistance .... 1°C/W

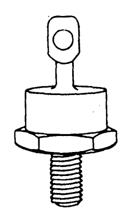
MECHANICAL SPECIFICATIONS

UES501-UES505



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



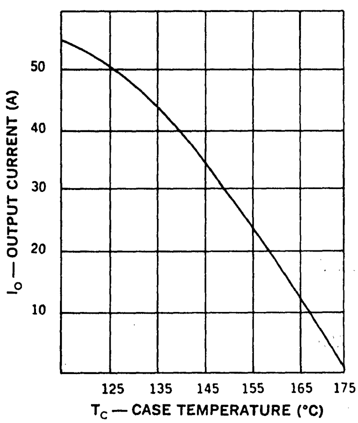
Notes:
1. Angular orientation of terminal is undefined.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds.
4. All dimensions in inches.
5. Polarity is cathode to stud; for anode to stud add suffix "R".

UNITRODE

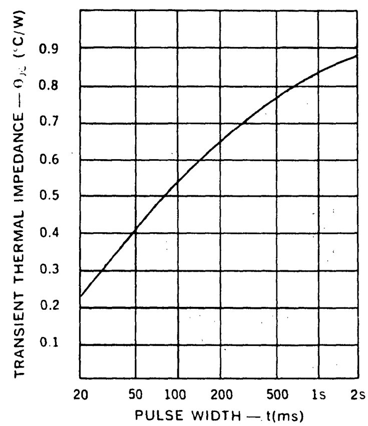
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Peak Inverse Voltage	Maximum Forward Voltage Drop	Maximum Leakage Current 25°C	Maximum Leakage Current 125°C	Maximum Reverse Recovery Time t_{rr} @ I_F-I_R-I_{REC}
UES501	50V	.95V @ 50A (pw = 250ms)	25μA	10mA	50ns, 1A-1A-0.5A
UES502	75V				
UES503	100V				
UES504	125V				
UES505	150V				

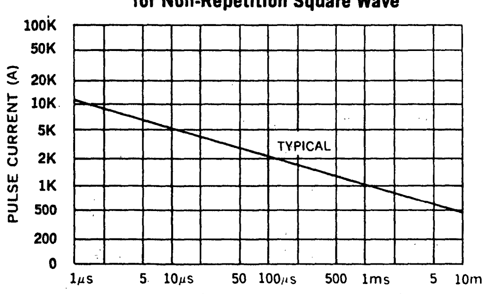
Output Current vs. Case Temp.



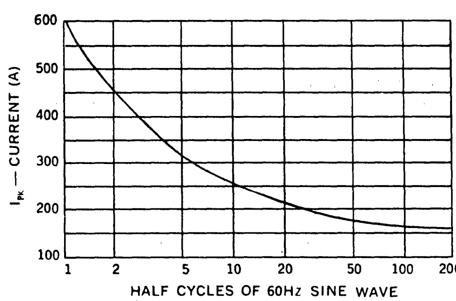
Pulse Thermal Impedance vs. Pulse Width



Square Pulse Current vs. Duration for Non-Repetition Square Wave

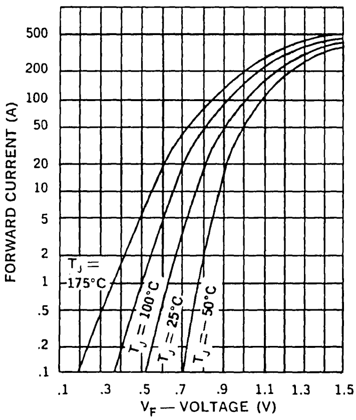


Multiple Surge Current vs. Duration

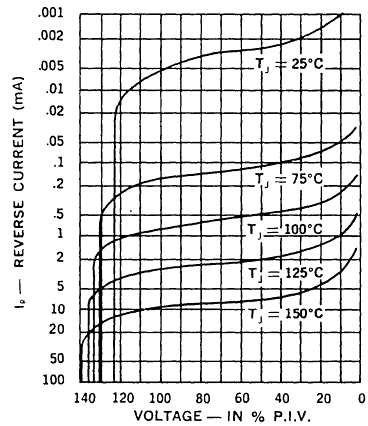


VI

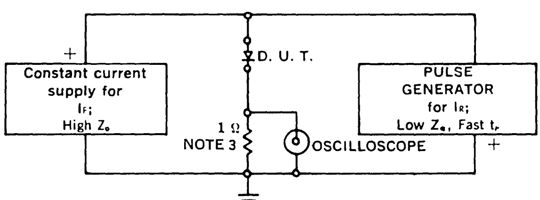
Typical Forward Current vs. Forward Voltage



Typical Reverse Current vs. Voltage

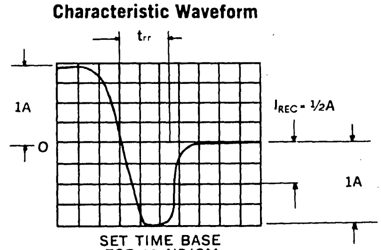


Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3 ns; input impedance = 50 Ω.
2. Pulse Generator: Rise time ≤ 8 ns; source impedance 10 Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Characteristic Waveform



SET TIME BASE FOR 10 NS/CM

RECTIFIERS
High Efficiency, 25 A

FEATURES
- Low Forward Voltage
- Very Fast Switching
- Low Thermal Resistance
- High Surge Capability
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION
Designed to meet the efficiency demand of switching type power supplies, these devices are useful in many switching applications.
The low thermal resistance and forward voltage drop of this series allows the user to replace DO-5 size devices in many applications.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage, UES701 .... 50V
Peak Inverse Voltage, UES702 .... 100V
Peak Inverse Voltage, UES703 .... 150V
Maximum Average D.C. Output Current at $T_C = 100°C$ 25A
Non-Repetitive Sinusoidal Surge Current at 8.3ms 400A
Thermal Resistance, Junction to Case .... 1.5°C/W
Operating and Storage Temperature Range .... −55°C to +175°C

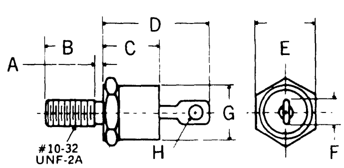
POWER CYCLING
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS
The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

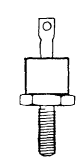
MECHANICAL SPECIFICATIONS

UES701-UES703



	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4



Notes:
1. Standard polarity is cathode-to-stud.
   For reverse Polarity (anode-to-stud) add suffix "R", ie. UES701R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 15 inch pounds.
4. Angular orientation of terminal is undefined.

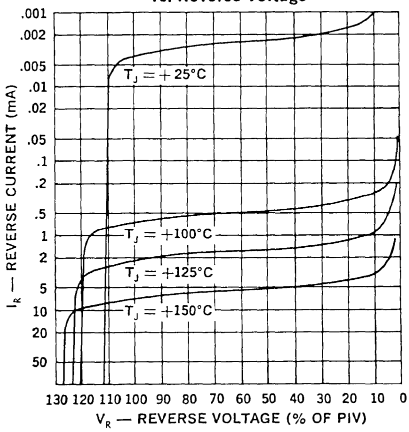
UNITRODE

ELECTRICAL SPECIFICATIONS

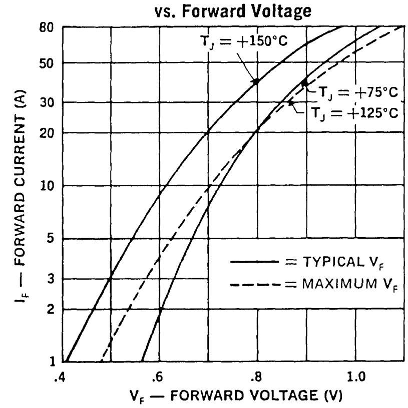
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES701 UES702 UES703	50V 100V 150V	.950 @ 25A $t_p = 300\mu S$	.825 @ 25A $t_p = 300\mu S$	20μA	4mA	35nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

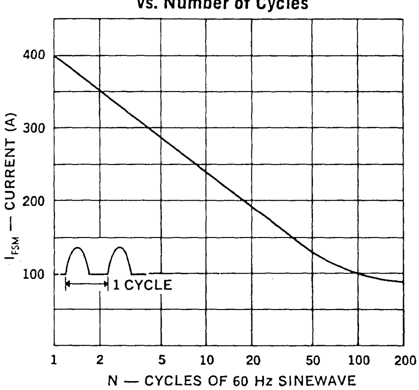
Typical Reverse Current vs. Reverse Voltage



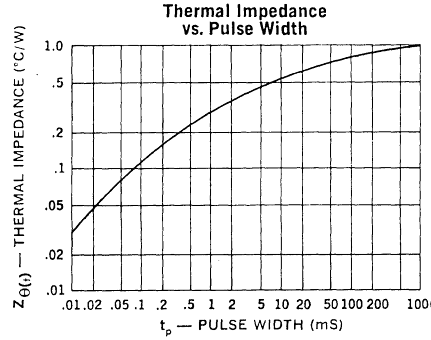
Forward Current vs. Forward Voltage



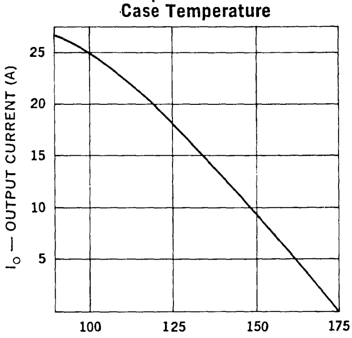
Maximum Forward Surge vs. Number of Cycles



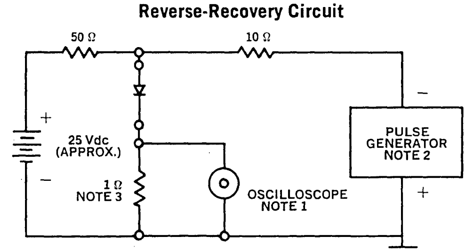
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 20A

FEATURES
- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- Low Thermal Resistance
- High Surge Capability
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION
The UES704 series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.
The low thermal resistance and forward voltage drop of this series allows the user to replace DO-5 size devices in many applications.

ABSOLUTE MAXIMUM RATINGS

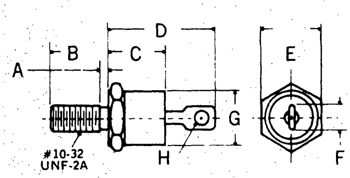
Peak Inverse Voltage, UES704	200V
Peak Inverse Voltage, UES705	300V
Peak Inverse Voltage, UES706	400V
Ave. D.C. Output Current, I_o @ $T_C = 100°C$	20A
Surge Current, 8.3mSec	300A
Thermal Resistance, Junction to Case	1.5°C/W
Operating and Storage Temperature Range	−55°C to +150°C

POWER CYCLING
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.
In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS
The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

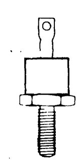
MECHANICAL SPECIFICATIONS

UES704-UES706



	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4



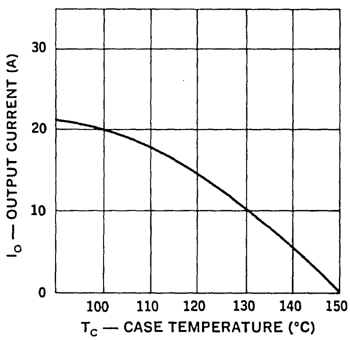
Notes:
1. Standard polarity is cathode-to-stud.
   For reverse Polarity (anode-to-stud) add suffix "R", ie. UES704R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 15 inch pounds.
4. Angular orientation of terminal is undefined.

ELECTRICAL SPECIFICATIONS

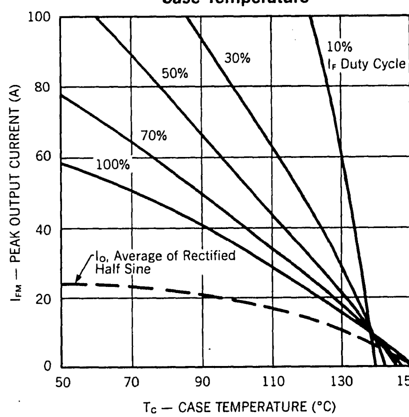
Type	PIV	Maximum Forward Voltage $T_C = 25°C$	Maximum Forward Voltage $T_C = 125°C$	Maximum Reverse Current $T_C = 25°C$	Maximum Reverse Current $T_C = 125°C$	Maximum Reverse Recovery Time*
UES704 UES705 UES706	200V 300V 400V	1.25V @ 20A $t_p = 300\mu S$	1.15V @ 20A $t_p = 300\mu S$	50μA	10mA	50nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

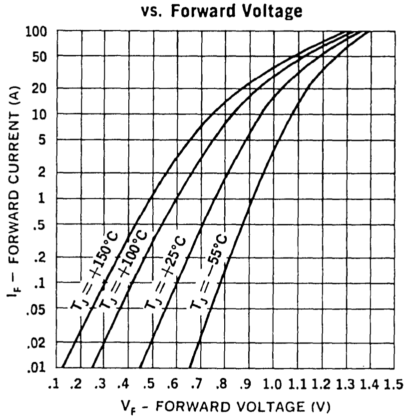
Output Current vs. Case Temperature



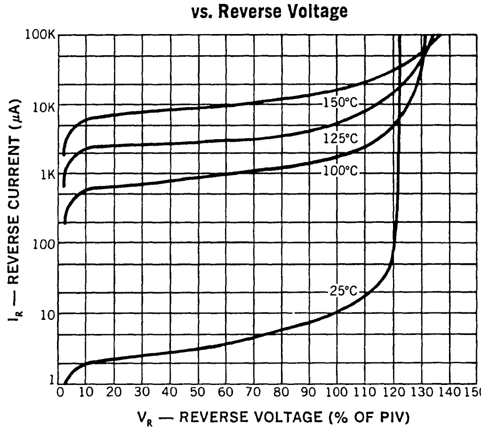
Peak Output Current vs. Case Temperature



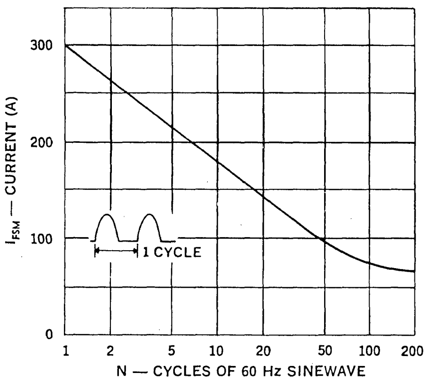
Typical Forward Current vs. Forward Voltage



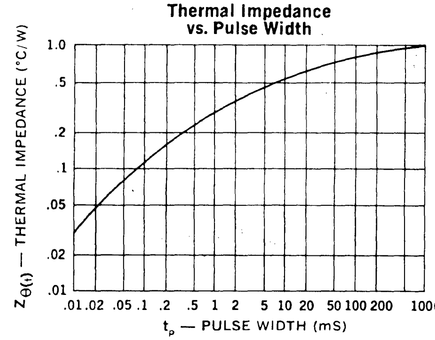
Typical Reverse Current vs. Reverse Voltage



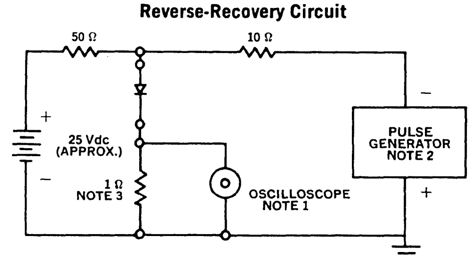
Maximum Forward Surge
vs. Number of Cycles



Thermal Impedance
vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 70 Amp

UES801-UES803

FEATURES

- High Continuous Current Rating
- Very Low Forward Voltage
- Very Fast Switching Speeds
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available
- Available with Flexible Top Lead

DESCRIPTION

The UES801 Series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz. The very low forward voltage and very fast recovery time make them particularly suited for switching type power supplies.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES801	50V
Peak Inverse Voltage, UES802	100V
Peak Inverse Voltage, UES803	150V
Maximum Average D.C. Output Current at $T_C = 100°C$	70A
Non-Repetitive Sinusoidal Surge Current 8.3 ms	800A
Thermal Resistance, Junction to Case	0.8°C/W
Operating and Storage Temperature Range	−55°C to +175°C

POWER CYCLING

. These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

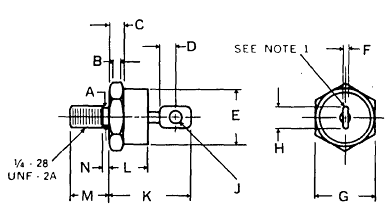
In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS

The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

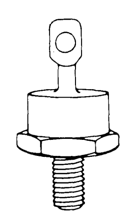
MECHANICAL SPECIFICATIONS

UES801-UES803



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



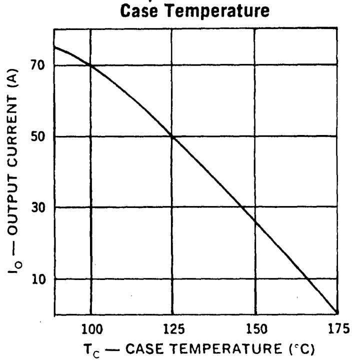
Notes:
1. Standard polarity is cathode-to-stud.
   For reverse polarity (anode-to-stud) add suffix "R", ie. UES801R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 20 inch pounds (20 kg. cm).
4. Angular orientation of terminal is undefined.

ELECTRICAL SPECIFICATIONS

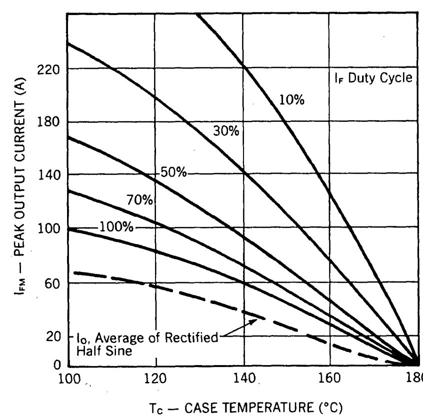
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 150°C$	$T_C = 25°C$	$T_C = 150°C$	
UES801 UES802 UES803	50V 100V 150V	.975V @ 70A $t_p = 300\mu S$	.840V @ 70A $t_p = 300\mu S$	25μA	30mA	50nS

Note: Add 0.03 Volts to Max Forward Voltage for Flexible Top Lead Option. * Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

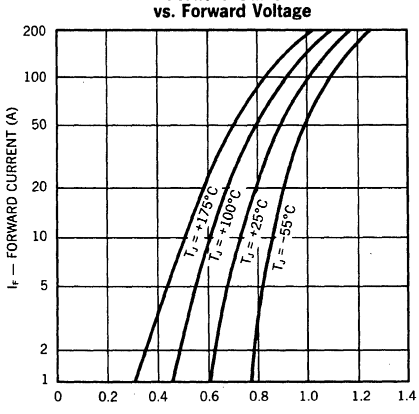
Output Current vs. Case Temperature



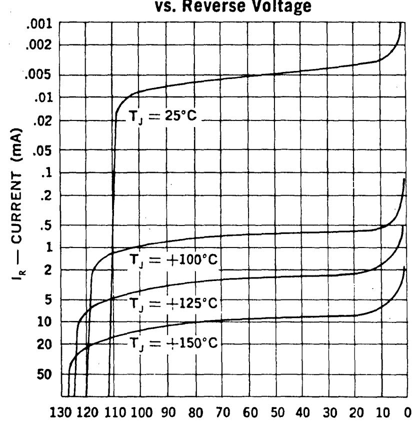
Peak Output Current vs. Case Temperature



Forward Current vs. Forward Voltage



Typical Reverse Current vs. Reverse Voltage



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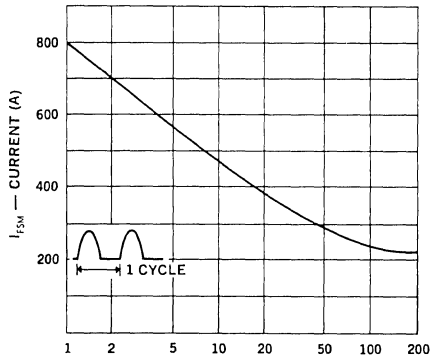
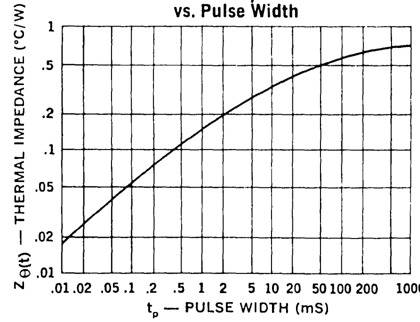
Maximum Forward Surge vs. Number of Cycles

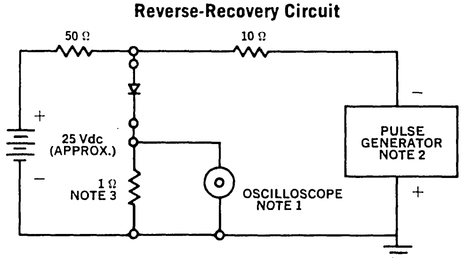


Thermal Impedance vs. Pulse Width



VI

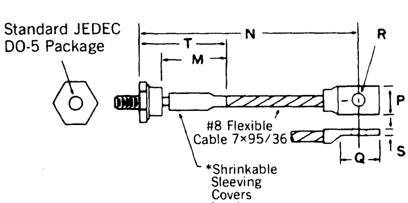
Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

MECHANICAL SPECIFICATIONS

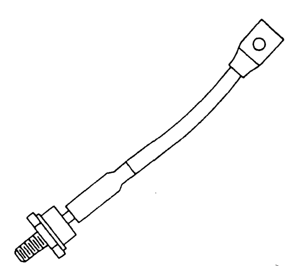
FLEXIBLE TOP LEAD (OPTIONAL)
Add an "F" Suffix to Part Number.



	INCHES	MILLIMETERS
M	.718 MAX.	18.24 MAX.
N	4.50 ± .250	114.3 ± 6.35
P	.525 MAX.	13.23 MAX.
Q	.675 ± .035	17.15 ± 0.89
R	.205 ± .005	5.21 ± 0.13
S	.075 ± .010	1.91 ± 0.25
T	1.125 MAX.	28.58 MAX.

*To 125°C (Ambient)

DO-5 with Flexible Lead



RECTIFIERS
High Efficiency, 50A

UES804–UES806

FEATURES
- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION
The UES804 is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage, UES804 .... 200V
Peak Inverse Voltage, UES805 .... 300V
Peak Inverse Voltage, UES806 .... 400V
Maximum Average D.C. Output Current @ $T_C = 100°C$ 50A
Surge Current, 8.3mSec 600A
Thermal Resistance, Junction to Case .... .8°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

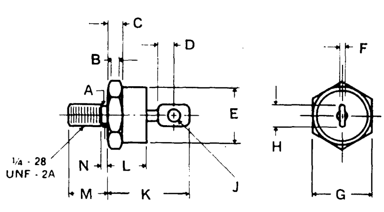
POWER CYCLING
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS
The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

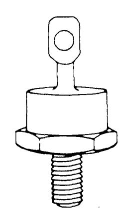
MECHANICAL SPECIFICATIONS

UES804-UES806



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



Notes:
1. Standard polarity is cathode-to-stud. For reverse polarity (anode-to-stud) add suffix "R", ie. UES804R.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds.
4. Angular orientation of terminal is undefined.

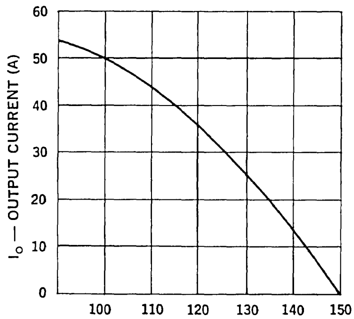
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage		Maximum Reverse Curent		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES804 UES805 UES806	200V 300V 400V	1.25V @ $I_F = 50A$ $t_p = 300\mu S$	1.15V @ $I_F = 50A$ $t_p = 300\mu S$	$70\mu A$	30mA	50nS

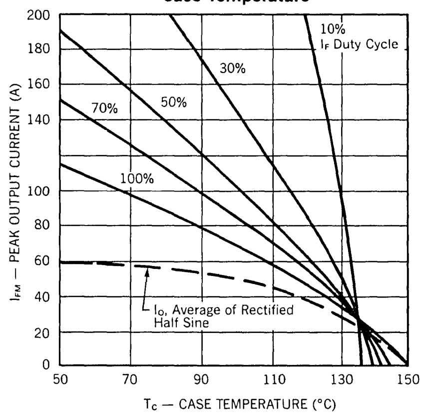
* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

VI

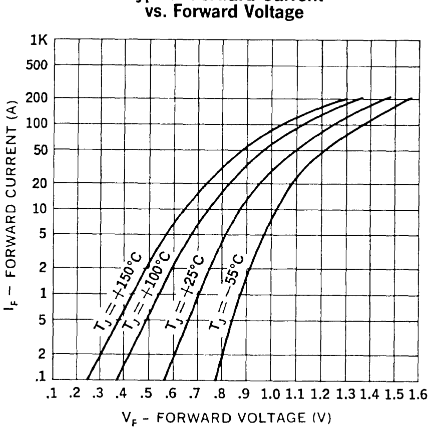
Output Current vs. Case Temperature



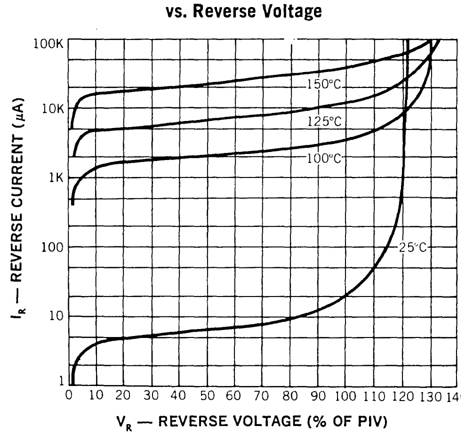
Peak Output Current vs. Case Temperature



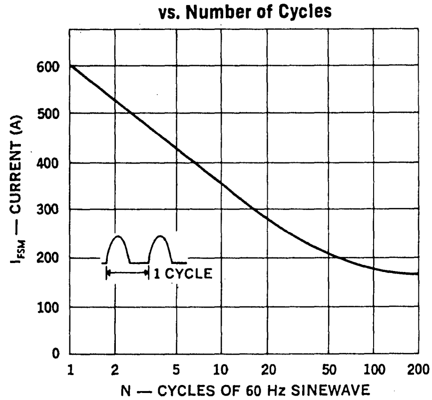
Typical Forward Current vs. Forward Voltage



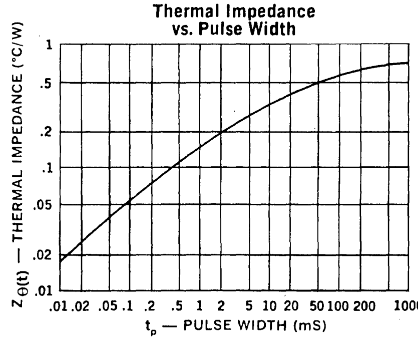
Typical Reverse Current vs. Reverse Voltage



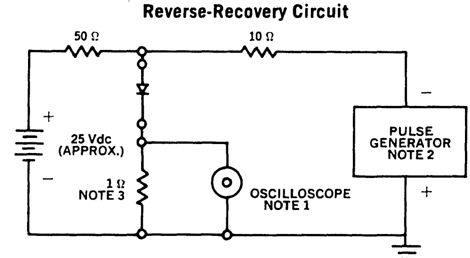
Maximum Forward Surge vs. Number of Cycles



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

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RECTIFIERS
High Efficiency, 1A

VI

FEATURES
- Very Fast Recovery Times
- Very Low Forward Voltage
- Small Size
- Convenient Package

DESCRIPTION
An axial leaded power rectifier useful in many switching applications. Particularly suited where very fast recovery and low forward voltage are required.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1001 .... 50V
Peak Inverse Voltage, UES1002 .... 100V
Peak Inverse Voltage, UES1003 .... 150V
Maximum Average D.C. Output Current at T_L = 75 °C, L = 3/8″ 1A
Non-Repetitive Surge Current at 8.3mS 30A
Thermal Resistance at L = 3/8″ .... 75 °C/W
Operating and Storage Temperature Range .... −55 °C +175 °C

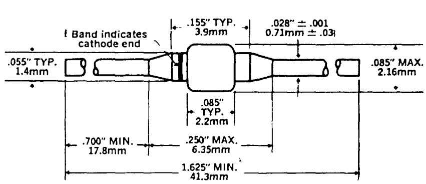
ELECTRICAL SPECIFICATIONS

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		T_J = 25°C	T_J = 100°C	@ T_J = 25°C	@ T_J = 100°C	
UES1001 UES1002 UES1003	50V 100V 150V	.975V @ 1A	.895V @ 1A	2μA	50μA	25nS

*Measured in circuit I_F = .5A, I_R = 1.0A, I_{REC} = .25A

MECHANICAL SPECIFICATIONS

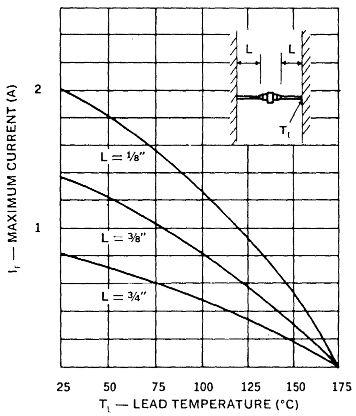
UES1001-UES1003



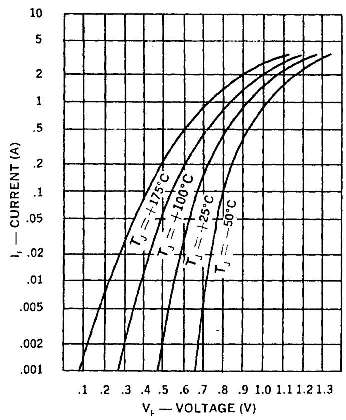
BODY A

UNITRODE

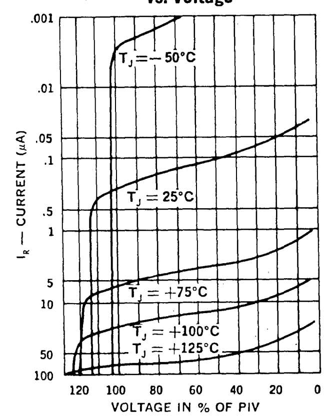
Output Current vs. Lead Temperature



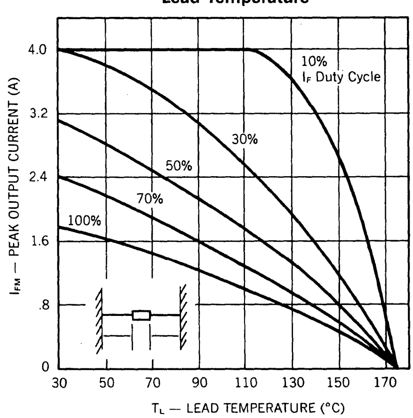
Typical Forward Current vs. Forward Voltage



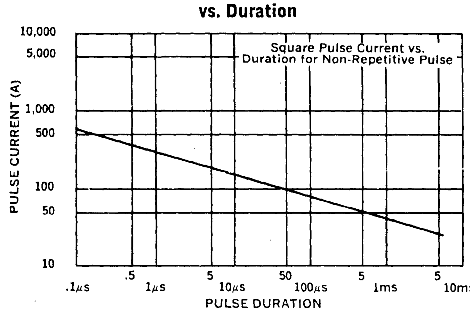
Typical Reverse Current vs. Voltage



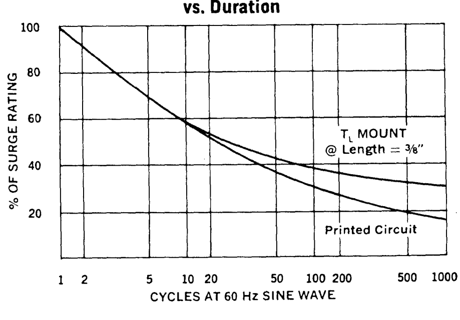
Peak Output Current vs. Lead Temperature



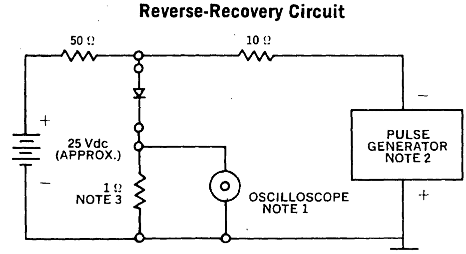
Forward Pulse Current vs. Duration



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time<3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time<8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 2.5A

UES1101 - UES1103

VI

FEATURES
- Very Fast Recovery Times
- Very Low Forward Voltage
- Small Size
- Convenient Package

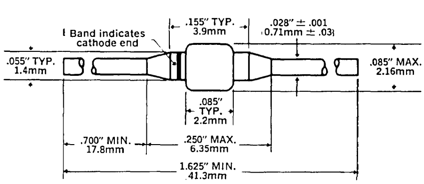
DESCRIPTION
An axial leaded power rectifier useful in many switching applications. Particularly suited where very fast recovery and low forward voltage are required.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1101	50V
Peak Inverse Voltage, UES1102	100V
Peak Inverse Voltage, UES1103	150V
Maximum Average D.C. Output Current at $T_L = 75°C$, L = 3/8"	2.5A
Non-Repetitive Surge Current at 8.3 ms	35A
Thermal Resistance at L = 3/8"	38°C/W
Operating and Storage Temperature Range	−55°C +175°C

MECHANICAL SPECIFICATIONS

UES1101-UES1103



BODY A

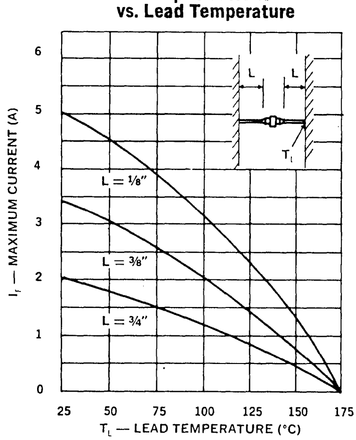
UNITRODE

ELECTRICAL SPECIFICATIONS

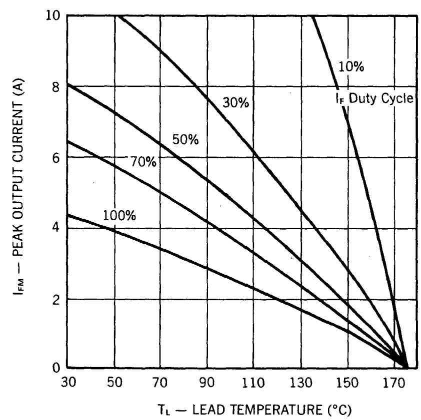
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_J = 25°C$	$T_J = 100°C$	$T_J = 25°C$	$T_J = 100°C$	
UES1101 UES1102 UES1103	50V 100V 150V	.975V @ 2A tp = 300μS	.895V @ 2A tp = 300μS	2μA	50μA	25nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

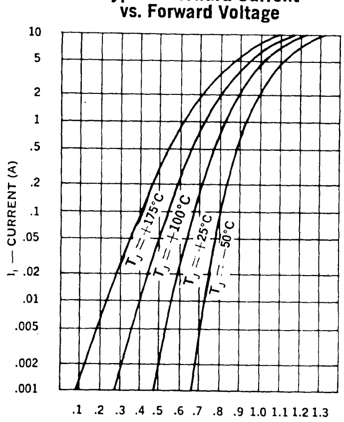
Output Current vs. Lead Temperature



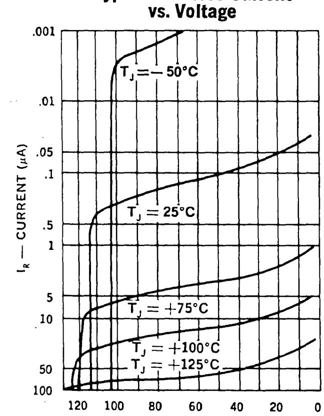
Peak Output Current vs. Lead Temperature

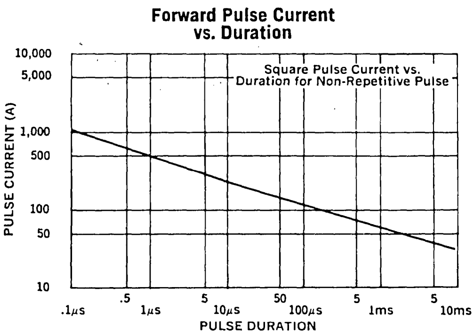


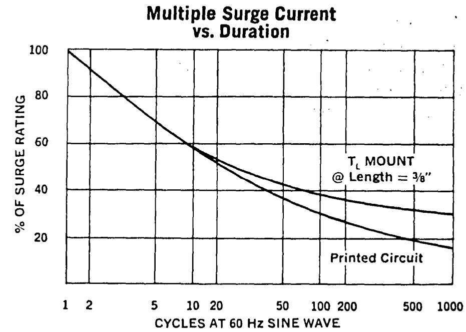
Typical Forward Current vs. Forward Voltage



Typical Reverse Current vs. Voltage

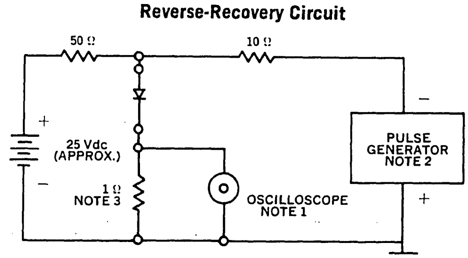






VI

Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

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RECTIFIERS
High Efficiency, 2A

FEATURES
- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- Small Size
- Convenient Package

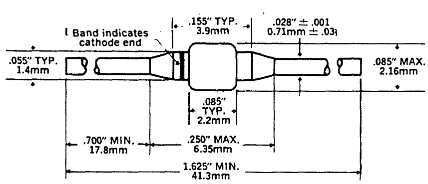
DESCRIPTION
The UES1104 series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1104	200V
Peak Inverse Voltage, UES1105	300V
Peak Inverse Voltage, UES1106	400V
Maximum Average D.C. Output Current, I_O	
@ T_A = 25°C (Free Air)	1A
@ T_L = 50°C, L= ⅜″	2A
Surge Current, 8.3mSec	20A
Thermal Resistance @ L = ⅜″	38°C/W
Operating and Storage Temperature Range	—55°C to +150°C

MECHANICAL SPECIFICATIONS

UES1104-UES1106



BODY A

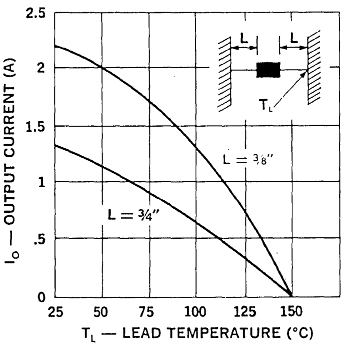
VI

ELECTRICAL SPECIFICATIONS

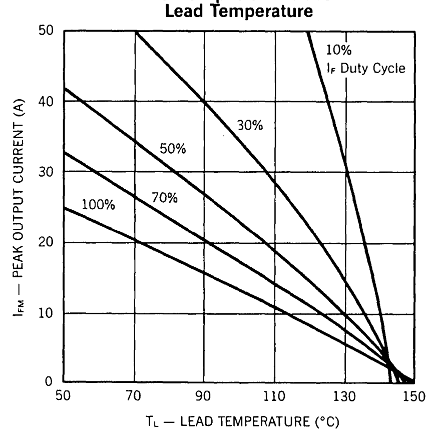
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current		Maximum Reverse Recovery Time*
		$T_J = 25°C$	$T_J = 100°C$	@ PIV, $T_J = 25°C$	$T_J = 100°C$	
UES1104 UES1105 UES1106	200V 300V 400V	1.25V @1A tp = 300μS	1.15V @1A tp = 300μS	10μA	200μA	50nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

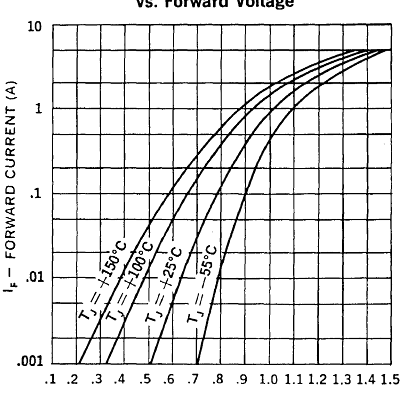
Output Current vs. Lead Temperature



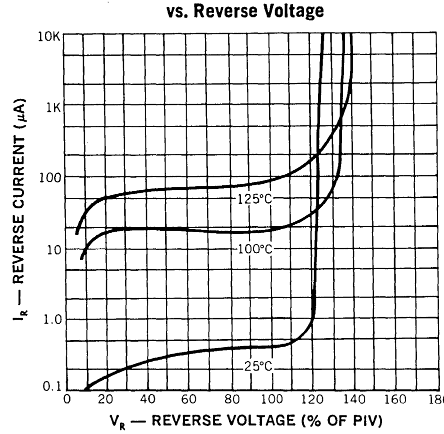
Peak Output Current vs. Lead Temperature



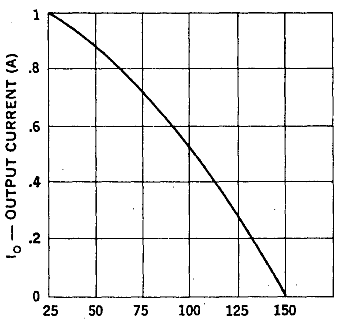
Typical Forward Current vs. Forward Voltage



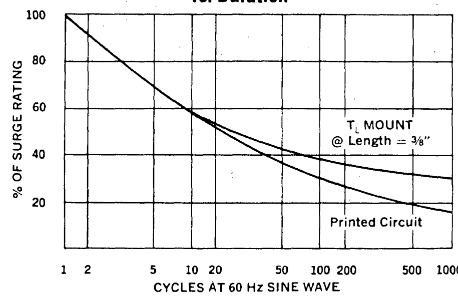
Typical Reverse Current vs. Reverse Voltage



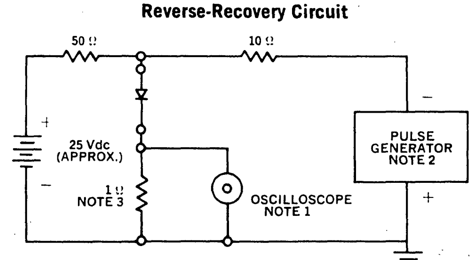
Output Current vs. Ambient Temperature



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

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RECTIFIERS
High Efficiency, 6A

UES1301-UES1303

FEATURES
- Very Low Forward Voltage
- Very Fast Recovery Times
- Small Size
- High Surge

DESCRIPTION
Now power rectifiers in axial leaded package to meet the most demanding switching applications. An industrial product with military reliability.

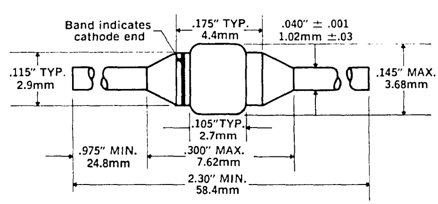
VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1301	50V
Peak Inverse Voltage, UES1302	100V
Peak Inverse Voltage, UES1303	150V
Maximum Average D.C. Output Current at $T_L = 75°C$, $L = 3/8''$	6.0A
Non-Repetitive Sinusoidal Surge Current at 8.3ms	125A
Thermal Resistance at $L = 3/8''$	20°C/W
Operating and Storage Temperature Range	−55°C to +175°C

MECHANICAL SPECIFICATIONS

UES1301-1303



BODY B

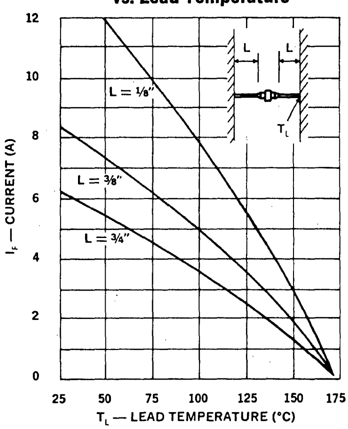
UNITRODE

ELECTRICAL SPECIFICATIONS

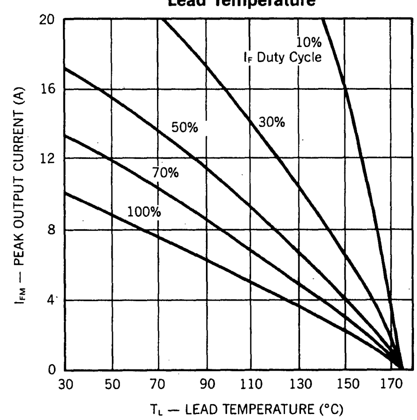
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_J = 25°C$	$T_J = 100°C$	$T_J = 25°C$	$T_J = 100°C$	
UES1301 UES1302 UES1303	50V 100V 150V	.925V @ 6A tp = 300μS	.850V @ 6A tp = 300μS	5μA	150μA	30nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

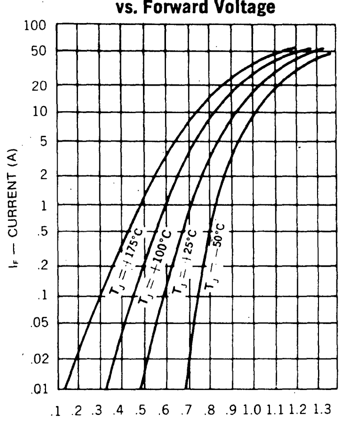
Output Current vs. Lead Temperature



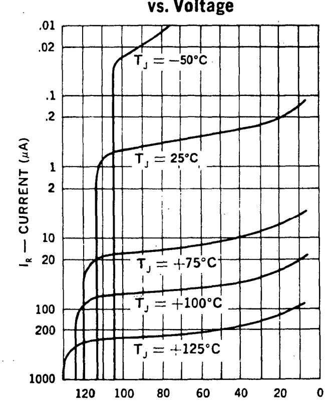
Peak Output Current vs. Lead Temperature



Typical Forward Current vs. Forward Voltage

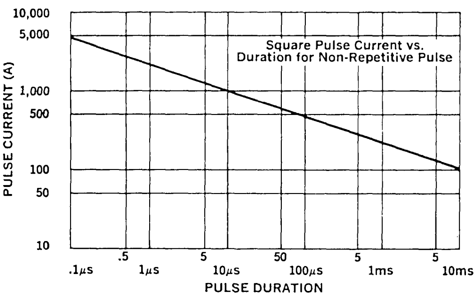


Typical Reverse Current vs. Voltage

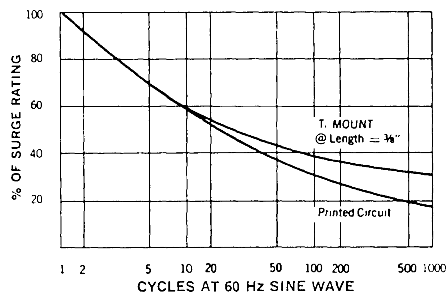


VI

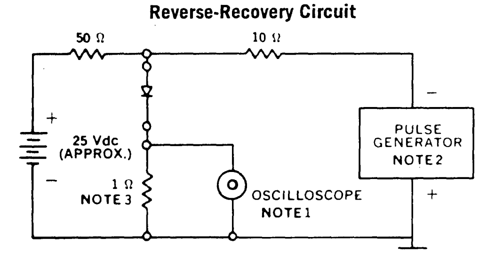
Forward Pulse Current vs. Duration



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 5A

UES1304–UES1306

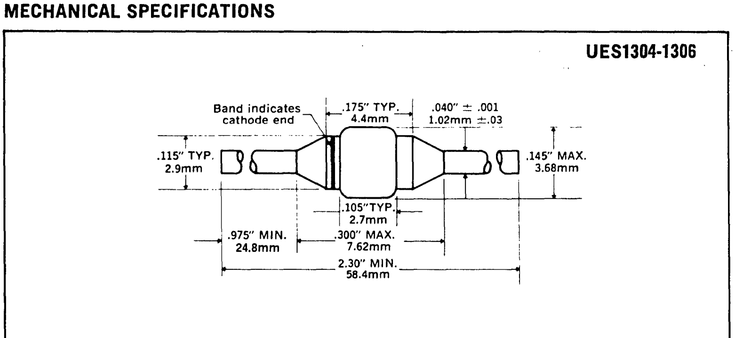
FEATURES
- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- Small Size
- High Surge

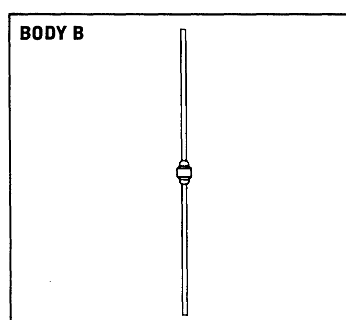
DESCRIPTION
The UES1304 series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1304	200V
Peak Inverse Voltage, UES1305	300V
Peak Inverse Voltage, UES1306	400V
Maximum Average D.C. Output Current, I_O	
@ $T_A = 25°C$ (Free Air)	3A
@ $T_L = 50°C$, L = ⅜"	5A
Surge Current, 8.3mSec	70A
Thermal Resistance @ L — ⅜"	20°C/W
Operating and Storage Temperature Range	—55°C to +150°C

MECHANICAL SPECIFICATIONS





4/79 (Rev. 1)

UNITRODE

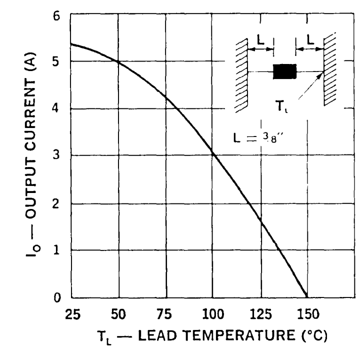
VI

ELECTRICAL SPECIFICATIONS

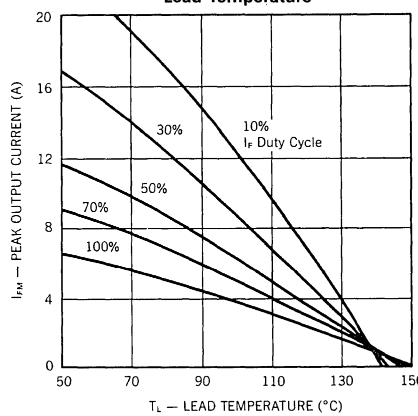
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current		Maximum Reverse Recovery Time*
		$T_J = 25°C$	$T_J = 100°C$	@ PIV, $T_J = 25°C$	$T_J = 100°C$	
UES1304 UES1305 UES1306	200V 300V 400V	1.25V @ 3A tp = 300μS	1.15V @ 3A tp = 300μS	20μA	500μA	50nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

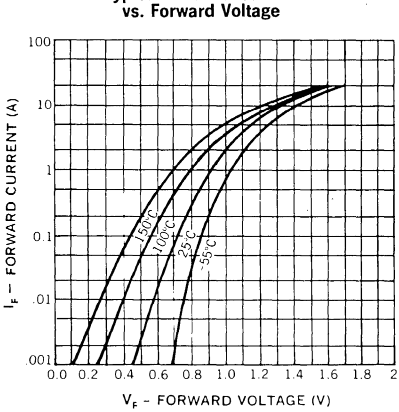
Output Current vs. Lead Temperature



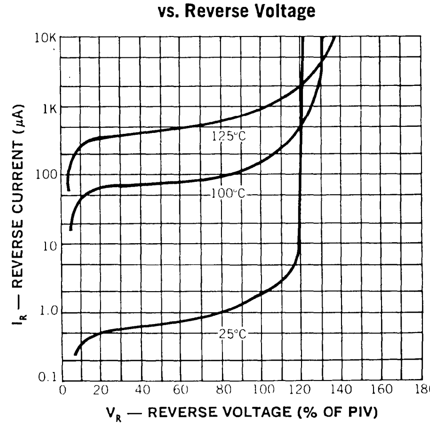
Peak Output Current vs. Lead Temperature



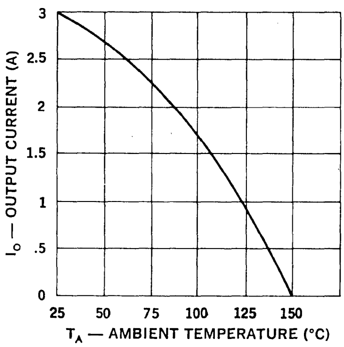
Typical Forward Current vs. Forward Voltage



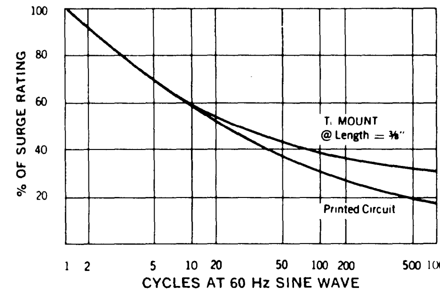
Typical Reverse Current vs. Reverse Voltage



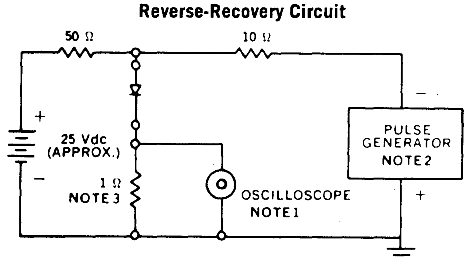
Output Current vs Ambient Temperature



Multiple Surge Current vs. Duration



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 8A

UES1401-UES1403

FEATURES
- Very Low Forward Voltage
- Very Fast Recovery Times
- Economical, Convenient Plastic Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION
The UES1401 Series, in a plastic package similar to the TO-220, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The very low forward voltage and very fast recovery time make them particularly suited for switching type power supplies.

VI

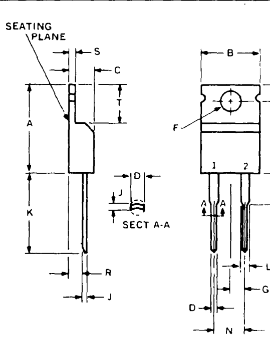
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES1401 .... 50V
Peak Inverse Voltage, UES1402 .... 100V
Peak Inverse Voltage, UES1403 .... 150V
Maximum Average D.C. Output Current
@ T_C = 125°C (Note 1) 8.0A
@ T_A = 25°C 3.0A
@ T_A = 25°C (Note 2) 8.0A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 80A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 2.5°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

Note 1. Above 100°C use the tab for electrical connection.
Note 2. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

MECHANICAL SPECIFICATIONS

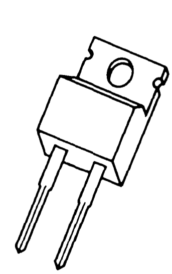
UES1401-1403



PIN 1. Cathode
2. Anode
Tab is connected to Cathode.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

SIMILAR TO TO-220

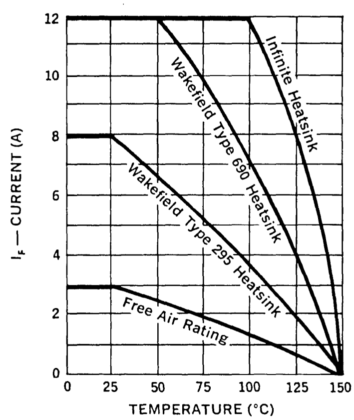


ELECTRICAL SPECIFICATIONS

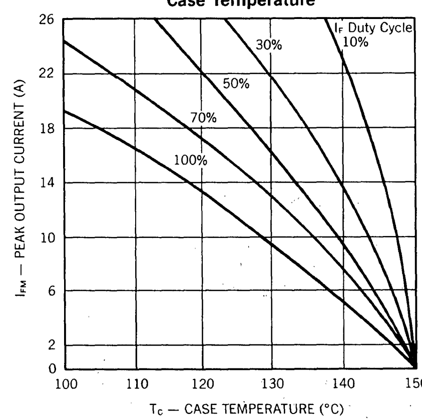
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current @ PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @ 1A t_r = 8nS
		$T_J = 25°C$	$T_J = 100°C$	$T_J = 25°C$	$T_J = 100°C$		
UES1401 UES1402 UES1403	50V 100V 150V	0.9V @ 4A 0.975V @ 8A tp = 300μS	0.8V @ 4A 0.895V @ 8A	5μA	150μA	35nS	1.4V

*Measured in circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

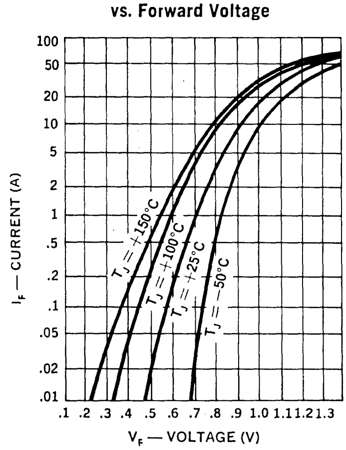
Output Current vs. Temperature



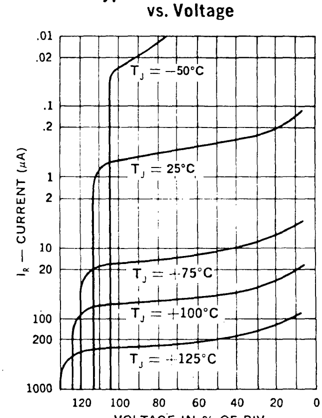
Peak Output Current vs. Case Temperature



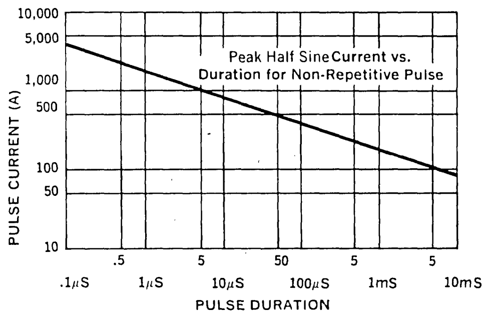
Typical Forward Current vs. Forward Voltage



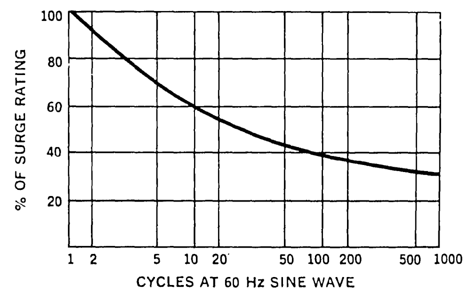
Typical Reverse Current vs. Voltage



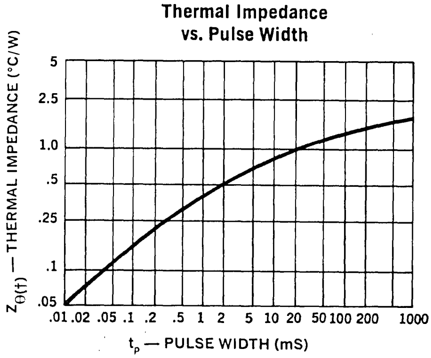
Forward Pulse Current vs. Duration



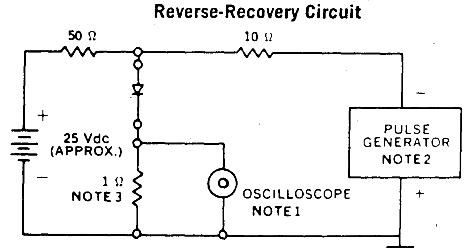
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 16A Center-Tap

FEATURES

- Very Low Forward Voltage
- Very Fast Recovery Times
- Economical, Convenient TO-220AB Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION

The UES2401 Series in the economical, convenient TO-220AB package, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The series combines two high efficiency devices into one package, simplifying installation, reducing heatsink requirements and the need to purchase matched components.

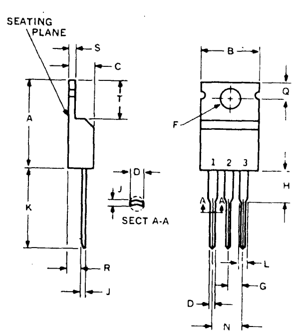
ABSOLUTE MAXIMUM RATINGS

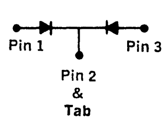
Peak Inverse Voltage, UES2401 .... 50V
Peak Inverse Voltage, UES2402 .... 100V
Peak Inverse Voltage, UES2403 .... 150V
Maximum Average D.C. Output Current
@ T_C = 125°C (Note 1) 16A
@ T_A = 25°C 3A
@ T_A = 25°C (Note 2) 10A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 80A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 1.75°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

Note 1. Above 8A use the tab for electrical connection.
Note 2. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

MECHANICAL SPECIFICATIONS

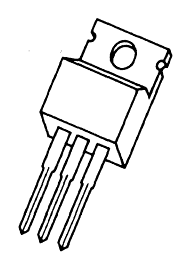
UES2401-2403





DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB

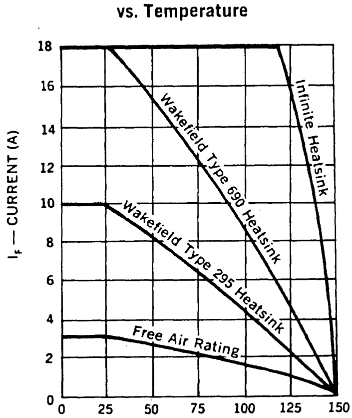


ELECTRICAL SPECIFICATIONS

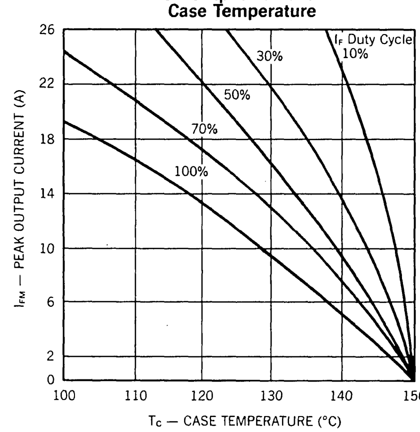
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current @ PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @ 1A t_r = 8nS
		T_J = 25°C	T_J = 100°C	T_J = 25°C	T_J = 100°C		
UES2401 UES2402 UES2403	50V 100V 150V	0.9V @ 4A 0.975V @ 8A tp = 300μS	0.8V @ 4A 0.895V @ 8A	5μA	150μA	35nS	1.4V

*Measured in circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

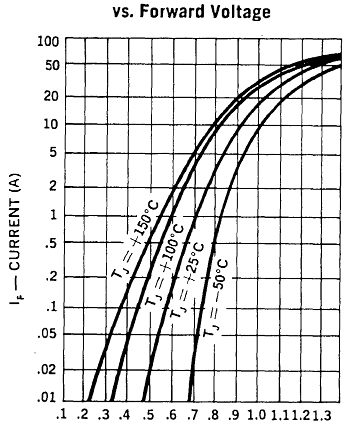
Output Current vs. Temperature



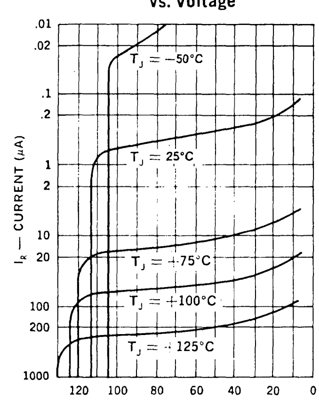
Peak Output Current vs. Case Temperature



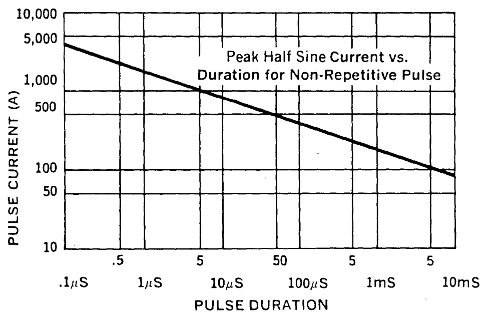
Typical Forward Current vs. Forward Voltage



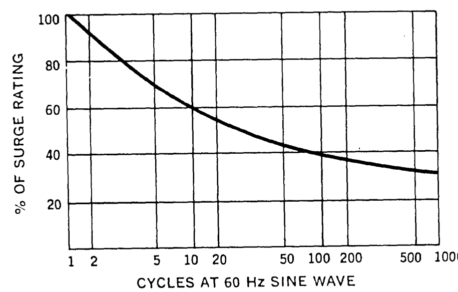
Typical Reverse Current vs. Voltage



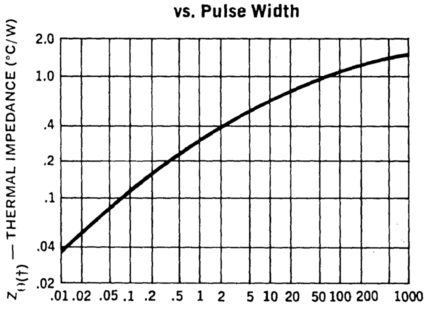
Forward Pulse Current vs. Duration



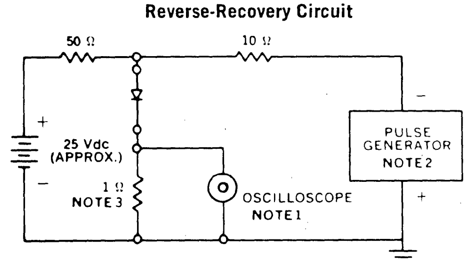
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 30A Center-Tap

UES2601–UES2603

FEATURES

- Very Low Forward Voltage
- Very Fast Switching Speed
- Convenient Package
- High Surge
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION

This series combines two high efficiency devices into one package, simplifying installation, reducing heat sink requirements and the need to purchase matched components.

VI

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES2601 .... 50V
Peak Inverse Voltage, UES2602 .... 100V
Peak Inverse Voltage, UES2603 .... 150V
Maximum Average D.C. Output Current at $T_C = 100°C$ 30A
Non-Repetitive Sinusoidal Surge Current 8.3 ms 400A
Thermal Resistance, Junction to Case .... 1°C/W
Operating and Storage Temperature Range .... –55°C to +175°C

POWER CYCLING

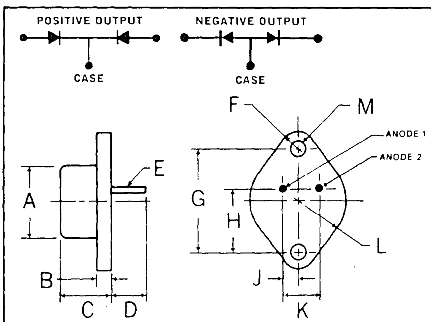
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS

The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

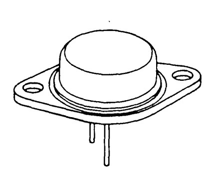
MECHANICAL SPECIFICATIONS



UES2601-UES2603

	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



Note:
Standard polarity is positive output.
For reverse polarity (negative output) add suffix "R", ie. UES2601R.

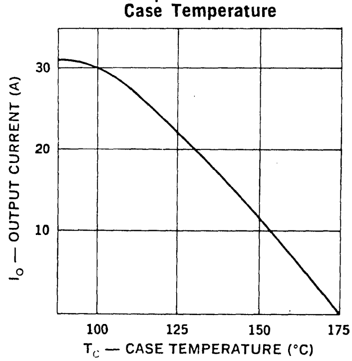
UNITRODE

ELECTRICAL SPECIFICATIONS

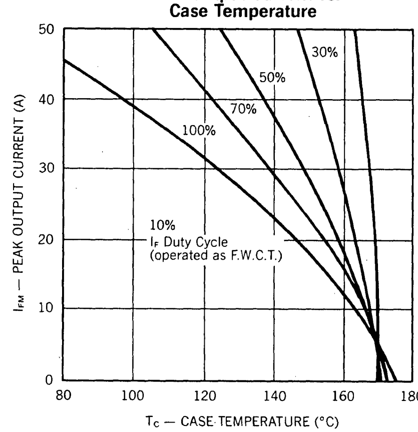
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES2601 UES2602 UES2603	50V 100V 150V	.930V @ 15A $t_p = 300\mu S$	.825V @ 15A $t_p = 300\mu S$	20μA	4mA	35nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

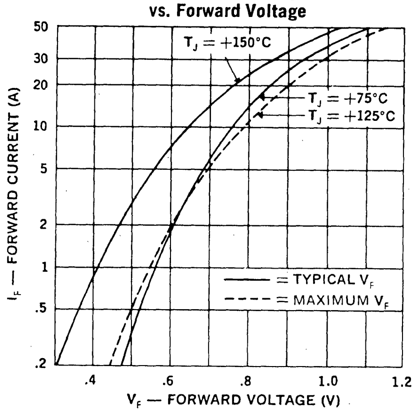
Output Current vs. Case Temperature



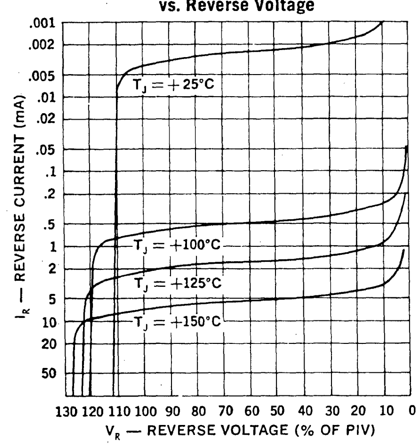
Peak Output Current vs. Case Temperature



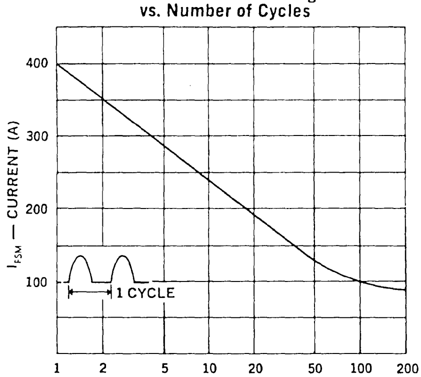
Forward Current vs. Forward Voltage



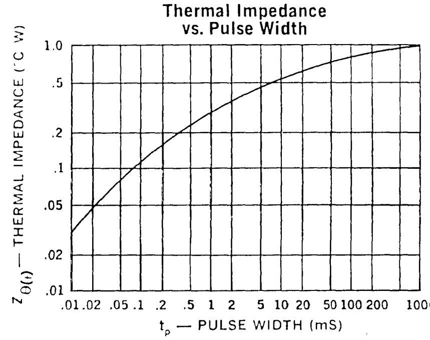
Typical Reverse Current vs. Reverse Voltage



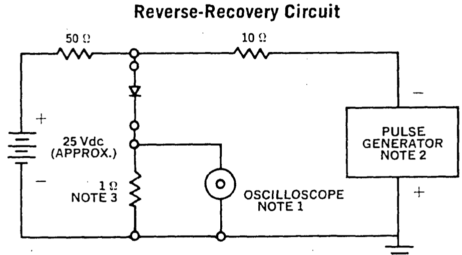
Maximum Forward Surge
vs. Number of Cycles



Thermal Impedance
vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 30A Center-Tap

FEATURES
- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- Low Profile Package
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION

The UES2604 series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.

This series combines two high efficiency devices into one package, simplifying installation, reducing heat sink requirements and the need to purchase matched components.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES2604	200V
Peak Inverse Voltage, UES2605	300V
Peak Inverse Voltage, UES2606	400V
Maximum Average D.C. Output Current @ $T_C = 100°C$	30A
Surge Current, 8.3mSec	300A
Thermal Resistance, Junction to Case	1°C/W
Operating and Storage Temperature Range	—55°C to +150°C

POWER CYCLING

These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

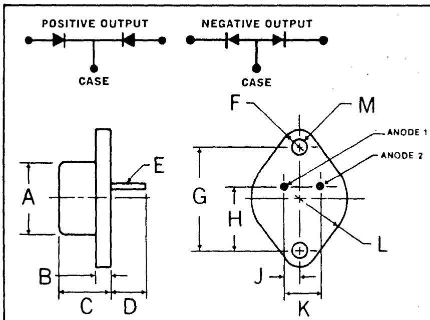
In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS

The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

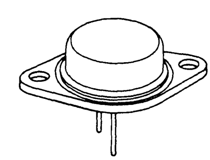
MECHANICAL SPECIFICATIONS

UES2604-UES2606



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



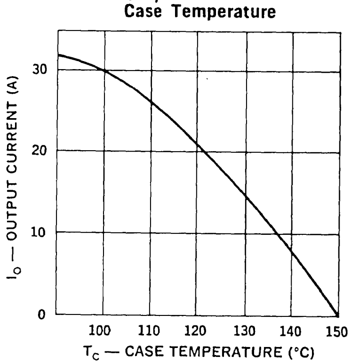
Note:
Standard polarity is positive output.
For reverse polarity (negative output) add suffix "R", ie. UES2604R.

ELECTRICAL SPECIFICATIONS, PER LEG

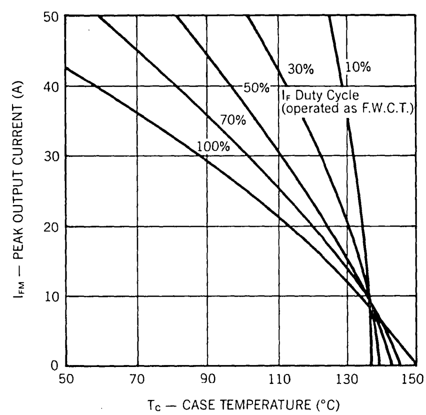
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES2604 UES2605 UES2606	200V 300V 400V	1.25V @ 15A $t_p = 300\mu S$	1.15V @ 15A $t_p = 300\mu S$	50μA	10mA	50nS

*Measured in circuit $I_F = .5A$, $I_R = 1A$, $I_{REC} = .25A$

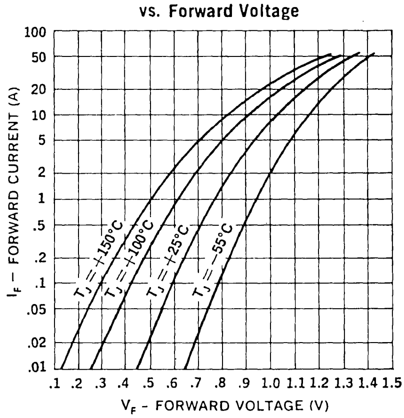
Output Current vs. Case Temperature



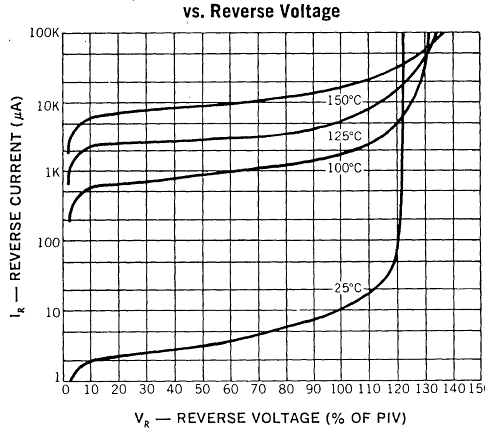
Peak Output Current vs. Case Temperature

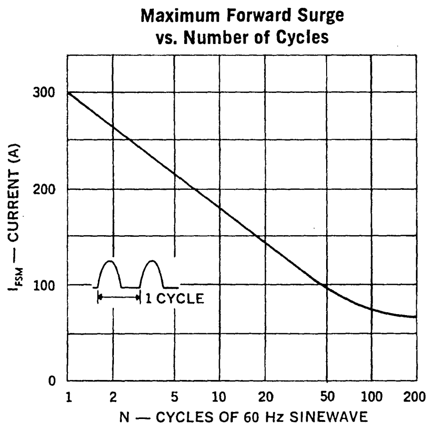


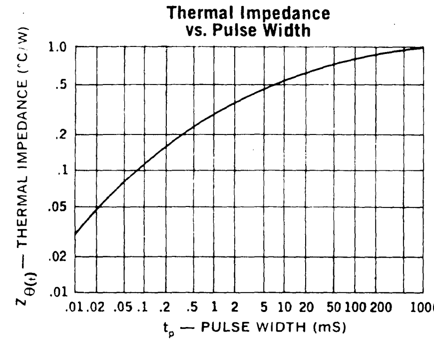
Forward Current vs. Forward Voltage

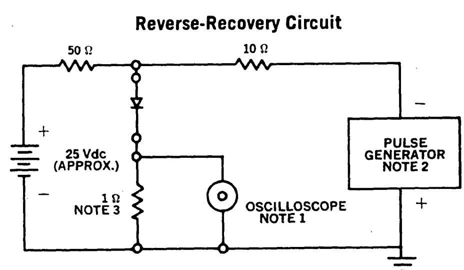


Typical Reverse Current vs. Reverse Voltage









NOTES:

1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

Radiation Tolerant, 1 Amp-2 Amp

UR105-UR125
UR205-UR225

FEATURES

- Radiation Tolerant: to 10^{16} NVT
- Continuous Rating: to 2A
- Controlled Avalanche
- Surge Rating: to 25A
- Miniature Package

DESCRIPTION

These devices are particularly suited to applications where radiation is present. These units have unique ability to withstand high levels of neutron, gamma and electron radiation.

VI

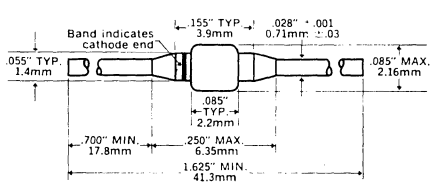
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1 Amp Series	2 Amp Series
50V	UR105	UR205
100V	UR110	UR210
150V	UR115	UR215
200V	UR120	UR220
250V	UR125	UR225

	1 AMP SERIES	2 AMP SERIES
Maximum Average D.C. Output Current		
@ $T_A = 25°C$	1A	2A
@ $T_A = 100°C$	0.5A	1A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	20A	25A
Operating Temperature Range	−195°C to +175°C	
Storage Temperature Range	−195°C to +200°C	
Thermal Resistance	See Lead Temperature Derating Curve	

MECHANICAL SPECIFICATIONS

UR105-UR125 UR205-UR225



Part Identification: White band indicates "UR." Part number printed on body.

Polarity: Denoted by white band.

Weight: 0.26 grams, typical.

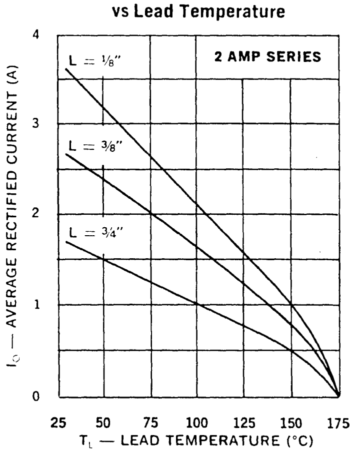
BODY A

UNITRODE

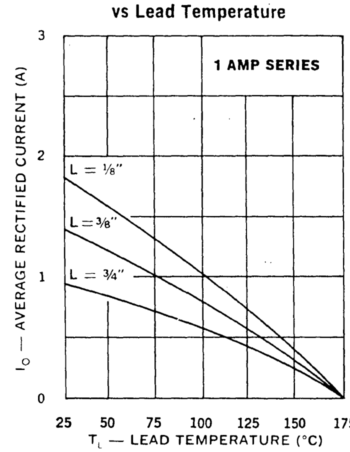
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV 25°C	Maximum Leakage Current @ PIV 100°C	Maximum Radiation Tolerance
UR205	50V	1.0V @ 1A	3μA	50μA	10^{16} NVT
UR210	100V				10^{16}
UR215	150V				10^{15}
UR220	200V				10^{14}
UR225	250V				10^{14}
UR105	50V	1.0V @ 0.5A	3μA	50μA	10^{16}
UR110	100V				10^{16}
UR115	150V				10^{15}
UR120	200V				10^{14}
UR125	250V				10^{14}

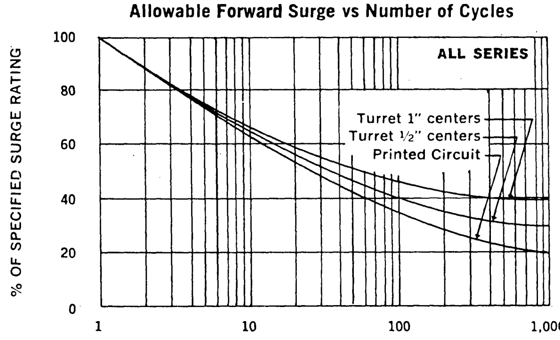
Maximum Current vs Lead Temperature



Maximum Current vs Lead Temperature



Allowable Forward Surge vs Number of Cycles



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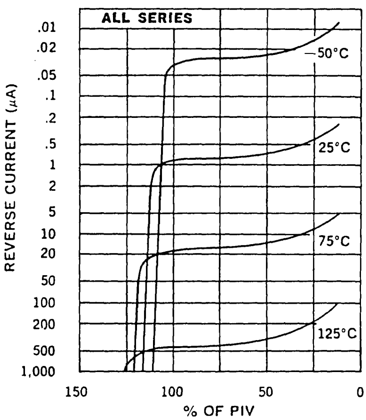
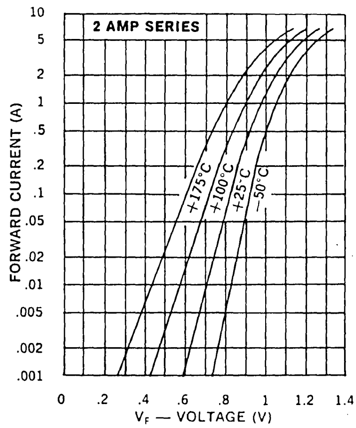
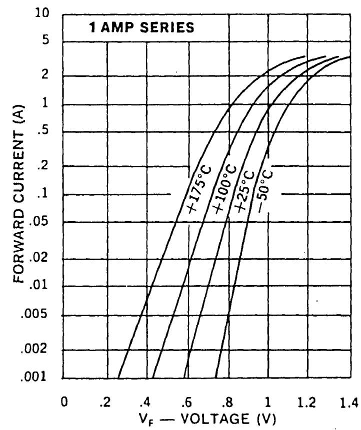
Typical Reverse Current vs PIV



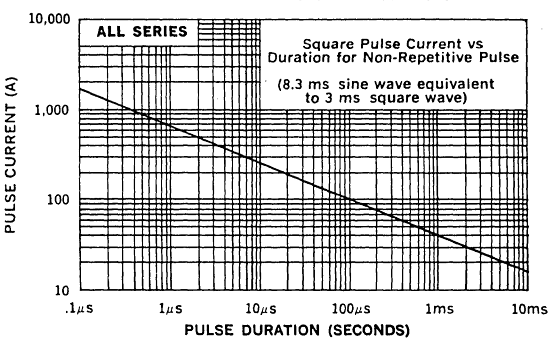
Typical Forward Current vs Forward Voltage



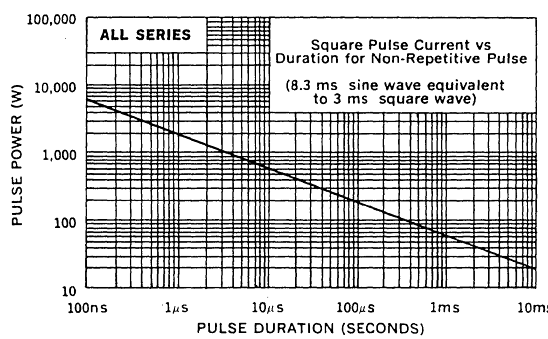
Typical Forward Current vs Forward Voltage



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



VI

DUAL POWER SCHOTTKY RECTIFIERS

60A Pk, 45V

USD320C
USD335C
USD345C

FEATURES

- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (TO-3)
- High Efficiency for Low Voltage Supplies
- 45V Blocking @ Rated T_{jmax}
- 50V Repetitive Surge Voltage
- Dual Schottky Rectifier in a Single Package

DESCRIPTION

The USD300C series has two Schottky barriers arranged in a common cathode configuration and is ideally suited for a full wave output rectifier in low voltage switching power supplies.

ABSOLUTE MAXIMUM RATINGS (Total for USD300C Series)	USD320C	USD335C	USD345C
Average Rectified Forward Current, I_O @ T_C = 100°C		30A	

ABSOLUTE MAXIMUM RATINGS (Per Diode)	USD320C	USD335C	USD345C
Working Peak Reverse Voltage V_{RWM}	20V	35V	45V
DC Blocking Voltage, V_R	20V	35V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	54V
Average Rectified Forward Current, I_O		30A in full wave configuration*	
Non-repetitive Peak Surge current (8.3 mS), I_{FSM}		500A	
Peak Reverse Transient Current, I_{RM}		2A	
Storage Temperature Range, T_{stg}		−55°C to +200°C	
Peak Operating Junction Temperature, $T_{j\,max}$		175°C	
Thermal Resistance, Junction to Case, $R_{\theta JC}$		1.4°C/W	

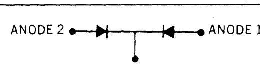
* Each Anode Pin Limited to 18A Average.
Package Capability 30A Average.

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

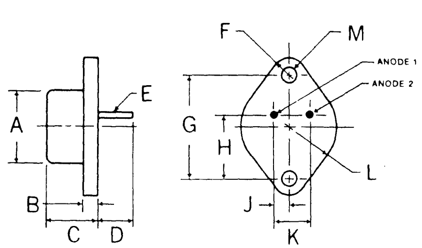
Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	10 50	mA mA	T_C = 25°C, V_R = V_{RWM} T_C = 125°C Pulse Width = 400μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	V_F	0.57 0.66 0.60	V V V	i_F = 10A, T_C = 25°C i_F = 20A, T_C = 25°C i_F = 20A, T_C = 125°C Pulse Width = 300μS Duty Cycle = 1 percent
Capacitance	C_t	2000	pF	V_R = 5.0V
Voltage Rate of Change	dv/dt	1000	v/μS	V_R = V_{RWM}

MECHANICAL SPECIFICATIONS

NOTE:
Leads may be soldered to within 1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

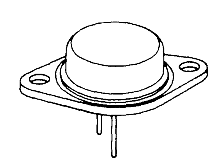


USD300C SERIES

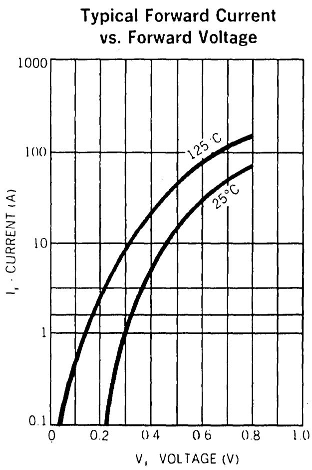


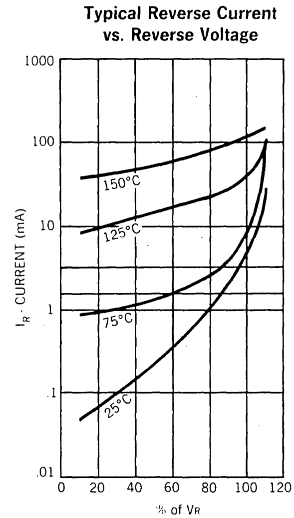
	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

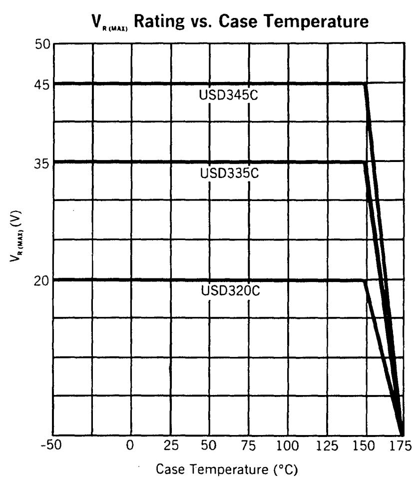
TO-3



Notes: All metal surfaces tin plated.


Typical Forward Current
vs. Forward Voltage
1000
100
10
1
0.1
0
0.2
0.4
0.6
0.8
1.0
125°C
25°C
I_F - CURRENT (A)
V_F VOLTAGE (V)


Typical Reverse Current
vs. Reverse Voltage
1000
100
10
1
.1
.01
0
20
40
60
80
100
120
150°C
125°C
75°C
25°C
I_R - CURRENT (mA)
% of VR


$V_{R(MAX)}$ Rating vs. Case Temperature
50
45
35
20
-50
0
25
50
75
100
125
150
175
USD345C
USD335C
USD320C
$V_{R(MAX)}$ (V)
Case Temperature (°C)

POWER SCHOTTKY RECTIFIERS

80A Pk, 45V

USD420
USD435
USD445

FEATURES

- Very Low Forward Voltage
- Low Recovered Charge
- Rugged Package Design (DO-4)
- High Efficiency for Low Voltage Supplies
- Dual Schottky Rectifiers in a Single Package
- 45V Blocking @ Rated T_{jmax}
- 50V Repetitive Surge Voltage

DESCRIPTION

The USD400 series has a Schottky barrier junction and is ideally suited for output rectifiers and catch diodes in low voltage power supplies. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

ABSOLUTE MAXIMUM RATINGS

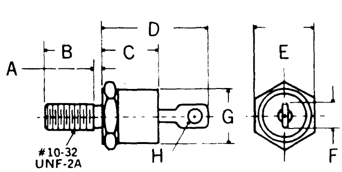
	USD420	USD435	USD445
Working Peak Reverse Voltage V_{RWM}	20V	35V	45V
DC Blocking Voltage, V_R	20V	35V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	54V
Average Rectified Forward Current, I_O @ T_C = 115°C		40A	
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20 KHz, 50 percent Duty cycle), I_{FRM} @ T_C = 115°C		80A	
Non-repetitive Peak Surge current (8.3 mS), I_{FSM}		700A	
Peak Reverse Transient Current, I_{RM}		2A	
Storage Temperature Range, T_{stg}		−55°C to +200°C	
Peak Operating Junction Temperature, $T_{j\,max}$		175°C	
Thermal Resistance, Junction to Case, $R_{\theta JC}$		1.6°C/W	

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	10 50	mA mA	T_C = 25°C, V_R = V_{RWM} T_C = 125°C Pulse Width = 400μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	V_F	0.47 0.63 0.55	V V V	i_F = 5A, T_C = 25°C i_F = 30A, T_C = 25°C i_F = 30A, T_C = 125°C Pulse Width = 300μS Duty Cycle = 1 percent
Capacitance	C_t	2000	pF	V_R = 5.0V
Voltage Rate of Change	dv/dt	1000	v/μs	V_R = V_{RWM}

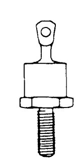
MECHANICAL SPECIFICATIONS

USD400 SERIES



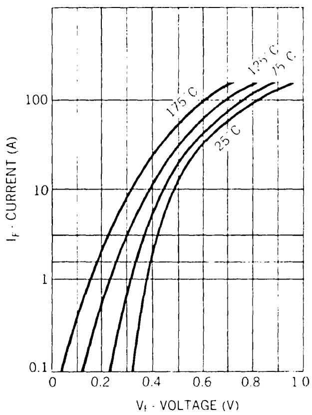
	ins.	mm
A	.078 MAX.	1.98 MAX.
B	.437 ± .015	11.10 ±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430 ± .010	10.92 ± 0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-4

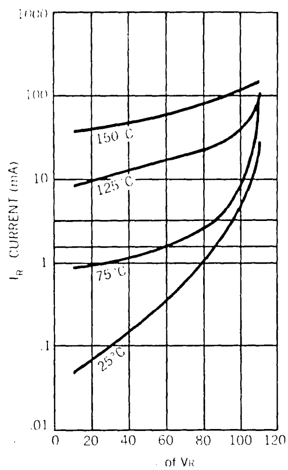


Notes:
1. Cathode is stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 10 inch pounds.
4. Angular orientation of terminal is undefined.

Typical Forward Current vs. Forward Voltage

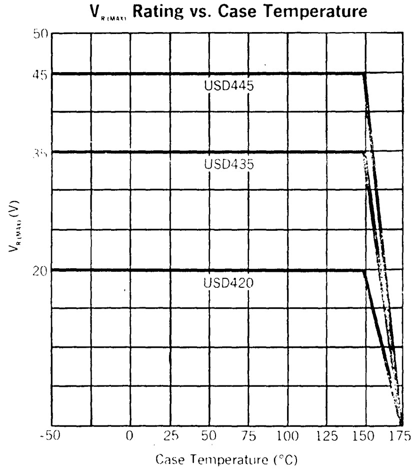


Typical Reverse Current vs. Reverse Voltage



VI

$V_{R(MAX)}$ Rating vs. Case Temperature



POWER SCHOTTKY RECTIFIERS

150 Amp Pk, Up to 45V

USD520
USD535
USD545

FEATURES

- Very Low Forward Voltage (0.6V at 60A, 125°C)
- Low Recovered Charge
- Rugged Package Design (DO-5)
- High Efficiency for Low Voltage Supplies
- Low Thermal Resistance (0.8°C/W)
- High Surge Current (1000A)
- Low Reverse Current (<50mA at rated V_R at 125°C)
- Available with Flexible Top Lead

DESCRIPTION

This series of Schottky barrier power rectifiers is ideally suited for output rectifiers and catch diodes in low voltage power supplies. The Unitrode high conductivity design, using a heavy copper top post and 4 point crimp, ensures cool thermal operation and low dynamic impedance. Rugged design absorbs stress that can damage glass-to-metal seal during installation and use.

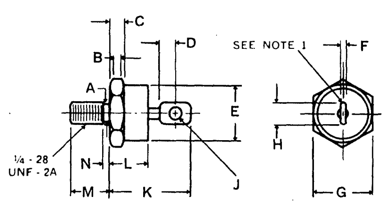
ABSOLUTE MAXIMUM RATINGS

	USD520	USD535	USD545
Working Peak Reverse Voltage, V_{RWM}	20V	35V	45V
DC Blocking Voltage, V_R	20V	35V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	54V

Peak Repetitive Forward Current
(Rated V_R, Square Wave, 20 KHz,
50 percent Duty Cycle), I_{FRM} .... 150A (at T_C = 115°C)
Average Rectified Forward Current, $I_{F(AV)}$ .... 75A (at T_C = 115°C)
Non-repetitive Peak Surge Current (8.3mS), I_{FSM} 1000A
Peak Reverse Transient Current, I_{RM} 2A
Storage Temperature Range, T_{Stg} .... −55°C to +200°C
Operating Junction Temperature, T_j .... +175°C
Thermal Resistance Junction-to-Case, $R_{\theta JC}$ .... 0.8°C/W

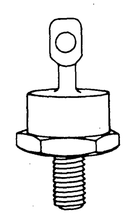
MECHANICAL SPECIFICATIONS

USD520
USD535
USD545



	ins.	mm
A	.225 ± .005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



Notes:
1. Cathode is stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds (35 kg. cm).
4. Angular orientation of terminal is undefined.

UNITRODE

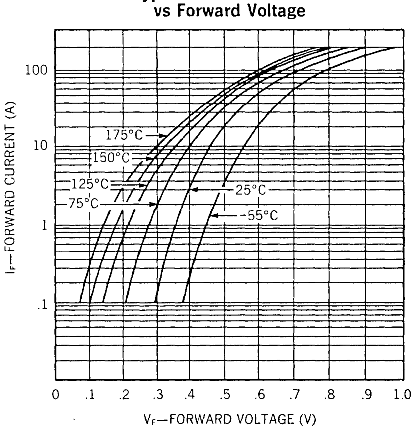
4/82

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

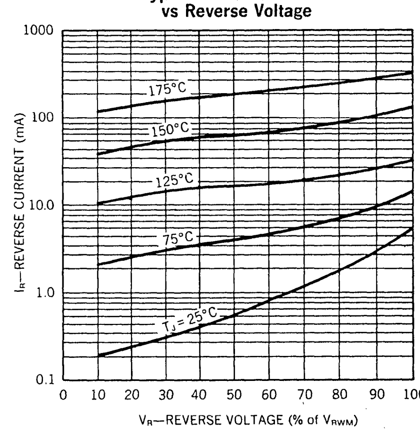
Characteristic	Symbol	Limit	Units	Conditions
Maximum Instantaneous Reverse Current	i_R	20 50	mA mA	$V_R = V_{RWM}$ T_C = 125°C Pulse Width = 300μs, Duty Cycle = 1 percent
Maximum Instantaneous Forward Voltage	v_F	0.50 0.68 0.60	V V V	i_F = 10A, T_C = 25°C i_F = 60A, T_C = 25°C i_F = 60A, T_C = 125°C
Flexible Top Lead Option	v_F	0.63	V	
Maximum Capacitance	C_t	4000	pF	V_R = 5.0V
Maximum Voltage Rate of Change	dv/dt	700	V/μS	v_R = rated

VI

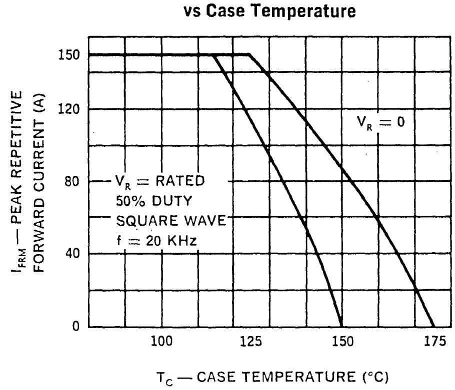
Typical Forward Current vs Forward Voltage



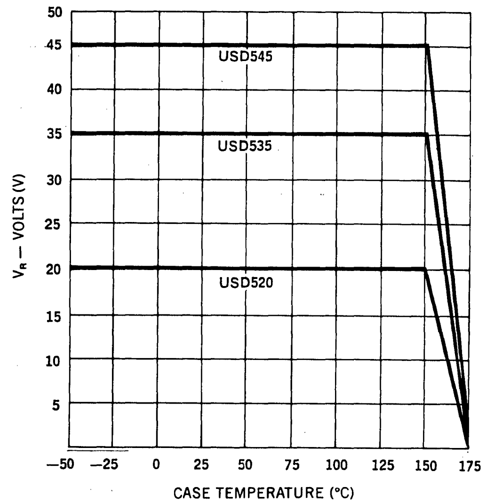
Typical Reverse Current vs Reverse Voltage



Maximum Current vs Case Temperature



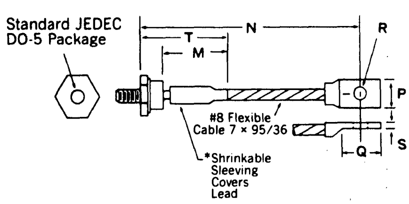
$V_{R(MAX)}$ Rating vs Case Temperature



MECHANICAL SPECIFICATIONS

FLEXIBLE TOP LEAD (OPTIONAL)
Add an "F" Suffix to Part Number.

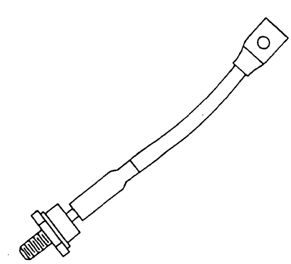
USD520F
USD535F
USD545F



	INCHES	MILLIMETERS
M	.718 MAX.	18.24 MAX.
N	4.50 ± .250	114.3 ± 6.35
P	.525 MAX.	13.23 MAX.
Q	.675 ± .035	17.15 ± 0.89
R	.205 ± .005	5.21 ± 0.13
S	.075 ± .010	1.91 ± 0.25
T	1.125 MAX.	28.58 MAX.

*To 125°C (Ambient)

DO-5 with Flexible Lead



Note: Consult Factory for Non-standard Lead Lengths.

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POWER SCHOTTKY RECTIFIERS
150A Pk, 45V

USD545HR2

VI

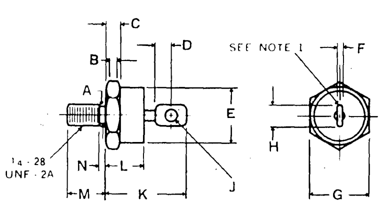
FEATURES
- Very Low Forward (0.6V at 75A, 125°C)
- High Reverse Surge Voltage (60V)
- Low Recovered Charge
- Rugged Package Design (DO-5)
- High Efficiency for Low Voltage Supplies
- Low Thermal Resistance (0.8° C/W)
- High Surge Current (1000A)
- Low Reverse Current (<50mA at rated V_R at 125°C)
- High Reliability Screening

DESCRIPTION
The USD545 Schottky barrier power rectifier is ideally suited for output rectifiers and catch diodes in low voltage power supplies. Unitrode semiconductors are inherently high-reliability devices; however, for those users who want the ultimate assurance of reliability, we offer the USD545 Schottky with 100% HR-SH screening as described elsewhere within this data sheet.

ABSOLUTE MAXIMUM RATINGS
Working Peak Reverse Voltage V_{RWM} 45V
DC Blocking Voltage, V_R 45V
Peak Repetitive Transient Voltage, V_{RSM} 60V
Peak Repetitive Forward Current
(Rated V_R, Square Wave, 20KHz,
50 percent Duty Cycle), I_{FRM} .... 150A (at T_C = 115°C)
Average Rectified Forward Current, $I_{F(AV)}$ .... 75A (at T_C = 115°C)
Non-repetitive Peak Surge Current (8.3mS), I_{FSM} 1000A
Peak Reverse Surge Current, I_{RM} 2A
Storage Temperature Range, T_{Stg} .... −55°C to +200°C
Operating Junction Temperature, T_j .... +175°C
Thermal Resistance Junction-to-Case, $R_{\theta JC}$ .... 0.8°C/W

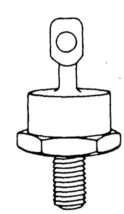
MECHANICAL SPECIFICATIONS

USD545HR2



	ins.	mm
A	.225 ± 005	5.72 ± 0.13
B	.060 MIN.	1.52 MIN.
C	.156 ± .020	3.96 ± 0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	677 ± .010	17.20 ± 0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438 ± .015	11.13 ± 0.38
N	.078 MAX.	1.98 MAX.

DO-5



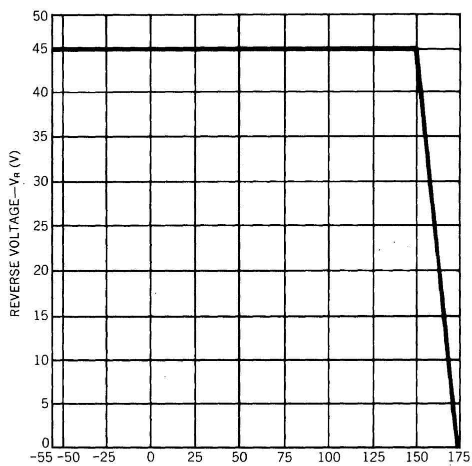
Notes:
1. Cathode is stud.
2. All metal surfaces tin plated.
3. Maximum unlubricated stud torque: 30 inch pounds (35 kg. cm).
4. Angular orientation of terminal is undefined.

ELECTRICAL CHARACTERISTICS (T_{CASE} =25°C)

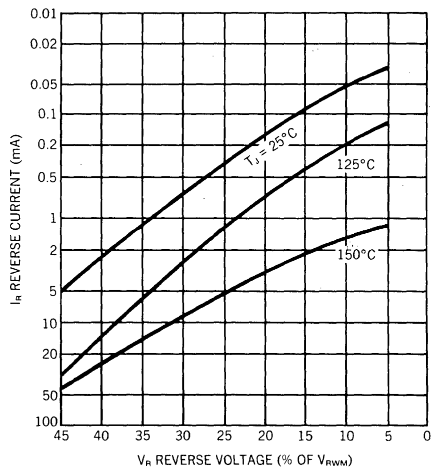
Characteristic	Symbol	Max.	Units	Conditions
Maximum Instantaneous Reverse Current	I_R	10 50 175	mA	V_R =45V T_C = 25°C T_C = 125°C T_C = 150°C Pulse Width = 300μS Duty Cycle = 1 percent
Maximum Instantaneous Forward Current	V_F	0.70 0.60 0.55	V	I_F = 75A T_C = 25°C T_C = 125°C T_C = 150°C Pulse Width = 300μS Duty Cycle = 1 percent
Capacitance	C_t	4000	pF	V_R =5V
Voltage Rate of Change	dv/dt	1000	V/μS	V_R = 45V
Reverse Energy [1]	E_R	3	A	Duty Cycle ≤ 1 percent

[1] See Reverse Energy Circuit.

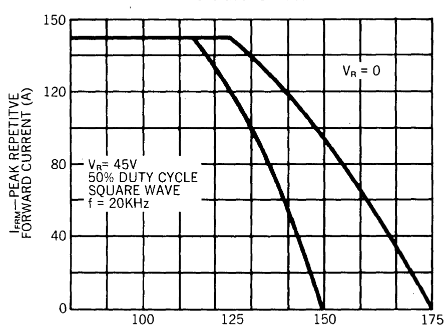
$V_{R(MAX)}$ VS Case Temperature



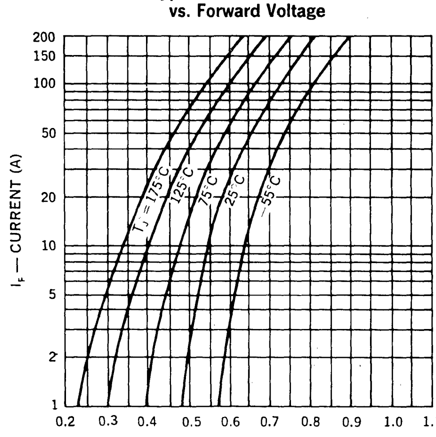
Typical Reverse Current vs Reverse Voltage



Peak Repetitive Forward Current



Typical Forward Current vs. Forward Voltage



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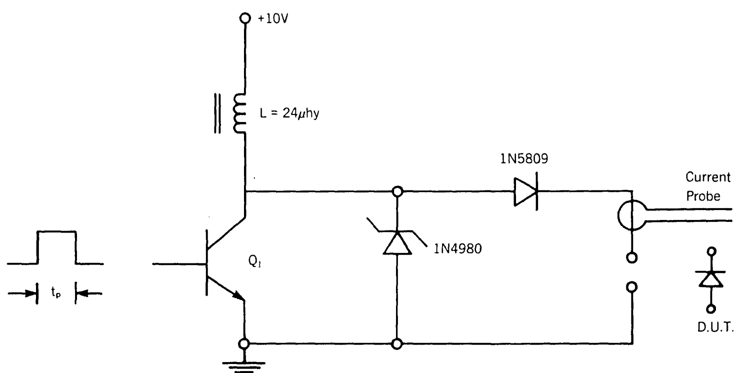
HR-SH

This specification outlines the screening operations to which devices shall be subjected.

1. ER with peak current of 2A (See Reverse Energy Circuit).
2. Hermetic Seal: Fine Leak / Gross Leak } per MIL-STD750 Method 1071
3. Thermal Cycling: Ten (10) cycles. Each cycle consists of fifteen (15) minutes at 200°C ambient, transfer immediately to −65°C ambient for fifteen (15) minutes and immediately return to 200°C again.
4. Reverse Bias Operation: 36V shall be applied for one-hundred and sixty -eight (168) hours at 150°C. Temperature is then reduced to 25°C over a period of not less than one (1) hour with full voltage maintained.
5. Electrical Measurements: All parameters shall be measured to insure conformance with specifications. Any parts exceeding specified limits or exhibiting unusual characteristics shall be removed from the lot.

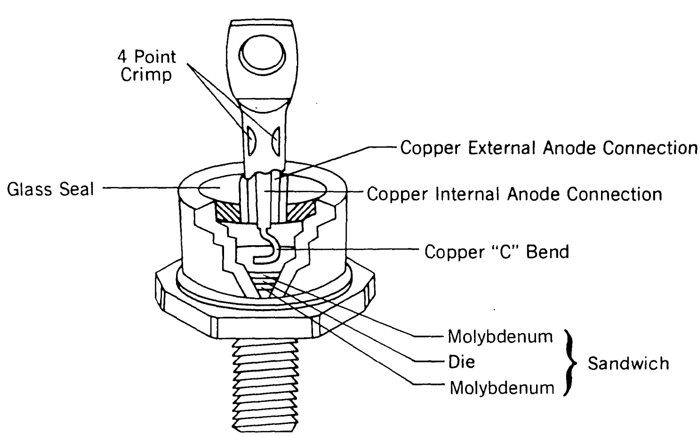
Reverse Energy Circuit



t_p, adjust for desired peak current in D.U.T. when Q turns off.

Q_1, must have fall time t_f of 100nS max.

DO-5



POWER SCHOTTKY RECTIFIERS
12A Pk, up to 45V

USD620
USD635
USD640
USD645

FEATURES
- Very Low Forward Voltage
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Working Voltage @ Rated $T_{j(max)}$

DESCRIPTION
The USD600 series of Schottky power rectifiers is ideally suited for output rectifiers and catch diodes in high frequency low voltage power supplies.

ABSOLUTE MAXIMUM RATINGS

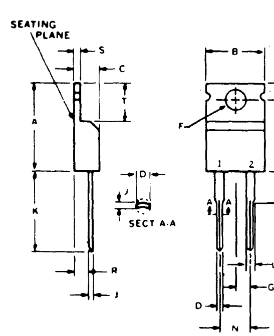
	USD620	USD635	USD640	USD645
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, $I_{F(AV)}$	6A			
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20 KHz, 50% Duty Cycle, @ T_C = 115°C), I_{FRM}	12A			
Non-repetitive Peak Surge Current (8.3ms), I_{FSM}	150A			
Peak Reverse Transient Current, I_{RM}	1A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	3.0°C/W			

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	5	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent
Maximum Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	v_F	0.55 0.65	V	i_F = 6A i_F = 12A
		0.48 0.60	V	i_F = 6A, i_F = 12A } T_C = 125°C
Capacitance	C_t	1000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μs	$V_R = V_{RWM}$

MECHANICAL SPECIFICATIONS

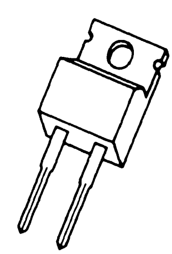
USD600 SERIES



PIN 1. Cathode
2. Anode
Tab is connected to Cathode.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

SIMILAR TO TO-220



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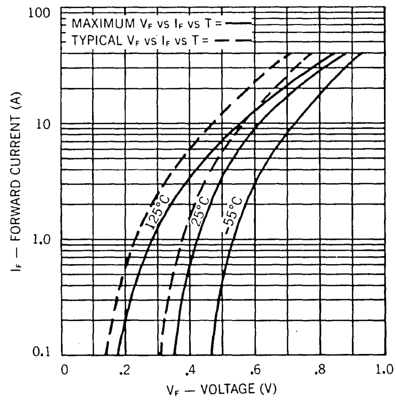
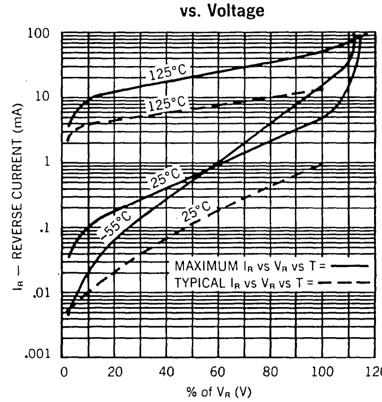
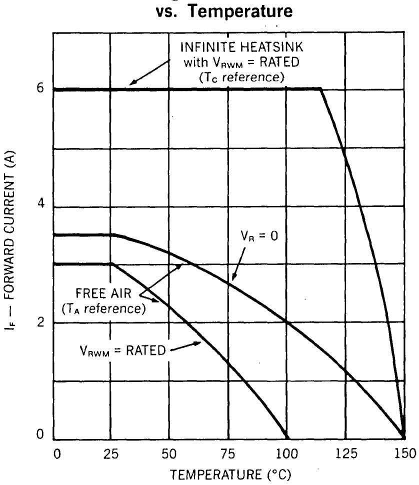
Forward Current vs. Forward Voltage



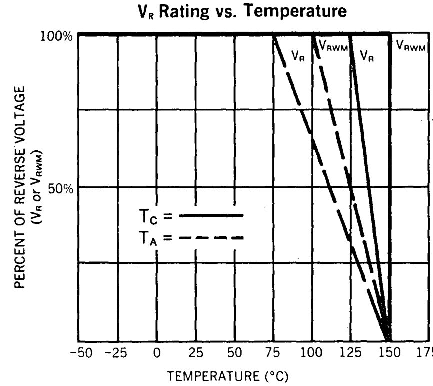
Reverse Current vs. Voltage



Average Forward Current vs. Temperature



V_R Rating vs. Temperature



DUAL POWER SCHOTTKY RECTIFIERS

12A Av, up to 45V

USD620C
USD635C
USD640C
USD645C

FEATURES
- Very Low Forward Voltage
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Working Voltage @ Rated $T_{j(max)}$

DESCRIPTION

The USD600C series of power Schottky rectifiers, in the industry standard TO-220 package, is specifically designed for operation in power switching circuits to frequencies in excess of 100 KHz. The series combines Schottky rectifiers in one convenient package; thus, simplifying installation, reducing heatsink requirements and component parts count.

ABSOLUTE MAXIMUM RATINGS (Per Diode Unless Otherwise Noted)

	USD620C	USD635C	USD640C	USD645C
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, I_O*	12A			
Non-repetitive Peak Surge Current (8.3ms), I_{FSM}	150A			
Peak Reverse Transient Current, I_{RM}	1A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{Stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	3.0°C/W			

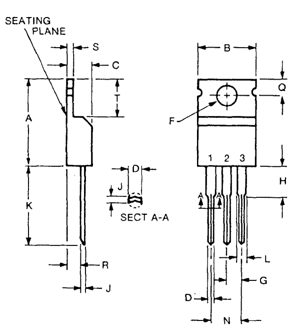
*Full Wave Center-Tap; $I_{O\,(AV)}$ 20 KHz Square Wave

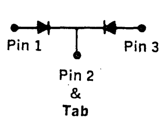
ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C) (Per Diode)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	5	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent
Maximum Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	V_F	0.55 0.65	V	i_F = 6A i_F = 12A
		0.48 0.60	V	i_F = 6A, i_F = 12A } T_C = 125°C
Capacitance	C_t	1000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μs	$V_R = V_{RWM}$

MECHANICAL SPECIFICATIONS

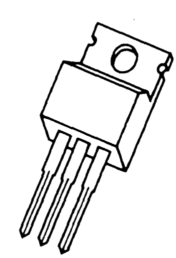
USD600C SERIES



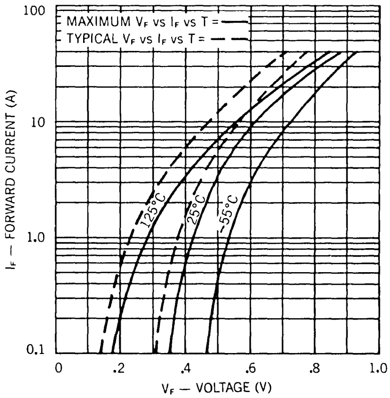


DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

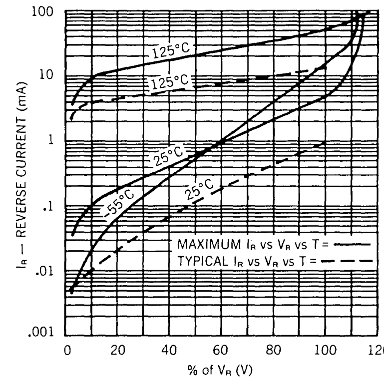
TO-220AB



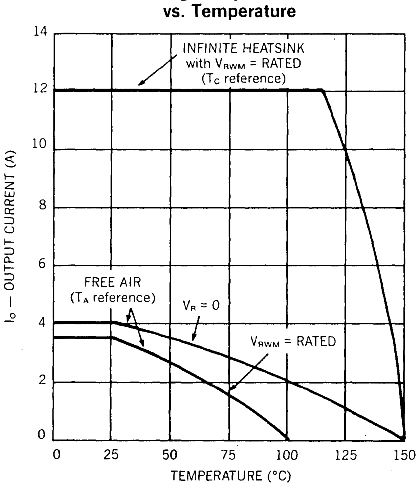
Forward Current vs. Forward Voltage



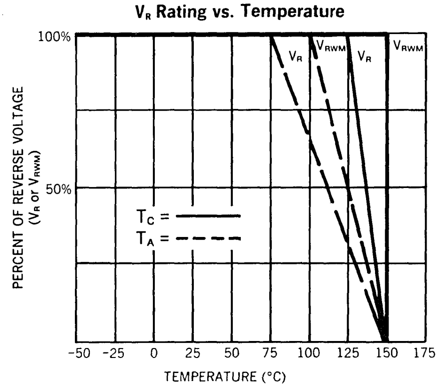
Reverse Current vs. Voltage



Average Output Current vs. Temperature



V_R Rating vs. Temperature



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POWER SCHOTTKY RECTIFIERS

16A Pk, up to 45V

USD720
USD735
USD740
USD745

FEATURES

- Very Low Forward Voltage
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Working Voltage @ Rated $T_{j(max)}$

DESCRIPTION

The USD700 series of Schottky power rectifiers is ideally suited for output rectifiers and catch diodes in high frequency low voltage power supplies.

ABSOLUTE MAXIMUM RATINGS

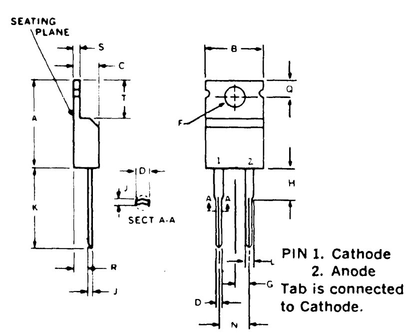
	USD720	USD735	USD740	USD745
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, $I_{F(AV)}$	8A			
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20 KHz, 50% Duty Cycle, @ T_C = 115°C), I_{FRM}	16A			
Non-repetitive Peak Surge Current (8.3ms), I_{FSM}	200A			
Peak Reverse Transient Current, I_{RM}	1A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{Stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	2.8°C/W			

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	5	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent
Maximum Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	V_F	0.55 0.65	V	i_F = 8A i_F = 16A
		0.48 0.60	V	i_F = 8A, i_F = 16A } T_C = 125°C
Capacitance	C_t	1000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μs	$V_R = V_{RWM}$

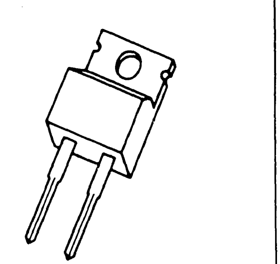
MECHANICAL SPECIFICATIONS

USD700 SERIES



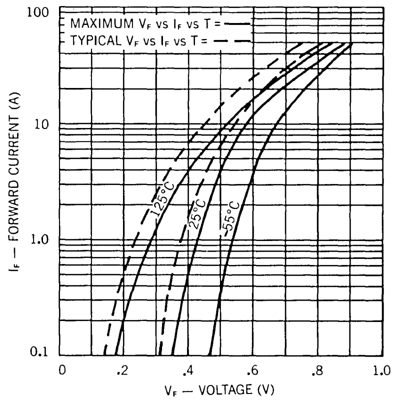
DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

SIMILAR TO TO-220

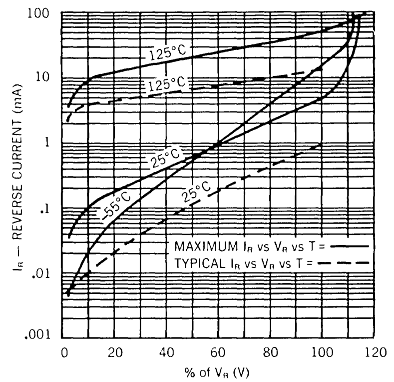


VI

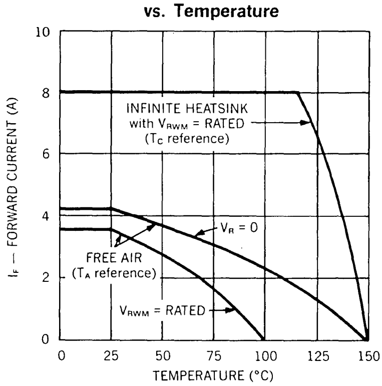
Forward Current vs. Forward Voltage



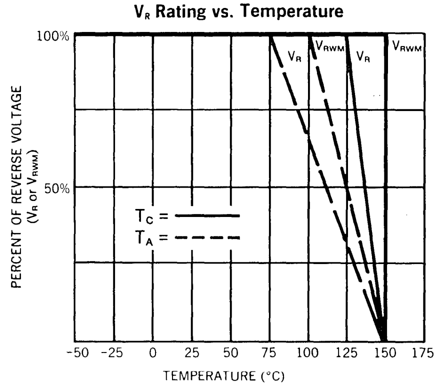
Reverse Current vs. Voltage



Average Forward Current vs. Temperature



V_R Rating vs. Temperature



DUAL POWER SCHOTTKY RECTIFIERS

16A Av, up to 45V

USD720C
USD735C
USD740C
USD745C

FEATURES

- Very Low Forward Voltage
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Working Voltage @ Rated $T_{j(max)}$

DESCRIPTION

The USD700C series of power Schottky rectifiers, in the industry standard TO-220 package, is specifically designed for operation in power switching circuits to frequencies in excess of 100 KHz. The series combines Schottky rectifiers in one convenient package; thus, simplifying installation, reducing heatsink requirements and component parts count.

ABSOLUTE MAXIMUM RATINGS (Per Diode Unless Otherwise Noted)

	USD720C	USD735C	USD740C	USD645C
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, I_O*	16A			
Non-repetitive Peak Surge Current (8.3ms), I_{FSM}	200A			
Peak Reverse Transient Current, I_{RM}	1A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{Stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	2.8°C/W			

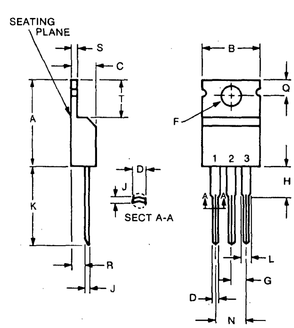
*Full Wave Center-Tap; $I_{O(AV)}$ 20KHz Square Wave

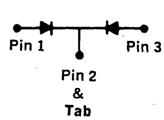
ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C) (Per Diode)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	5	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent
Maximum Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μs Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	V_F	0.55 0.65	V	i_F = 8A i_F = 16A
		0.48 0.60	V	i_F = 8A, i_F = 16A } T_C = 125°C
Capacitance	C_t	1000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μs	$V_R = V_{RWM}$

MECHANICAL SPECIFICATIONS

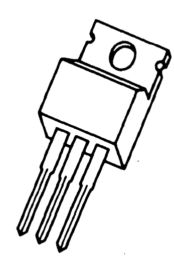
USD700C SERIES





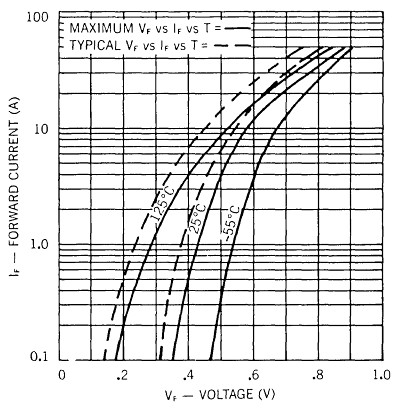
DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB

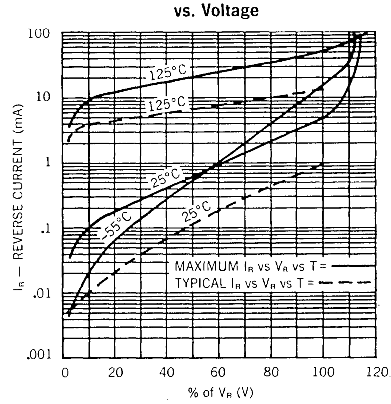


VI

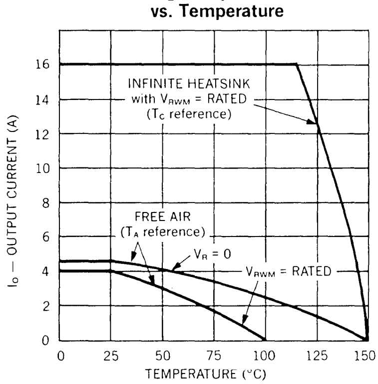
Forward Current vs. Forward Voltage



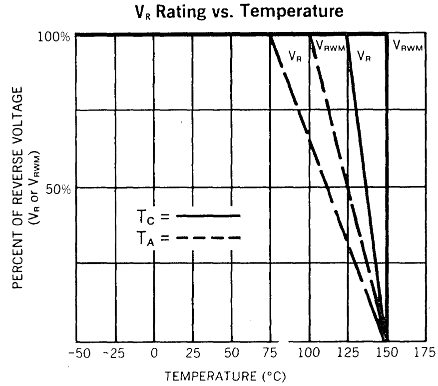
Reverse Current vs. Voltage



Average Output Current vs. Temperature



V_R Rating vs. Temperature



POWER SCHOTTKY RECTIFIERS

24A Pk, up to 45V

USD820
USD835
USD840
USD845

FEATURES

- Very Low Forward Voltage (0.45V max @ 12A)
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Blocking Voltage @ Rated T_{jmax}

DESCRIPTION

The USD800 series of Schottky barrier power rectifiers is ideally suited for output rectifiers and catch diodes in low voltage power supplies.

ABSOLUTE MAXIMUM RATINGS

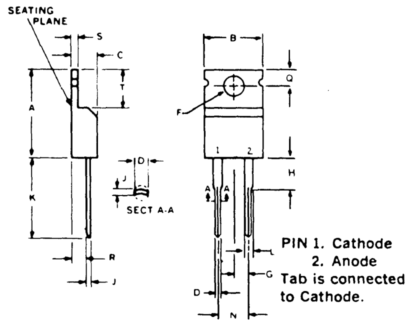
	USD820	USD835	USD840	USD845
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, I_O	12A			
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20KHz, 50% Duty Cycle, @ T_C = 115°C), I_{FRM}	24A			
Non-repetitive Peak Surge Current (8.3mS), I_{FSM}	200A			
Peak Reverse Transient Current, I_{RM}	1A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	2.4°C/W			

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	20	mA	$V_R = V_{RWM}$ Pulse Width = 400μS Duty Cycle = 1 percent
Typical Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μS Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	V_F	0.55	V	i_F = 12A
		0.45	V	i_F =12A T_C = 125°C
Capacitance	C_t	2000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μS	$V_R = V_{RWM}$

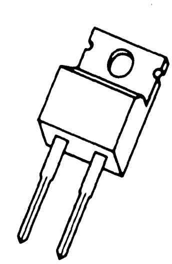
MECHANICAL SPECIFICATIONS

USD800 SERIES



DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

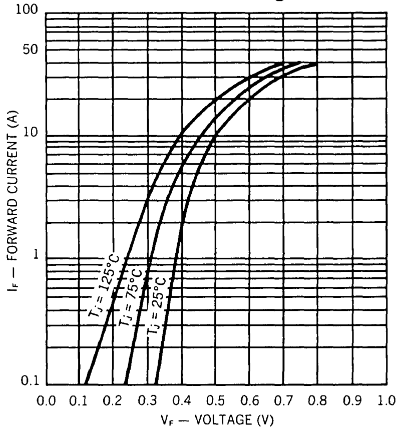
SIMILAR TO TO-220



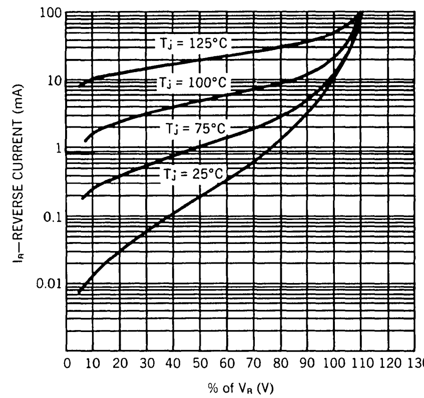
UNITRODE

VI

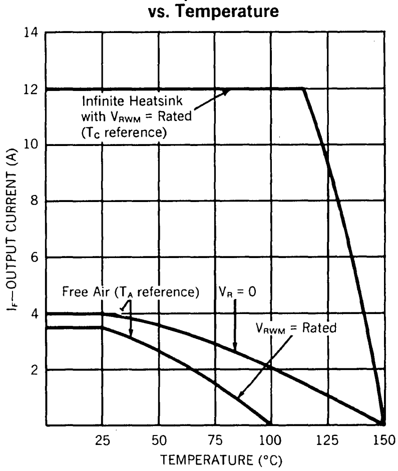
Typical Forward Current vs. Forward Voltage



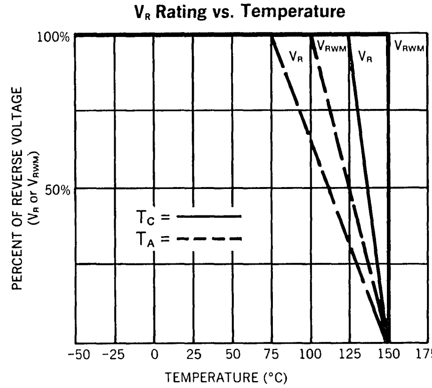
Typical Reverse Current vs. Voltage



Output Current vs. Temperature



V_R Rating vs. Temperature



POWER SCHOTTKY RECTIFIERS

32A Pk, up to 45V

USD920
USD935
USD940
USD945

FEATURES

- Very Low Forward Voltage (0.5V max @ 16A)
- Reverse Transient Capability
- Economical Convenient Plastic Package
- Mechanically Rugged
- 45V Blocking Voltage @ Rated T_{jmax}

DESCRIPTION

The USD900 series of Schottky barrier power rectifiers is ideally suited for output rectifiers and catch diodes in low voltage power supplies.

ABSOLUTE MAXIMUM RATINGS

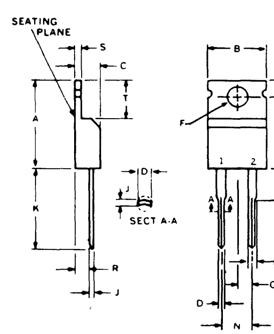
	USD920	USD935	USD940	USD945
Working Peak Reverse Voltage, V_{RWM}	20V	35V	40V	45V
DC Blocking Voltage, V_R	20V	35V	40V	45V
Peak Repetitive Surge Voltage, V_{RSM} @ I_{RM}	24V	42V	48V	54V
Average Rectified Forward Current @ T_C = 115°C, I_O	16A			
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20KHz, 50% Duty Cycle, @ T_C = 115°C), I_{FRM}	32A			
Non-repetitive Peak Surge Current (8.3mS), I_{FSM}	250A			
Peak Reverse Transient Current, I_{RM}	2A			
Operating Junction Temperature, T_j	150°C			
Storage Temperature Range, T_{stg}	−55°C to +150°C			
Thermal Resistance, Junction to Case, $R_{\theta JC}$	2°C/W			

ELECTRICAL CHARACTERISTICS (T_{CASE} = 25°C)

CHARACTERISTIC	SYMBOL	LIMIT	UNITS	CONDITIONS
Maximum Instantaneous Reverse Current	i_R	20	mA	$V_R = V_{RWM}$ Pulse Width = 400μS Duty Cycle = 1 percent
Typical Instantaneous Reverse Current	i_R	50	mA	$V_R = V_{RWM}$ Pulse Width = 400μS Duty Cycle = 1 percent T_C = 125°C
Maximum Instantaneous Forward Voltage	V_F	0.6	V	i_F = 16A
		0.5	V	i_F =16A T_C = 125°C
Capacitance	C_t	2000	pF	V_R = 5V
Voltage Rate of Change	dv/dt	1000	V/μS	$V_R = V_{RWM}$

MECHANICAL SPECIFICATIONS

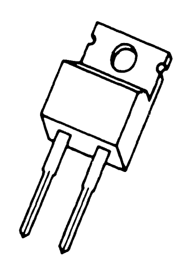
USD900 SERIES



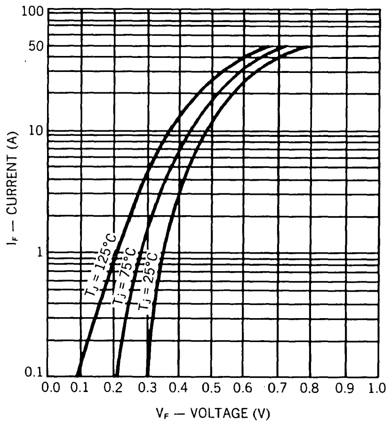
PIN 1. Cathode
2. Anode
Tab is connected to Cathode.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

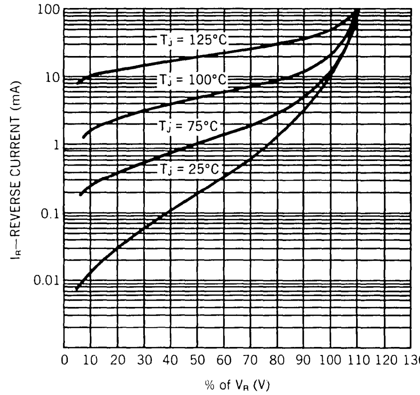
SIMILAR TO TO-220



Typical Forward Current vs. Forward Voltage

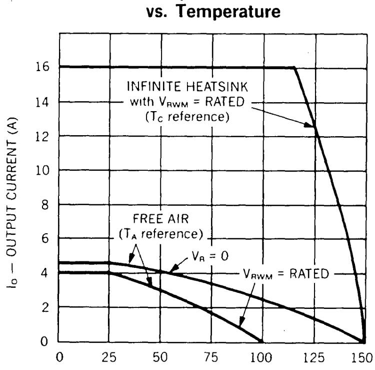


Typical Reverse Current vs. Voltage

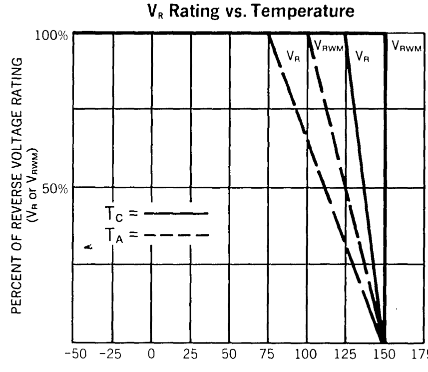


VI

Output Current vs. Temperature



V_R Rating vs. Temperature



RECTIFIERS

Standard Recovery, 1 Amp to 2 Amp

UT236-UT347
UT249-UT363
UT251-UT364
UT261-UT268

FEATURES

- Continuous Rating: to 2A
- Controlled Avalanche
- Surge Rating: to 30A
- PIV: to 1000V
- Miniature Package

DESCRIPTION

These miniature power rectifiers offer the user extreme reliability for high-rel military supplies.

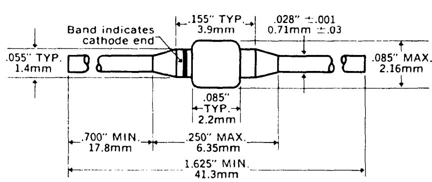
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1 Amp Series	1.25 Amp Series	1.5 Amp Series	2 Amp Series
100V	UT236	UT249	UT251	UT261
200V	UT234	UT242	UT252	UT262
400V	UT235	UT244	UT254	UT264
500V	UT237	UT245	UT255	UT265
600V	UT238	UT247	UT257	UT267
800V	UT361	UT362	UT258	UT268
1000V	UT347	UT363	UT364	

	1 AMP SERIES	1.25 AMP SERIES	1.5 AMP SERIES	2 AMP SERIES
Maximum Average D.C. Output Current				
@ T_A = 25°C	1.0A	1.25A	1.5A	2.0A
@ T_A = 100°C	0.5A	0.65A	0.75A	1.0A
Non-Repetitive Sinuosoidal Surge (8.3ms)	20A	20A	25A	30A
Operating Temperature Range	—195°C to +175°C			
Storage Temperature Range	—195°C to +175°C			
Thermal Resistance	See lead temperature derating curve			

MECHANICAL SPECIFICATIONS

UT236-UT347 UT249-UT363 UT251-UT364 UT261-UT268



Part Identification: Orange band indicates "UT." Part number printed on body.

Polarity: Denoted by orange band.

Weight: 0.26 grams, typical.

BODY A

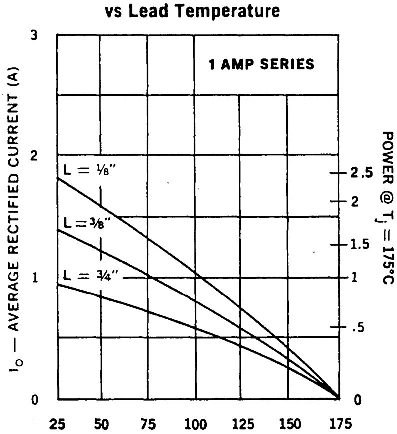
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

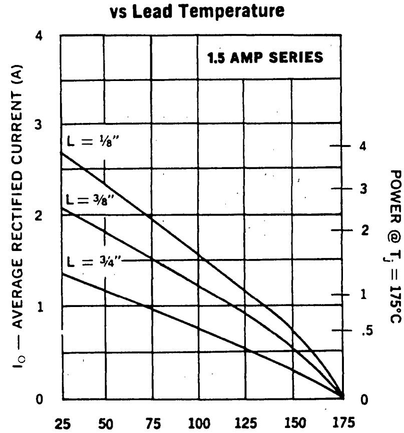
Type	PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV	
			25°C	100°C
UT261 UT262 UT264 UT265 UT267 UT268	100V 200V 400V 500V 600V 800V	1V @ 900mA	2μA	75μA
UT251 UT252 UT254 UT255 UT257 UT258 UT364	100V 200V 400V 500V 600V 800V 1000V	1V @ 750mA	2μA	75μA
UT249 UT242 UT244 UT245 UT247 UT362 UT363	100V 200V 400V 500V 600V 800V 1000V	1V @ 500mA	2μA	75μA
UT236 UT234 UT235 UT237 UT238 UT361 UT347	100V 200V 400V 500V 600V 800V 1000V	1V @ 400mA	2μA	75μA

VI

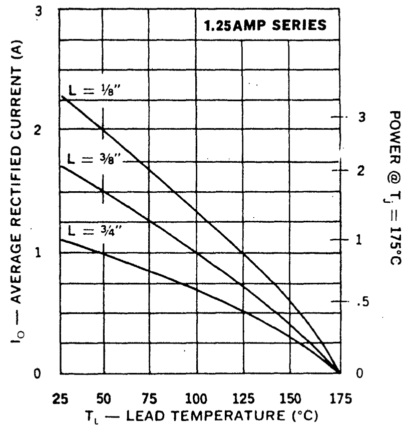
Maximum Current vs Lead Temperature



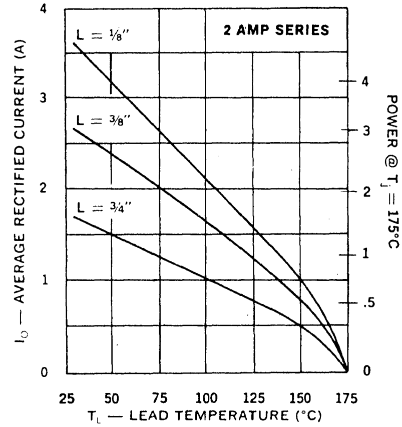
Maximum Current vs Lead Temperature



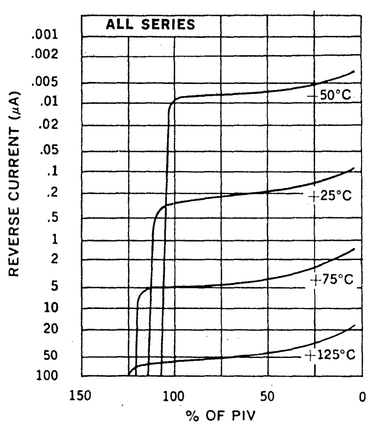
Maximum Current vs Lead Temperature



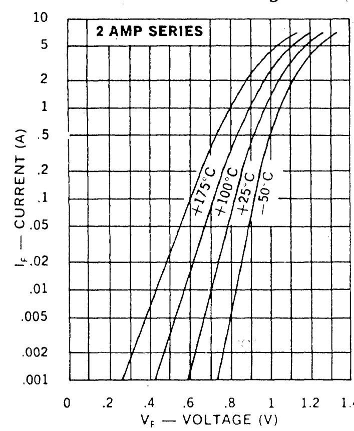
Maximum Current vs Lead Temperature



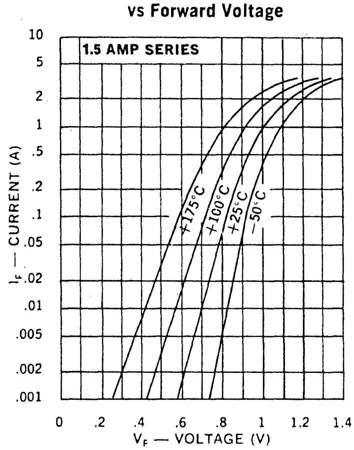
Typical Leakage Current vs. PIV



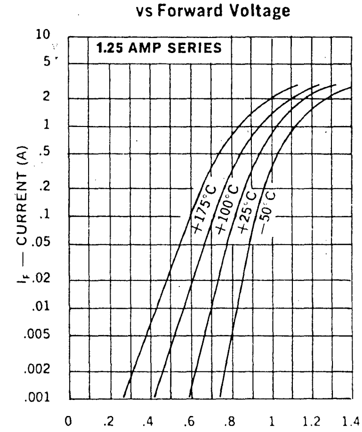
Typical Forward Current vs Forward Voltage



Typical Forward Current vs Forward Voltage

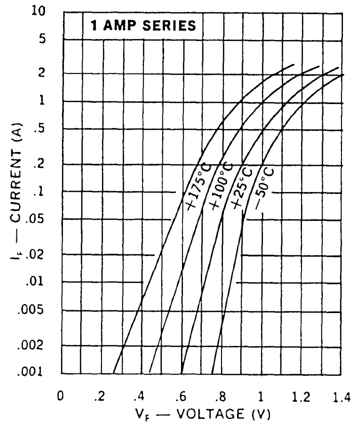


Typical Forward Current vs Forward Voltage

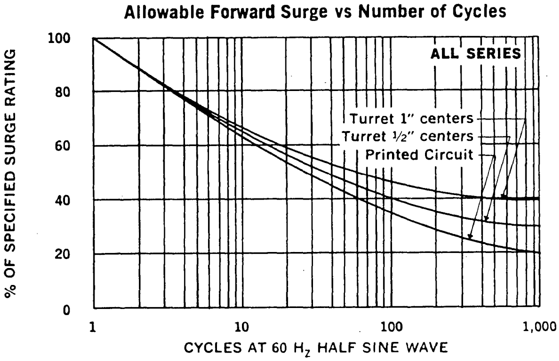


VI

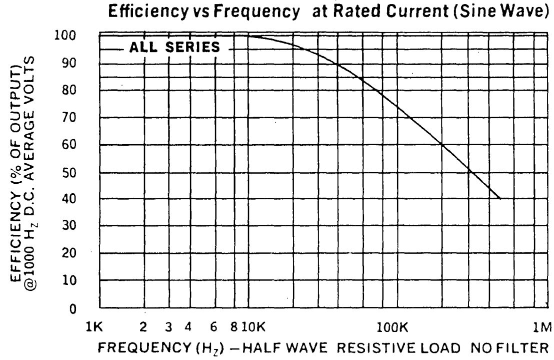
Typical Forward Current vs Forward Voltage



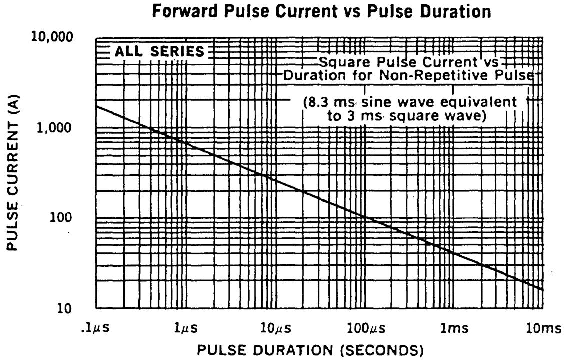
Allowable Forward Surge vs Number of Cycles



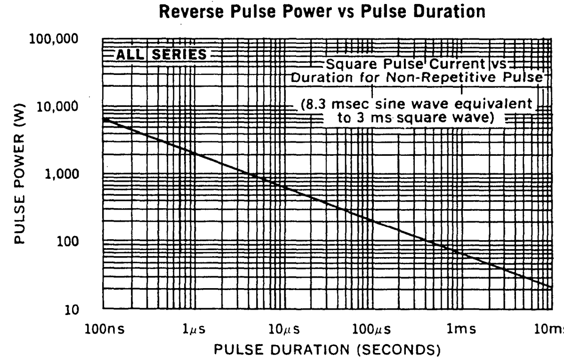
Efficiency vs Frequency at Rated Current (Sine Wave)



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



RECTIFIERS

Standard Recovery, 2 Amp to 4 Amp

UT2005-UT2060
UT3005-UT3060
UT4005-UT4060

FEATURES

- Continuous Rating: to 4A
- Controlled Avalanche
- Surge Rating: to 100A
- PIV: to 600 V
- Miniature Package

DESCRIPTION

High average power and surge capability make these series of devices attractive in many high-rel applications.

All Unitrode rectifiers have a sleeve of pure hard glass fused to the silicon junction. Since the silicon sees only this glass, electrical characteristics are permanently stable. This voidless, monolithic package is totally unaffected by the most severe moisture or temperature testing.

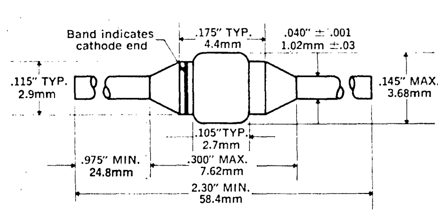
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	2 Amp Series	3 Amp Series	4 Amp Series
50V	UT2005	UT3005	UT4005
100V	UT2010	UT3010	UT4010
200V	UT2020	UT3020	UT4020
400V	UT2040	UT3040	UT4040
600V	UT2060	UT3060	UT4060

	2 AMP SERIES	3 AMP SERIES	4 AMP SERIES
Maximum Average D.C. Output Current			
@ $T_A = 25°C$	2.0A	3.0A	4.0A
@ $T_A = 100°C$	1.0A	1.5A	2.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	60A	80A	100A
Operating Temperature Range	−195°C to +175°C		
Storage Temperature Range	−195°C to +200°C		
Thermal Resistance	See lead temperature derating curve		

MECHANICAL SPECIFICATIONS

UT2005-UT2060 UT3005-UT3060 UT4005-UT4060

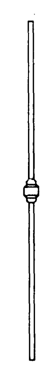


Part Identification: Orange band indicates "UT." Part number printed on body.

Polarity: Denoted by orange band.

Weight: 0.75 grams, typical.

BODY B



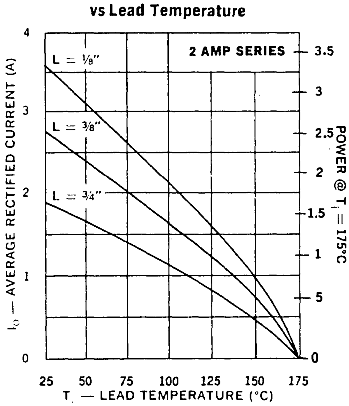
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

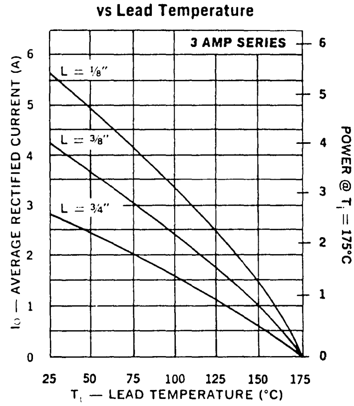
Type	PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV	
			25°C	100°C
UT4005 UT4010 UT4020 UT4040 UT4060	50V 100V 200V 400V 600V	1V @ 3A	5μA	100μA
UT3005 UT3010 UT3020 UT3040 UT3060	50V 100V 200V 400V 600V	1V @ 2A	5μA	100μA
UT2005 UT2010 UT2020 UT2040 UT2060	50V 100V 200V 400V 600V	1V @ 1A	5μA	100μA

VI

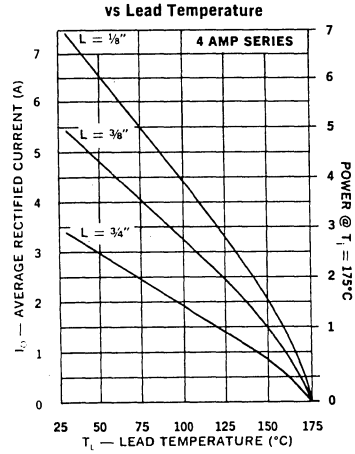
Maximum Current vs Lead Temperature



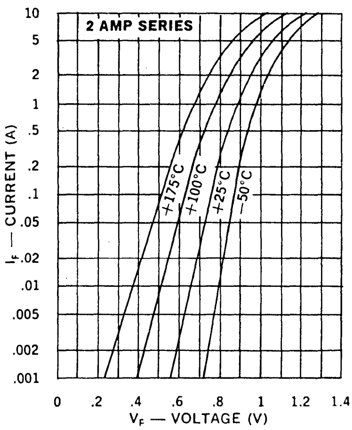
Maximum Current vs Lead Temperature



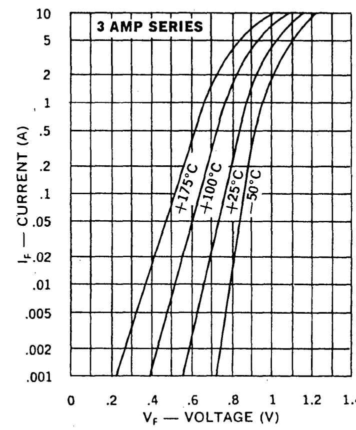
Maximum Current vs Lead Temperature



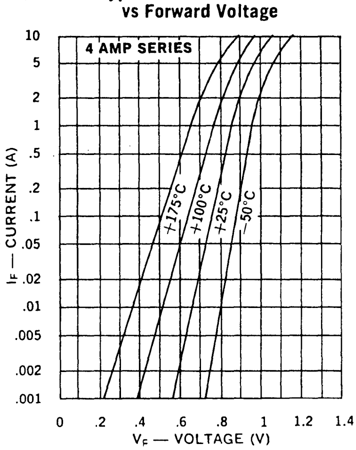
Typical Forward Current vs Forward Voltage



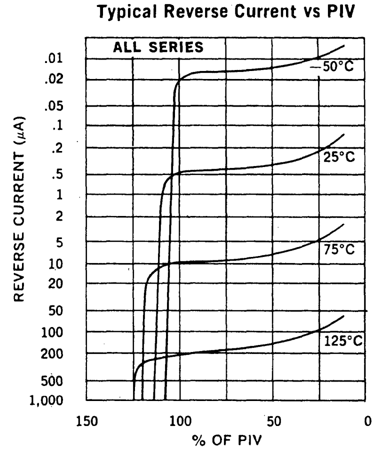
Typical Forward Current vs Forward Voltage



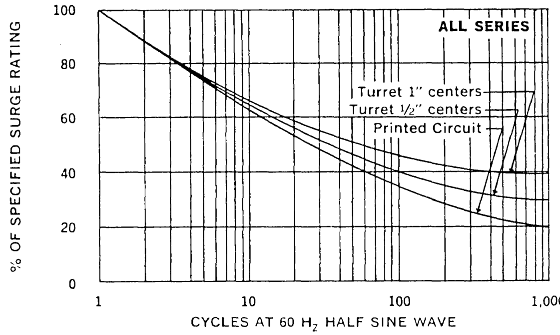
Typical Forward Current vs Forward Voltage



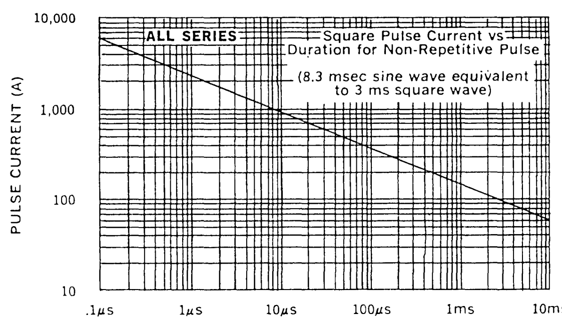
Typical Reverse Current vs PIV



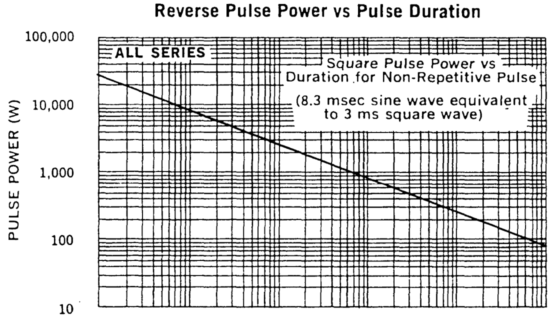
Allowable Forward Surge vs Number of Cycles



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



RECTIFIERS

Standard Recovery, 7.5 Amp to 12 Amp

UT5105-UT5160
UT6105-UT6160
UT8105-UT8160

FEATURES
- Rating: 12A
- Controlled Avalanche
- Miniature Package
- Surge Rating: 200A

DESCRIPTION
These series of high current rectifiers offers opportunity for size and weight reduction in high power supplies.

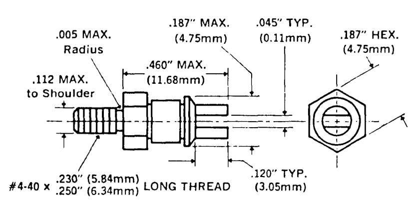
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	12 Amp Series	9 Amp Series	7.5 Amp Series
50V	UT8105	UT6105	UT5105
100V	UT8110	UT6110	UT5110
200V	UT8120	UT6120	UT5120
400V	UT8140	UT6140	UT5140
600V	UT8160	UT6160	UT5160

	12 AMP SERIES	9 AMP SERIES	7.5 AMP SERIES
Maximum Average D.C. Output Current @ $T_C = 100°C$	12.0A	9.0A	7.5A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	200A	175A	150A
Operating and Storage Temperature Range	—65°C to +175°C		
Thermal Resistance, Junction to Case	7.5°C/Watt		
Current Derating	See current vs. case temperature curve		

MECHANICAL SPECIFICATIONS

UT5105-UT5160 UT6105-UT6160 UT8105-UT8160



Part Identification: Numerals and polarity letter indicate "UT" type number; e.g., 8105R.

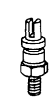
Polarity: Cathode to Stud is standard. Reverse polarity denoted by "R" Suffix.

Finish: Metal parts gold plated per MIL-G-45204, Type II.

Max. Weight: 1.5 grams.

Also available with insulated stud. Reference Design Note-17.

BODY C — Stud Mount



Installation
Maximum unlubricated stud torque: 28 inch-ounces.
Insulating hardware supplied.
Do not use a screwdriver in the turret slot for installation purposes, or damage may result.

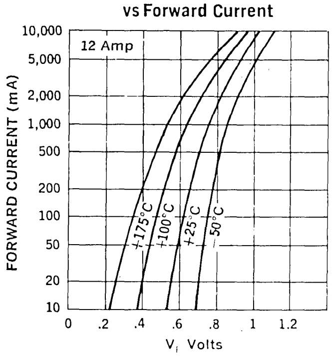
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25 C unless noted)

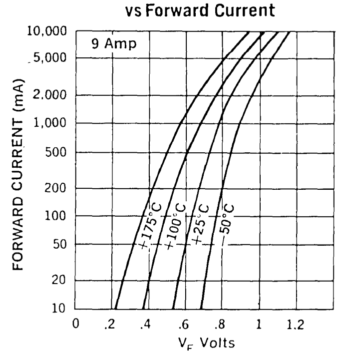
Type	Peak Inverse Voltage	Maximum Forward Voltage	Max. Reverse Current at PIV	
			25°C	100°C
UT8105 UT8110 UT8120 UT8140 UT8160	50V 100V 200V 400V 600V	1V @ 8A	10μA	300μA
UT6105 UT6110 UT6120 UT6140 UT6160	50V 100V 200V 400V 600V	1V @ 6A	10μA	300μA
UT5105 UT5110 UT5120 UT5140 UT5160	50V 100V 200V 400V 600V	1V @ 5A	10μA	300μA

VI

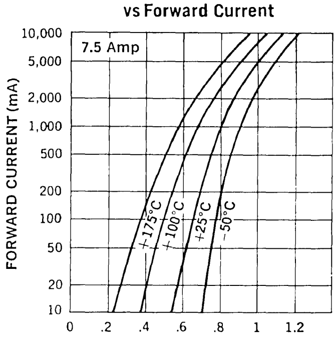
Typical Forward Voltage vs Forward Current



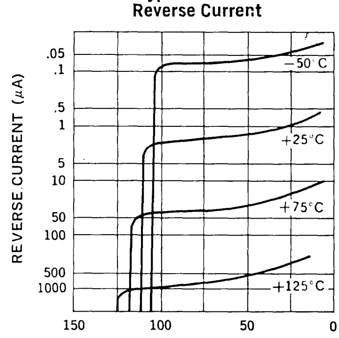
Typical Forward Voltage vs Forward Current



Typical Forward Voltage vs Forward Current



Typical P.I.V. vs Reverse Current



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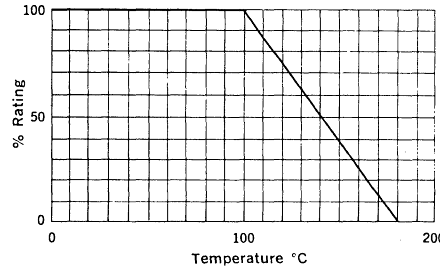
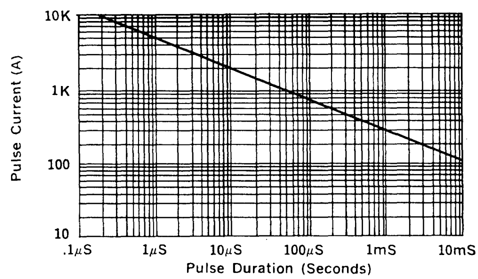
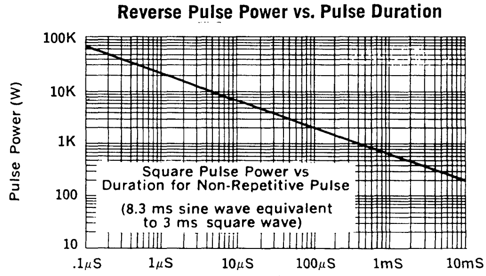
Current Rating vs Case Temperature



Forward Pulse Current vs. Pulse Duration



Reverse Pulse Power vs. Pulse Duration



RECTIFIERS

Fast Recovery, 0.5 Amp to 2 Amp

UTR10-UTR60
UTR01-UTR61
UTR02-UTR62

FEATURES

- Continuous Rating: to 2A
- Controlled Avalanche
- Surge Rating: to 25A
- Fast Recovery 40kHz Operation
- PIV: to 600V
- Miniature Package

DESCRIPTION

These miniature fast recovery rectifiers permit operation at full frequencies as high as 40kHz square wave. They have the unique Unitrode Fused in Glass construction.

VI

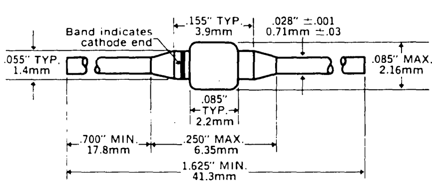
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	½ Amp Series	1 Amp Series	2 Amp Series
50V		UTR01	UTR02
100V	UTR10	UTR11	UTR12
200V	UTR20	UTR21	UTR22
300V	UTR30	UTR31	UTR32
400V	UTR40	UTR41	UTR42
500V	UTR50	UTR51	UTR52
600V	UTR60	UTR61	UTR62

	½ AMP SERIES	1 AMP SERIES	2 AMP SERIES
Maximum Average D.C. Output Current			
@ $T_A = 25°C$	0.5A	1.0A	2.0A
@ $T_A = 100°C$	0.25A	0.5A	1.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	15A	20A	25A
Operating Temperature Range	—195°C to +175°C		
Storage Temperature Range	—195°C to +200°C		
Thermal Resistance	See lead temperature derating curves		

MECHANICAL SPECIFICATIONS

UTR10-UTR60 UTR01-UTR61 UTR02-UTR62



Part Identification: Green band indicates "UTR." Part number printed on body.

Polarity: Denoted by Green band.

Weight: 0.26 grams, typical.

BODY A

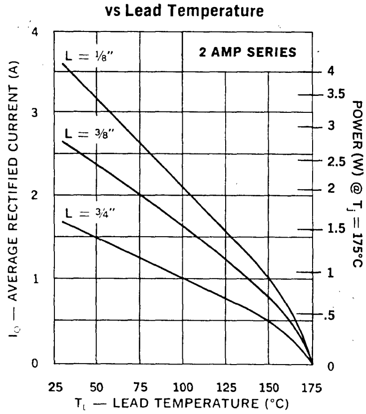
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

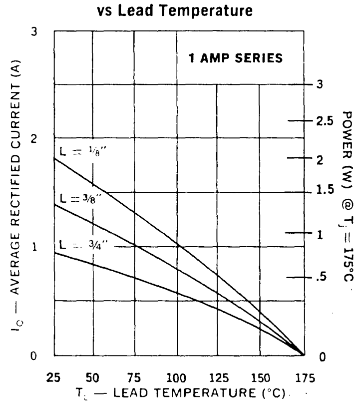
Type	PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV 25°C	Maximum Leakage Current @ PIV 100°C	Maximum Reverse Recovery Time*	Maximum Junction Capacitance @ 25°C 0V	Maximum Junction Capacitance @ 25°C —10V
UTR02	50V				250ns	150pf	60pf
UTR12	100V				250ns	100pf	40pf
UTR22	200V				250ns	80pf	32pf
UTR32	300V	1.1V @ 1000mA	3μA	100μA	300ns	70pf	28pf
UTR42	400V				350ns	60pf	24pf
UTR52	500V				400ns	50pf	20pf
UTR62	600V				400ns	40pf	16pf
UTR01	50V				250ns	150pf	60pf
UTR11	100V				250ns	100pf	40pf
UTR21	200V				250ns	80pf	32pf
UTR31	300V	1.1V @ 500mA	3μA	100μA	300ns	70pf	28pf
UTR41	400V				350ns	60pf	24pf
UTR51	500V				400ns	50pf	20pf
UTR61	600V				400ns	40pf	16pf
UTR10	100V				250ns	100pf	40pf
UTR20	200V				250ns	80pf	32pf
UTR30	300V	1.1V @ 200mA	3μA	100μA	300ns	70pf	28pf
UTR40	400V				350ns	60pf	24pf
UTR50	500V				400ns	50pf	20pf
UTR60	600V				400ns	40pf	16pf

*Recovery time is measured from 10.0mA to 10.0mA recovery to 5.0mA

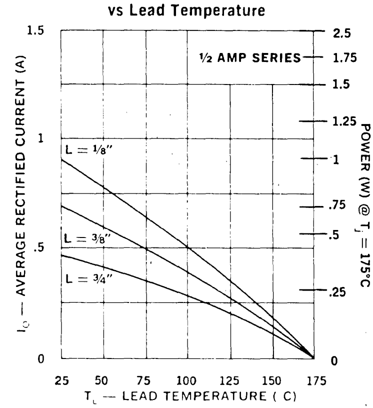
Maximum Current vs Lead Temperature



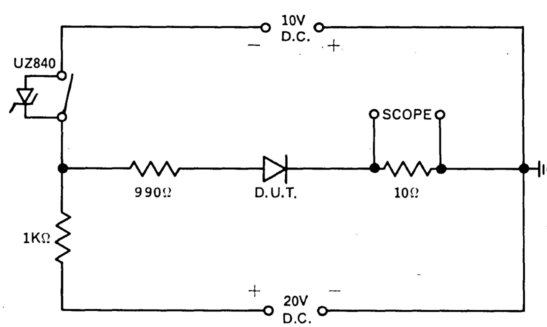
Maximum Current vs Lead Temperature



Maximum Current vs Lead Temperature



Reverse-Recovery Circuit



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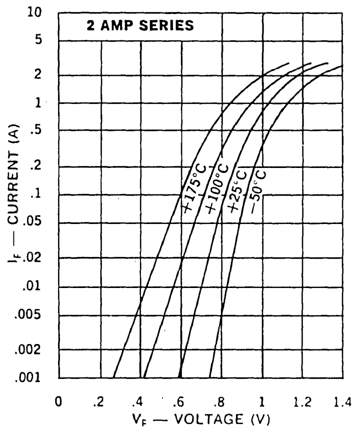
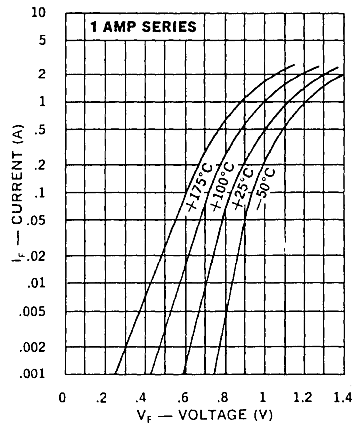
VI

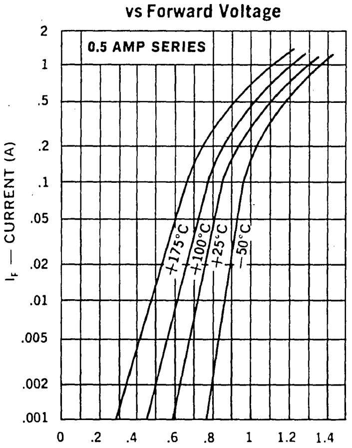
Typical Forward Current vs Forward Voltage



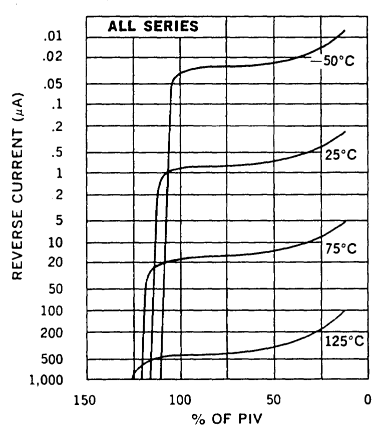
Typical Forward Current vs Forward Voltage



Typical Forward Current vs Forward Voltage



Typical Reverse Current vs PIV



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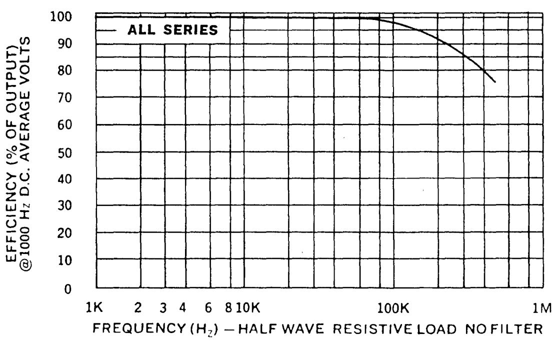
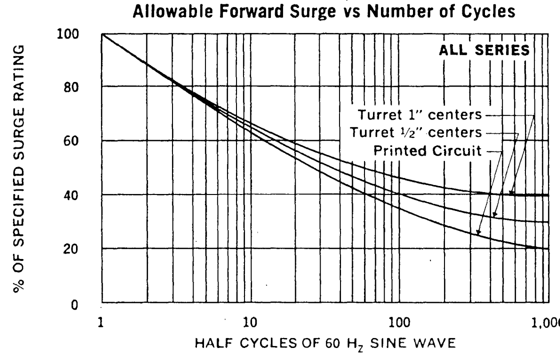
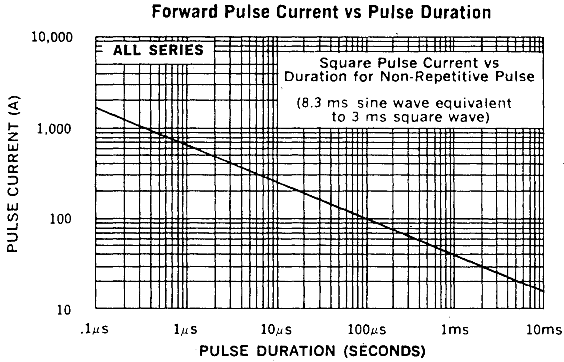
Efficiency vs Frequency at Rated Current (Sine Wave)



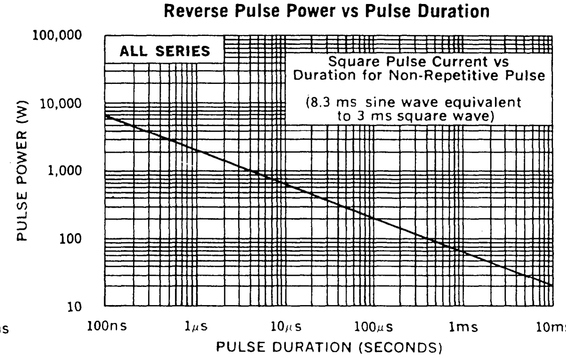
Allowable Forward Surge vs Number of Cycles



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



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RECTIFIERS

Fast Recovery, 2 Amp to 4 Amp

UTR2305-UTR2360
UTR3305-UTR3360
UTR4305-UTR4360

FEATURES
- Continuous Rating: to 4A
- Controlled Avalanche
- Surge Rating: to 100A
- PIV: to 600V
- Miniature Package

DESCRIPTION
Small size and high surge capability make this series of power switching rectifiers desirable for power supplies where size, weight and reliability are important.

VI

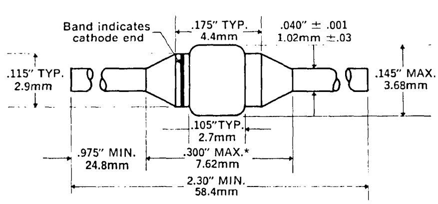
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	2 Amp Series	3 Amp Series	4 Amp Series
50V	UTR2305	UTR3305	UTR4305
100V	UTR2310	UTR3310	UTR4310
200V	UTR2320	UTR3320	UTR4320
400V	UTR2340	UTR3340	UTR4340
500V	UTR2350	UTR3350	UTR4350
600V	UTR2360	UTR3360	UTR4360

	2 AMP SERIES	3 AMP SERIES	4 AMP SERIES
Maximum Average D.C. Output Current			
@ $T_A = 25°C$	2.0A	3.0A	4.0A
@ $T_A = 100°C$	1.0A	1.5A	2.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	60A	80A	100A
Operating Temperature Range	—195°C to +175°C		
Storage Temperature Range	—195°C to +200°C		
Thermal Resistance	See lead temperature derating curve		

MECHANICAL SPECIFICATIONS

UTR4305-UTR4360 UTR3305-UTR3360 UTR2305-UTR2360



Part Identification: Green band indicates "UTR." Part number printed on body.
Polarity: Denoted by Green band.
Weight: 0.75 grams, typical.

BODY B

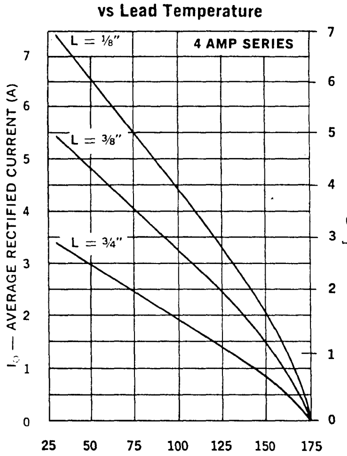
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

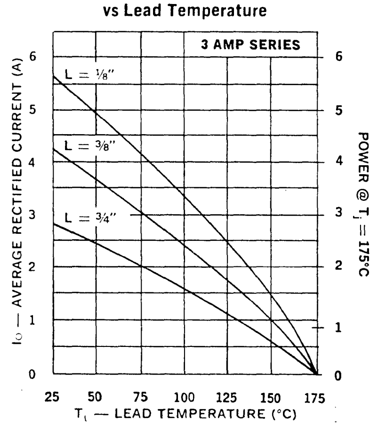
Type	PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV		Maximum Reverse Recovery Time*	Maximum Junction Capacitance @ 25°C	
			25°C	100°C		0V	—10V
UTR4305	50V				250ns	600pf	240pf
UTR4310	100V				250ns	400pf	160pf
UTR4320	200V				250ns	320pf	128pf
UTR4340	400V	1.1V @ 4A	5μA	100μA	400ns	240pf	96pf
UTR4350	500V				400ns	200pf	80pf
UTR4360	600V				400ns	160pf	64pf
UTR3305	50V				250ns	600pf	240pf
UTR3310	100V				250ns	400pf	160pf
UTR3320	200V				250ns	320pf	128pf
UTR3340	400V	1.1V @ 3A	5μA	100μA	300ns	240pf	96pf
UTR3350	500V				350ns	200pf	80pf
UTR3360	600V				400ns	160pf	64pf
UTR2305	50V				250ns	600pf	240pf
UTR2310	100V				250ns	400pf	160pf
UTR2320	200V				250ns	320pf	128pf
UTR2340	400V	1.1V @ 2A	5μA	100μA	300ns	240pf	96pf
UTR2350	500V				350ns	200pf	80pf
UTR2360	600V				400ns	160pf	64pf

*Recovery time is measured from 1A to 1A recovering to 0.5A.

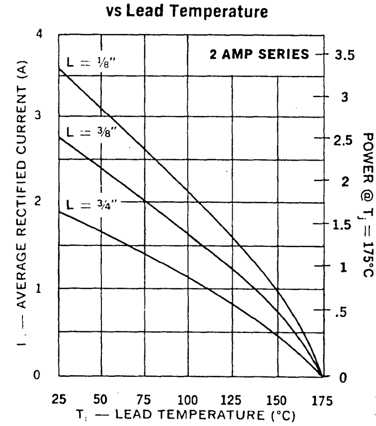
Maximum Current vs Lead Temperature



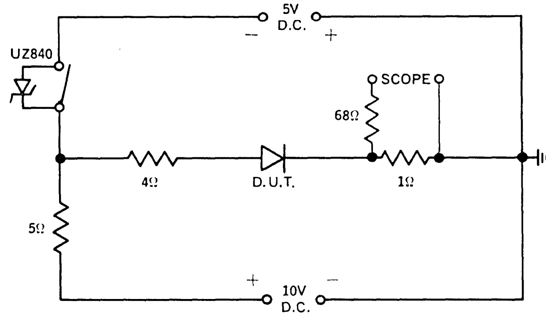
Maximum Current vs Lead Temperature



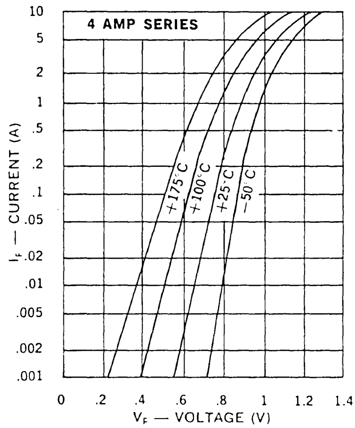
Maximum Current vs Lead Temperature



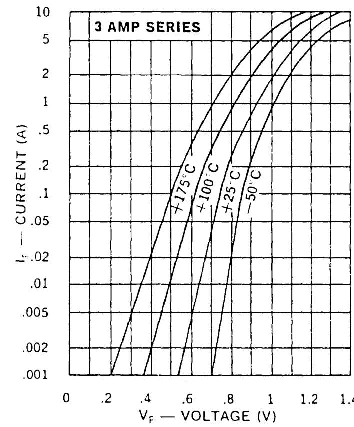
Reverse Recovery Circuit



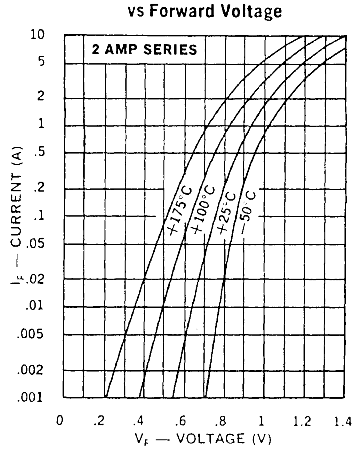
Typical Forward Current vs Forward Voltage



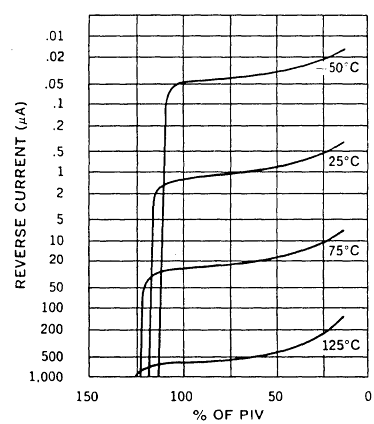
Typical Forward Current vs Forward Voltage



Typical Forward Current vs Forward Voltage



Typical Reverse Current vs PIV



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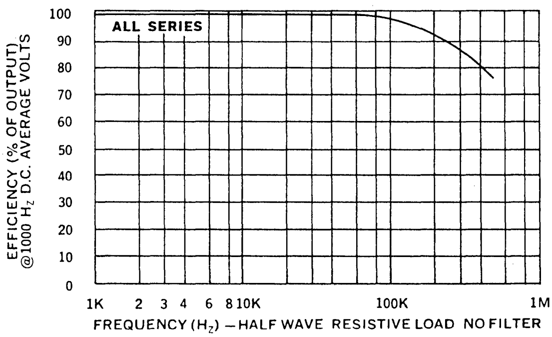
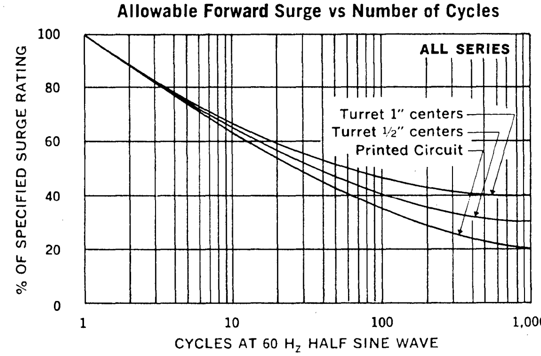
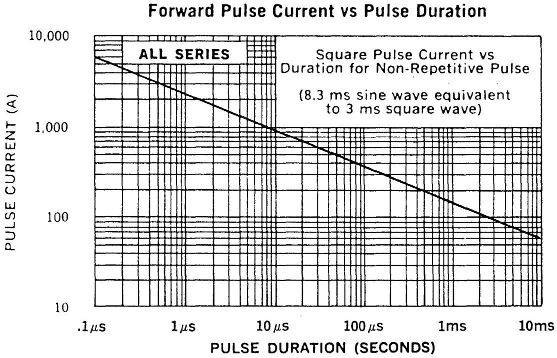
Efficiency vs Frequency at Rated Current (Sine Wave)



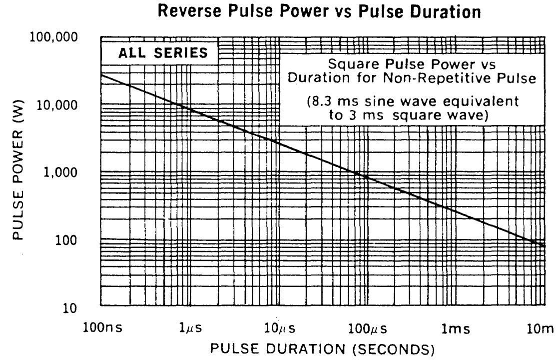
Allowable Forward Surge vs Number of Cycles



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



RECTIFIERS
Fast Recovery, 6 Amp to 9 Amp

UTR4405-UTR4440
UTR5405-UTR5440
UTR6405-UTR6440

FEATURES
- Continuous Rating: to 9A
- Controlled Avalanche
- Surge Rating: to 150A
- Fast Recovery, 40kHz Operation
- PIV: to 400V
- Miniature Package

DESCRIPTION
The same basic construction as all Unitrode diodes, but using a miniature stud mounting and larger junction area, provides a 9 Amp continuous and 150 Amp surge rating in a package only one fifth the weight and one quarter the volume of conventional types.

VI

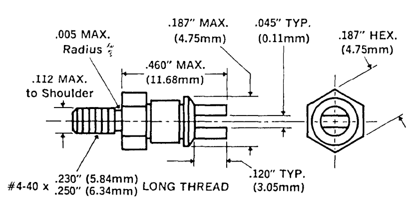
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	6 Amp Series	7.5 Amp Series	9 Amp Series
50V	UTR4405	UTR5405	UTR6405
100V	UTR4410	UTR5410	UTR6410
200V	UTR4420	UTR5420	UTR6420
400V	UTR4440	UTR5440	UTR6440

	6 AMP SERIES	7.5 AMP SERIES	9.0 AMP SERIES
Maximum Average D.C. Output Current @ $T_C = 100°C$	6.0A	7.5A	9.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	120A	135A	150A
Operating Temperature Range		−195°C to +175°C	
Storage Temperature Range		−195°C to +200°C	
Thermal Resistance		7.5°C/W	

MECHANICAL SPECIFICATIONS

UTR6405-UTR6440 UTR5405-UTR5440 UTR4405-UTR4440



Part Identification: Numerals and polarity letter indicate UTR type number, e.g., UTR 4405.

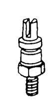
Polarity: Cathode to Stud is standard. Reverse polarity denoted by "R" suffix.

Finish: Metal parts gold plated per MIL-G-45204, Type II.

Weight: 1.5 grams, typical.

Also available with insulated stud. Reference Design Note-17.

BODY C — Stud Mount



Installation
Maximum unlubricated stud torque: 28 inch-ounces.
Insulating hardware supplied.
Do not use a screwdriver in the turret slot for installation purposes, or damage may result.

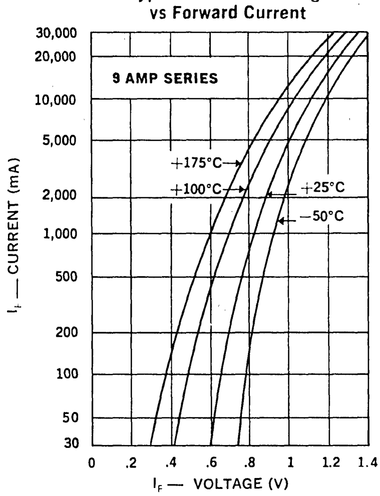
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

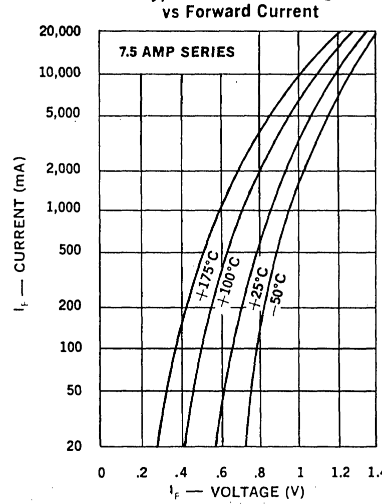
Type	PIV	Maximum Forward Voltage Drop	Maximum Reverse Current @ PIV 25°C	Maximum Reverse Current @ PIV 100°C	Maximum Reverse Recovery Time*
UTR6405	50V	1.1V @ 6.0A	10μA	300μA	300ns
UTR6410	100V				300ns
UTR6420	200V				400ns
UTR6440	400V				500ns
UTR5405	50V	1.1V @ 5.0A	10μA	300μA	300ns
UTR5410	100V				300ns
UTR5420	200V				400ns
UTR5440	400V				500ns
UTR4405	50V	1.1V @ 4.0A	10μA	300μA	300ns
UTR4410	100V				300ns
UTR4420	200V				400ns
UTR4440	400V				500ns

*Recovery time is measured from 1A to 1A, recovering to 0.5A.

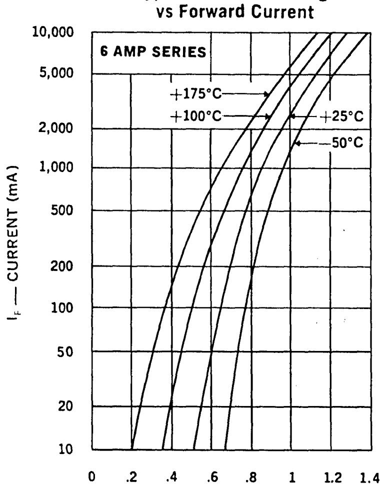
Typical Forward Voltage vs Forward Current



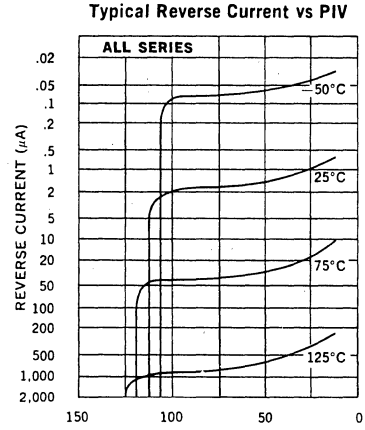
Typical Forward Voltage vs Forward Current



Typical Forward Voltage vs Forward Current

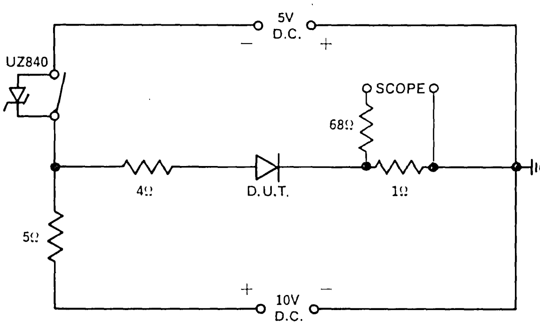


Typical Reverse Current vs PIV

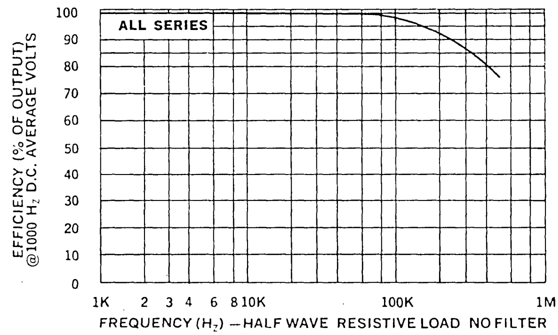


VI

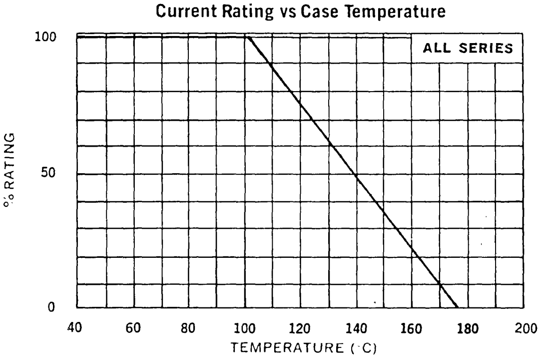
Reverse Recovery Circuit



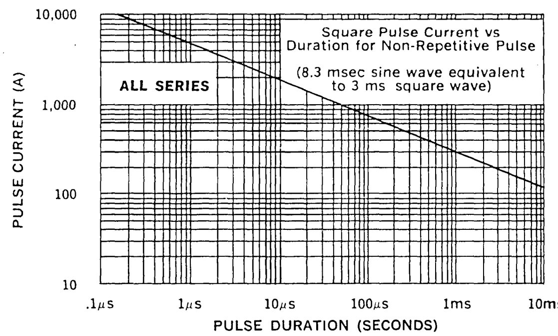
Efficiency vs Frequency at Rated Current (Sine Wave)



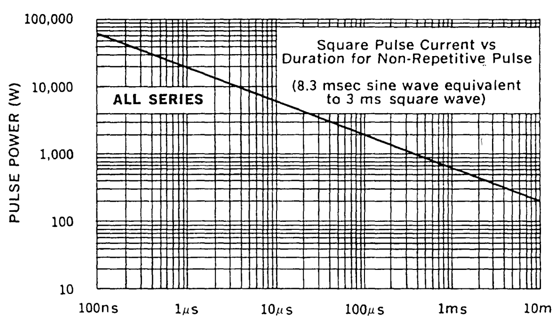
Current Rating vs Case Temperature



Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



RECTIFIERS

Ultra-Fast Recovery, 1 Amp and 2 Amp

UTX105-UTX125
UTX205-UTX225

FEATURES

- Continuous Rating: to 2A
- Controlled Avalanche
- Surge: to 25A
- Recovery Time less than 75ns
- Miniature Package

DESCRIPTION

These miniature ultra-fast recovery rectifiers permit operation at full power at frequencies as high as 100kHz square wave. They may be used as half wave rectifiers or as legs of a bridge.

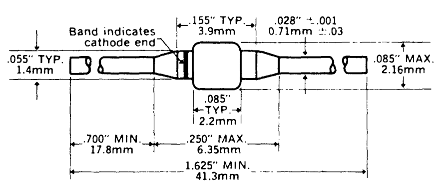
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1 Amp Series	2 Amp Series
50V	UTX105	UTX205
100V	UTX110	UTX210
150V	UTX115	UTX215
200V	UTX120	UTX220
250V	UTX125	UTX225

	1 AMP SERIES	2 AMP SERIES
Maximum Average D.C. Output Current		
@ $T_A = 25°C$	1.0A	2.0A
@ $T_A = 100°C$	0.5A	1.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	20A	25A
Operating Temperature Range	—195°C to +175°C	
Storage Temperature Range	—195°C to +200°C	
Thermal Resistance	See Lead Temperature Derating Curve	

MECHANICAL SPECIFICATIONS

UTX105-UTX125 UTX205-UTX225



Part Identification: Green band indicates "UTX." Part number printed on body.

Polarity: Denoted by green band.

Weight: 0.26 grams, typical.

BODY A

UNITRODE

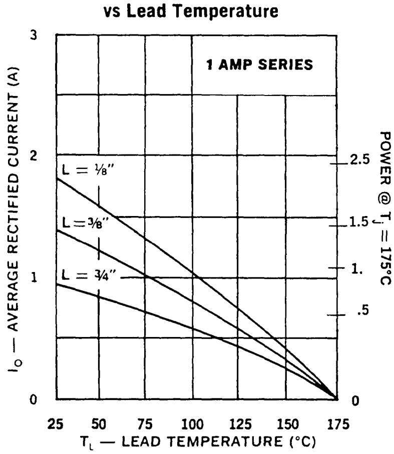
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	PIV	Maximum Voltage Forward Drop	Leakage Current @ PIV		Max. Reverse Recovery Time*
			25°C	100°C	
UTX 205 UTX 210 UTX 215 UTX 220 UTX 225	50V 100V 150V 200V 250V	1.0V @ 1 Adc	3μA	50μA	75ns
UTX 105 UTX 110 UTX 115 UTX 120 UTX 125	50V 100V 150V 200V 250V	1.0V @ 0.5 Adc	3μA	50μA	75ns

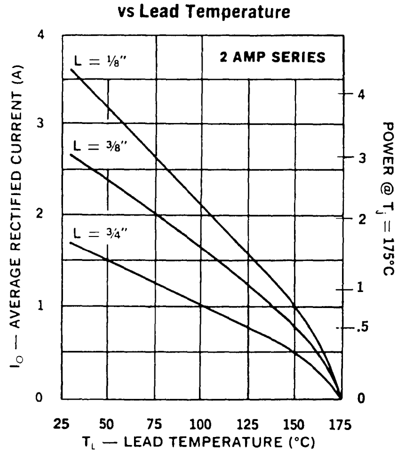
*Recovery time is measured from 10.0mA to 10.0mA recovery to 5.0mA.

VI

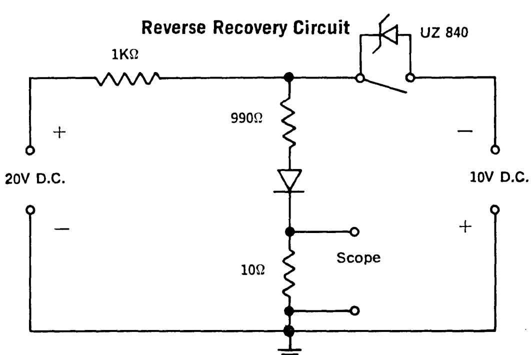
Maximum Current vs Lead Temperature



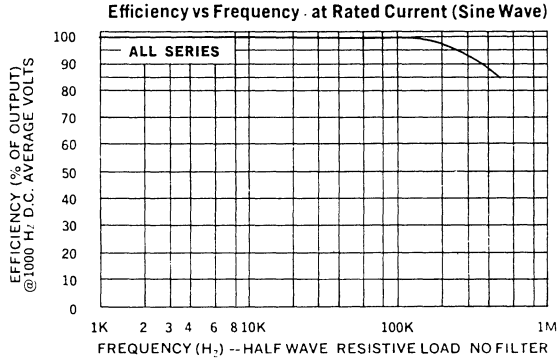
Maximum Current vs Lead Temperature



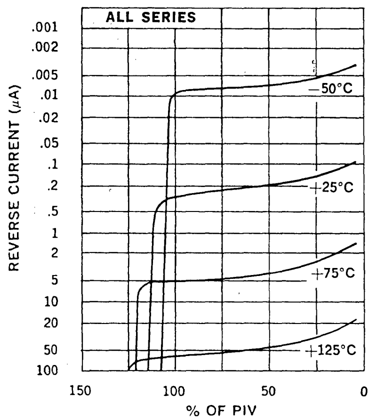
Reverse Recovery Circuit



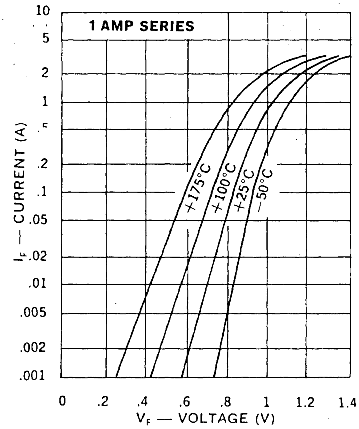
Efficiency vs Frequency at Rated Current (Sine Wave)



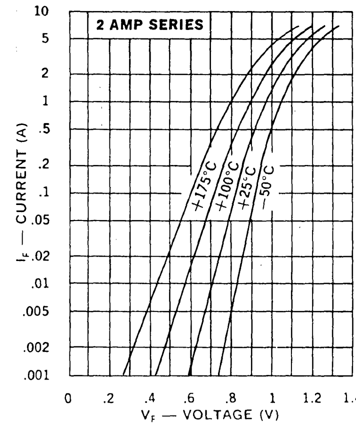
Typical Leakage Current vs. PIV



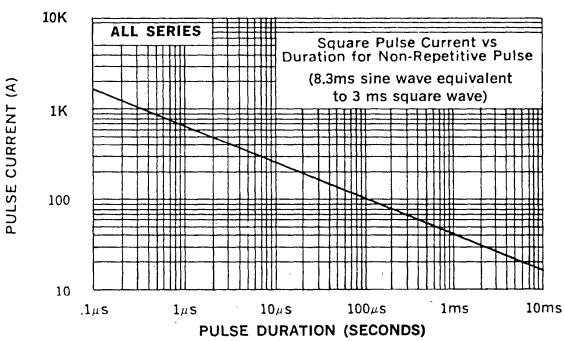
Typical Forward Current vs Forward Voltage



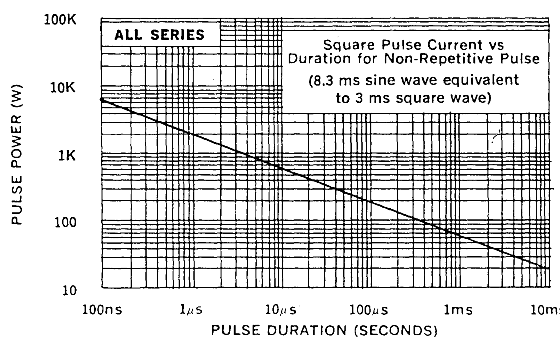
Typical Forward Current vs Forward Voltage



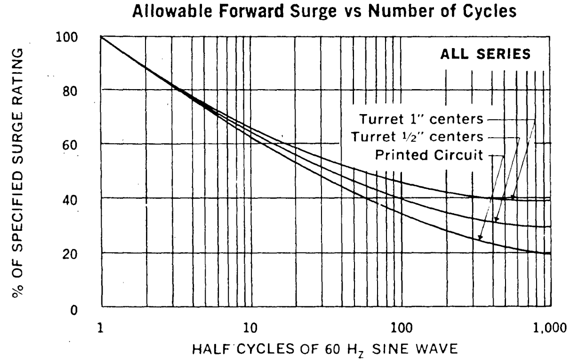
Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



Allowable Forward Surge vs Number of Cycles



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RECTIFIERS

Ultra-Fast Recovery, 3 Amp and 4 Amp

UTX 3105-UTX 3120
UTX 4105-UTX 4120

FEATURES

- Continuous Rating: to 4A
- Controlled Avalanche
- Surge: to 80A
- Recovery Time less than 100ns
- Miniature Package

DESCRIPTION

These miniature ultra-fast recovery rectifiers permit operation at full power at frequencies as high as 100kHz square wave. They have the same unique Unitrode construction as the familiar 2 amp UTX series, but are scaled up in size to provide higher continuous and surge current capability.

VI

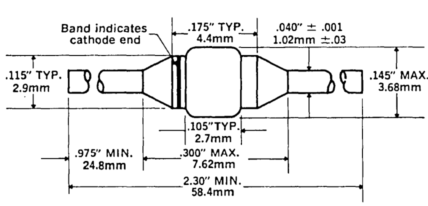
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	3 Amp Series	4 Amp Series
50V	UTX 3105	UTX 4105
100V	UTX 3110	UTX 4110
150V	UTX 3115	UTX 4115
200V	UTX 3120	UTX 4120

	3 AMP SERIES	4 AMP SERIES
Maximum Average D.C. Output Current		
@ $T_A = 25°C$	3.0A	4.0A
@ $T_A = 100°C$	1.5A	2.0A
Non-Repetitive Sinusoidal Surge Current (8.3ms)	60A	80A
Operating Temperature Range	—195°C to +175°C	
Storage Temperature Range	—195°C to +200°C	
Thermal Resistance	See Lead Temperature Derating Curve	

MECHANICAL SPECIFICATIONS

UTX 3105-UTX 3120 UTX 4105-UTX 4120



UTX Prefix is identified by a Green Cathode Band

BODY B

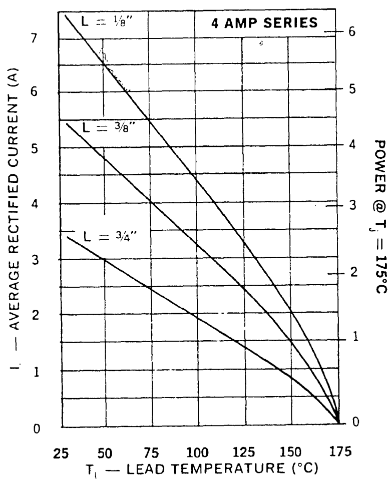
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

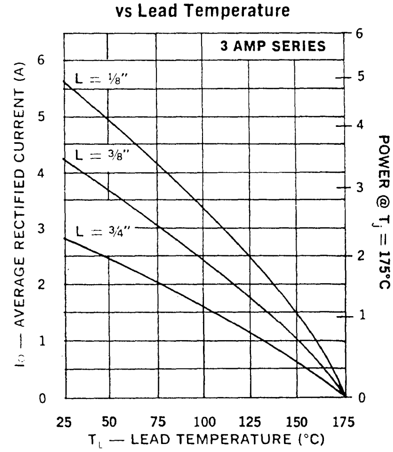
Type	PIV	Maximum Forward Voltage Drop*	Maximum Leakage Current @ PIV 25°C	Maximum Leakage Current @ PIV 100°C	Maximum Reverse Recovery Time**
UTX 4105 UTX 4110 UTX 4115 UTX 4120	50V 100V 150V 200V	1V @ 3 Adc	5μA	75μA	100ns
UTX 3105 UTX 3110 UTX 3115 UTX 3120	50V 100V 150V 200V	1V @ 2 Adc	5μA	75μA	100ns

*Forward voltage is measured at least 1 second after application of current.
**Recovery time is measured from 1A to 1A recovering to 0.5A.

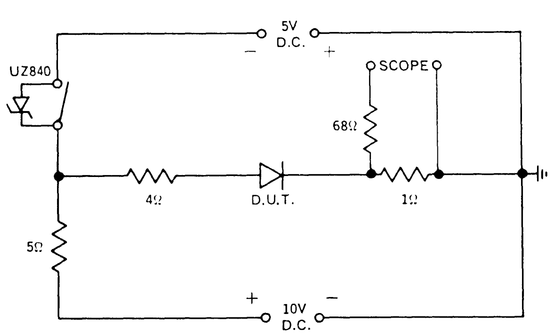
Maximum Current vs Lead Temperature



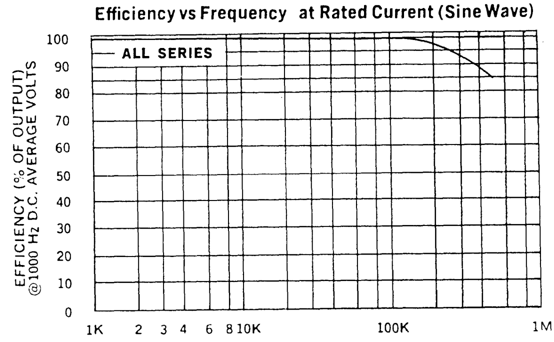
Maximum Current vs Lead Temperature



Reverse Recovery Circuit



Efficiency vs Frequency at Rated Current (Sine Wave)



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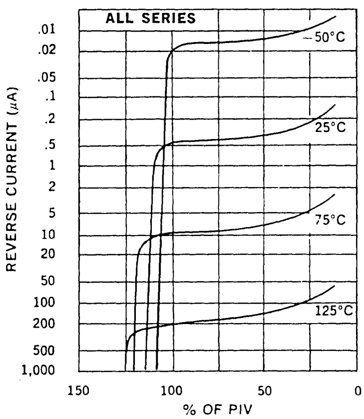
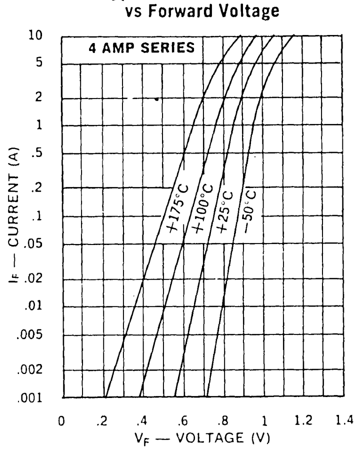
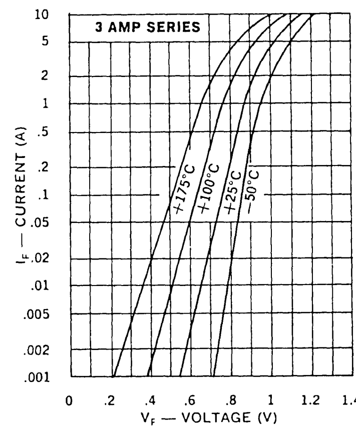
Typical Leakage Current vs PIV



Typical Forward Current vs Forward Voltage

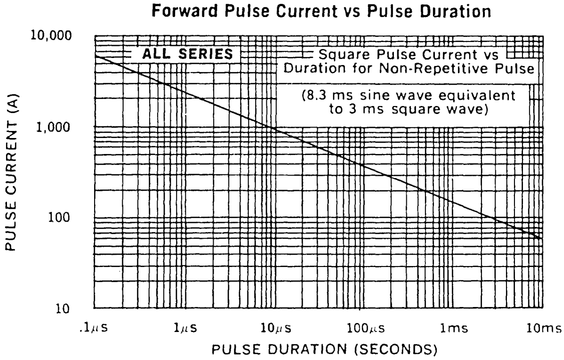


Typical Forward Current vs Forward Voltage

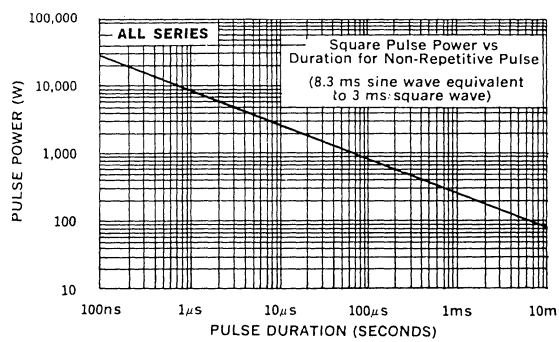


VI

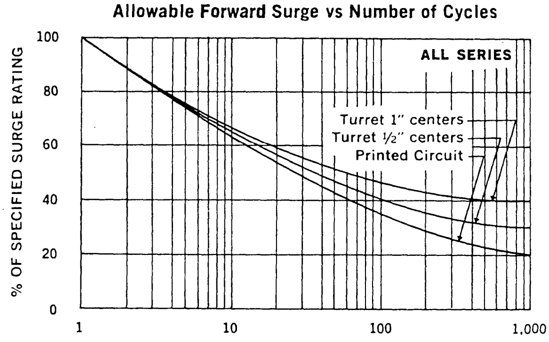
Forward Pulse Current vs Pulse Duration



Reverse Pulse Power vs Pulse Duration



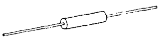
Allowable Forward Surge vs Number of Cycles



HIGH VOLTAGE RECTIFIERS, RECTIFIER MODULES & MULTIPLIERS VII

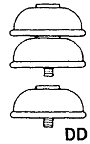
HIGH VOLTAGE RECTIFIERS & RECTIFIER MODULES

PRODUCT SELECTION GUIDE

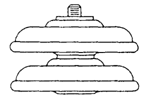


SA–SM

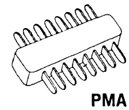
PC



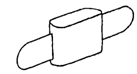
DD



DG



PMA



PME

VII

STANDARD RECOVERY

Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT											
	.025-.050A	.050-.100A	.100-.250A	.250-.50A	.50-.75A	.75-1A	1-1.5A	1.5-2A	2-2.5A	2.5-5A	5-6A	6-7A
1.0kV			HVE10 **SJ** HS10 **SK** 1N3643 **SJ**			SXS10 **SL**						
1.2kV							(US12) **SA**					
1.5kV		LS15 **SH** LMS15 **SG** MS15 **SH** MXS15 **SG**	HS15 **SK** HVE15 **SJ** 1N3644 **SJ**			SXS15 **SL** (US15) **SA**				KXS15 **SM**		
1.8kV					(US18) **SA**							
2.0kV		LS20 **SH** LMS20 **SG** MS20 **SH** MXS20 **SG**	HS20 **SK** HVE20 **SJ** 1N3645 **SJ**		(US20) **SA**	SXS20 **SL**				KXS20 **SM**		
2.5kV		LS25 **SH** LMS25 **SG** MS25 **SH** MXS25 **SG**	HS25 **SK** HVE25 **SJ** 1N3646 **SJ**		(US25) **SB**	SXS25 **SL** PME101 **PME**	(USB2.5) **DH**	PMA201 **PMA**	HVHS 2500 **PC**	KXS25 **SM** (UDB2.5) **DD**	(UDE2.5) **DD**	(UGE2.5) **DG**
3.0kV	LS30 **SH** LMS30 **SG** MS30 **SH** MXS30 **SG**		HS30 **SK** HVE30 **SJ** 1N3647 **SJ**		SXS30 **SL** (US30) **SB**				KXS30 **SM**			
3.5kV				(US35) **SC**								
4.0kV	LS40 **SH** LMS40 **SG** MS40 **SH** MXS40 **SG**	HS40 **SK** HVE40 **SJ** 1N5181 **SJ**		(US40) **SC**	SXS40 **SL** PME102 **PME**				KXS40 **SM**			
4.5kV				(US45A) **SD**								

Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.

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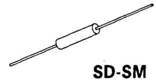
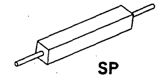
HIGH VOLTAGE RECTIFIERS & RECTIFIER MODULES



SD-SM



SP

STANDARD RECOVERY

Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT													
	≤.025A	.025-.050A	.050-.100A	.100-.250A	.250-.50A	.50-.75A	.75-1A	1-1.5A	1.5-2A	2-2.5A	2.5-3A	3-4A	4-5A	5-6A
5.0kV		LS50 **SH** LMS50 **SG** MS50 **SH** MXS50 **SG**	HS50 **SK** HVE50 **SJ** 1N5182 **SJ**		HVH 5000 **PB** HVHF 5000 **PB** (US50A) **SD**	SXS50 **SL** (USB5) **DH** (USS5) **DH**	PMA101 **PMA**		(UDA5) **DD** (UDB5) **DD** (1N5600)* **DE** PMA202 **PMA**	KXS50 **SM** HVHS 5000 **PC**			(UDE5) **DG** (UGB5) **DD**	(UGE5) **DG** (1N5603)* **DF**
6.0kV	LS60 **SH** LMS60 **SG** MS60 **SH** MXS60 **SG**				SXS60 **SL** (US60A) **SD**			KXS60 **SM**						
7.0kV					(US70A) **SD**									
7.5kV			HS75 **SK** HVF75 **SJ** 1N5183 **SJ**		HVH 7500 **PB** HVHF 7500 **PB** (USS7.5) **DH**	(USB7.5) **DH**	PMA102 **PMA**	(UDA7.5) **DD** (UDB7.5) **DD**	PMA203 **PMA**	HVHS 7500 **PC**	(UGB7.5) **DG**	(UGE7.5) **DG**		
8.0kV	LS80 **SH** LMS80 **SG** MS80 **SH** MXS80 **SG**			(US80A) **SE**	SXS80 **SL** PME103 **PME**			KXS80 **SM**						
10kV	LS100 **SH** LMS100 **SG** MS100 **SH** MXS100 **SG**		HS100 **SK** HVE100 **SJ** 1N5184 **SJ**	(US100A) **SE**	HVH 10000 **PB** HVHF 10000 **PB** SXS100 **SL** (USB10) **DH** (USS10) **DH**	(688-10) **BE**	(UDA10) **DD** * (1N5597) **DE** PMA103 **PMA**	KXS100 **SM**	PMA204 **PMA**	HVHS 10000 **PC** (UGB10) **DG**				
12kV	LS120 **SH** LMS120 **SG** MS120 **SH** MXS120 **SG**			(US120A) **SE**	(688-12) **BE**									
12.5kV					HVH 12500 **PB** HVHF 12500 **PB**					HVHS 12500 **PC**				

Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.
*Available as JAN

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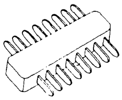
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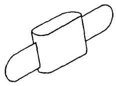
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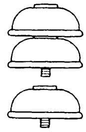
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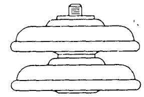
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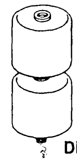
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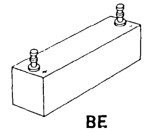
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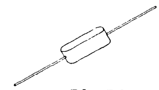

PA PC

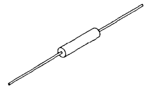
VII

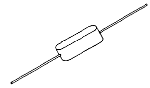
STANDARD RECOVERY

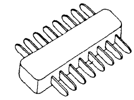
Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT														
	≤.025A	.025-.050A	.050-.100A	.100-.250A	.250-.50A	.50-.75A	.75-1A	1-1.5A	1.5-2A	2-2.5A	2.5-3A	3-4A	4-5A	5-6A	6-7A
15kV	LMS150 **SG** MXS150 **SG** VXS15 **SP**	HVHJ 15K **PA**		(US150A) **SF** (USS15) **DH**	HVH 15000 **PB** HVHF 15000 **PB** (688-15) **BE**	(UDA15) **DD**	PMA104 **PMA**		PMA205 **PMA**	HVHS 15000 **PC**					
17.5kV										HVHS 17500 **PC**					
18kV	LMS180 **SG**			(US180A) **SF**	(688-18) **BE**										
20kV	MXS200 **SG** VXS20 **SP**	HVHJ 20K **PA**		(US200A) **SF**	HVH 20000 **PB** HVHF 20000 **PB** (688-20) **BE**		PMA105 **PMA**		PMA206 **PMA**	HVHS 20000 **PC**					
22.5kV		HVHJ 22.5K **PA**													
25kV	VXS25 **SP**	HVHJ 25K **PA**		(688-25) **BE**	HVH 25000 **PB** HVHF 25000 **PB**		PMA106 **PMA**		PMA207 **PMA**						
30kV	VXS30 **SP**	HVHJ 30K **PA**					PMA107 **PMA**		PMA208 **PMA**						
35kV		HVHJ 35K **PA**					PMA108 **PMA**								
37.5kV		HVHJ 37.5K **PA**													
40kV	VXS40 **SP**	HVHJ 40K **PA**					PMA109 **PMA**								
45kV		HVHJ 45K **PA**													
50kV	VXS50 **SP**						PMA110 **PMA**								
60kV							PMA111 **PMA**								

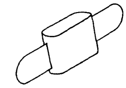
Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.

HIGH VOLTAGE RECTIFIERS & RECTIFIER MODULES


SA– SN


PA– PC


PMA


PME

FAST RECOVERY

Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT									
	.025- .050A	.050- .100A	.100- .250A	.250- .50A	.50- .75A	.75- 1.5A	1.5- 2A	2- 2.5A	2.5- 4A	4- 6A
1.0kV			HA10* **SK** HVX10* **SJ**			SX10* **SL**				
1.2kV						(USR12) **SA**				
1.5kV		LA15 **SH** LM15* **SG** MA15* **SH** MX15 **SG**	HA15* **SK** HVX15 **SJ**		(USR15) **SA**	SX15* **SL**			KX15* **SM**	
1.8kV					(USR18) **SA**					
2.0kV		LA20 **SH** LM20 **SG** MA20* **SH** MX20* **SG**	HA20* **SK** HVX20* **SJ**		(USR20) **SB**	SX20* **SL**			KX20* **SM**	
2.5kV		LA25 **SH** LM25 **SG** MA25* **SH** MX25* **SG**	HA25* **SK** HVX25* **SJ**	HVF 2500† **PB** (USR25) **SB**		SX25* **SL** (UFB2.5) **DH** PME101X* **PME**	PMA201X **PMA**	HVFS 2500† **PC** (UDD2.5) **DD**	KX25* **SM**	(UDF2.5) **DD** (UGF2.5) **DG**
3.0kV	LA30 **SH** LM30 **SG** MA30* **SH** MX30* **SG**		HA30* **SK** HVX30* **SJ**	(USR30) **SC**	SX30* **SL**			KX30* **SM**		
3.5kV				(USR35) **SC**						
4.0kV	LA40 **SH** LM40 **SG** MA40* **SH** MX40* **SG**	HA40* **SK** HVX40* **SJ**		(USR40A) **SD**	SX40* **SL** PME102X* **PME**			KX40* **SM**		
4.5kV			(USR45A) **SD**							
Reverse Recovery Time (Max.)	300ns 250ns*	300ns 250ns*	500ns 250ns*	500ns 250ns†	500ns 250ns*	500ns 250ns*	500ns 250ns	500ns 250ns* 150ns†	250ns*	500ns

Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.

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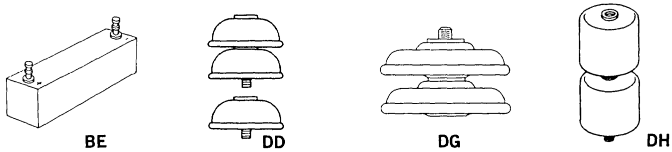


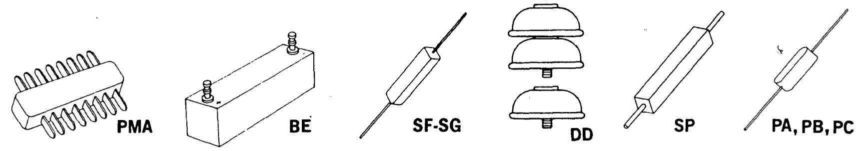
PRODUCT SELECTION GUIDE

FAST RECOVERY

Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT										
	≤.025A	.025- .050A	.050- .100A	.100- .250A	.250- .50A	.50- .75A	.75- 1A	1- 1.5A	1.5- 2A	2- 2.5A	2.5- 4A
5.0kV		LA50 **SH** LM50 **SG** MA50* **SH** MX50* **SG**	HA50 **SK** MVX50 **SJ**	(USR50A) **SD**	HVF 5000† **PB** (UFS5) **DH**	SX50* **SL** (UFB5) **DH**	PMA101X* **PMA**	(UDC5) **DD** (UDD5) **DD**	PMA202X* **PMA**	HVFS 5000† **PC** KX50* **SM**	(UDF5) **DD** (UGD5) **DG** (UGF5) **DG**
6.0kV	LA60 **SN** LM60 **SG** MA60* **SH** MX60* **SG**			(USR60A) **SD**	SX60* **SL**			KX60* **SM**			
7.0kV				(USR70A) **SE**							
7.5kV			HA75 **SK** HVX75 **SJ**		HVF 7500† **PB** (UFB7.5) **DH** (UFS7.5) **DH**		(UDC7.5) **DD** (UDD7.5) **DD** PMA102X* **PMA**		PMA203X* **PMA**	HVFS 7500† **PC** (UGD7.5) **DG** (UGF7.5) **DG**	
8.0kV	LA80 **SH** LM80 **SG** MA80* **SH** MX80* **SG**			(USR80A) **SE**	SX80* **SL** PME103X* **PME**			KX80* **SM**			
10kV	LA100 **SH** LM100 **SG** MA100* **SH** MX100* **SG**		HA100 **SK** HVX100 **SJ**	(USR100A) **SE**	HVF 10000† **PB** SX100* **SL** (UFS10) **DH**	(UDC10) **DD** (688-10R) **BE**	PMA103X* **PMA**	KX100* **SM**	(UGD10) **DG** PMA204X* **PMA**	HVFS 10000† **PC**	
12kV	LA120 **SH** LM120 **SG** MA120* **SH** MX120* **SG**			(USR120A) **SF**	(688-12R) **BE**						
12.5kV					HVF 12500† **PB**						HVFS 12500† **PC**
Reverse Recovery Time (Max.)	300ns 250ns*	300ns 250ns*	250ns	500ns	500ns 250ns* 150ns†	500ns 250ns*	500ns 250ns*	500ns 250ns*	500ns 250ns*	500ns 250ns* 150ns†	500ns

Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.

HIGH VOLTAGE RECTIFIERS & RECTIFIER MODULES



FAST RECOVERY

Peak Inverse Voltage	AVERAGE D.C. OUTPUT CURRENT						
	≤.025A	.025- .100A	.100- .250A	.250- .75A	.75- 1.5A	1.5- 2A	2- 2.5A
15kV	LM150 **SG** MX150* **SG** VX15* **SP**	HVJX 15K **PA**	(USR150A) **SF**	HVF 15000† **PB** (UDC15) **DD** (688-15R) **BE**	PMA104X **PMA**	PMA205X **PMA**	HVFS 15000 **PC**
17.5kV							HVFS 17500 **PC**
18kV	LM180 **SG**		(USR180A) **SF**	(688-18R) **BE**			
20kV	MX200 **SG** VX20* **SP**	HVJX 20K **PA**	(688-20R) **BE**	HVF 20000† **PB**	PMA105X **PMA**	PMA206X **PMA**	HVFS 20000 **PC**
22.5kV		HVJX 22.5K **PA**					
25kV	VX25* **SP**	HVJX 25K **PA**	(688-25R) **BE**	HVF 25000† **PB**	PMA106X **PMA**	PMA207X **PMA**	
30kV	VX30* **SP**	HVJX 30K **PA**			PMA107X **PMA**	PMA208X **PMA**	
35kV		HVJX 35K **PA**			PMA108X **PMA**		
37.5kV		HVJX 37.5K **PA**					
40kV	VX40* **SP**	HVJX 40K **PA**			PMA109X **PMA**		
45kV		HVJX 45K **PA**					
50kV	VX50* **SP**				PMA110X **PMA**		
60kV					PMA111X **PMA**		
Reverse Recovery Time (Max.)	300ns 250ns*	250ns	500ns	500ns 150ns†	250ns	250ns	150ns

Parentheses ( ) designates product using fused-in-glass single chip rectifiers; all others use stacked chips.

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HIGH VOLTAGE MULTIPLIERS

PRODUCT SELECTION GUIDE

VII

The voltage multiplier is an efficient power conversion device used to generate high voltage DC, from a lower level AC potential. This is accomplished with a network of silicon rectifiers and capacitors which rectifies the AC voltage and additively charges the capacitors to a desired high voltage level. High voltage power supply designs can be simplified by the proper selection of a voltage multiplier circuit that can optimize the critical parameters of the application.

Recent technological advances in high voltage silicon rectifiers, high voltage capacitors and packaging techniques have resulted in the development of ultra high reliablity voltage multipliers. These Unitrode innovations allow voltage multipliers to be supplied as a basic component which can meet the exacting requirements of commercial, industrial and Hi-Rel military applications.

Lack of manufacturing control of the basic components in a multiplier can make user fabricated devices costly and with marginal technical performance.

A comprehensive knowledge of high voltage multipliers provides a complete service from design, to prototype through production quantities. High performance devices can be developed and tested to meet virtually any electrical specification and mechanical configuration, with production units supplied at a very minimum of cost.

The major factors that guarantee the technical performance and reliability of our production assemblies are:

- COMPLETE "IN HOUSE" SILICON RECTIFIER FABRICATION
- CORONA FREE CERAMIC CAPACITORS
- 100% SCREENING OF DISCRETE COMPONENTS PRIOR TO ASSEMBLY
- CORONA FREE PACKAGING
- EXTENDED OPERATING AND STORAGE TEMPERATURE CAPABILITY
- CIRCUITRY SELECTED TO MEET SYSTEM REQUIREMENTS
- INCLUSION OF FILTERS, BLEEDERS, DIVIDER NETWORKS AND SPECIAL TERMINATIONS WITHIN THE MULTIPLIER PACKAGE

Consideration of these major factors gives a greater insight to their importance in obtaining high reliability voltage multipliers.

HIGH VOLTAGE MULTIPLIERS

COMPLETE "IN HOUSE" SILICON RECTIFIER FABRICATION

The "MULTIVOLT" silicon rectifiers are engineered for often overlooked parameters that are essential for reliable multiplier design. Capacitor charging currents require high repetitive surge and conservative steady state current ratings while reverse voltage must be high enough to compensate for overload and transient conditions. Closely matched fast recovery junctions with low reverse leakage and minimal junction capacitance directly affect efficiency, particularly in high frequency applications. The "MULTIVOLT" rectifiers meet all of this criteria. Proprietary innovations in manufacturing technique incorporating cylindrical die construction, metallurgical bonds and corona free packaging minimize electrical and mechanical stress and insure the production of high reliability voltage multipliers.

CORONA FREE CAPACITORS

The most important parameter measurable in high voltage capacitors that is directly related to reliability, is corona. Technological advances in design and manufacturing provide corona free, high K dielectric ceramic capacitors specifically for voltage multiplier applications. Their temperature characteristic, capacitance, voltage coefficient and dissipation factor are also devised to guarantee that each multiplier will technically perform within the required environmental conditions.

100% SCREENING OF DISCRETE COMPONENTS PRIOR TO ASSEMBLY

The individual rectifiers, capacitors and resistors incorporated into each multiplier are selected and 100% tested to meet the specific requirements of the application. "On line" lot control through final assembly with verification in final test, guarantees technical performance.

CORONA FREE PACKAGING

High voltage multiplier packaging is as critical as the initial selection of reliable components. Component positioning to minimize electrical gradients and interelement coupling are a necessity. Encapsulating materials are most critical and must exhibit expansion coefficient compatibility to allow operation over the specified temperature range. The encapsulents have to adhere to all components, require high dielectric strength, low dielectric constant, high thermal conductivity, low thermal expansion, low leakage and be relatively easy to process for assurance of a corona free device.

EXTENDED OPERATING AND STORAGE TEMPERATURE CAPABILITY

Technological advances incorporated in these silicon rectifiers and capacitors coupled with the availability of compatible packaging materials allows the manufacture of Hi-Rel voltage multipliers that can operate from −65° to +100°C ambient temperature.

CIRCUITRY SELECTED TO MEET SYSTEM REQUIREMENTS

Each multiplier application has to be evaluated on the basis that the customer's system is to meet specific electrical, mechanical, environmental and cost design criteria. A comprehensive understanding of high voltage multiplier applications permits the suggestion, design, testing and manufacture of devices that meet or exceed the user's system requirements. A multiplier tailored to a system, rather than a system "designed around" a device, results in ultra high reliability.

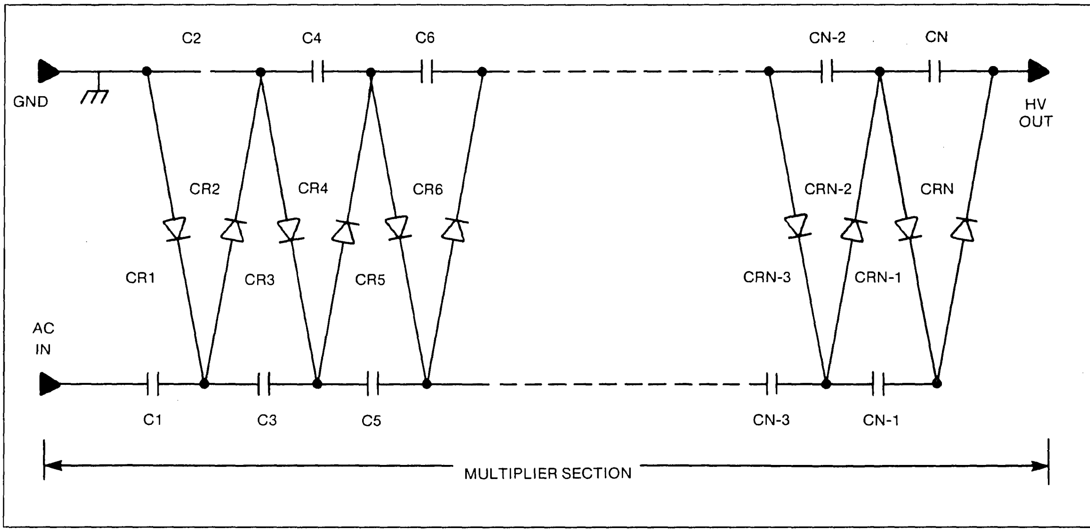
INCLUSION OF FILTERS, BLEEDERS, DIVIDER NETWORKS AND SPECIAL TERMINATIONS WITHIN THE MULTIPLIER PACKAGE

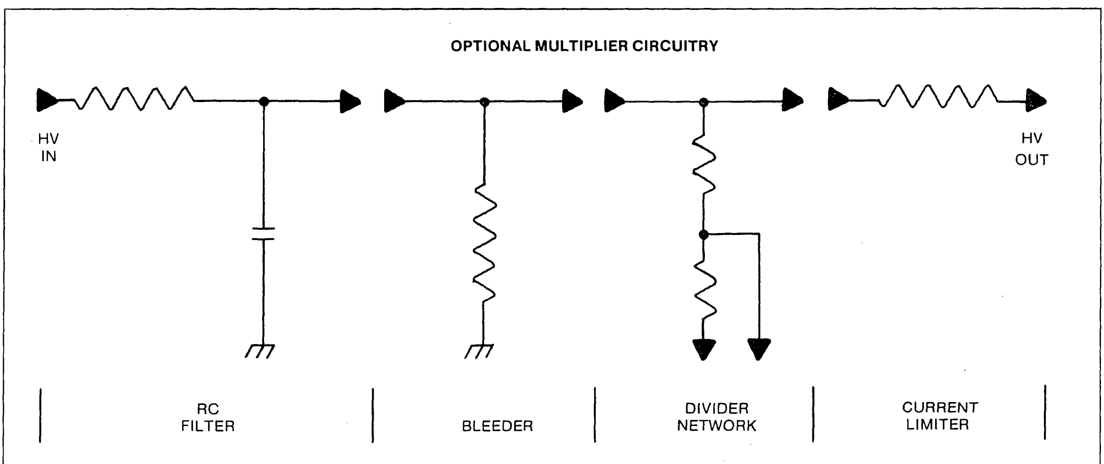
Voltage multipliers designed to include ripple reduction filters, bleeders, precision TC and ratio matched divider networks and special terminations, enhance the device as a "basic component". The ability to incorporate these components within the assembly, eliminates potential corona sources, simplifies a system's mechanical design and provides another edge in the quest for reliability.

VOLTAGE MULTIPLIER CIRCUITS

There are numerous circuits available to the designer which perform the function of voltage multiplication. The most commonly used are the basic series, parallel or a hybrid of the two.

Voltage multiplier circuits can be designed to accept sine, square or single ended (flyback) input wave forms. In any multiplier, a stage (N) is considered to be one rectifier and capacitor unit which multiplies one times the peak input voltage. The relative merits of the basic circuits are outlines in the following.





The circuits shown can be included, in any combination, within a series, parallel or hybrid voltage multiplier assembly.

THE SERIES MULTIPLIER

A typical half wave series multiplier, as illustrated with optional associated circuitry, is the most commonly used and economical type circuit. Low cost is achieved by capacitor and rectifier voltage rating only required to be the equivalent of the peak to peak input voltage.

Performance and multiplication efficiency is governed by regulation and ripple being proportional to the number of stages (N) utilized to the third power (N^3) and squared (N^2), respectively. High multiplication factors are restricted by a rapid increase in internal impedance which limits its useable output current capability.

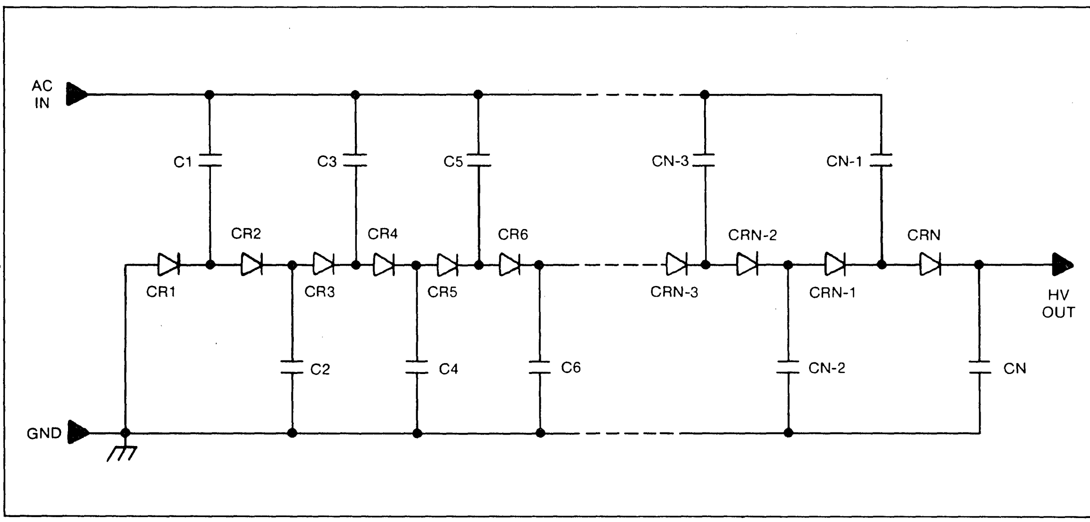
HIGH VOLTAGE MULTIPLIERS

THE PARALLEL MULTIPLIER

The parallel voltage multiplier shown offers many technical advantages over other circuits. Each rectifier sees the equivalent peak to peak input voltage while the capacitors in each succeeding stage (N) sees a higher voltage, being equal to the peak input voltage times the number of stages (N).

Regulation is proportional to the number of stages (N) and ripple is independent of them, the value of the capacitors being the determining factor. Low internal impedance provides greater efficiency, minimal power dissipation and higher useable output current capability.

The parallel circuit can achieve higher multiplication ratios with the added advantage of smaller size packages, an important consideration for portable and airborne electronic systems.



SPECIFYING A CUSTOM VOLTAGE MULTIPLIER

The selection of a voltage multiplier circuit for a specific application is dependent upon the systems overall operating parameters and cost. Each custom design requires detailed information about the application in order to determine the proper approach. The MULTIPLIER DESIGN INFORMATION SHEET was developed to assist a customer in describing his multiplier requirement, providing us with the basis for recommending a specific design.

A review of the MULTIPLIER DESIGN INFORMATION SHEET will reveal its self explanatory format.

Attention to detail in the information initially provided, will assure an accurate and prompt response from our applications department. Particular attention should be given to mechanical considerations. Where non standard shapes are required, include sketches or drawings whenever possible.

Copies of the MULTIPLIER DESIGN INFORMATION SHEET can be obtained from our representative or from the factory.

MULTIPLIER DESIGN INFORMATION SHEET

COMPANY NAME ______________________ DATE ______________________
ADDRESS ______________________ CUSTOMER PART NUMBER ______________________
______________________ UNITRODE PART NUMBER ______________________
TELEPHONE ______________________ QUANTITY (time span) ______________________
ENGINEER (Ext) ______________________ PROGRAM ______________________
PURCHASING (Ext) ______________________ APPLICATION ______________________
SALES ENG ______________________

1. Power Supply System - Regulated ______ Unregulated ______
2. Type of Multiplier - Series ________ Parallel ________ Other (Supply Schematic) ________
3. No. of Stages (Optional) ________ *(Each rectifier and capacitor unit represents one stage).*
4. Input Characteristics
   Wave Form - Sine ________ Square ________ Fly Back ________ Other ________
   Frequency ______________________
   Nominal peak to peak A.C. input voltage ______________________ Max. ______________________
5. Output Characteristics
   Polarity - Positive ______________ Negative ______________
   No load output voltage with nominal input ______________________ Max. ______________________
   Nature of load - Resistive ________ Capacitive ________ Inductive ________ Other ________
   Full load output current ______________________
   Minimum output voltage at full load ______________________
   (Or % regulation required)
   Maximum peak to peak A.C. ripple at full load ______________________ Preferred ______________________
6. Mechanical
   Size - Preferred W ______ L ______ H ______ Max. W ______ L ______ H ______ (include sketch)
   Terminations - Wire ______________ Terminals ______________ Connector ______________
   (Include sketch and preferred locations)
   Mounting Requirements ______________________ (Specify locations and ground planes)
7. Environmental
   Temperature range - Operating ______________________ Non-operating ______________________
   Type of Environment ______________________
   Other requirements ______________________
8. Miscellaneous
   Voltage taps (specify voltage and current) ______________________
   Divider / Bleeder network ______________________ Temperature co-efficient req. ______________________
   Filter ______________________
   Current Limiting ______________________
   Special Requirements ______________________

CUSTOMER SPECIFICATION SHEET FOR SPECIAL RECTIFIER ASSEMBLIES

Date ____________

Company Name ____________ Phone ____________

Address ____________ City ____________ State ____________

Engineer ____________ Ext. ________ Buyer ____________ Ext. ________

________ New Application, ________ Existing Application, Presently Using ____________

Quantities to Quote ____________

ELECTRICAL REQUIREMENTS

Rectifier Application:

1. Circuit: ________ Half Wave ________ Center Tap ________ Doubler ________ Bridge
2. AC Input: ________ Volts ________ CPS ________ Phase ________ Wave Shape
3. DC Output: ________ Volts ________ Amps At ________ °C
4. Max. Transient Voltage: ____________ Volts
5. Max. Fault Current: ________ Amps For ________ Sec.
6. Type of Load ____________

Modulator Application:

1. Use ____________
2. Peak Voltage ____________ V
3. Wave Shape ____________
4. Rise or Switching Time ____________ Sec.
5. Peak Pulse Current ________ Amps At ________ °C
6. Pulse Duration ____________ Sec.
7. Average Current ____________ Amps
8. PRF ____________ PPS

ENVIRONMENTAL REQUIREMENTS

Operating Medium ____________

Operating Temperature Range ____________

Storage Temperature Range ____________

Other Requirements ____________

____

MECHANICAL REQUIREMENTS

Maximum Size ____________

Maximum Weight ____________

Terminal Provisions ____________

Mounting Provisions ____________

RECTIFIER ASSEMBLIES

High Voltage Stacks, 1 Amp to 5 Amp, Military Approved

JAN 1N5597
JAN 1N5600
JAN 1N5603

FEATURES

- Qualified to MIL-S-19500/404A
- PIV: to 10kV
- Surge Ratings: to 200A
- Current Ratings: to 5A
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Modular Package For Easy Stacking

DESCRIPTION

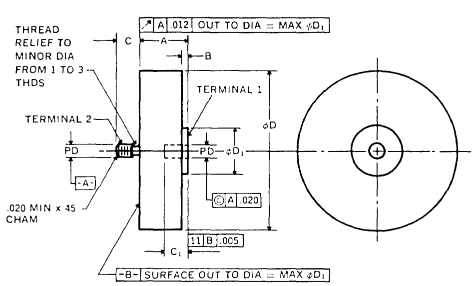
This series of military high-voltage high-current stacks offers the utmost in reliability as required in military system designs. The rectifiers are assembled with diodes which have been subjected to TX type screening tests.

VII

ABSOLUTE MAXIMUM RATINGS

	JAN 1N5597	JAN 1N5600	JAN 1N5603
Peak Inverse Voltage	10kV	5kV	5kV
Maximum Average D.C. Output Current @ $T_C = 75°C$	1A	2A	5A
Non-Repetitive Sinusoidal Surge (8.3ms) @ $T_C = 75°C$	30A	80A	200A
Operating and Storage Temperature Range	−65°C to +150°C		

MECHANICAL SPECIFICATIONS



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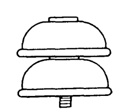
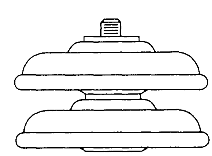


DF



JAN 1N5597 JAN 1N5600

Ltr	Dimensions in inches with metric equivalents (mm) in parentheses		NOTES
	Minimum	Maximum	
A	.73 (18.54)	.83 (21.08)	8
B		.080 (2.03)	
C	.240 (6.10)	.264 (6.71)	2,6
C_1	.265 (6.73)	.400 (10.16)	4
φD	1.85 (46.99)	1.95 (49.53)	
$φD_1$	.57 (14.48)	.67 (17.02)	

JAN 1N5603

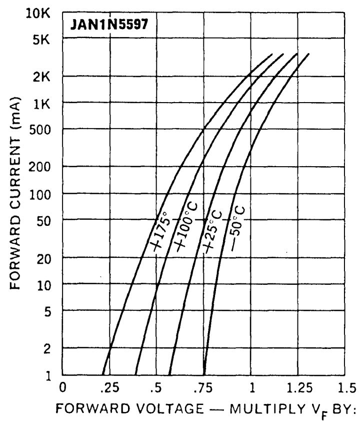
Ltr	Dimensions in inches with metric equivalents (mm) in parentheses		NOTES
	Minimum	Maximum	
A	.970 (24.64)	1.020 (25.91)	8
B	.050 (1.27)	.080 (2.03)	
C	.307 (7.80)	.317 (8.05)	3
C_1	.318 (8.08)	.400 (10.16)	5,7
φD	3.450 (87.63)	3.650 (92.71)	
$φD_1$	.95 (24.13)	1.250 (31.75)	

1. All marking shall be on cathode side of module.
2. Threaded stud 1/4-28UNF-2A.
3. Threaded stud 3/8-24UNF-2A.
4. Threaded insert 1/4-28UNF-2B.
5. Threaded insert 3/8-24UNF-2B.
6. Cathode connected to terminal 2.
7. Cathode connected to terminal 1.
8. Module contour within dimension A is not specified.

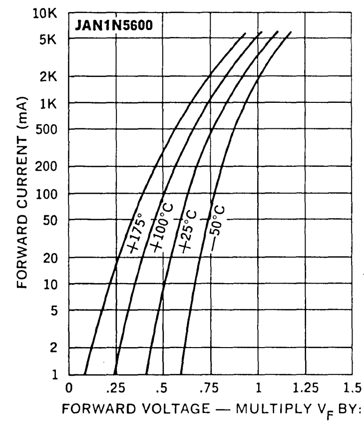
Electrical Specifications (at 25°C unless noted)

Type	PIV	Forward Voltage Drop		Maximum Leakage Current @ PIV		Capacitance @ V_R = 100V		Maximum Reverse Transient Energy Absorption
		Min.	Max.	T_A = 25°C	T_A = 100°C	Min.	Max.	
	kV			µA	µA	pf	pf	joules
JAN 1N5597	10	13V @ 1A	19V @ 1A	1	75	5	30	2
JAN 1N5600	5	6V @ 2A	10V @ 2A	5	100	7	30	6
JAN 1N5603	5	6V @ 5A	10V @ 5A	5	100	15	40	12

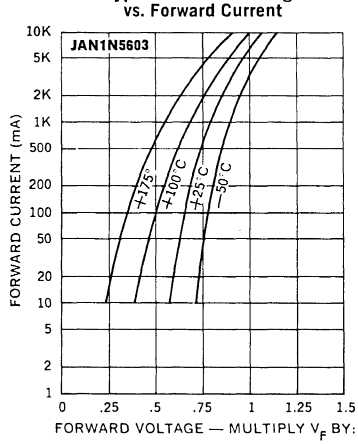
Typical Forward Voltage vs. Forward Current



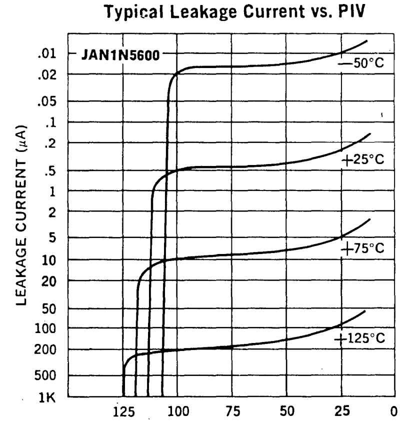
Typical Forward Voltage vs. Forward Current



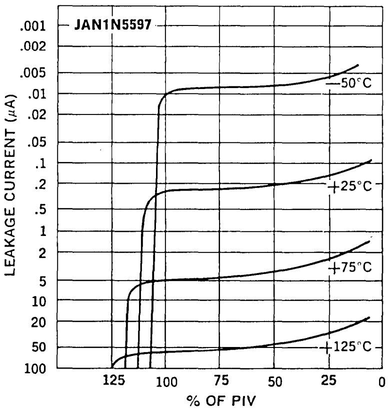
Typical Forward Voltage vs. Forward Current



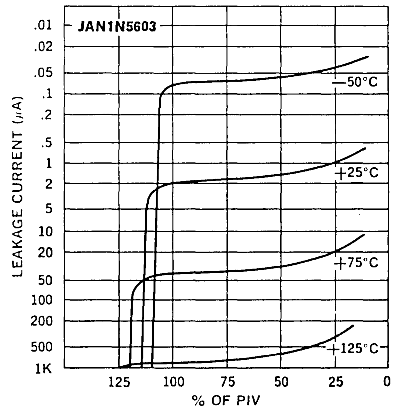
Typical Leakage Current vs. PIV



Typical Leakage Current vs. PIV

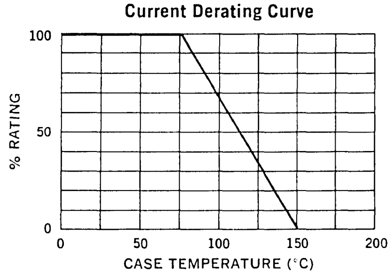


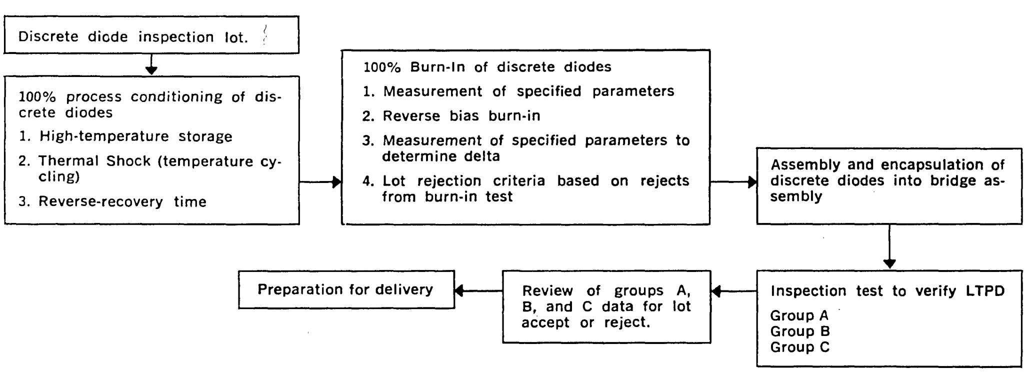
Typical Leakage Current vs. PIV



VII

Current Derating Curve





RECTIFIER ASSEMBLIES

High Voltage Stacks, Standard and Fast Recovery

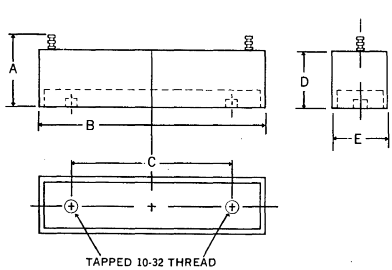
FEATURES
- PIV: from 10kV to 25kV
- Surge Rating: to 20A
- Recovery Time Available: to 500ns
- Current Ratings: to 0.6A
- Bonded Plate for Maximum Heat Transfer
- Controlled Avalanche Characteristics
- Only Fused-in-Glass Diodes Used

DESCRIPTION
This series of high power stacks has a unique packaging design that provides characteristics not obtainable in conventional molded epoxy packages. This series, therefore, is ideally suited for high-voltage, high-power applications.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	10kV to 25kV
Maximum Average D.C. Output Current	See Electrical Specifications
Non-repetitive Sinusoidal Surge (8.3ms)	20A
Operating and Storage Temperature Range	−65°C to +150°C
Thermal Resistance Junction to Ambient	25°C/W
Junction to Case	10°C/W

688 SERIES

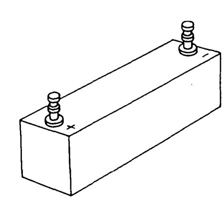


	ins.	mm.
A	1.140 MAX.	28.96 MAX.
B	2.985-3.015	75.82-76.58
C	2.110-2.140	53.59-54.36
D	.740-.770	18.80-19.56
E	.720-.750	18.29-19.05

Add suffix R to denote Fast Recovery version. For example, for recovery time, $t_{rr} = 500$ns; order 688-10R.

Typical Weight — 2.5 ounces
70 grams

BE



MARKING

Cathode — Positive Output	+
Anode — Negative	—

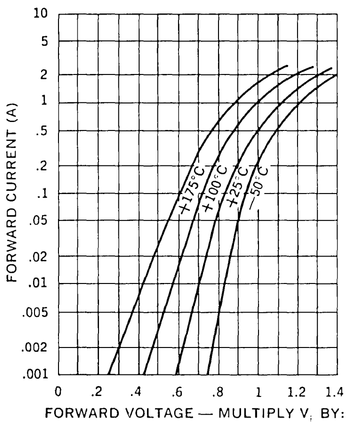
Part number is printed on the body.

UNITRODE

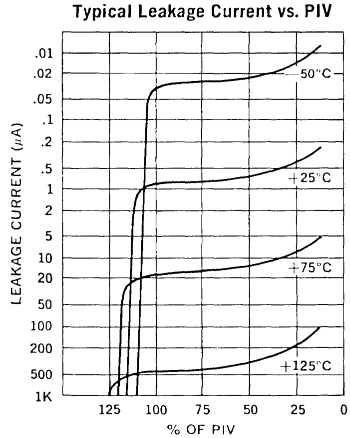
Electrical Specifications (at 25°C unless noted)						Maximum Ratings
Type		PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV		Maximum Average D.C. Output Current
				$T_A = 25°C$	$T_A = 100°C$	$T_C = 100°C$
		kV		μA	μA	Amps
Standard And Fast Recovery*	688-10	10	17V @ 0.4A	2	100	0.60
	688-12	12	20V @ 0.4A			0.50
	688-15	15	25V @ 0.4A			0.40
	688-18	18	30V @ 0.4A			0.35
	688-20	20	34V @ 0.4A			0.30
	688-25	25	42V @ 0.4A			0.20

*Add suffix R to denote Fast Recovery version.

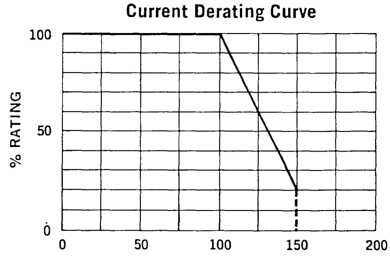
Typical Forward Voltage Per Leg vs. Forward Current



Typical Leakage Current vs. PIV



Current Derating Curve



VII

UNITRODE CORPORATION • 5 FORBES ROAD
LEXINGTON, MA 02173 • TEL. (617) 861-6540
TWX (710) 326-6509 • TELEX 95-1064

HIGH VOLTAGE SILICON RECTIFIERS
100-250mA
Fast Recovery, Miniature

HA10-100
HVX10-100

FEATURES
- PIV: From 1.0kV to 10kV
- 250nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

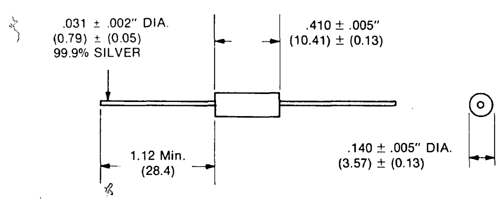
DESCRIPTION
The HVX/HA silicon rectifier series combine a medium rectified current capability and high reliabilty in a miniature package for commercial, industrial and military applications. The use of cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The fast reverse recovery characteristics enhance applications in high frequency power conversion and control circuits.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1.0kV to 10kV
Maximum Average Rectified Current	See Electrical Specifications
Maximum One Cycle Surge 8.3mS	See Electrical Specifications
Maximum Recurrent Peak Current Surge	See Electrical Specifications
Operating and Storage Temperature Range	−65°C to +150°C

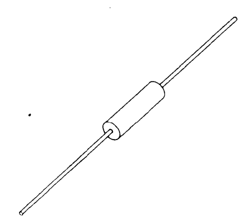
MECHANICAL SPECIFICATIONS

HVX10-100

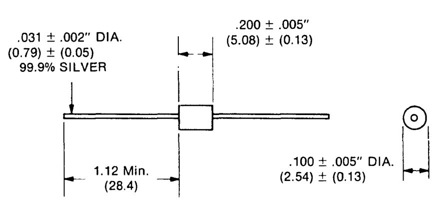


Dimensions in inches and (millimeters)

SJ

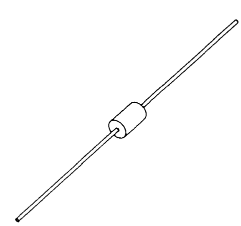


HA10-100



Dimensions in inches and (millimeters)

SK



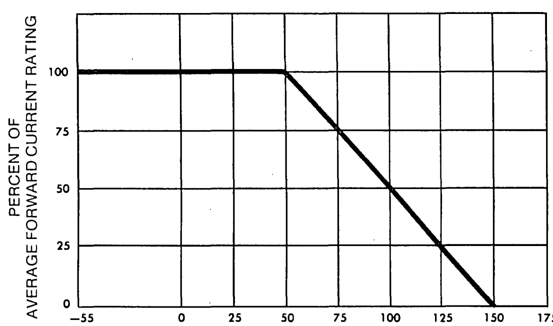
UNITRODE

Type	Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				
		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ 100mA	Maximum Reverse Recovery Time	Maximum Average Rectified Current†			Maximum Recurrent Peak Current	Maximum One Cycle Surge 8.3mS Surge
		PIV	I_R		V_F	T_{RR}	I_O			I_F	$I_{F(surge)}$
		V	25°C	100°C	V	nS	50°C	100°C	125°C	A	A
			μA	μA			mA	mA	mA		
HVX10	HA10	1000	1	20	5	250	250	125	62.5	2.5	14
HVX15	HA15	1500	1	20	5	250	250	125	62.5	2.5	14
HVX20	HA20	2000	1	20	5	250	250	125	62.5	2.5	14
HVX25	HA25	2500	1	20	5	250	250	125	62.5	2.5	14
HVX30	HA30	3000	1	20	5	250	250	125	62.5	2.5	14
HVX40	HA40	4000	1	20	12	250	100	50	25	1.0	4
HVX50	HA50	5000	1	20	12	250	100	50	25	1.0	4
HVX75	HA75	7500	1	20	12	250	100	50	25	1.0	4
HVX100	HA100	10000	1	20	12	250	100	50	25	1.0	4

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C, 3/8" (9.5mm) from case for 5 seconds maximum.

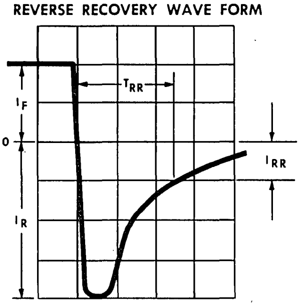
VII

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE

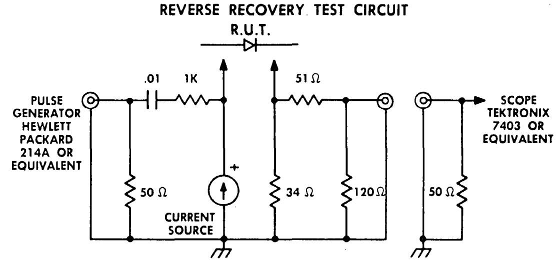


REVERSE RECOVERY TEST CONDITIONS: I_F = 50 mA, I_R = 100 mA, I_{RR} = 25 mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS
100-250mA
Standard Recovery, Miniature

HS10-100
HVE10-30 (1N3643-47)
HVE40-100 (1N5181-84)

FEATURES
- PIV: From 1.0kV to 10kV
- JEDEC Types
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

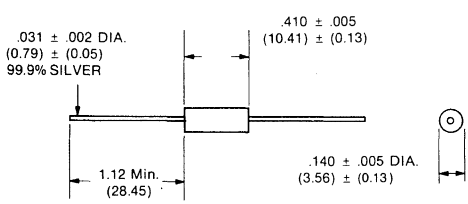
DESCRIPTION
The HVE/HS silicon rectifier series combine a medium average rectified current capability and high reliability in a miniature package for commercial, industrial and military applications. The use of cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. A 2 microsecond reverse recovery characteristic improves the circuit efficiency of power conversion and control systems.

ABSOLUTE MAXIMUM RATINGS

	HS	HVE
Peak Inverse Voltage	1.0kV	10kV
Maximum Average Rectified Current	See Electrical Specifications.	
Maximum One Cycle Surge 8.3mS	See Electrical Specifications.	
Maximum Recurrent Peak Current Surge	See Electrical Specifications.	
Operating and Storage Temperature Range	−65°C to +175°C	

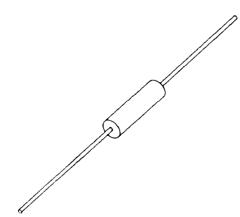
MECHANICAL SPECIFICATIONS

HVE10-30 (1N3643-47)
HVE40-100 (1N5181-84)

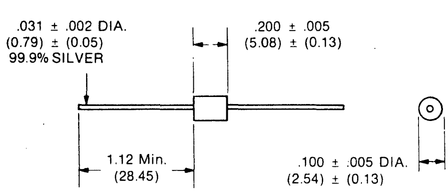


Dimensions in inches and (millimeters)

SJ

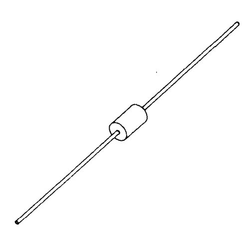


HS10-100



Dimensions in inches and (millimeters)

SK



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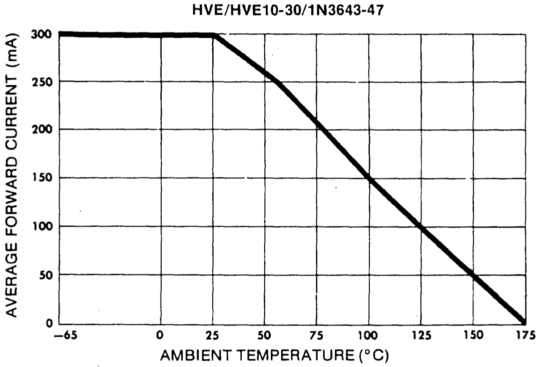
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS				
Maximum Reverse Recovery Time		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ 100mA Max.	Maximum Average Rectified Current†			Maximum Recurrent Peak Current Surge	Maximum One Cycle Surge 8.3mS
		PIV	I_R		V_F	I_O			I_F	$I_{F(surge)}$
2μS	2μS		25°C	100°C	25°C	50°C	100°C	150°C		
Type	Type	V	μA	μA	V	mA	mA	mA	A	A
HS10	HVE10 (1N3643)	1000	1	20	3.5	250	150	50	2.5	14
HS15	HVE15 (1N3644)	1500	1	20	3.5	250	150	50	2.5	14
HS20	HVE20 (1N3645)	2000	1	20	3.5	250	150	50	2.5	14
HS25	HVE25 (1N3646)	2500	1	20	3.5	250	150	50	2.5	14
HS30	HVE30 (1N3647)	3000	1	20	3.5	250	150	50	2.5	14
HS40	HVE40 (1N5181)	4000	1	20	10.0	100	60	20	1.0	4
HS50	HVE50 (1N5182)	5000	1	20	10.0	100	60	20	1.0	4
HS75	HVE75 (1N5183)	7500	1	20	10.0	100	60	20	1.0	4
HS100	HVE100 (1N5184)	10000	1	20	10.0	100	60	20	1.0	4

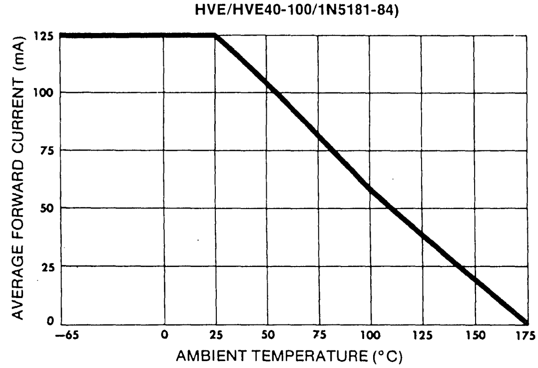
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
†The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds maximum.

VII

HVE/HVE10-30/1N3643-47

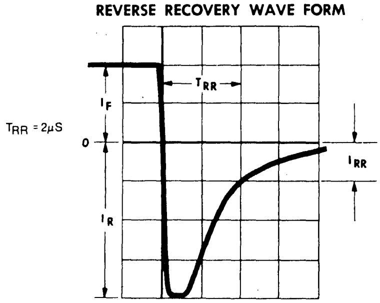


HVE/HVE40-100/1N5181-84)

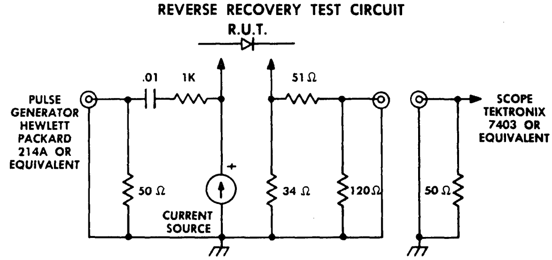


REVERSE RECOVERY TEST CONDITIONS: I_F = 50 mA, I_R = 100 mA, I_{RR} = 25 mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC

Fast Recovery, High Current

FEATURES
- PIV: From 2.5kV to 25kV
- 150nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

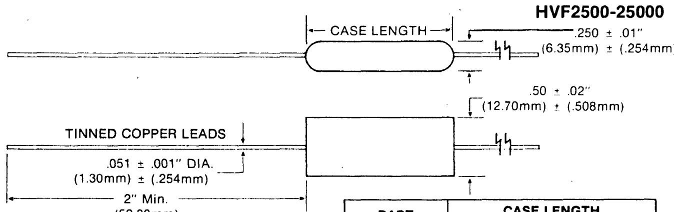
DESCRIPTION
The HVF MULTISTAC high current, high voltage silicon rectifier's convenient size and high power capability meets the reliability requirements of commercial, industrial and military applications. Reliability with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	2.5kV to 25kV
Maximum Average Rectified Current	See Electrical Specifications
Maximum One Cycle Surge 8.3mS	See Electrical Specifications
Operating and Storage Temperature Range	-55°C to +150°C

MECHANICAL SPECIFICATIONS

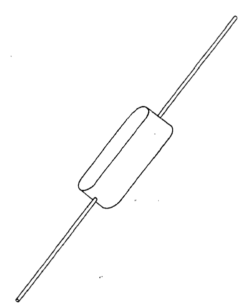
HVF2500-25000



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVF2500	1.125 ± .02	28.58 ± .508
HVF5000	2.000 ± .02	50.80 ± .508
HVF7500	2.750 ± .02	69.85 ± .508
HVF10000	3.500 ± .02	88.90 ± .508
HVF12500	4.250 ± .02	107.95 ± .508
HVF15000	4.250 ± .02	107.95 ± .508
HVF20000	4.250 ± .02	107.95 ± .508
HVF25000	4.250 ± .02	107.95 ± .508

Dimensions in inches and (millimeters)

PB

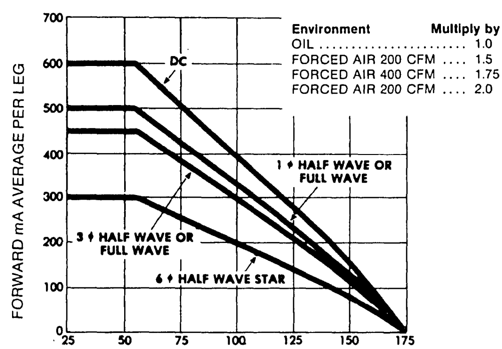


Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O Max.	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
		25°C	100°C			55°C	100°C	25°C	100°C		
	V	μA	μA	V	nS	A	A	A	A	Ins.	MM
HVF2500	2500	0.1	15	5.5	150	.5	.33	40	20	1.125	28.58
HVF5000	5000	0.1	15	11.0	150	.5	.33	40	20	2.000	50.80
HVF7500	7500	0.1	15	16.5	150	.5	.33	40	20	2.750	69.85
HVF10000	10000	0.1	15	22.0	150	.5	.33	40	20	3.500	88.90
HVF12500	12500	0.1	15	27.5	150	.5	.33	40	20	4.250	107.95
HVF15000	15000	0.1	15	33.0	150	.5	.33	40	20	4.250	107.95
HVF20000	20000	0.1	15	38.5	150	.5	.33	40	20	4.250	107.95
HVF25000	25000	0.1	15	44.0	150	.5	.33	40	20	4.250	107.95

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

VII

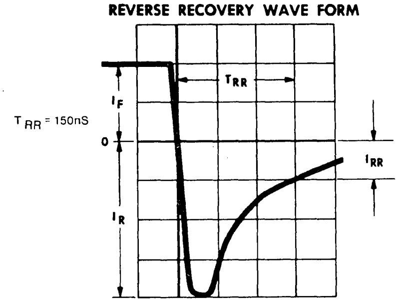
MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE



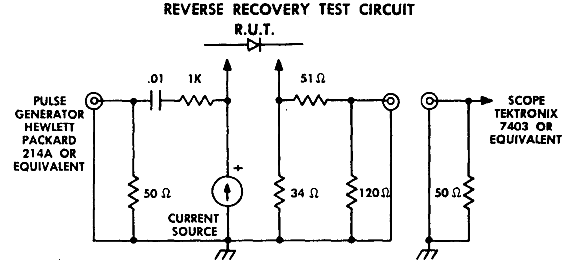
FORWARD CURRENT PER LEG VS. AMBIENT TEMPERATURE (°C)

REVERSE RECOVERY TEST CONDITIONS: I_F = 0.1A, I_R = 0.2A, I_{RR} = 0.05A

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



Reverse recovery is measured on each rectifier stack prior to manufacture of the assembly.

HVFS2500-20000

HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC

Fast Recovery, High Current

FEATURES

- PIV: From 2.5kV to 20kV
- 150nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION

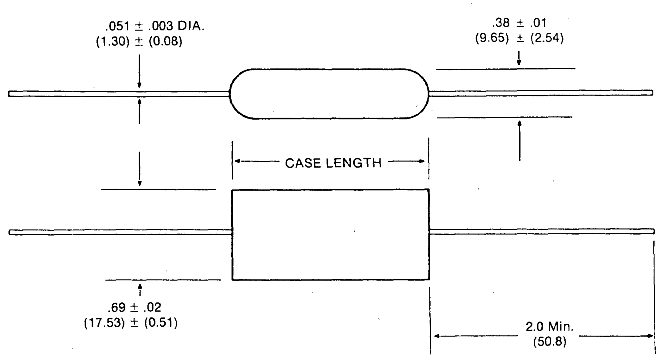
The HVFS MULTISTAC high current, high voltage silicon rectifier's convenient size and high power capability meets the reliability requirements of commercial, industrial and military applications. Reliability with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 2.5kV to 20kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

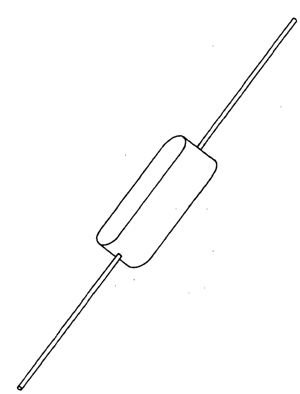
HVFS2500-20000



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVS2500	1.5 ± .03	38.1 ± 0.76
HVS5000	2.5 ± .03	63.5 ± 0.76
HVS7500	3.5 ± .03	88.9 ± 0.76
HVS10000	4.5 ± .03	114.3 ± 0.76
HVS12500	5.5 ± .03	139.7 ± 0.76
HVS15000	6.5 ± .03	165.1 ± 0.76
HVS17500	6.5 ± .03	165.1 ± 0.76
HVS20000	6.5 ± .03	165.1 ± 0.76

Dimensions in inches and (millimeters)

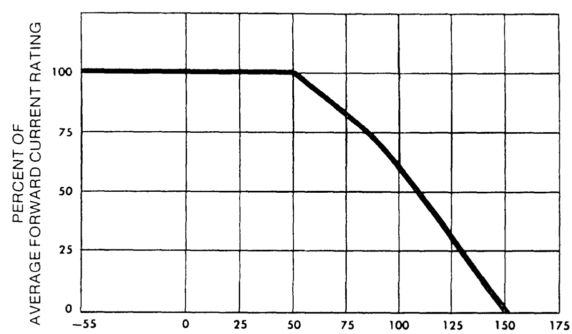
PC



Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
	V	25°C	100°C	V	nS	55°C	100°C	25°C	100°C		
		μA	μA			A	A	A	A	Ins.	MM
HVFS2500	2500	10	120	8	150	2.2	1.3	200	100	1.5	38.1
HVFS5000	5000	10	120	16	150	2.2	1.3	200	100	2.5	63.5
HVFS7500	7500	10	120	21	150	2.2	1.3	200	100	3.5	88.9
HVFS10000	10000	10	120	29	150	2.2	1.3	200	100	4.5	114.9
HVFS12500	12500	10	120	36	150	2.2	1.3	200	100	5.5	139.7
HVFS15000	15000	10	120	44	150	2.2	1.3	200	100	6.5	165.1
HVFS17500	17500	10	120	51	150	2.2	1.3	200	100	6.5	165.1
HVFS20000	20000	10	120	58	150	2.2	1.3	200	100	6.5	165.1

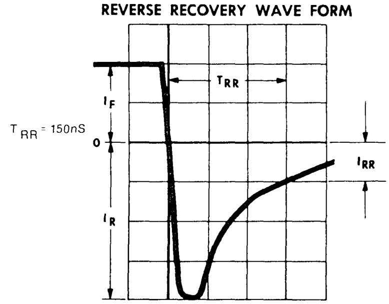
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE

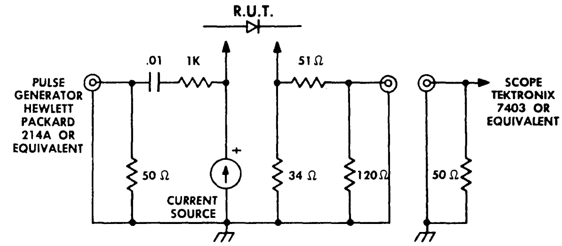


REVERSE RECOVERY TEST CONDITIONS: I_F = 12.5A, I_R = 25A, I_{RR} = 6.25A

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC
Standard Recovery

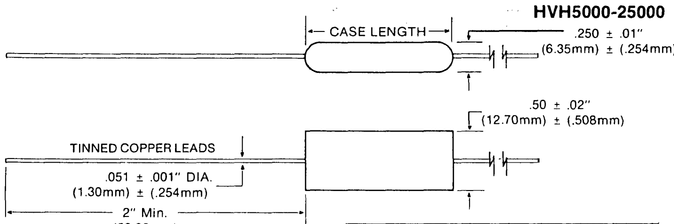
FEATURES
- PIV: From 5kV to 25kV
- 2μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION
The HVH MULTISTAC silicon rectifier assemblies meet the stringent reliability requirements of commercial, industrial and military users through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The 2 microsecond reverse recovery time improves the circuit efficiency of power conversion and control systems.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage .... 5kV to 25kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

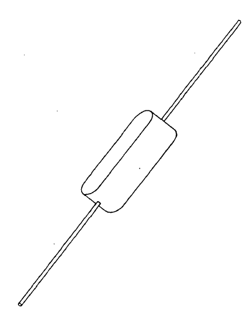
HVH5000-25000



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVH5000	1.125 ± .02	28.58 ± .508
HVH7500	1.625 ± .02	41.28 ± .508
HVH10000	2.000 ± .02	50.80 ± .508
HVH12500	2.375 ± .02	60.33 ± .508
HVH15000	2.750 ± .02	69.85 ± .508
HVH20000	3.500 ± .02	88.90 ± .508
HVH25000	4.250 ± .02	107.95 ± .508

Dimensions in inches and (millimeters)

PB

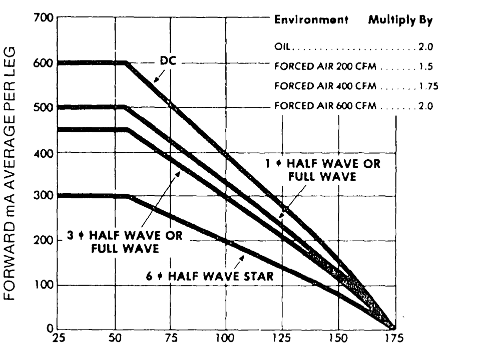


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
Maximum Reverse Recovery Time	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Average Rectified Current†		Maximum One Cycle Surge			
2µS	PIV	I_R		V_F	I_O		I_F(surge)			
Type	V	25°C	100°C	25°C	55°C	100°C	25°C	100°C		
		µA	µA	V	A	A	A	A	Ins.	MM
HVH 5000	5000	0.1	15	7	.5	.33	60	30	1.125	28.58
HVH 7500	7500	0.1	15	10	.5	.33	60	30	1.625	41.28
HVH10000	10000	0.1	15	14	.5	.33	60	30	2.000	50.80
HVH12500	12500	0.1	15	17	.5	.33	60	30	2.375	60.33
HVH15000	15000	0.1	15	20	.5	.33	60	30	2.750	69.85
HVH20000	20000	0.1	15	27	.5	.33	60	30	3.500	88.90
HVH25000	25000	0.1	15	33	.5	.33	60	30	4.250	107.95

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
†The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

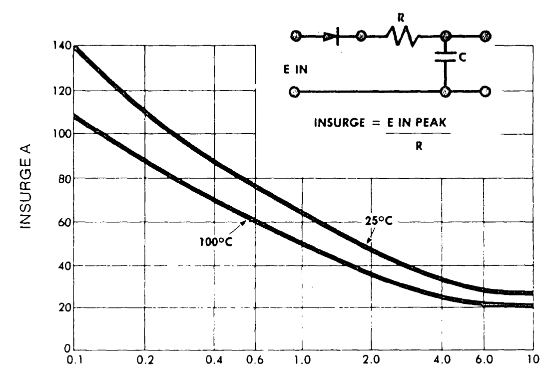
VII

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE



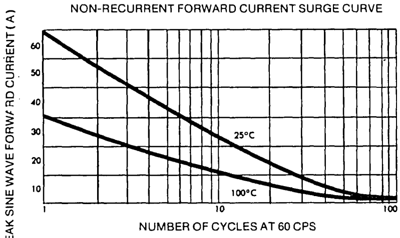
FORWARD CURRENT PER LEG VS. AMBIENT TEMPERATURE (°C)

MAXIMUM RATINGS FOR CAPACITY LOADS

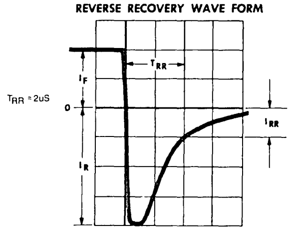


RC TIME CONSTANT (mS)

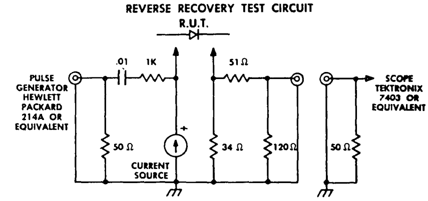
NON-RECURRENT FORWARD CURRENT SURGE CURVE



REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



Reverse recovery is measured on each rectifier stack prior to manufacture of the assembly.

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HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC

Standard Recovery, High Current

FEATURES

- PIV: From 5kV to 25kV
- 1μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION

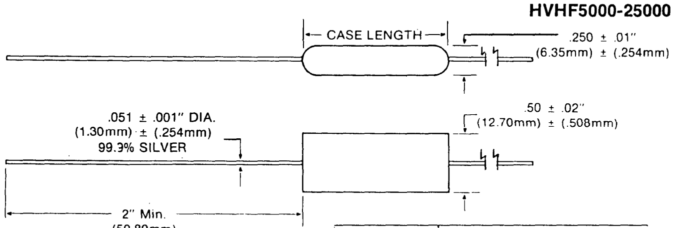
The HVHF MULTISTAC high current, high voltage silicon rectifier's convenient size and high power capability meets the reliability requirements of commercial, industrial and military applications. Reliability with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 5kV to 25kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

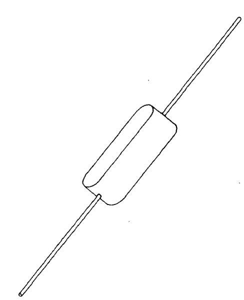
HVHF5000-25000



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVHF5000	1.125 ± .02	28.58 ± 0.508
HVHF7500	1.625 ± .02	41.28 ± 0.508
HVHF10000	2.000 ± .02	50.80 ± 0.508
HVHF12500	2.375 ± .02	60.33 ± 0.508
HVHF15000	2.750 ± .02	69.85 ± 0.508
HVHF20000	3.500 ± .02	88.90 ± 0.508
HVHF25000	4.250 ± .02	107.95 ± 0.508

Dimensions in inches and (millimeters)

PB

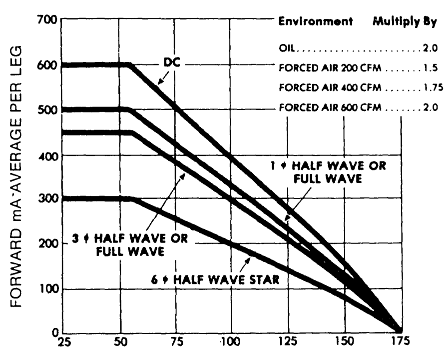


Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
	V	25°C	100°C	V	µS	55°C	100°C	25°C	100°C		
		µA	µA			A	A	A	A	Ins.	MM
HVHF5000	5000	0.1	15	7	1	.5	.33	60	30	1.125	28.58
HVHF7500	7500	0.1	15	10	1	.5	.33	60	30	1.625	41.28
HVHF10000	10000	0.1	15	14	1	.5	.33	60	40	2.000	50.80
HVHF12500	12500	0.1	15	17	1	.5	.33	60	40	2.375	60.33
HVHF15000	15000	0.1	15	20	1	.5	.33	60	40	2.750	69.85
HVHF20000	20000	0.1	15	27	1	.5	.33	60	40	3.500	88.90
HVHF25000	25000	0.1	15	33	1	.5	.33	60	40	4.250	107.95

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

VII

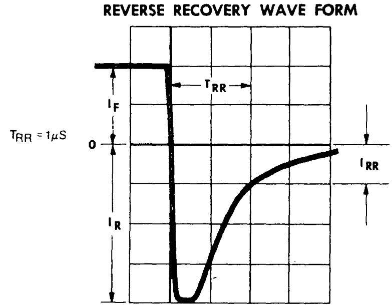
MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE



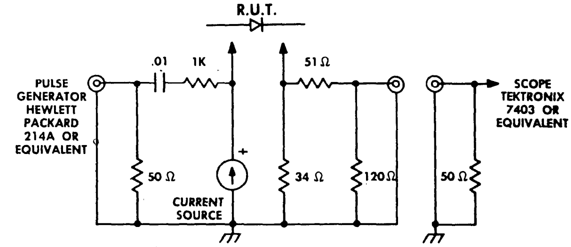
FORWARD CURRENT PER LEG VS. AMBIENT TEMPERATURE (°C)

REVERSE RECOVERY TEST CONDITIONS: I_F = 100mA, I_R = 200mA, I_{RR} = 50mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



Reverse recovery is measured on each rectifier stack prior to manufacture of the assembly.

HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC

Medium Recovery, Medium Current

FEATURES

- PIV: From 15kV to 45kV
- 2μS Reverse Recovery
- High Surge
- Low Reverse Leakage
- Corona Free

DESCRIPTION

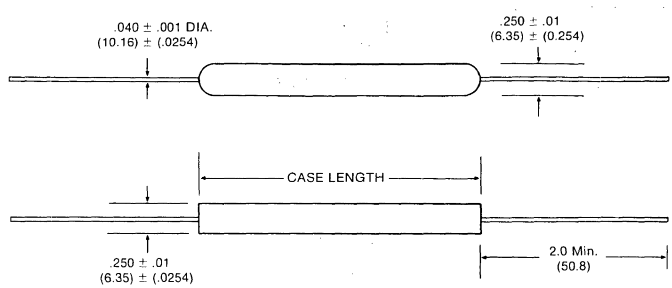
The HVHJ MULTISTAC medium current, high voltage silicon rectifier assembly's small size and high power capability meets the stringent reliability requirements of commercial, industrial and military applications. Reliabilty with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 15kV to 45kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

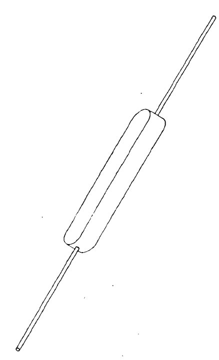
HVHJ15K-45K



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVHJ15K	1.5 ± .02	38.1 ± .508
HVHJ20K	2.0 ± .02	50.8 ± .508
HVHJ22.5K	2.0 ± .02	50.8 ± .508
HVHJ25K	2.5 ± .02	63.5 ± .508
HVHJ30K	2.5 ± .02	63.5 ± .508
HVHJ35K	3.0 ± .02	76.2 ± .508
HVHJ37.5K	3.0 ± .02	76.2 ± .508
HVHJ40K	3.5 ± .02	88.9 ± .508
HVHJ45K	3.5 ± .02	88.9 ± .508

Dimensions in inches and (millimeters)

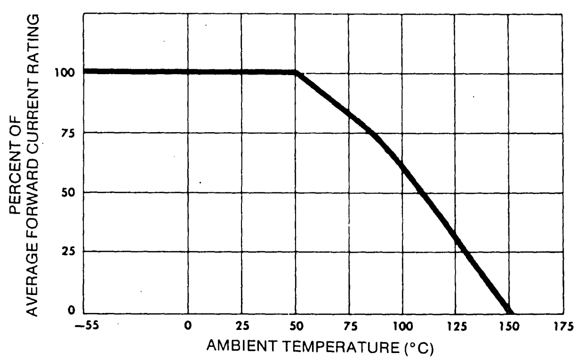
PA



Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
		25°C	100°C			55°C	100°C	25°C	100°C		
	V	µA	µA	V	µS	mA	mA	A	A	Ins.	MM
HVHJ15K	15000	0.1	25	20	2	50	30	5	2.5	1.5	38.1
HVHJ20K	20000	0.1	25	30	2	50	30	5	2.5	2.0	50.8
HVHJ22.5K	22500	0.1	25	30	2	50	30	5	2.5	2.0	50.8
HVHJ25K	25000	0.1	25	40	2	50	30	5	2.5	2.5	63.5
HVHJ30K	30000	0.1	25	40	2	50	30	5	2.5	2.5	63.5
HVHJ35K	35000	0.1	25	50	2	50	30	5	2.5	3.0	76.2
HVHJ37.5K	37500	0.1	25	50	2	50	30	5	2.5	3.0	76.2
HVHJ40K	40000	0.1	25	60	2	50	30	5	2.5	3.5	88.9
HVHJ45K	45000	0.1	25	60	2	50	30	5	2.5	3.5	88.9

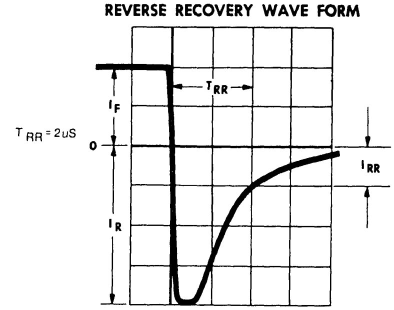
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE

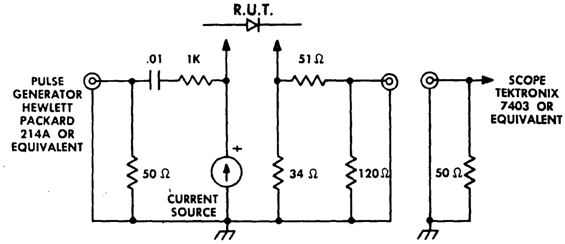


REVERSE RECOVERY TEST CONDITIONS: I_F =50mA, I_R =100mA, I_{RR} =25mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC

Medium Recovery, High Current

FEATURES

- PIV: From 2.5kV to 20kV
- 2μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION

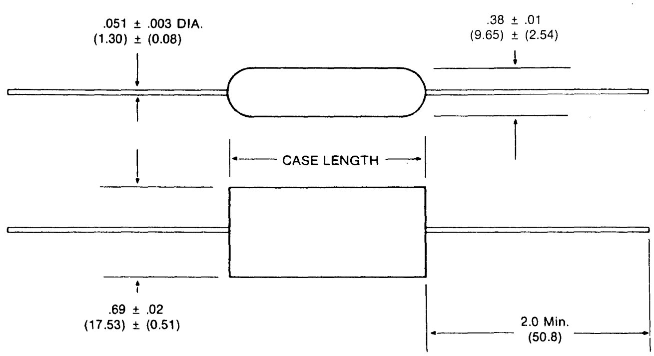
The HVHS MULTISTAC high current, high voltage silicon rectifier's convenient size and high power capability meets the reliability requirements of commercial, industrial and military applications. Reliability with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 2.5kV to 20kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3 mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

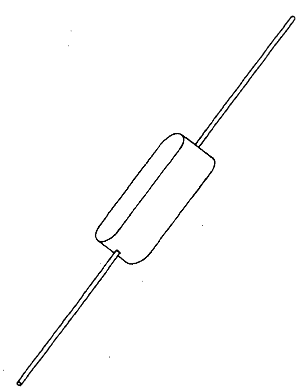
HVHS2500-20000



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVHS2500	1.5 ± .03	38.1 ± 0.76
HVHS5000	2.5 ± .03	63.5 ± 0.76
HVHS7500	3.5 ± .03	88.9 ± 0.76
HVHS10000	4.5 ± .03	114.3 ± 0.76
HVHS12500	5.5 ± .03	139.7 ± 0.76
HVHS15000	6.5 ± .03	165.1 ± 0.76
HVHS17500	6.5 ± .03	165.1 ± 0.76
HVHS20000	6.5 ± .03	165.1 ± 0.76

Dimensions in inches and (millimeters)

PC

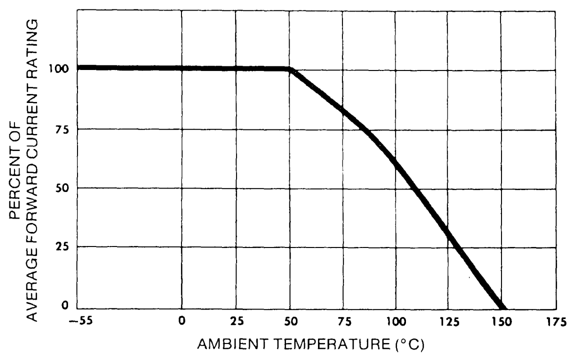


Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
		25°C	100°C			55°C	100°C	25°C	100°C		
	V	µA	µA	V	µS	A	A	A	A	Ins.	MM
HVHS2500	2500	10	120	5	2	2.2	1.3	200	100	1.5	38.1
HVHS5000	5000	10	120	10	2	2.2	1.3	200	100	2.5	63.5
HVHS7500	7500	10	120	15	2	2.2	1.3	200	100	3.5	88.9
HVHS10000	10000	10	120	20	2	2.2	1.3	200	100	4.5	114.9
HVHS12500	12500	10	120	25	2	2.2	1.3	200	100	5.5	139.7
HVHS15000	15000	10	120	30	2	2.2	1.3	200	100	6.5	165.1
HVHS17500	17500	10	120	35	2	2.2	1.3	200	100	6.5	165.1
HVHS20000	20000	10	120	40	2	2.2	1.3	200	100	6.5	165.1

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

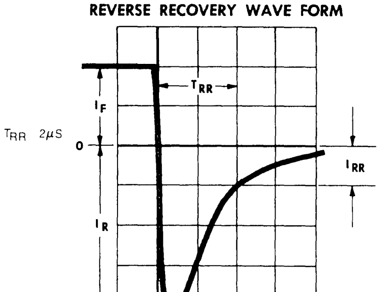
VII

MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE

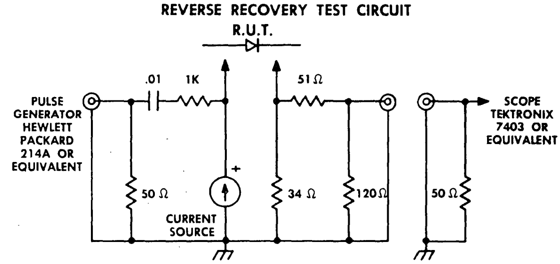


REVERSE RECOVERY TEST CONDITIONS: I_F =0.4mA, I_R =0.8mA, I_{RR} =0.2mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



Reverse recovery is measured on each rectifier stack prior to manufacture of the assembly.

HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC
Fast Recovery, Medium Current

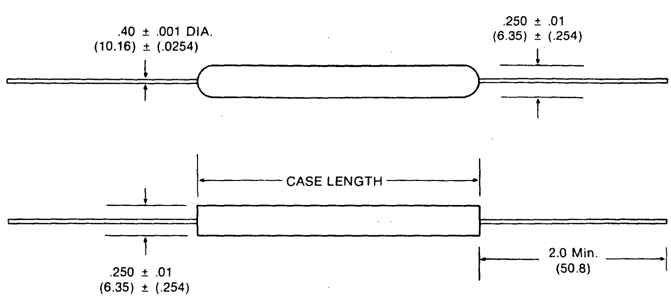
FEATURES
- PIV: From 15kV to 45kV
- 200nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION
The HVJX MULTISTAC medium current high voltage silicon rectifier assembly's small size and high power capabilty meets the stringent reliabilty requirements of commercial, industrial and military applications. Reliability with economy are obtained through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage .... 15kV to 45kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3 mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −55°C to +150°C

MECHANICAL SPECIFICATIONS

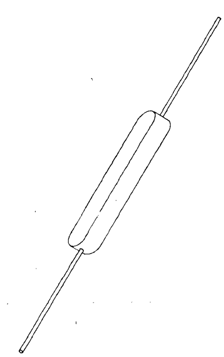
HVJX15K-45K



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
HVJX15K	1.5 ± .02	38.1 ± .508
HVJX20K	2.0 ± .02	50.8 ± .508
HVJX22.5K	2.0 ± .02	50.8 ± .508
HVJX25K	2.5 ± .02	63.5 ± .508
HVJX30K	2.5 ± .02	63.5 ± .508
HVJX35K	3.0 ± .02	76.2 ± .508
HVJX37.5K	3.0 ± .02	76.2 ± .508
HVJX40K	3.5 ± .02	88.9 ± .508
HVJX45K	3.5 ± .02	88.9 ± .508

Dimensions in inches and (millimeters)

PA

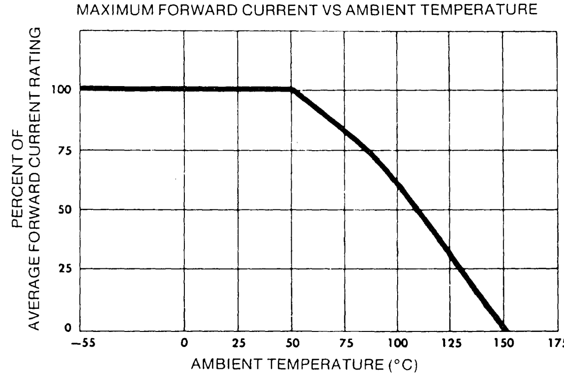


Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)					MAXIMUM RATINGS				Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS			
	PIV	I_R		V_F	T_{RR}	I_O		I_F(surge)			
		25°C	100°C			55°C	100°C	25°C	100°C		
	V	μA	μA	V	nS	mA	mA	A	A	Ins.	MM
HVJX15K	15000	0.1	25	24	200	50	30	5	2.5	1.5	38.1
HVJX20K	20000	0.1	25	36	200	50	30	5	2.5	2.0	50.8
HVJX22.5K	22500	0.1	25	36	200	50	30	5	2.5	2.0	50.8
HVJX25K	25000	0.1	25	48	200	50	30	5	2.5	2.5	63.5
HVJX30K	30000	0.1	25	48	200	50	30	5	2.5	2.5	63.5
HVJX35K	35000	0.1	25	60	200	50	30	5	2.5	3.0	76.2
HVJX37.5K	37500	0.1	25	60	200	50	30	5	2.5	3.0	76.2
HVJX40K	40000	0.1	25	72	200	50	30	5	2.5	3.5	88.9
HVJX45K	45000	0.1	25	72	200	50	30	5	2.5	3.5	88.9

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

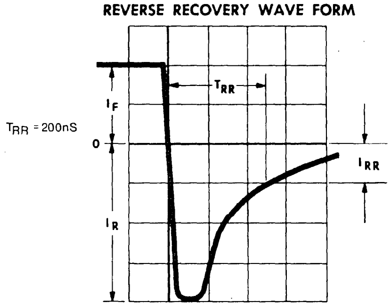
VII

MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE

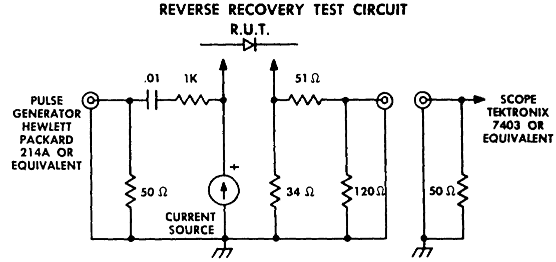


REVERSE RECOVERY TEST CONDITIONS: I_F = 50mA, I_R = 100mA, I_{RR} = 25mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS

KX15-100
KXS15-100

POWERSTACK
1.5 to 3.0A
Very High Current, Miniature

FEATURES
- PIV: From 1.5kV to 10kV
- 1.5 to 3.0A
- 250nS Reverse Recovery
- High Surge Ratings
- Low Reverse Leakage
- Corona Free

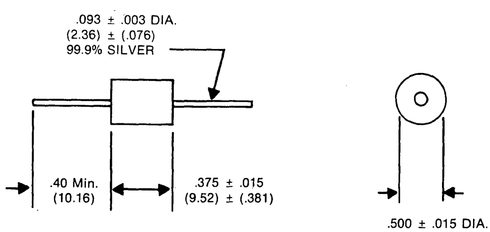
DESCRIPTION
The KX/KXS silicon rectifier series is a unique concept for high current high voltage applications. Matched junction characteristics and low stray capacitance due to metallurgically bonded junctions eliminates the need for external compensation networks. These rectifiers utilize HVD's cylindrical die construction, which minimizes electrical and mechanical stress, insuring long life for commercial, military and industrial applications.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1.5kV to 10kV
Maximum Average Rectified Current	See Electrical Specifications
Maximum One Cycle Surge 8.3mS	See Electrical Specifications
Operating Temperature Range	-55°C to +150°C
Storage Temperature Range	-55°C to +175°C

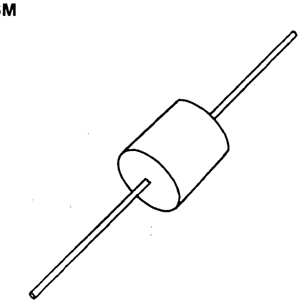
MECHANICAL SPECIFICATIONS

KX15-100
KXS15-100



Dimensions in inches and (millimeters)

SM



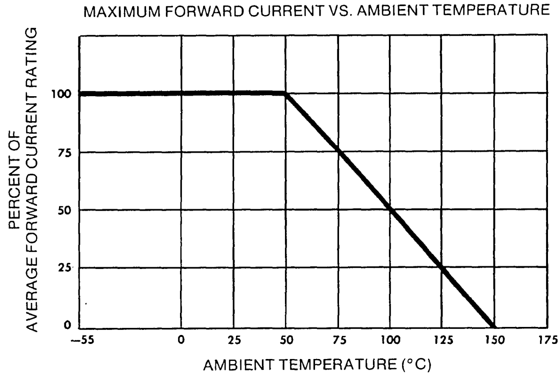
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS				
Maximum Reverse Recovery Time		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS	Typical Thermal Impedance††
250nS	2uS	PIV	I_R		V_F	I_O			I_F(surge)	$R_{\theta JL}$
Type	Type	V	25°C	100°C	V	50°C	100°C	120°C		
			µA	µA		A	A	A	A	°C/Watt
KX15	KXS15	1500	2.0	100	5.0	3.00	1.50	.75	200	2.0
KX20	KXS20	2000	2.0	100	5.0	3.00	1.50	.75	200	2.0
KX25	KXS25	2500	2.0	100	5.0	3.00	1.50	.75	200	2.0
KX30	KXS30	3000	2.0	100	7.0	2.20	1.10	.55	150	2.5
KX40	KXS40	4000	2.0	100	7.0	2.20	1.10	.55	150	2.5
KX50	KXS50	5000	2.0	100	7.0	2.20	1.10	.55	150	2.5
KX60	KXS60	6000	2.0	100	11.0	1.50	.75	.37	100	3.0
KX80	KXS80	8000	2.0	100	11.0	1.50	.75	.37	100	3.0
KX100	KXS100	10000	2.0	100	11.0	1.50	.75	.37	100	3.0

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
††Typical thermal impedance determined with rectifier mounted on infinite heat sinks 0.10" from device body using temperature of center junction and lead temperature adjacent to body.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

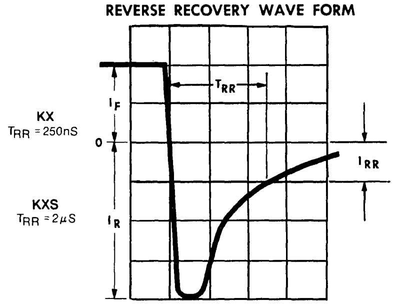
VII

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE



REVERSE RECOVERY TEST CONDITIONS: I_F = 400mA, I_R = 800mA, I_{RR} = 200mA

REVERSE RECOVERY WAVE FORM



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HIGH VOLTAGE SILICON RECTIFIERS

10-80mA
Fast Recovery, Miniature

LA15-120
LM15-180

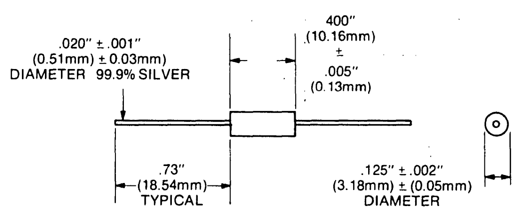
FEATURES
- 1,500 to 18,000V
- 300nS reverse recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION
The LM/LA silicon rectifier series are designed to meet the economical needs of commercial and industrial requirements. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. Fast reverse recovery characteristics improve circuit efficiency in high frequency power conversion and control applications.

ABSOLUTE MAXIMUM RATINGS	LA	LM
Peak Inverse Voltage	1,500 to 12,000V	1,500 to 18,000V
Maximum Average Rectified Current	See Electrical Specifications	
Maximum One Cycle Surge 8.3mS	See Electrical Specifications	
Maximum Recurrent Peak Current Surge	See Electrical Specifications	
Operating Temperature Range	-55° C to +90° C	
Storage Temperature Range	-55° C to +175° C	

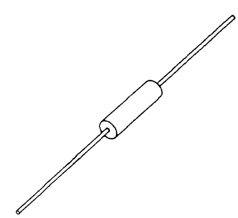
MECHANICAL SPECIFICATIONS

LM15-180

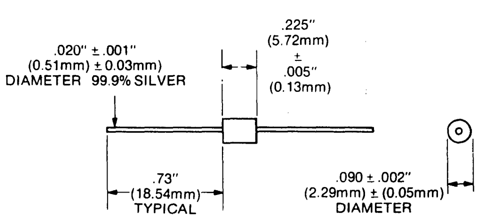


Dimensions in inches and (millimeters)

SG

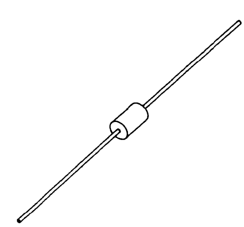


LA15-120



Dimensions in inches and (millimeters)

SH

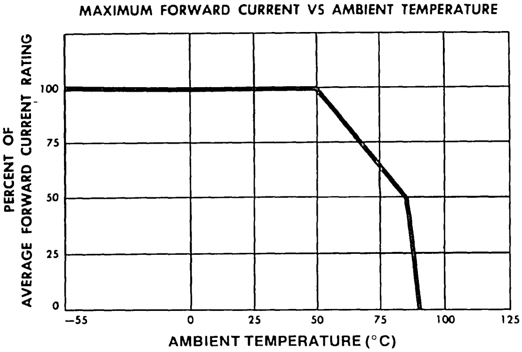


Type	Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS			
		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time §	Maximum Junction Capacitance @ 100V	Maximum Average Rectified Current†		Maximum Recurrent Peak Current Surge	Maximum One Cycle Surge 8.3mS
		PIV	I_R		V_F	T_{RR}	C_J	I_O		I_F	I_F(surge)
			25°C	85°C				50°C	85°C		
		V	μA	μA	V	nS	pF	mA	mA	A	A
LM15	LA15	1500	.25	10	5	300(A)	2.0	80	40	0.8	8
LM20	LA20	2000	.25	10	5	300(A)	2.0	80	40	0.8	8
LM25	LA25	2500	.25	10	5	300(A)	2.0	80	40	0.8	8
LM30	LA30	3000	.25	10	8	300(B)	1.0	40	20	0.4	4
LM40	LA40	4000	.25	10	8	300(B)	1.0	40	20	0.4	4
LM50	LA50	5000	.25	10	8	300(B)	1.0	40	20	0.4	4
LM60	LA60	6000	.25	10	12	300(C)	1.0	25	12.5	0.2	2
LM80	LA80	8000	.25	10	12	300(C)	1.0	25	12.5	0.2	2
LM100	LA100	10000	.25	10	12	300(C)	1.0	25	12.5	0.2	2
LM120	LA120	12000	.25	10	24	300(D)	1.0	10	5	0.1	1
LM150		15000	.25	10	24	300(D)	1.0	10	5	0.1	1
LM180		18000	.25	10	24	300(D)	1.0	10	5	0.1	1

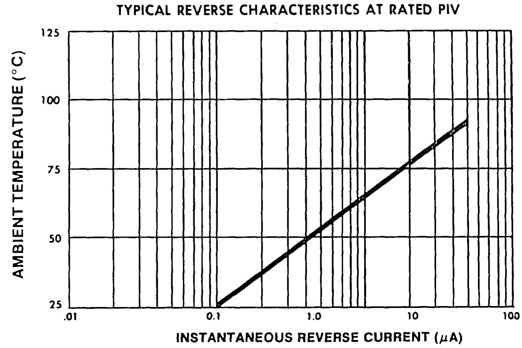
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C, 3/8" (9.5mm) from case for 5 seconds.

VII

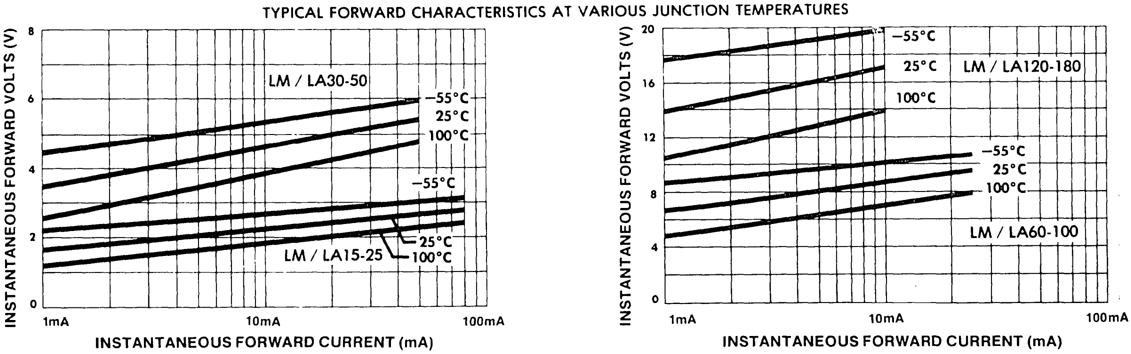
MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE



TYPICAL REVERSE CHARACTERISTICS AT RATED PIV



TYPICAL FORWARD CHARACTERISTICS AT VARIOUS JUNCTION TEMPERATURES

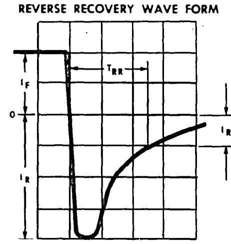


REVERSE RECOVERY TEST CONDITIONS §

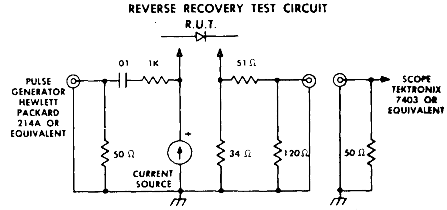
TEST	I_F mA	I_R mA	I_{RR} mA
A	40	80	20
B	20	40	10
C	12.5	25	6.25
D	5	10	2.5

T_{RR} = 300nS

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



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HIGH VOLTAGE SILICON RECTIFIERS

10-80mA

Standard Recovery, Miniature

LS15-120
LMS15-180

FEATURES

- PIV: From 1.5kV to 18kV
- 2μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

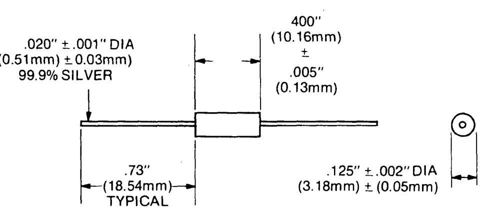
DESCRIPTION

The LMS/LS silicon rectifier series are designed to meet the economical needs of commercial and industrial requirements. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life.

ABSOLUTE MAXIMUM RATINGS	LS	LMS
Peak Inverse Voltage	1.5kV to 12kV	1.5kV to 18kV
Maximum Average Rectified Current	See Electrical Specifications	
Maximum One Cycle Surge 8.3mS	See Electrical Specifications	
Maximum Recurrent Peak Current Surge	See Electrical Specifications	
Operating Temperature Range	-55° C to + 90° C	
Storage Temperature Range	-65° C to +175° C	

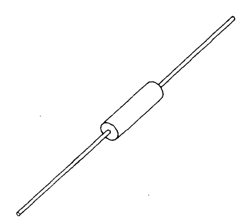
MECHANICAL SPECIFICATIONS

LMS15-180

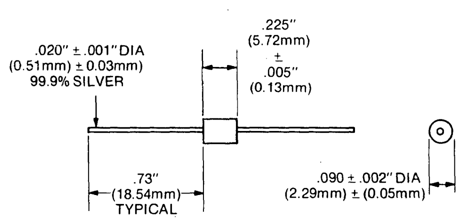


Dimensions in inches and (millimeters)

SG

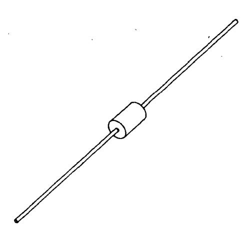


LS15-120



Dimensions in inches and (millimeters)

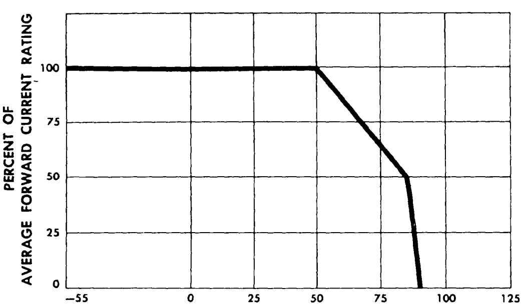
SH



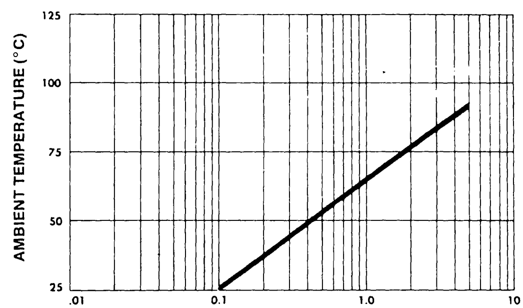
Type	Type	ELECTRICAL SPECIFICATIONS (@ 25°C unless noted)							MAXIMUM RATINGS			
		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time §	Maximum Junction Capacitance @ 100 Volts		Maximum Average Rectified Current†		Max. Recurrent Peak Current Surge	Max. One Cycle Surge 8.3mS
Pkg. Style SG	Pkg. Style SH	PIV	I_R		V_F	T_{RR}	C_J		I_O		I_F	I_F (surge)
			25°C	85°C	25°C				50°C	85°C		
		V	μA	μA	V	nS	pF		mA	mA	A	A
LMS 15	LS 15	1500	.25	10	5	2(A)	2.0		80	40	0.8	8
LMS 20	LS 20	2000	.25	10	5	2(A)	2.0		80	40	0.8	8
LMS 25	LS 25	2500	.25	10	5	2(A)	2.0		80	40	0.8	8
LMS 30	LS 30	3000	.25	10	8	2(B)	1.0		40	20	0.4	4
LMS 40	LS 40	4000	.25	10	8	2(B)	1.0		40	20	0.4	4
LMS 50	LS 50	5000	.25	10	8	2(B)	1.0		40	20	0.4	4
LMS 60	LS 60	6000	.25	10	12	2(C)	1.0		25	12.5	0.2	2
LMS 80	LS 80	8000	.25	10	12	2(C)	1.0		25	12.5	0.2	2
LMS 100	LS 100	10000	.25	10	12	2(C)	1.0		25	12.5	0.2	2
LMS 120	LS120	12000	.25	10	24	2(D)	1.0		10	5	0.1	1
LMS 150		15000	.25	10	24	2(D)	1.0		10	5	0.1	1
LMS 180		18000	.25	10	24	2(D)	1.0		10	5	0.1	1

*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C, 3/8 inch (9.5 mm) from case for 5 seconds maximum.

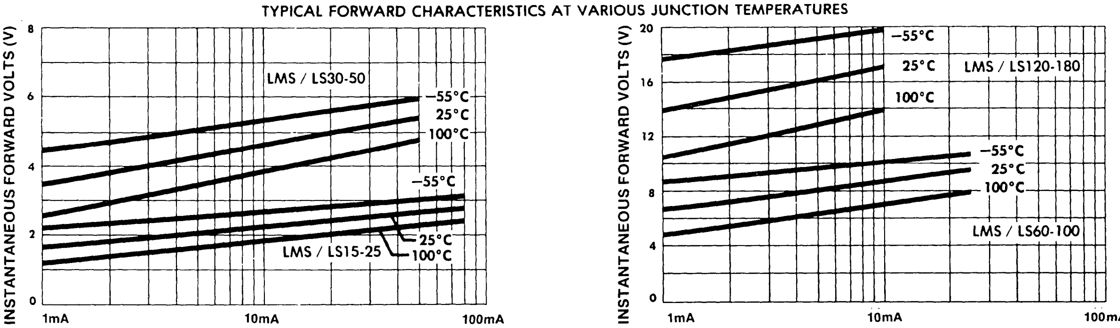
MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE



TYPICAL DYNAMIC REVERSE CHARACTERISTICS AT RATED PIV



TYPICAL FORWARD CHARACTERISTICS AT VARIOUS JUNCTION TEMPERATURES

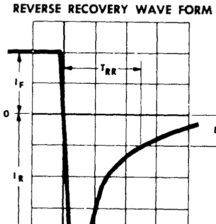


REVERSE RECOVERY TEST CONDITIONS §

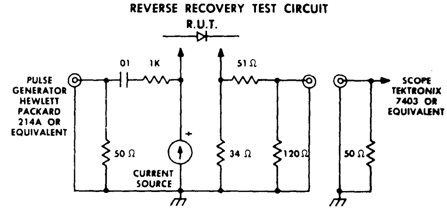
TEST	I_F mA	I_R mA	I_{RR} mA
A	40	80	20
B	20	40	10
C	12.5	25	6.25
D	5	10	2.5

$T_{RR} = 2\mu S$

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



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HIGH VOLTAGE SILICON RECTIFIERS

15-200mA
Fast Recovery, Miniature

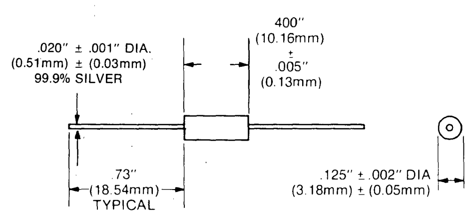
FEATURES
- PIV: From 1.5kV to 20kV
- 250nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION
The MX/MA silicon rectifier series utilizes manufacturing techniques that meet the reliability standards of commercial, industrial and military users. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The fast reverse recovery characteristics enhance applications in high frequency power supply circuits and voltage multipliers for television, CRT displays and instruments.

ABSOLUTE MAXIMUM RATINGS	MA	MX
Peak Inverse Voltage	1.5kV to 12kV	1.5kV to 20kV
Maximum Average Rectified Current	See Electrical Specifications	
Maximum One Cycle Surge 8.3mS	See Electrical Specifications	
Maximum Recurrent Peak Current Surge	See Electrical Specifications	
Operating Temperature Range	-55° C to +150° C	
Storage Temperature Range	-65° C to +175° C	

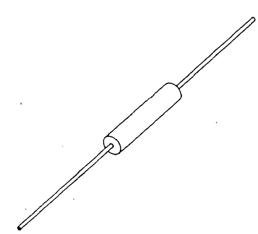
MECHANICAL SPECIFICATIONS

MX15-200

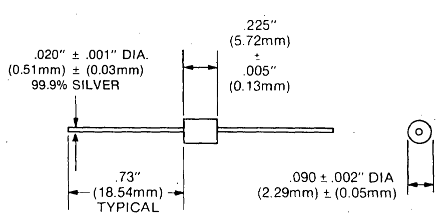


Dimensions in inches and (millimeters)

SG

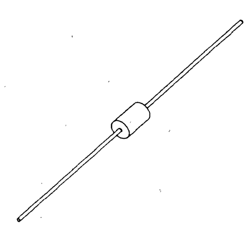


MA15-120



Dimensions in inches and (millimeters)

SH

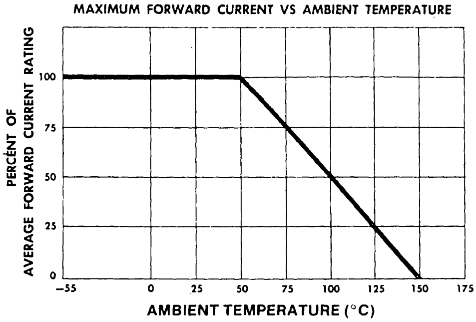


Type	Type	ELECTRICAL SPECIFICATIONS (@ 25°C unless noted)							MAXIMUM RATINGS				
		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time §	Maximum Junction Capacitance @ 100 Volts	Maximum Average Rectified Current †			Max. Recurrent Peak Current Surge	Max. One Cycle Surge 8.3mS
Pkg. Style SG	Pkg. Style SH	PIV	I_R		V_F	T_{RR}	C_J	I_O			I_F	$I_{F(surge)}$
			25°C	100°C	25°C			50°C	100°C	125°C		
		V	µA	µA	V	nS	pF	mA	mA	mA	A	A
MX15	MA15	1500	0.1	10	5	250(A)	2.0	80	40	20	0.8	8
MX20	MA20	2000	0.1	10	5	250(A)	2.0	80	40	20	0.8	8
MX25	MA25	2500	0.1	10	5	250(A)	2.0	80	80	20	0.8	8
MX30	MA30	3000	0.1	10	8	250(B)	1.0	40	20	10	0.4	4
MX40	MA40	4000	0.1	10	8	250(B)	1.0	40	20	10	0.4	4
MX50	MA50	5000	0.1	10	8	250(B)	1.0	40	20	10	0.4	4
MX60	MA60	6000	0.1	10	12	250(C)	1.0	25	12.5	6.25	0.2	2
MX80	MA80	8000	0.1	10	12	250(C)	1.0	25	12.5	6.25	0.2	2
MX100	MA100	10000	0.1	10	12	250(C)	1.0	25	12.5	6.25	0.2	2
MX120	MA120	12000	0.1	10	24	250(D)	1.0	10	5	2.5	0.1	1
MX150		15000	0.1	10	24	250(D)	1.0	10	5	2.5	0.1	1
MX200		20000	0.1	10	24	250(D)	1.0	10	5	2.5	0.1	1

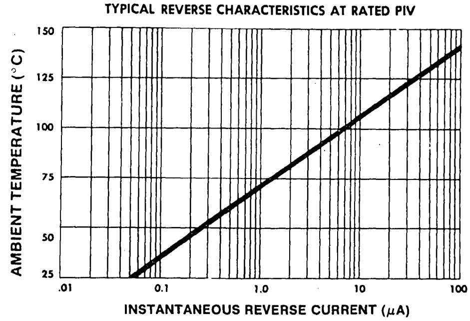
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

VII

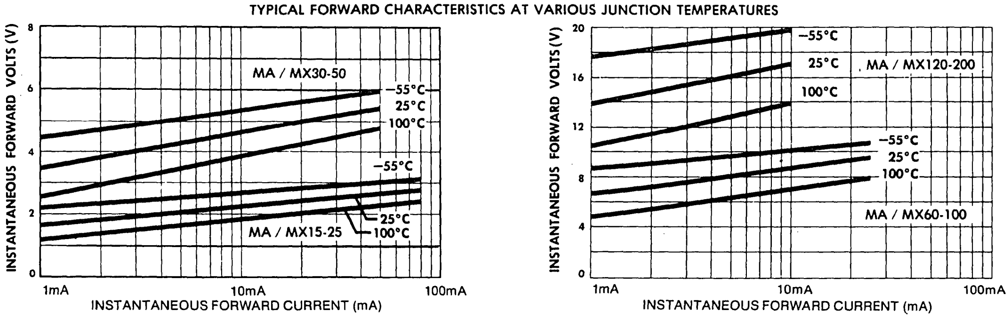
MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE



TYPICAL REVERSE CHARACTERISTICS AT RATED PIV



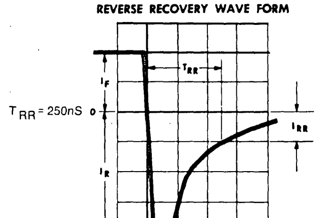
TYPICAL FORWARD CHARACTERISTICS AT VARIOUS JUNCTION TEMPERATURES



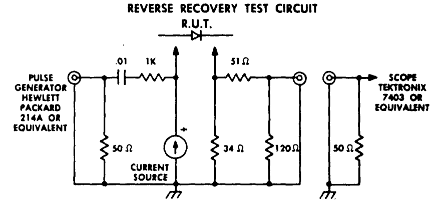
REVERSE RECOVERY TEST CONDITIONS §

TEST	I_F mA	I_R mA	I_{RR} mA
A	40	80	20
B	20	40	10
C	12.5	25	6.25
D	5	10	2.5

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



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HIGH VOLTAGE SILICON RECTIFIERS

10-80mA
Standard Recovery, Miniature

MS15-120
MXS15-200

FEATURES
- PIV: From 1.5kV to 20kV
- 2μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

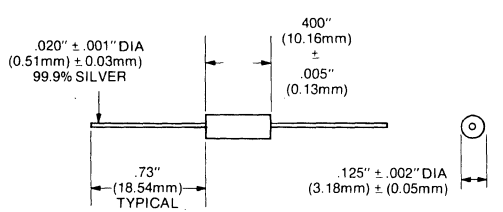
DESCRIPTION

The MXS/MS silicon rectifier series utilizes manufacturing techniques that meet the reliability standards of commercial, industrial and military users. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The medium reverse recovery characteristics improve the circuit efficiency of power conversion and control systems.

ABSOLUTE MAXIMUM RATINGS	MS	MXS
Peak Inverse Voltage	1.5kV to 12kV	1.5kV to 20kV
Maximum Average Rectified Current	See Electrical Specifications	
Maximum One Cycle Surge 8.3mS	See Electrical Specifications	
Maximum Recurrent Peak Current Surge	See Electrical Specifications	
Operating Temperature Range	-55° C to +150° C	
Storage Temperature Range	-65° C to +175° C	

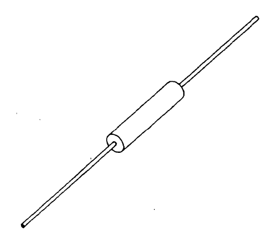
MECHANICAL SPECIFICATIONS

MXS15-200

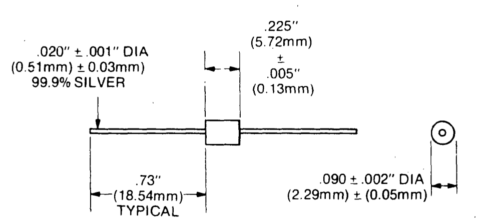


Dimensions in inches and (millimeters)

SG

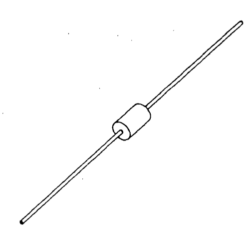


MS15-120



Dimensions in inches and (millimeters)

SH



UNITRODE

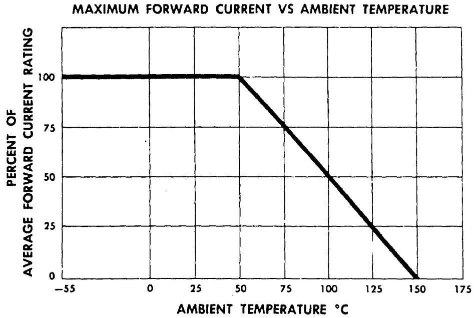
Type	Type	ELECTRICAL SPECIFICATIONS (at 25°C unless noted) Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O Max.	Maximum Reverse Recovery Time §	Maximum Junction Capacitance @ 100V	MAXIMUM RATINGS Maximum Average Rectified Current†			Maximum Recurrent Peak Current Surge	Maximum One Cycle Surge 8.3mS
Pkg Style SG	Pkg Style SH	PIV	I_R		V_F	T_{RR}	C_J	I_O			I_F	I_F(surge)
			25°C	100°C	25°C			50°C	100°C	125°C		
		V	μA	μA	V	μS	pF	mA	mA	mA	A	A
MXS15	MS15	1500	0.1	10	5	2(A)	2.0	80	40	20	0.8	8
MXS20	MS20	2000	0.1	10	5	2(A)	2.0	80	40	20	0.8	8
MXS25	MS25	2500	0.1	10	5	2(A)	2.0	80	40	20	0.8	8
MXS30	MS30	3000	0.1	10	8	2(B)	1.0	40	20	10	0.4	4
MXS40	MS40	4000	0.1	10	8	2(B)	1.0	40	20	10	0.4	4
MXS50	MS50	5000	0.1	10	8	2(B)	1.0	40	20	10	0.4	4
MXS60	MS60	6000	0.1	10	12	2(C)	1.0	25	12.5	6.25	0.2	2
MXS80	MS80	8000	0.1	10	12	2(C)	1.0	25	12.5	6.25	0.2	2
MXS100	MS100	10000	0.1	10	12	2(C)	1.0	25	12.5	6.25	0.2	2
MXS120	MS120	12000	0.1	10	24	2(D)	1.0	10	5	2.5	0.1	1
MXS150		15000	0.1	10	24	2(D)	1.0	10	5	2.5	0.1	1
MXS200		20000	0.1	10	24	2(D)	1.0	10	5	2.5	0.1	1

VII

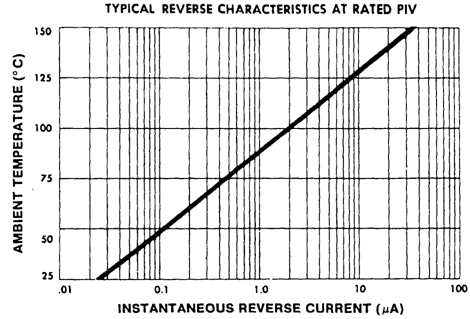
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
†The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.

NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

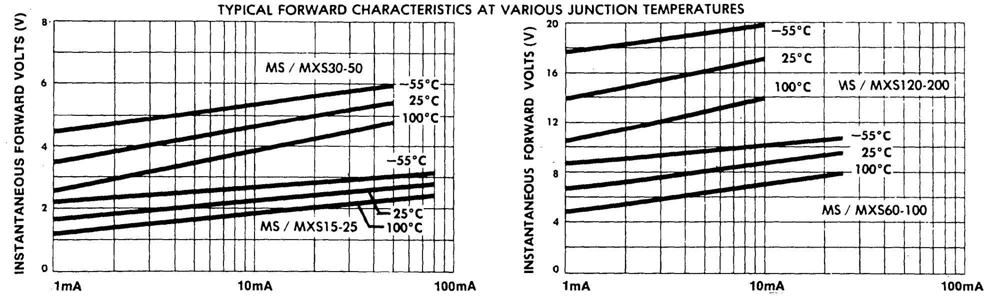
MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE



TYPICAL REVERSE CHARACTERISTICS AT RATED PIV



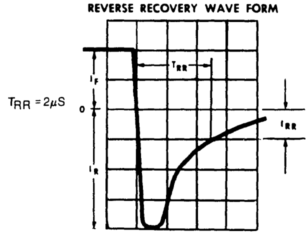
TYPICAL FORWARD CHARACTERISTICS AT VARIOUS JUNCTION TEMPERATURES



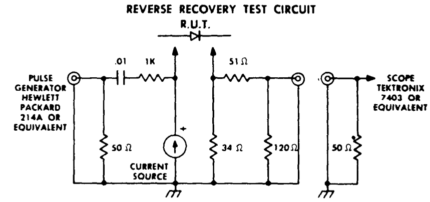
REVERSE RECOVERY TEST CONDITIONS §

TEST	I_F mA	I_R mA	I_{RR} mA
A	40	80	20
B	20	40	10
C	12.5	25	6.25
D	5	10	2.5

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



RECTIFIER ASSEMBLIES
PMA Power Modules
High Voltage, High Current

PMA101–PMA111
PMA101X–PMA111X
PMA201–PMA208
PMA201X–PMA208X

FEATURES
- PIV: From 2.5kV to 60kV
- 6A in Oil
- 300A Surge Current
- Dense Packaging
- Convenient Mounting

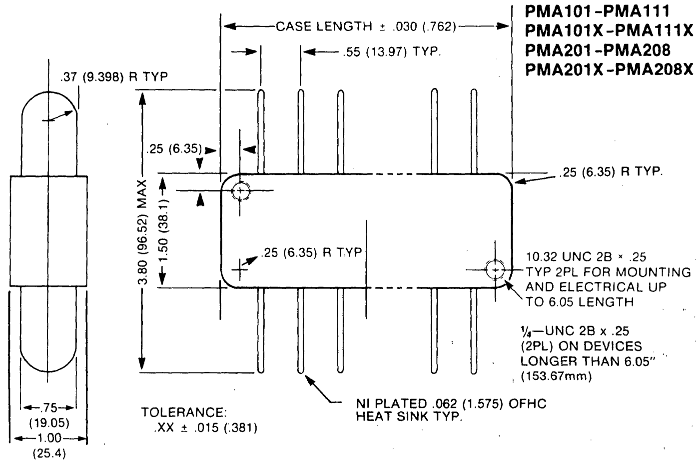
DESCRIPTION
The PMA POWER MODULE is ideally suited for high current applications such as charging, hold off and clipper diodes in large ground based radar systems. This device can be operated in static air, forced air or oil for many different high power applications where size and reliability are important design parameters.

ABSOLUTE MAXIMUM RATINGS

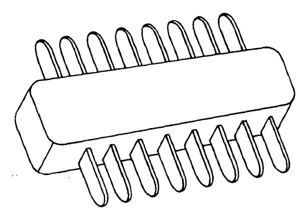
Peak Inverse Voltage .... 2.5kV to 60kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... –65°C to +150°C

MECHANICAL SPECIFICATIONS

PMA101-PMA111
PMA101X-PMA111X
PMA201-PMA208
PMA201X-PMA208X



PMA



PART NUMBER	CASE LENGTH INCHES	CASE LENGTH MILLIMETERS
PMA101, 101X	1.65	41.91
PMA102, 102X	2.20	55.88
PMA103, 103X	2.75	69.85
PMA104, 104X	3.85	97.79
PMA105, 105X	4.95	125.73
PMA106, 106X	6.05	153.67
PMA107, 107X	7.15	181.61
PMA108, 108X	8.25	209.55
PMA109, 109X	9.35	237.49
PMA110, 110X	11.55	293.37
PMA111, 111X	13.75	349.25

PART NUMBER	CASE LENGTH INCHES	CASE LENGTH MILLIMETERS
PMA201. 201X	1.65	41.91
PMA202. 202X	2.75	69.85
PMA203. 203X	3.85	97.79
PMA204. 204X	4.95	125.73
PMA205. 205X	7.15	181.61
PMA206. 206X	9.35	237.49
PMA207. 207X	11.55	293.37
PMA208. 208X	13.75	349.25

Polarity indicated by diode symbol

Dimensions in inches and (millimeters)

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS					
Maximum Reverse Recovery Time		Peak Inverse Voltage	Maximum Reverse Current @ PIV		Maximum Forward Voltage	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS	Case Length	
T_{RR}*		PIV	I_R		V_F	I_O @ 50°C			I_F(surge)		
Type	Type	kV	25°C	100°C	@ 3.0A Peak	NC	FA	Oil			
2µS	250nS		µA	µA	V	A**	A***	A	A	Inches	MM
PMA101	PMA101X	5.0	2	100	10	1.0	2.4	3.0	150	1.65	41.91
PMA102	PMA102X	7.5	2	100	15	1.0	2.4	3.0	150	2.20	55.88
PMA103	PMA103X	10	2	100	20	1.0	2.4	3.0	150	2.75	69.85
PMA104	PMA104X	15	2	100	30	1.0	2.4	3.0	150	3.85	97.79
PMA105	PMA105X	20	2	100	40	1.0	2.4	3.0	150	4.95	125.73
PMA106	PMA106X	25	2	100	50	1.0	2.4	3.0	150	6.05	153.67
PMA107	PMA107X	30	2	100	60	1.0	2.4	3.0	150	7.15	181.61
PMA108	PMA108X	35	2	100	70	1.0	2.4	3.0	150	8.25	209.55
PMA109	PMA109X	40	2	100	80	1.0	2.4	3.0	150	9.35	237.49
PMA110	PMA110X	50	2	100	100	1.0	2.4	3.0	150	11.55	293.37
PMA111	PMA111X	60	2	100	120	1.0	2.4	3.0	150	13.75	349.25
					@ 6.0A Peak						
PMA201	PMA201X	2.5	2	100	5	2.0	4.8	6.0	300	1.65	41.91
PMA202	PMA202X	5	2	100	10	2.0	4.8	6.0	300	2.75	69.85
PMA203	PMA203X	7.5	2	100	15	2.0	4.8	6.0	300	3.85	97.79
PMA204	PMA204X	10	2	100	20	2.0	4.8	6.0	300	4.95	125.73
PMA205	PMA205X	15	2	100	30	2.0	4.8	6.0	300	7.15	181.61
PMA206	PMA206X	20	2	100	40	2.0	4.8	6.0	300	9.35	237.49
PMA207	PMA207X	25	2	100	50	2.0	4.8	6.0	300	11.55	293.37
PMA208	PMA208X	30	2	100	60	2.0	4.8	6.0	300	13.75	349.25

* Reverse recovery test conditions for each cell prior to assembly I_F = 400mA, I_R = 800mA, I_{RR} = 200mA.
** For natural air convection operation unit must by mounted horizontally with no air restrictions.
*** Forced air ratings are with a minimum air flow of 600 linear feet per minute.

Notes: 1. Junction to heat sink thermal resistance 2.5°C per watt.
2. Consult factory for series and/or parallel applications for special matching.
3. I_O ratings @ 50°C linearly derate to 0 @ 150°C.
4. Oil and forced air operation any position.
5. Heat sinks are electrrically "hot".

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RECTIFIER ASSEMBLIES

PME Power Modules
High Voltage

PME101–PME103
PME101X–PME103X

FEATURES

- PIV: From 2.5kV to 8.0kV
- 3A Current
- Small Size
- Integral Heat Sinks
- 200A Surge Mounting
- Fast Recovery Time

DESCRIPTION

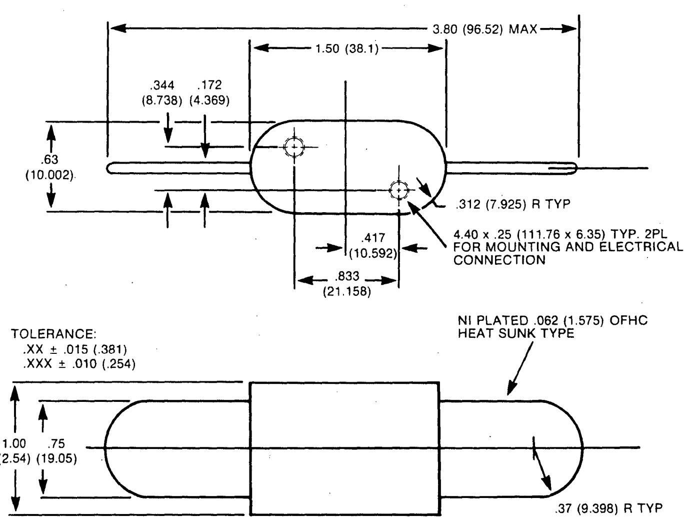
The PME POWER MODULE is a high voltage high current single cell silicon rectifier assembly. This device is designed with common mounting and electrical inserts and integral heat sinks for oil operation. The PME unit is ideal for use in high current TWT power supply applications and high-power transmitters to name a few.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 2.5kV to 8.0kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −65°C to +150°C

MECHANICAL SPECIFICATIONS

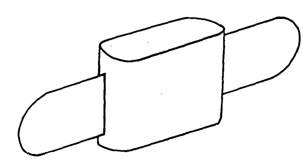
PME101 - PME103
PME101X - PME103X



Dimensions in inches and (millimeters)

Polarity indicated by diode symbol.

PME



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25° C unless noted)						MAXIMUM RATINGS			
Maximum Reverse Recovery Time		Peak Inverse Voltage	Maximum Reverse Current @ PIV		Maximum Forward Voltage	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS
T_{RR} *		PIV	I_R		V_F	I_O @ 50° C			I_F(surge)
Type	Type	kV	25° C	100° C	V	NC	FA	Oil	A
2μS	250nS		μA	μA		A **	A***	A	
PME101	PME101X	2.5	2	100	5 @ 3.0A peak	1.0	2.4	3.0	200
PME102	PME102X	4	2	100	7 @ 2.2A peak	.75	1.75	2.2	150
PME103	PME103X	8	2	100	11 @ 1.5A peak	.50	1.2	1.5	100

* Reverse recovery test conditions for each cell prior to assembly I_F = 400mA, I_R = 800mA, I_{RR} = 200mA.
** For natural air convection operation unit must by mounted horizontally with no air restrictions.
*** Forced air ratings are with a minimum air flow of 600 linear feet per minute.

Notes:
1. Junction to heat sink thermal resistance 2.5° C per watt.
2. Consult factory for series and/or parallel applications for special matching.
3. I_O ratings @ 50° C linearly derate to 0 @ 150° C.
4. Oil and forced air operation any position.
5. Heat sinks are electrrically "hot".

VII

HIGH VOLTAGE SILICON RECTIFIERS

SX10-100
SXS10-100

POWERSTACK
400mA-1.0A
High Current, Miniature

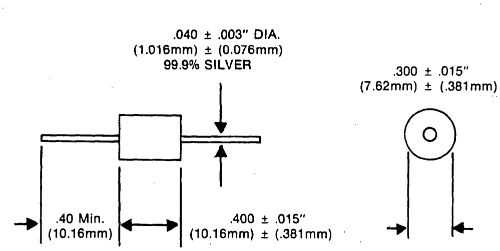
FEATURES
- PIV: From 1kV to 10kV
- 400mA to 1.0A
- 250nS Reverse Recovery
- High Surge Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION
The SX/SXS silicon rectifier series is a unique concept for high current high voltage applications. Matched junction characteristics and low stray capacitance due to metallurgically bonded junctions eliminate the need for external compensation networks. These rectifiers utilize HVD's cylindrical die construction, which minimizes electrical and mechanical stress, insuring long life for commercial, military and industrial applications.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage .... 1kV to 10kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range......................... −65°C to +150°C

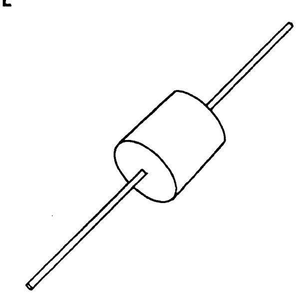
MECHANICAL SPECIFICATIONS

SX10-100
SXS10-100



Dimensions in inches and (millimeters)

SL



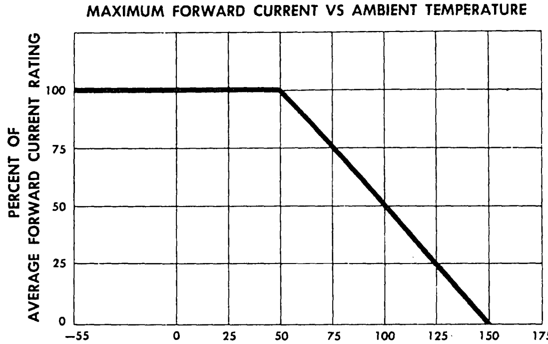
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS			
Maximum Reverse Recovery Time §		Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS
250nS	2μS	PIV	I_R		V_F	I_O			I_F(surge)
Type	Type	V	25°C	100°C	25°C	50°C	100°C	125°C	A
			μA	μA	V	mA	mA	mA	
SX10	SXS10	1000	1.0	25	5.5	1000	500	250	60
SX15	SXS15	1500	1.0	25	5.5	1000	500	250	60
SX20	SXS20	2000	1.0	25	5.5	1000	500	250	60
SX25	SXS25	2500	1.0	25	5.5	1000	500	250	60
SX30	SXS30	3000	1.0	25	7.5	600	300	150	40
SX40	SXS40	4000	1.0	25	7.5	600	300	150	40
SX50	SXS50	5000	1.0	25	7.5	600	300	150	40
SX60	SXS60	6000	1.0	25	11.0	400	200	100	25
SX80	SXS80	8000	1.0	25	11.0	400	200	100	25
SX100	SXS100	10000	1.0	25	11.0	400	200	100	25

VII

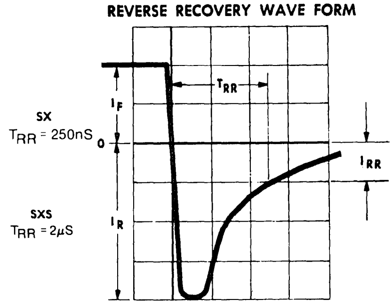
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated, AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250°C 3/8" (9.5mm) from case for 5 seconds.

MAXIMUM FORWARD CURRENT VS AMBIENT TEMPERATURE



Reverse recovery test conditions: I_F = 100mA, I_R = 200mA, I_{RR} = 50mA

REVERSE RECOVERY WAVE FORM



RECTIFIER ASSEMBLIES

High Voltage Doorbell® Modules, Standard and Fast Recovery

UDA, UDB, UDC, UDD, UDE, UDF SERIES

FEATURES

- PIV: from 2.5kV to 15kV
- Stackable to 600kV
- Current Ratings: to 7.7A
- Controlled Avalanche Characteristics
- Only Fused-in-Glass Diodes Used
- Recovery Time: to 500ns
- Modular Package For Easy Stacking

DESCRIPTION

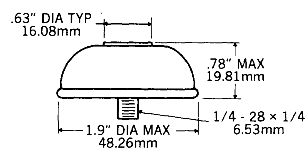
This series of high-voltage, high-current stacks that incorporate a unique modular design makes it ideally suited for high power applications such as in radar systems as charger, hold-off and clipper diodes.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	
UDA, UDC Series	5kV to 15kV
UDB, UDD Series	2.5kV to 7.5kV
UDE, UDF Series	2.5kV to 5kV
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C

MECHANICAL SPECIFICATIONS

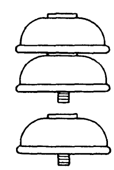
UDA, UDB, UDC, UDD, UDE, UDF SERIES



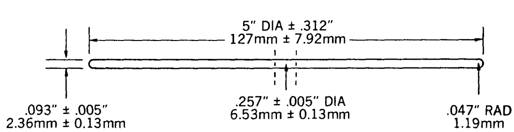
1. Polarity — Cathode connected to base.
2. Part Number — On base of unit.

Typical Weight — 2.1 ounces 60 grams

DD



EXTENDER PLATE D



Typical Weight — 2.75 ounces 78 grams

UNITRODE

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Electrical Specifications (at 25°C unless noted)						Maximum Ratings				
						Maximum Average D.C. Output Current				
Type		PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV	Maximum Reverse Recovery Time	$T_C = 75°C$ Air	$T_C = 60°C$ Air with Extender Plate**	$T_C = 50°C$ Oil	Non-Repetitive Sinusoidal Surge (8.3ms) $T_C = 100°C$	Maximum Reverse Transient Energy Absorption
		kV		μA	ns	Amps	Amps	Amps	Amps	joules
Standard	UDE-2.5	2.5	5V @ 3.00A	10		‡ 6.00	7.00	7.70	200	8
Recovery	UDB-2.5	2.5	4V @ 1.50A	5		3.00	3.75	4.25	100	4
	UDE-5	5	10V @ 2.20A	10		‡ 4.50	5.00	5.50	200	14
	UDB-5	5	8V @ 1.00A	5		2.00	2.50	2.75	100	8
	UDA-5	5	8V @ 0.82A	2	—	1.65	2.00	2.20	30	1.5
	UDB-7.5	7.5	12V @ 0.70A	5		1.33	1.65	2.00	100	12
	UDA 7.5	7.5	12V @ 0.60A	2		1.25	1.55	1.75	30	2.5
	UDA-10	10	16V @ 0.50A	2		1.00	1.25	1.40	30	3
	UDA-15	15	25V @ 0.33A	2		0.67	0.80	0.90	30	5
Fast	UDF-2.5	2.5	6V @ 2.20A	10		4.50	5.00	5.30	150	8
Recovery	UDD-2.5	2.5	6V @ 1.20A	5		2.25	2.80	3.30	80	4
	UDF-5	5	11V @ 1.60A	10		3.30	4.00	4.40	150	14
	UDD-5	5	11V @ 0.75A	5		1.50	1.85	2.00	80	8
	UDC-5	5	10V @ 0.70A	2	500*	1.20	1.50	1.70	25	1.5
	UDD-7.5	7.5	17V @ 0.50A	5	350†	1.00	1.25	1.50	80	12
	UDC-7.5	7.5	15V @ 0.50A	2		0.90	1.10	1.25	25	2.5
	UDC-10	10	20V @ 0.37A	2		0.75	0.90	1.00	25	3
	UDC-15	15	30V @ 0.25A	2		0.50	0.60	0.70	25	5

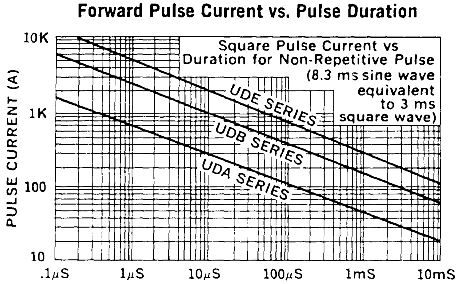
*Measured in a reverse recovery circuit switching from 1.0A forward to 1.0A reverse current recovering to 0.5A.
†Measured in a reverse recovery circuit switching from 0.5A forward to 1.0A reverse current recovering to 0.25A.

**These ratings are based on using "extender plates" that provide additional surface area to radiate heat. Because of possible corona effects caused by scratches on these plates, extreme care is necessary in their handling and they are not recommended where the working voltage exceeds 7.5KV/module. They should be carefully polished prior to installation.

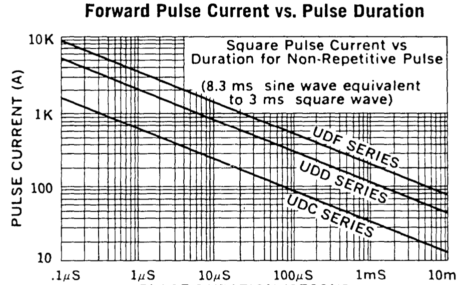
‡These ratings are based on $T_C = 100°C$.

VII

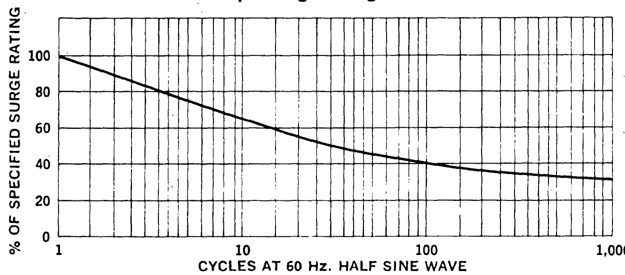
Forward Pulse Current vs. Pulse Duration



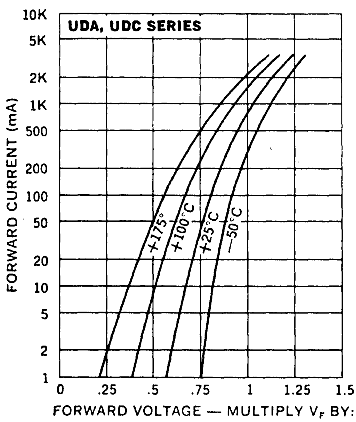
Forward Pulse Current vs. Pulse Duration



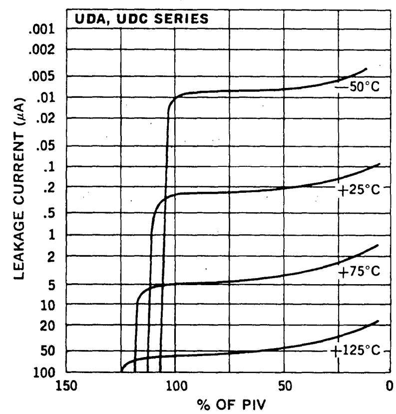
Multiple Surge Rating vs. Duration



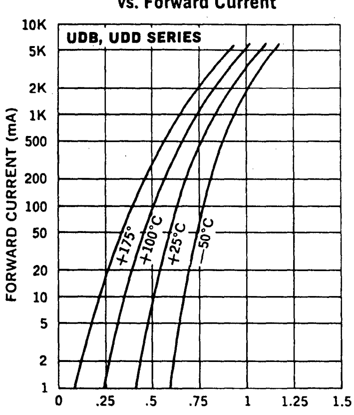
Typical Forward Voltage vs. Forward Current



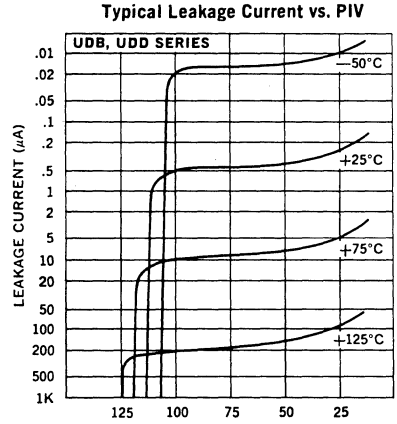
Typical Leakage Current vs. PIV



Typical Forward Voltage vs. Forward Current



Typical Leakage Current vs. PIV



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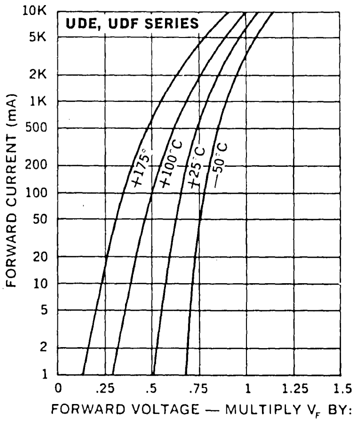
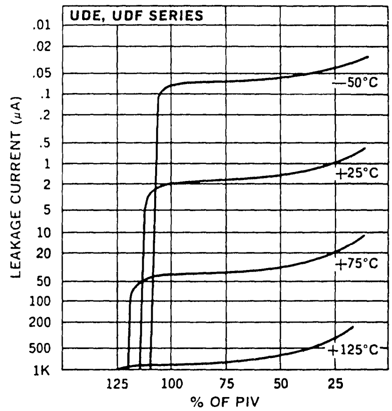
VII

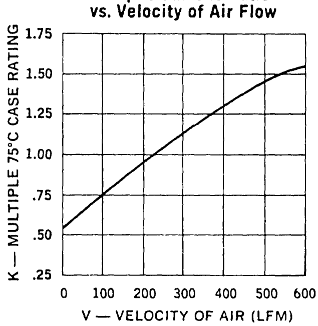
Typical Forward Voltage vs. Forward Current



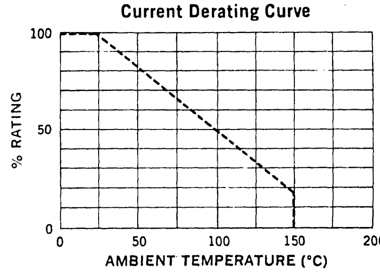
Typical Leakage Current vs. PIV



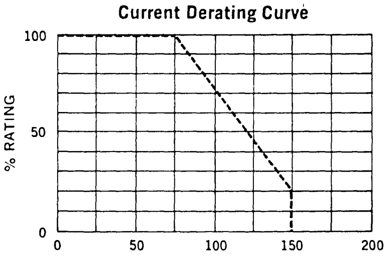
Output Current Ratio vs. Velocity of Air Flow



Current Derating Curve

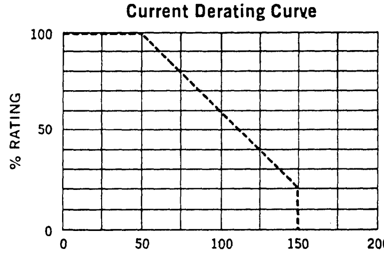


Current Derating Curve



Air Cooled

Current Derating Curve



Oil Immersed

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RECTIFIER ASSEMBLIES

High Voltage Stacks, Standard and Fast Recovery

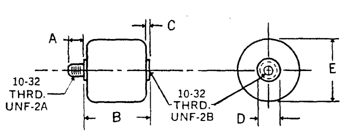
FEATURES
- Controlled Avalanche Characteristics
- Only Fused-in-Glass Diodes Used
- High Forward and Reverse Surge Capability
- Transfer Molded for Voidless Construction
- Modular for Easy Stacking
- PIV: from 2.5 kV to 15 kV
- Recovery Times: to 500ns
- Continuous Ratings: to 2.3A

DESCRIPTION
These assemblies uniquely combine a versatile stackable design with all the requirements for reliable high voltage operation. All modules are suitable for bridge or series operations.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage, USS Series .... 5.0 kV to 15 kV
Peak Inverse Voltage, USB Series .... 2.5 kV to 10 kV
Peak Inverse Voltage, UFS Series .... 5.0 kV to 10 kV
Peak Inverse Voltage, UFB Series .... 2.5 kV to 7.5 kV
Maximum Average D.C. Output Current .... See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms) .... See Electrical Specifications
Operating and Storage Temperature Range .... —65°C to +150°C

MECHANICAL SPECIFICATIONS

UFB, UFS, USB, USS SERIES

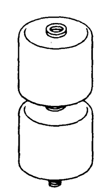


	ins.	mm.
A	.230-.235	5.84-5.97
B	.980-1.10	24.89-27.94
C	.020-.040	0.51-1.02
D	.320-.330	8.13-8.38
E	.97-1.00	24.64-25.40

Typical Weight: USS & UFS Series — 1.0 ounce
28 grams

USB & UFB Series — 1.1 ounce
31 grams

DH



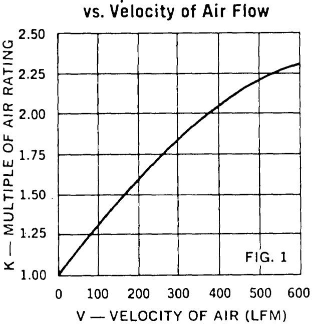
MARKING
Type number marked on unit.
Polarity — Cathode connected to stud.

UNITRODE

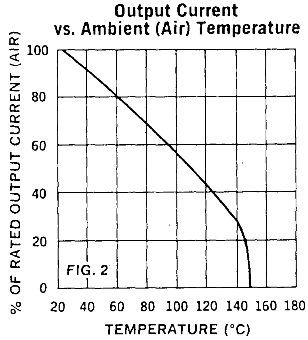
Electrical Specifications (at 25°C unless noted)							Maximum Ratings		
Type		PIV	Maximum Forward Voltage Drop	Leakage Current @ PIV	Maximum Reverse Recovery Time	Maximum Reverse Transient Energy Absorption	Maximum Average D.C. Output Current $T_A = 25°C$ AIR	Maximum Average D.C. Output Current $T_A = 50°C$ OIL	Non-Repetitive Sinusoidal Surge (8.3ms)
		kV		μA	ns	joules	Amps	Amps	Amps
Standard Recovery	USS 5	5.0	9V @ 0.6A	5	—	1.5	0.60	1.1	25
	USS 7.5	7.5	13V @ 0.5A			2.5	0.45	0.91	
	USS 10	10	17V @ 0.3A			3.0	0.35	0.71	
	USS 15	15	25V @ 0.2A			5.0	0.25	0.51	
Standard Recovery	USB 2.5	2.5	5V @ 1.1A	10	—	3.0	1.1	2.3	80
	USB 5	5.0	9V @ 0.7A			6.0	0.68	1.5	
	USB 7.5	7.5	13V @ 0.5A			9.0	0.53	1.2	
	USB 10	10	17V @ 0.4A			12	0.43	1.0	
Fast Recovery	UFS 5	5.0	12V @ 0.5A	5	500* 350†	1.5	0.50	0.90	20
	UFS 7.5	7.5	18V @ 0.4A			2.5	0.38	0.75	
	UFS 10	10	23V @ 0.3A			3.0	0.30	0.58	
Fast Recovery	UFB 2.5	2.5	6V @ 0.9A	10	500* 350†	3.0	0.90	2.0	70
	UFB 5	5.0	12V @ 0.6A			6.0	0.58	1.3	
	UFB 7.5	7.5	18V @ 0.4A			9.0	0.45	1.0	

*Measured in a reverse recovery circuit switching from 1A forward to 1A reverse current recovering to 0.5A.
†Measured in a reverse recovery circuit switching from .5A foward current to 1A reverse current, recovery to .25A.

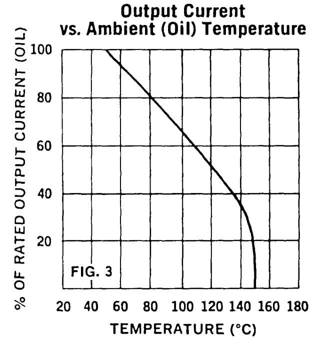
Output Current Ratio vs. Velocity of Air Flow



Output Current vs. Ambient (Air) Temperature

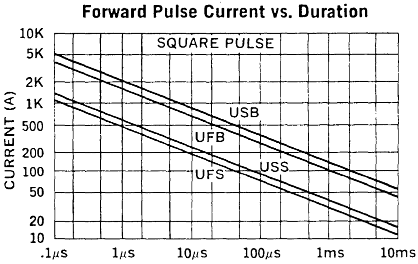


Output Current vs. Ambient (Oil) Temperature

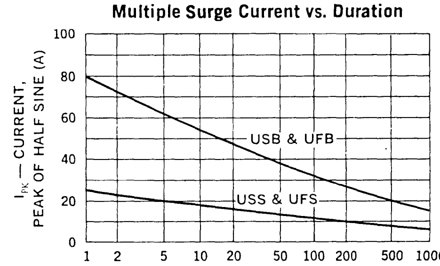


Application example: The rectifier is to be used in a cabinet at 60°C with ambient air moving at 400 LFM. The rating is reduced (Fig. 2) by a factor of 0.81 due to the elevated temperature, but it is enhanced by 2X (Fig. 1) due to the air flow. Hence the DC output current is 0.81 x 2, or 1.6 times the 25°C air rating.

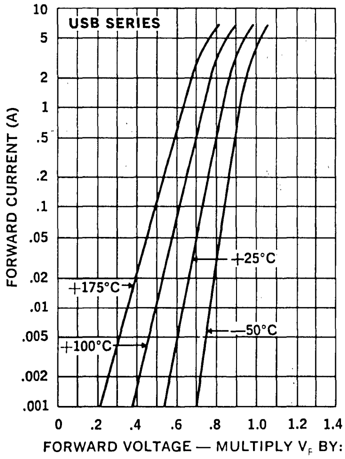
Forward Pulse Current vs. Duration



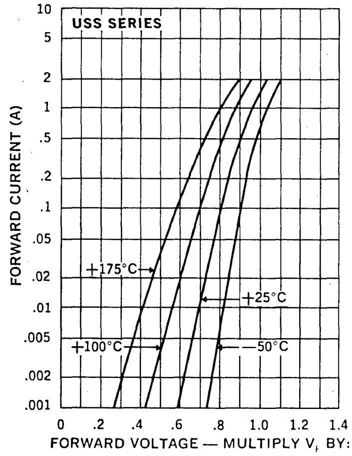
Multiple Surge Current vs. Duration



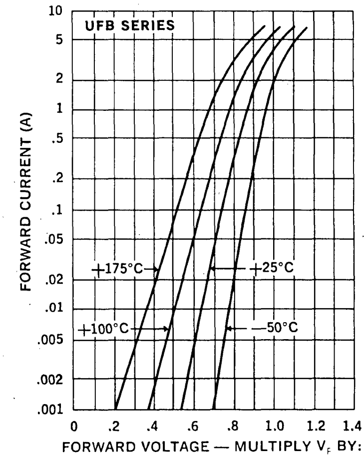
Typical Forward Voltage vs. Forward Current



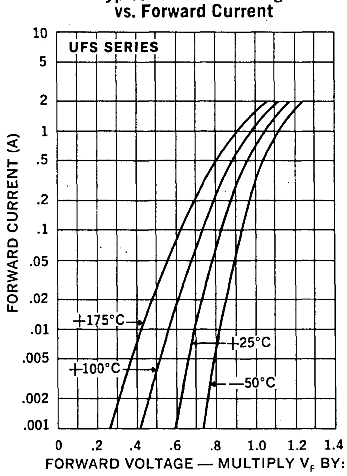
Typical Forward Voltage vs. Forward Current



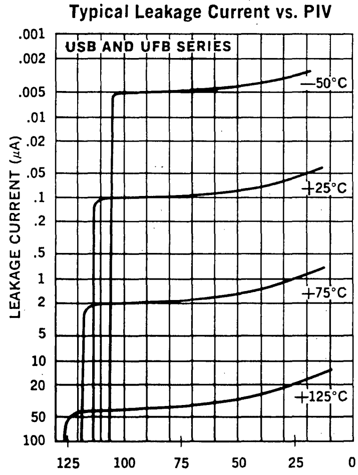
Typical Forward Voltage vs. Forward Current



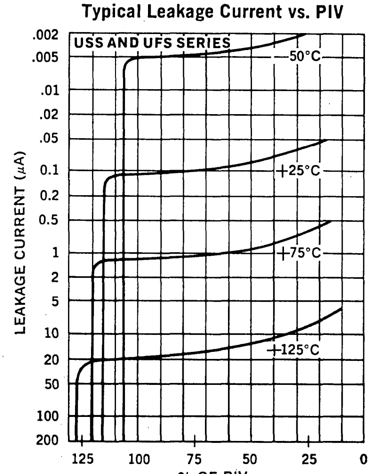
Typical Forward Voltage vs. Forward Current



Typical Leakage Current vs. PIV



Typical Leakage Current vs. PIV



RECTIFIER ASSEMBLIES

UGB, UGD, UGE, UGF SERIES

High Voltage Doorbell® Modules
Standard and Fast Recovery

FEATURES

- Current Ratings: to 10A
- PIV: 2.5 kV to 10kV
- Recovery Times: to 500ns
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Stackable to 600KV
- Modular Package for Easy Stacking

DESCRIPTION

This series of high-voltage, high-current stacks that incorporate a unique modular design makes it particularly well-suited for high power applications such as in radar systems as charge, hold-off and clipper diodes.

VII

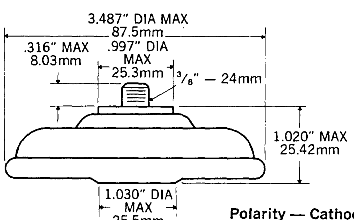
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage

UGB, UGD Series	5 kV to 10 kV
UGS, UGF Series	2.5 kV to 7.5 kV
Maximum Average D.C. Output Current	See Electrical Specifications
Non-repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	−65°C to +150°C

MECHANICAL SPECIFICATIONS

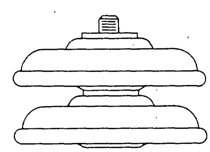
UGB, UGD, UGE, UGF SERIES



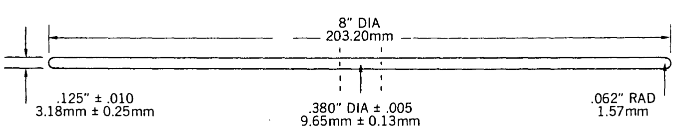
Polarity — Cathode connected to base.
Part Number — On base of unit.

Typical Weight — 7.0 ounces
200 grams

DG



EXTENDER PLATE G



Typical Weight — 9.25 ounces
265 grams

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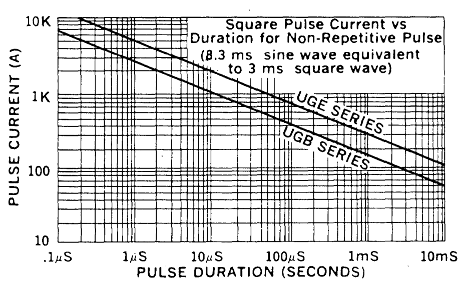
UNITRODE

Electrical Specifications (at 25°C unless noted)						Maximum Ratings				
						Maximum Average D.C. Output Current			Non-repetitive Sinusoidal Surge (8.3ms)	Maximum Reverse Transient Energy Absorption
Type		PIV	Maximum Forward Voltage Drop	Maximum Leakage Current @ PIV	Maximum Reverse Recovery Time	$T_C = 75°C$ Air	$T_C = 60°C$ Air with Extender Plate**	$T_C = 50°C$ Oil	$T_C = 100°C$	
		kV		μA	ns	Amps	Amps	Amps	Amps	joules
Standard Recovery	UGE-2.5	2.5	5V @ 3.30A	10		6.60	8.25	10.00	200	8
	UGE-5	5	10V @ 2.50A	15		5.00	6.25	7.50	200	14
	UGB-5	5	9V @ 2.20A	5	—	4.40	5.50	6.60	100	7
	UGE-7.5	7.5	13V @ 1.60A	10		3.30	4.10	5.00	200	20
	UGB-7.5	7.5	13V @ 1.50A	5		3.00	3.75	5.00	100	10
	UGB-10	10	17V @ 1.10A	5		2.30	2.85	3.50	100	14
Fast Recovery	UGF-2.5	2.5	6V @ 2.50A	10		5.00	6.25	8.00	150	8
	UGF-5	5	11V @ 1.80A	10		3.75	4.70	6.00	150	14
	UGD-5	5	11V @ 1.60A	5	500*	3.30	4.10	4.80	80	7
	UGF-7.5	7.5	17V @ 1.20A	10	350†	2.50	3.10	4.00	150	20
	UGD-7.5	7.5	17V @ 1.10A	5		2.25	2.80	3.50	80	10
	UGD-10	10	22V @ 0.85A	5		1.75	2.20	2.50	80	14

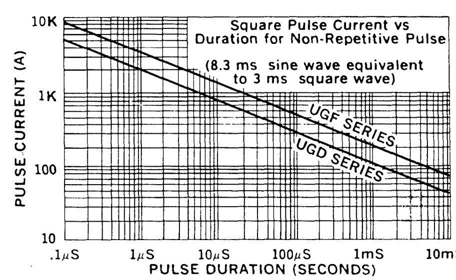
*Measured in a reverse recovery circuit switching from 1.0A forward to 1.0A reverse current recovering to 0.5A.
†Measured in a reverse recovery circuit switching from 0.5A forward to 1.0A reverse current recovering to 0.25A.

**These ratings are based on using "extender plates" that provide additional surface area to radiate heat. Because of possible corona effects caused by scratches on these plates, extreme care is necessary in their handling and they are not recommended where the working voltage exceeds 7.5KV/module. They should be carefully polished prior to installation.

Forward Pulse Current vs. Pulse Duration



Forward Pulse Current vs. Pulse Duration



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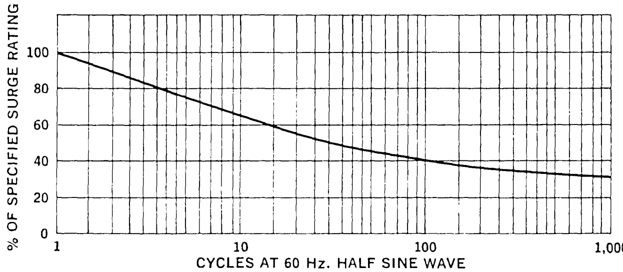
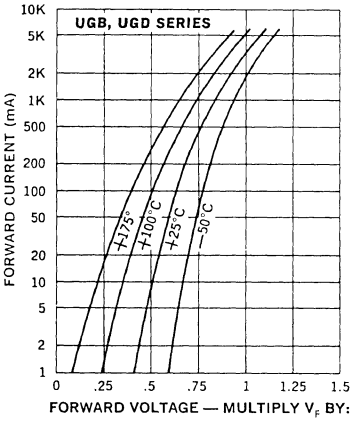
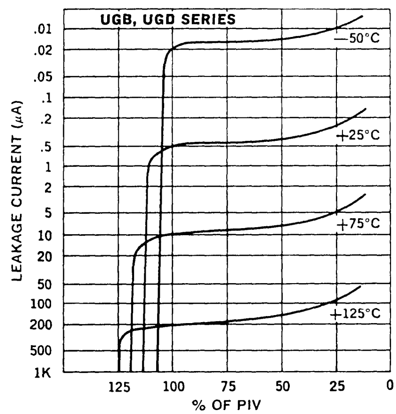
Multiple Surge Rating vs. D·uration



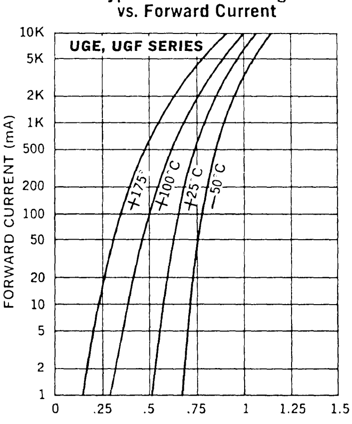
Typical Forward Voltage vs. Forward Current



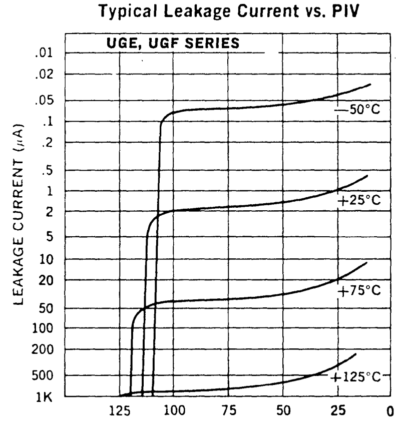
Typical Leakage Current vs. PIV



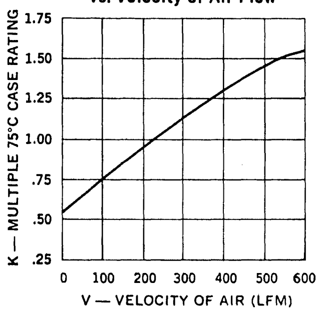
Typical Forward Voltage vs. Forward Current



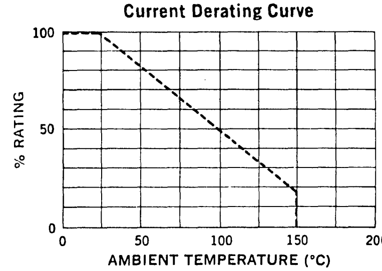
Typical Leakage Current vs. PIV



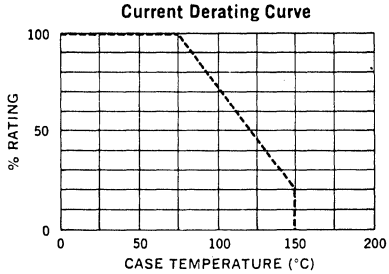
Output Current Ratio vs. Velocity of Air Flow



Current Derating Curve

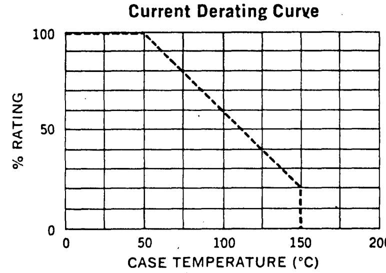


Current Derating Curve



Air Cooled

Current Derating Curve



Oil Immersed

RECTIFIER ASSEMBLIES

High Voltage Stacks, .125 Amp to 1 Amp, Standard and Fast Recovery

US12–US200A
USR12–USR180A

FEATURES
- Controlled Avalanche Characteristics
- Recovery Times: to 500ns
- Transfer Molded for Voidless Encapsulation
- High Forward and Reverse Surge Capability
- PIV: from 1200 to 20,000V
- Only Fused-in-Glass Diodes Used

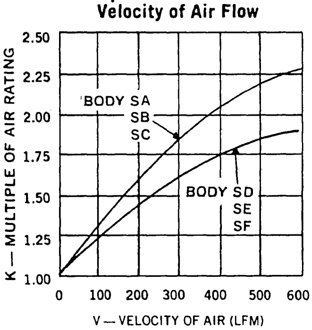
DESCRIPTION
This series of High Voltage, Medium Current Stacks are assembled from hermetically sealed, controlled avalanche individual diodes. Therefore, they offer the ultimate in reliability for such applications as clipper diodes, back swing diodes and hold-off diodes in pulse modulators.

VII

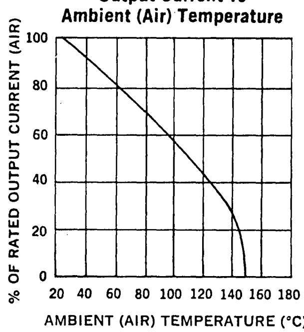
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1200 to 20,000V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	20A
Operating and Storage Temperature Range	−65°C to +150°C

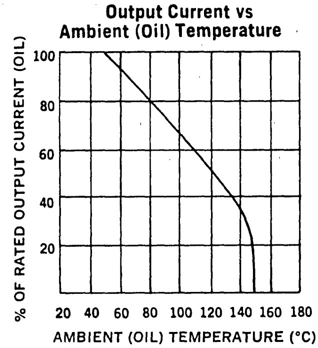
Output Current Ratio vs Velocity of Air Flow



Output Current vs Ambient (Air) Temperature



Output Current vs Ambient (Oil) Temperature



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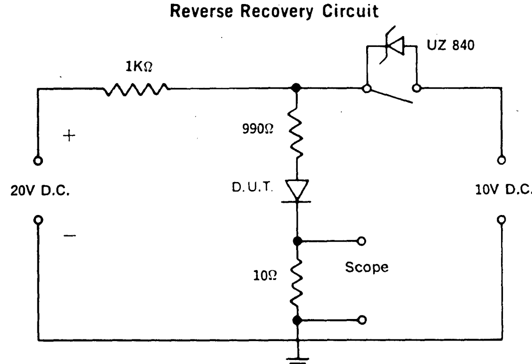
Type	PIV	Maximum Leakage Current at PIV $T_A = 25°C$	Maximum Leakage Current at PIV $T_A = 100°C$	Maximum Forward Voltage Drop	Maximum Reverse Recovery Time†	Body Size	Maximum Ratings: Max. Avg. D.C. Output Current $T_A = 25°C$ (Air)	Maximum Ratings: Max. Avg. D.C. Output Current $T_A = 50°C$ (Oil)
	V	μA	μA		ns		mA	mA
Standard Recovery								
US 12	1200	2	100	2.0V @ 400mA	—	SA	1000	2500
US 15	1500	2	100	3.0V @ 400mA		SA	800	2000
US 18	1800	2	100	3.0V @ 400mA		SA	700	1750
US 20	2000	2	100	4.0V @ 400mA		SA	600	1500
US 25	2500	2	100	5.0V @ 400mA	—	SB	600	1500
US 30	3000	2	100	6.0V @ 400mA		SB	500	1250
US 35	3500	2	100	7.0V @ 200mA	—	SC	400	1000
US 40	4000	2	100	7.0V @ 200mA		SC	350	850
US 45A	4500	2	100	8.0V @ 200mA	—	SD	330	750
US 50A	5000	2	100	9.0V @ 200mA		SD	330	750
US 60A	6000	2	100	10.0V @ 200mA		SD	300	620
US 70A	7000	2	100	12.0V @ 200mA		SD	300	620
US 80A	8000	2	100	14.0V @ 100mA	—	SE	250	500
US 100A	10000	2	100	17.0V @ 100mA		SE	250	500
US 120A	12000	2	100	21.0V @ 100mA		SE	200	400
US 150A	15000	2	100	26.0V @ 100mA	—	SF	200	400
US 180A	18000	2	100	31.0V @ 100mA		SF	180	360
US 200A	20000	2	100	34.0V @ 100mA		SF	180	360
Fast Recovery								
USR 12	1200	5	150	3.3V @ 400mA	500	SA	750	1850
USR 15	1500	5	150	4.0V @ 400mA	500	SA	600	1500
USR 20	2000	5	150	5.5V @ 400mA	500	SB	500	1250
USR 25	2500	5	150	6.6V @ 400mA	500	SB	400	1000
USR 30	3000	5	150	7.7V @ 400mA	500	SC	400	1000
USR 35	3500	5	150	8.8V @ 200mA	500	SC	350	850
USR 40A	4000	5	150	9.9V @ 200mA	500	SD	300	750
USR 45A	4500	5	150	11.0V @ 100mA	500	SD	250	625
USR 50A	5000	5	150	13.0V @ 100mA	500	SD	250	625
USR 60A	6000	5	150	15.4V @ 100mA	500	SD	220	500
USR 70A	7000	5	150	17.6V @ 100mA	500	SE	220	500
USR 80A	8000	5	150	20.0V @ 100mA	500	SE	200	400
USR 100A	10000	5	150	24.0V @ 100mA	500	SE	200	400
USR 120A	12000	5	150	31.0V @ 100mA	500	SF	150	300
USR 150A	15000	5	150	33.0V @ 100mA	500	SF	150	300
USR 180A	18000	5	150	35.0V @ 100mA	500	SF	125	250

†Measured in a reverse recovery circuit switching from 10mA forward to 10mA reverse current recovering to 5mA.

Reverse Recovery Circuit



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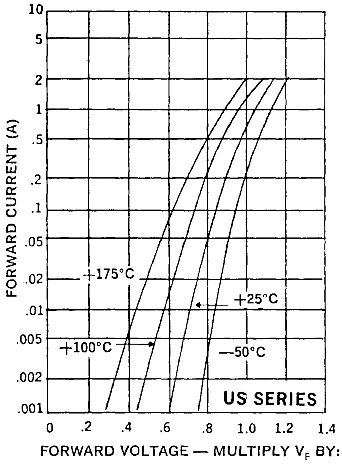
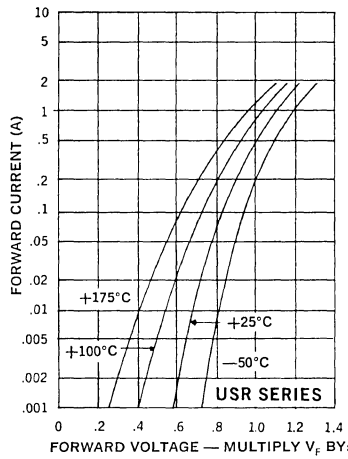
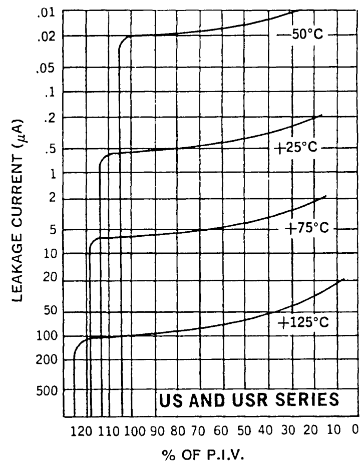
Typical Forward Current vs. Forward Voltage



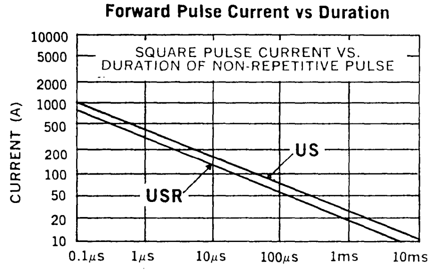
Typical Forward Current vs. Forward Voltage



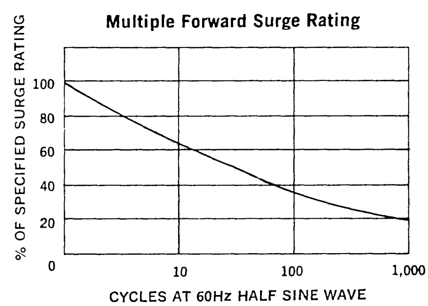
Typical Leakage Current vs. Voltage



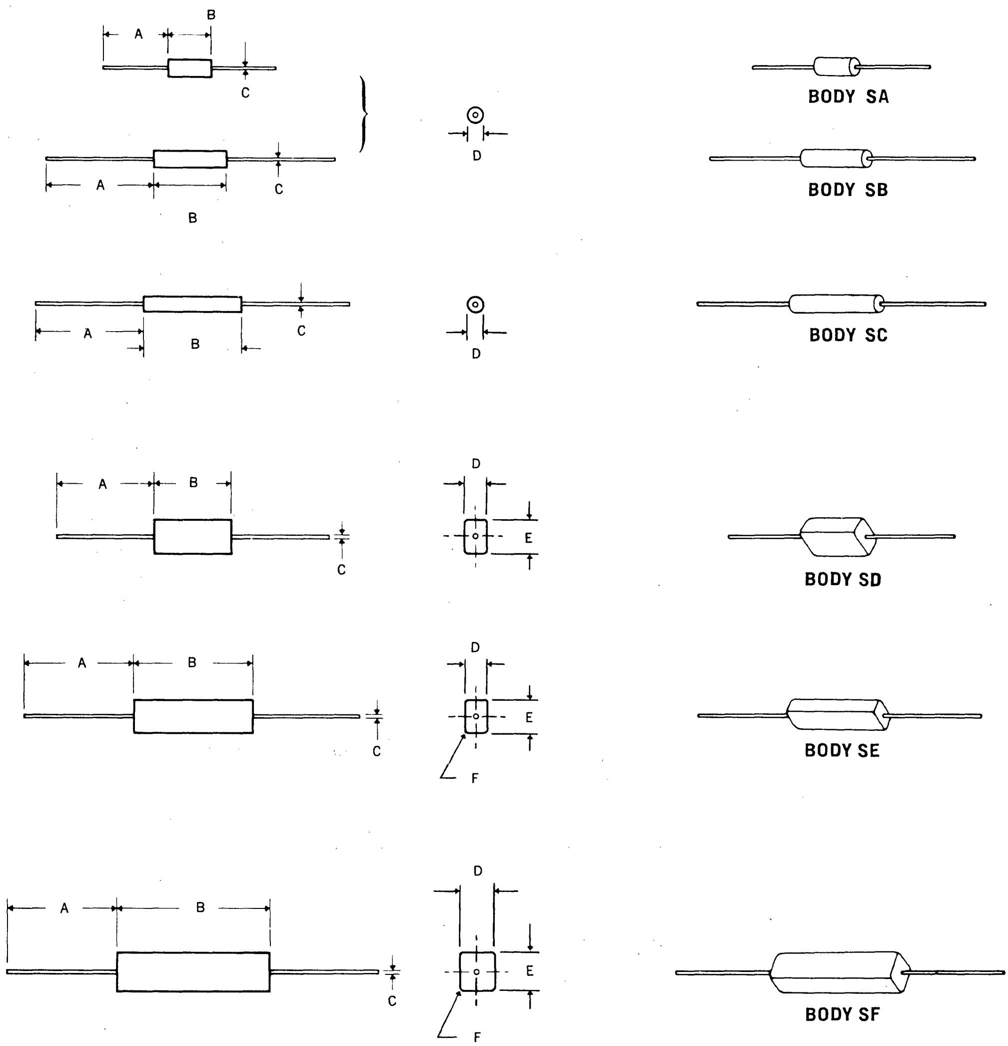
Forward Pulse Current vs Duration



Multiple Forward Surge Rating



MECHANICAL SPECIFICATIONS



	SA		SB		SC		SD		SE		SF	
	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.
A	.75 MIN.	19.05 MIN.	1.25 MIN.	31.75 MIN.	1.25 MIN.	31.75 MIN.	1.25 MIN.	31.75 MIN.	1.25 MIN.	31.75 MIN.	1.25 MIN.	31.75 MIN.
B	.50 MAX.	12.70 MAX.	0.85 MAX.	21.59 MAX.	1.125 MAX.	28.58 MAX.	.875 MAX.	22.23 MAX.	1.375 MAX.	34.93 MAX.	1.75 MAX.	44.45 MAX.
C	.028 DIA.	.71 DIA.	.032 DIA.	.81 DIA.	.032 DIA.	.81 DIA.	.032 DIA.	.81 DIA.	.032 DIA.	.81 DIA.	.032 DIA.	.81 DIA.
D	.187 MAX.	4.75 MAX.	.187 MAX.	4.75 MAX.	.187 MAX.	4.75 MAX.	.250 MAX.	6.35 MAX.	.250 MAX.	6.35 MAX.	.400 MAX.	10.16 MAX.
E							.375 MAX.	9.53 MAX.	.375 MAX.	9.53 MAX.	.400 MAX.	10.16 MAX.
F									.078	1.98	.078	1.98

HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC
Fast Recovery

FEATURES

- PIV: From 15kV to 50kV
- 250nS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION

The VX MULTISTAC silicon rectifier assemblies meet the stringent reliability requirements of commercial, industrial and military users through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The fast reverse recovery characteristics enhance applications in high frequency power conversion and control circuits.

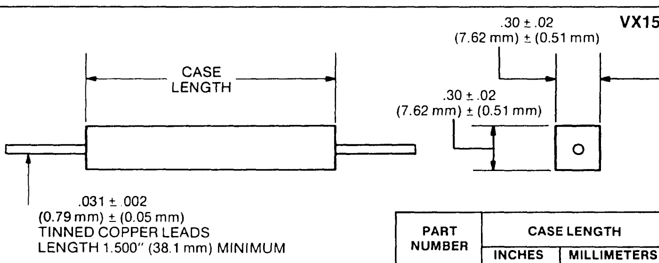
VII

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 15kV to 50kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3 mS .... See Electrical Specifications
Operating Temperature Range .... -55° C to +150° C
Storage Temperature Range .... -65° C to +150° C

MECHANICAL SPECIFICATIONS

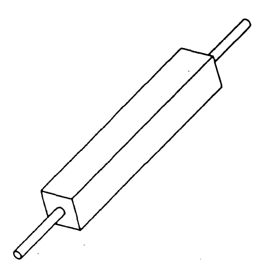
VX15-50



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
VX15	1.50 ± .03	38.10 ± 0.76
VX20, 25	2.00 ± .03	50.80 ± 0.76
VX30, 40, 50	2.50 ± .03	63.50 ± 0.76

Dimensions in inches and (millimeters)

SP



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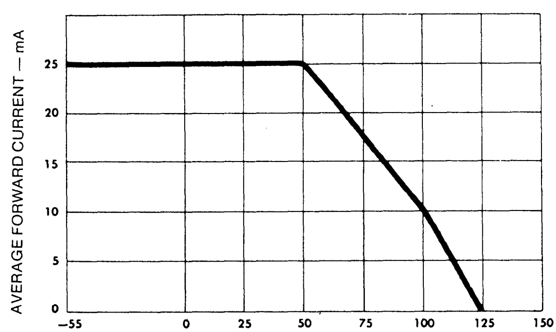
ELECTRICAL SPECIFICATIONS (@ 25° C unless noted)						MAXIMUM RATINGS			Case Length	
Maximum Reverse Recovery Time	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Junction Capacitance @ 100V	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS		
250nS	PIV	I_R		V_F	C_J	I_O		$I_{F(surge)}$		
Type	V	25° C μA	100° C μA	V	pF	50° C mA	100° C mA	A	Ins	MM
VX15	15000	0.1	10	24	1.0	25	10	2	1.50	38.10
VX20	20000	0.1	10	36	1.0	25	10	2	2.00	50.80
VX25	25000	0.1	10	36	1.0	25	10	2	2.00	50.80
VX30	30000	0.1	10	48	1.0	25	10	2	2.50	63.50
VX40	40000	0.1	10	48	1.0	25	10	2	2.50	63.50
VX50	50000	0.1	10	60	1.0	25	10	2	2.50	63.50

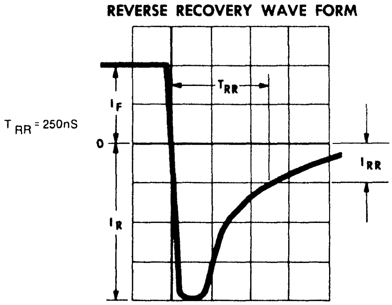
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250° C 3/8" (9.5 mm) from case for 5 seconds.

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE

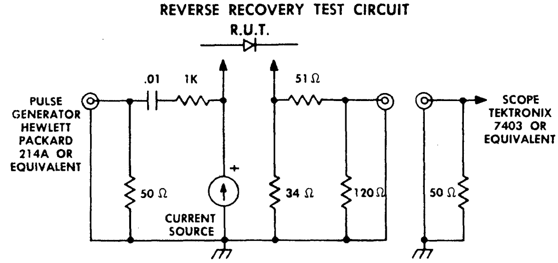


REVERSE RECOVERY TEST CONDITIONS: I_F = 12.5mA, I_R = 25mA, I_{RR} = 6.25mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



HIGH VOLTAGE SILICON RECTIFIERS

MULTISTAC
Standard Recovery

FEATURES
- PIV: From 15kV to 50kV
- 2μS Reverse Recovery
- High Surge Current Ratings
- Low Reverse Leakage
- Corona Free

DESCRIPTION

The VXS MULTISTAC silicon rectifier assemblies meet the stringent reliability requirements of commercial, industrial and military users through the use of proprietary innovations in manufacturing technique. Cylindrical die construction and metallurgical bonds minimize electrical and mechanical stress, contributing to long life. The 2 microsecond reverse recovery time improves the circuit efficiency of power conversion and control systems.

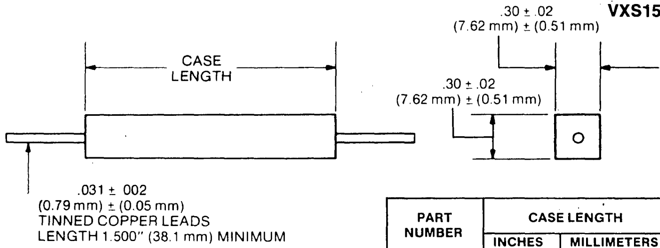
VII

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	15kV to 50kV
Maximum Average Rectified Current	See Electrical Specifications
Maximum One Cycle Surge 8.3mS	See Electrical Specifications
Operating Temperature Range	−55°C to +150°C
Storage Temperature Range	−65°C to +150°C

MECHANICAL SPECIFICATIONS

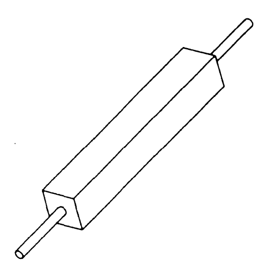
VXS15-50



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
VXS15	1.50 ± .03	38.10 ± 0.76
VXS20, 25	2.00 ± .03	50.80 ± 0.76
VXS30, 40, 50	2.50 ± .03	63.50 ± 0.76

Dimensions in inches and (millimeters)

SP



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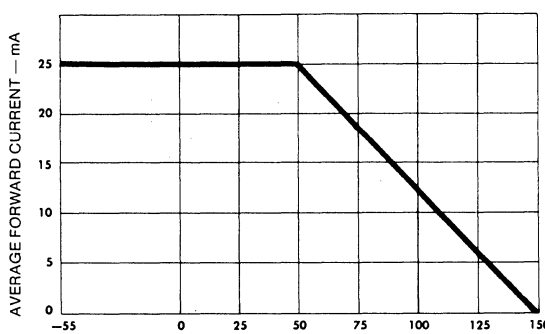
Type	ELECTRICAL SPECIFICATIONS (@ 25° C unless noted)						MAXIMUM RATINGS			Case Length	
	Peak Inverse Voltage*	Maximum Reverse Current @ PIV		Maximum Forward Voltage @ I_O	Maximum Reverse Recovery Time	Maximum Junction Capacitance @ 100 V	Maximum Average Rectified Current†		Maximum One Cycle Surge 8.3mS		
	PIV	I_R		V_F	T_{RR}	C_J	I_O		$I_{F (surge)}$		
		25° C	100° C				50° C	100° C			
	V	μA	μA	V	μS	pF	mA	mA	A	Ins	MM
VXS15	15000	0.1	10	24	2	1	25	12.5	2	1.50	38.10
VXS20	20000	0.1	10	36	2	1	25	12.5	2	2.00	50.80
VXS25	25000	0.1	10	36	2	1	25	12.5	2	2.00	50.80
VXS30	30000	0.1	10	48	2	1	25	12.5	2	2.50	63.50
VXS40	40000	0.1	10	48	2	1	25	12.5	2	2.50	63.50
VXS50	50000	0.1	10	60	2	1	25	12.5	2	2.50	63.50

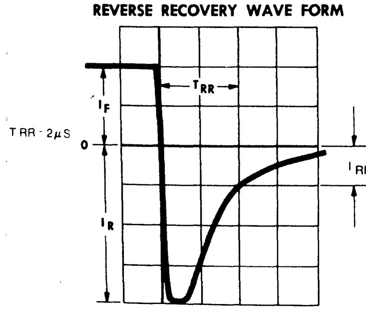
*Operation and testing of devices over 10,000 V/inch may require re-encapsulation or immersion in a suitable dielectric material.
† The stated AVERAGE RECTIFIED CURRENT ratings require no heat sinking, special mounting or forced air across the body of the device.
NOTE: Maximum lead temperature for soldering is 250° C 3/8" (9.5 mm) from case for 5 seconds.

MAXIMUM FORWARD CURRENT VS. AMBIENT TEMPERATURE

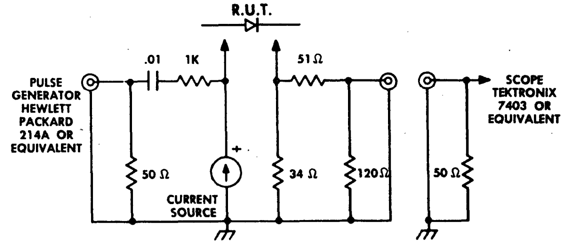


REVERSE RECOVERY TEST CONDITIONS: I_F = 12.5mA, I_R = 25mA, I_{RR} = 6.25mA

REVERSE RECOVERY WAVE FORM



REVERSE RECOVERY TEST CIRCUIT



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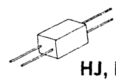
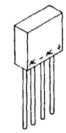
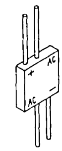
RECTIFIER BRIDGES, DOUBLERS & CENTER-TAPS VIII

RECTIFIER BRIDGES
Single Phase Full-Wave Bridges


HJ, HK, HL, HM,
HN, HO, HP


S


G, GA, GH

STANDARD RECOVERY

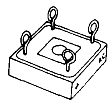
Peak Inverse Voltage Per Leg	AVERAGE D.C. OUTPUT CURRENT					
	≤.25A	.25—.75A	.75—1.5A	1.5—2.5A	4—10A	10—25A
100V			673-1 **G or S**	697-1 **GA**	680-1 **NA**	679-1 **NB** SPA25* **MC**
200V			673-2 **G or S**	697-2 **GA**	680-2 **NA** 469-1** **MD**	679-2 **NB** SPB25* **MC**
300V			673-3 **G or S**	697-3 **GA**	680-3 **NA**	679-3 **NB**
400V			673-4 **G or S**	697-4 **GA**	680-4 **NA** 469-2** **MD**	679-4 **NB** SPC25* **MC**
500V			673-5 **G or S**	697-5 **GA**	680-5 **NA**	679-5 **NB**
600V			673-6 **G or S**	697-6 **GA**	680-6 **NA** 469-3** **MD**	679-6 **NB** SPD25* **MC**
1.2kV		673-7 **GH**				
1.8kV		673-75 **HJ**				
2.4kV		673-8 **HK**				
2.5kV				(PMC101) **PMA**	(PMC201) **PMA**	
3.0kV		673-85 **HL**				
3.6kV	673-9 **HM**					
4.0kV						
4.2kV	673-10 **HN**					
4.8kV	673-11 **HO**					
5.0kV	673-12 **HO**			(PMC102) **PMA**	(PMC202) **PMA**	
7.5kV				(PMC103) **PMA**	(PMC203) **PMA**	
10kV				(PMC104) **PMA**		
15kV				(PMC105) **PMA**		

*Available as JAN
**Available as JAN, JANTX
Parentheses (   ) designates product using stacked chips

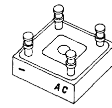
VIII

RECTIFIER BRIDGES
Single Phase Full Wave Bridges

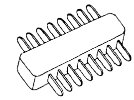
FAST RECOVERY



NA, NB



MA, MB, MC, MD



PMA

Peak Inverse Voltage Per Leg	AVERAGE D.C. OUTPUT CURRENT							
	≤.25A	.25—.75A	.75—1.5A	1.5—2.5A	4—10A	10—25A		25—35A
50V							803-1 **MB**	802-1 **MA**
100V			676-1 **G or S**	698-1 **GA**	684-1 **NA**	683-1 **NB**	803-2 **MB**	802-2 **MA**
125V							803-3 **MB**	802-3 **MA**
150V							803-4 **MB**	802-4 **MA**
200V			676-2 **G or S**	698-2 **GA**	684-2 **NA**	683-2 **NB**		
300V			676-3 **G or S**	698-3 **GA**	684-3 **NA**	683-3 **NB**		
400V			676-4 **G or S**	698-4 **GA**	684-4 **NA**	683-4 **NB**		
500V			676-5 **G or S**	698-5 **GA**	684-5 **NA**	683-5 **NB**		
600V			676-6 **G or S**	698-6 **GA**	684-6 **NA**	683-6 **NB**		
1.2kV		676-12 **HJ**						
1.8kV		676-18 **HK**						
2.4kV		676-24 **HL**						
2.5kV				(PMC101X) **PMA**	(PMC201X) **PMA**			
3.0kV		676-30 **HM**						
3.6kV	676-36 **HN**							
4.0kV								
4.2kV	676-42 **HO**							
4.8kV	676-48 **HP**							
5.0kV	676-50 **HP**			(PMC102X) **PMA**	(PMC202X) **PMA**			
7.5kV				(PMC103X) **PMA**	(PMC203X) **PMA**			
10kV				(PMC104X) **PMA**				
15kV				(PMC105X) **PMA**				
Reverse Recovery Time (max.)	500ns	500ns	500ns	500ns (X)250ns	500ns (X)250ns	500ns	50ns	50ns

Parentheses ( ) designates product using stacked chips

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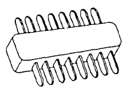
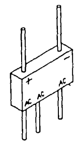
Three Phase Full-Wave Bridge



PMA



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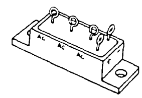
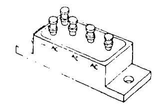


NC



ME

ARD RECOVERY

ak rse ge Leg	AVERAGE D.C. OUTPUT CURRENT			
	1—3A	4.5—15A	15—25A	
V				
0V	700-1 **F**	695-1 **NC**	678-1 **NC**	
5V				
0V				
0V	700-2 **F**	695-2 **NC**	678-2 **NC**	483-1* **ME**
0V	700-3 **F**	695-3 **NC**	678-3 **NC**	
0V	700-4 **F**	695-4 **NC**	678-4 **NC**	483-2* **ME**
0V	700-5 **F**	695-5 **NC**	678-5 **NC**	
0V	700-6 **F**	695-6 **NC**	678-6 **NC**	483-3* **ME**
kV	(PMD101) **PMA**	(PMD201) **PMA**		
kV	(PMD102) **PMA**	(PMD202) **PMA**		
kV	(PMD103) **PMA**			
V	(PMD104) **PMA**			

e as JANTX

ses ( ) designates product using stacked chips

FAST RECOVERY

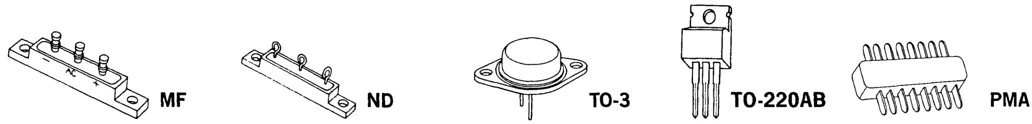
Peak Inverse Voltage Per Leg	AVERAGE D.C. OUTPUT CURRENT				
	1—3A	4.5—15A	15—25A		25—40A
50V				801-1 **ME**	800-1 **ME**
100V	701-1 **F**	696-1 **NC**	682-1 **NC**	801-2 **ME**	800-2 **ME**
125V				801-3 **ME**	800-3 **ME**
150V				801-4 **ME**	800-4 **ME**
200V	701-2 **F**	696-2 **NC**	682-2 **NC**		
300V	701-3 **F**	696-3 **NC**	682-3 **NC**		
400V	701-4 **F**	696-4 **NC**	682-4 **NC**		
500V	701-5 **F**	696-5 **NC**	682-5 **NC**		
600V	701-6 **F**	696-6 **NC**	682-6 **NC**		
2.5kV	(PMD101X) **PMA**	(PMD201X) **PMA**			
3.0kV	(PMD102X) **PMA**	(PMD202X) **PMA**			
4.0kV	(PMD103X) **PMA**				
5.0kV	(PMD104X) **PMA**				
Reverse Recovery Time (max.)	500ns (X)250ns	500ns (X)250ns	500ns	50ns	50ns

Parentheses ( ) designates product using stacked chips

VIII

RECTIFIER BRIDGES

Doublers and Center-Tap Rectifiers



Peak Inverse Voltage Per Leg	SCHOTTKY	STANDARD RECOVERY		FAST RECOVERY		SUPER FAST RECOVERY		ULTRA-FAST RECOVERY		
	AVERAGE D.C. OUTPUT CURRENT									
	30A	0—2A	2—15A	1—2A	2—15A	1—16A	25A	1—16A	20A	30A
20V	USD320C* **TO-3**									
35V	USD335C* **TO-3**									
45V	USD345C* SD241* **TO-3**									
50V						SES5401C* **TO-220AB**	SES5601C* **TO-3**	UES2401* **TO-220AB**	804-1 **MF**	UES2601 **TO-3**
100V			681-1 **ND**		689-1 **ND**	SES5402C* **TO-220AB**	SES5602C* **TO-3**	UES2402* **TO-220AB**	804-2 **MF**	UES2602 **TO-3**
125V									804-3 **MF**	
150V						SES5403C* **TO-220AB**	SES5603C* **TO-3**	UES2403* **TO-220AB**	804-4 **MF**	UES2603 **TO-3**
200V			681-2 **ND**		689-2 **ND**					UES2604 **TO-3**
300V			681-3 **ND**		689-3 **ND**					UES2605 **TO-3**
400V			681-4 **ND**		689-4 **ND**					UES2606 **TO-3**
500V			681-5 **ND**		689-5 **ND**					
600V			681-6 **ND**		689-6 **ND**					
2.5kV		(PMB101) (PMB201) **PMA**		(PMB101X) (PMB201X) **PMA**						
5kV		(PMB102) (PMB202) **PMA**		(PMB102X) (PMB202X) **PMA**						
7.5kV		(PMB103) (PMB203) **PMA**		(PMB103X) (PMB203X) **PMA**						
10kV		(PMB104) (PMB204) **PMA**		(PMB104X) (PMB204X) **PMA**						
15kV		(PMB105) (PMB205) **PMA**		(PMB105X) (PMB205X) **PMA**						
20kV		(PMB106) **PMA**		(PMB106X) **PMA**						
30kV		(PMB107) **PMA**		(PMB107X) **PMA**						
Reverse Recovery Time (max.)				250ns	500ns	100ns	100ns	35ns	50ns	35-50ns

*Center-tap only

Parentheses ( ) designates product using stacked chips

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RECTIFIER ASSEMBLIES

Single Phase Bridges, 10 Amp, Military Approved

JAN & JANTX 469-1
JAN & JANTX 469-2
JAN & JANTX 469-3

FEATURES
- Qualified to MIL-S-19500/469
- Current Rating: to 10A
- PIV: from 200 to 600V
- Surge Ratings: to 100A
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION
This series of military high-current single-phase bridge offer the utmost in reliability as required in military system designs. The TX series is assembled with diodes which have been subjected to 100% screening tests.

VIII

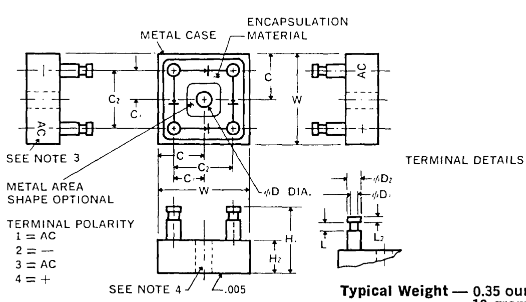
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage .... 200 to 600V
Maximum Average D.C. Output Current
@ $T_C = +55°C$ 10A
@ $T_C = +100°C$ 6A
Non-Repetitive Sinusoidal Surge (8.3ms)
@ $T_C = +55°C$ 100A
Operating and Storage Temperature Range .... —65°C to +150°C
Thermal Resistance Junction to Ambient .... 25°C/W
Junction to Case .... 5°C/W

Ltr	Dimensions INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
C_1	.367	.375	9.32	9.53
C_2	.350	.450	8.89	11.43
C_3	.175	.225	4.45	5.72
ϕD_1	.139	.149	3.53	3.78
ϕD_2	.091	.101	2.31	2.57
ϕD_3	.066	.076	1.68	1.93
H_1		.570		14.48
H_2		.370		9.40
L_1	.088	.098	2.24	2.49
L_2	.020	.030	.51	.76
W	.735	.750	18.67	19.05

MECHANICAL SPECIFICATIONS

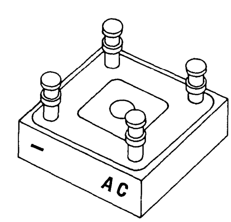
JAN & JANTX 469-1, JAN & JANTX 469-2, JAN & JANTX 469-3



See table above

Typical Weight — 0.35 ounces
10 grams

MD



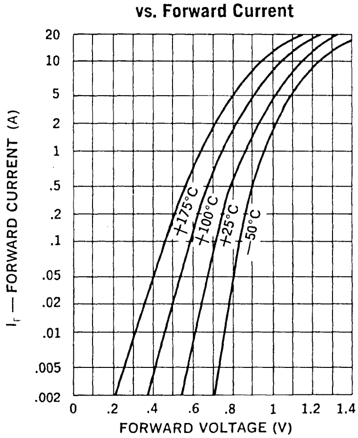
NOTES:
1. Metric equivalents (to the nearest .01 mm) are given for general information only and are based upon 1 inch = 25.4 mm.
2. Terminals shall be tinned.
3. Polarity shall be marked on the bridge body adjacent to terminals. Terminal numbers are for reference and do not have to be marked on the bridge; however, terminal (1) shall be indicated by a mechanical index such as a line, flattened corner, etc., visible from the top (terminal surface) of the device.
4. Point at which T_C is read shall be in metal part of a case as shown on drawing.

Electrical Specification (at 25°C unless noted)

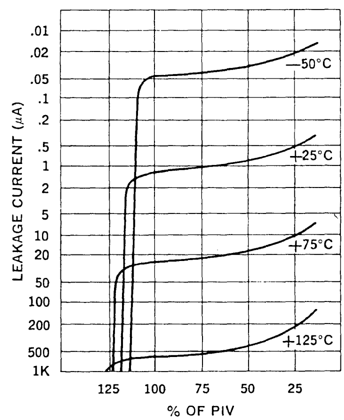
Type	PIV Per Leg	Minimum Reverse Breakdown Voltage Per Leg @ 50μA	Maximum Forward Voltage Drop Per Leg*	Maximum Reverse Recovery Time†	Maximum Leakage Current Per Leg @ PIV	
					$T_C = 25°C$	$T_C = 100°C$
	Volts	Volts		μS	μA	μA
JAN & JANTX 469-1 JAN & JANTX 469-2 JAN & JANTX 469-3	200 400 600	240 460 660	1.35V @ 15.7A(pk)	2	2	125

*Maximum forward voltage drop is measured at a pulse width of 8.3ms.
†Measured in a reverse-recovery circuit switching from 0.5A forward to 1.0A reverse current recovering to 0.25A.

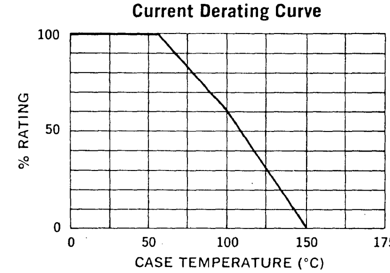
Typical Forward Voltage Per Leg vs. Forward Current

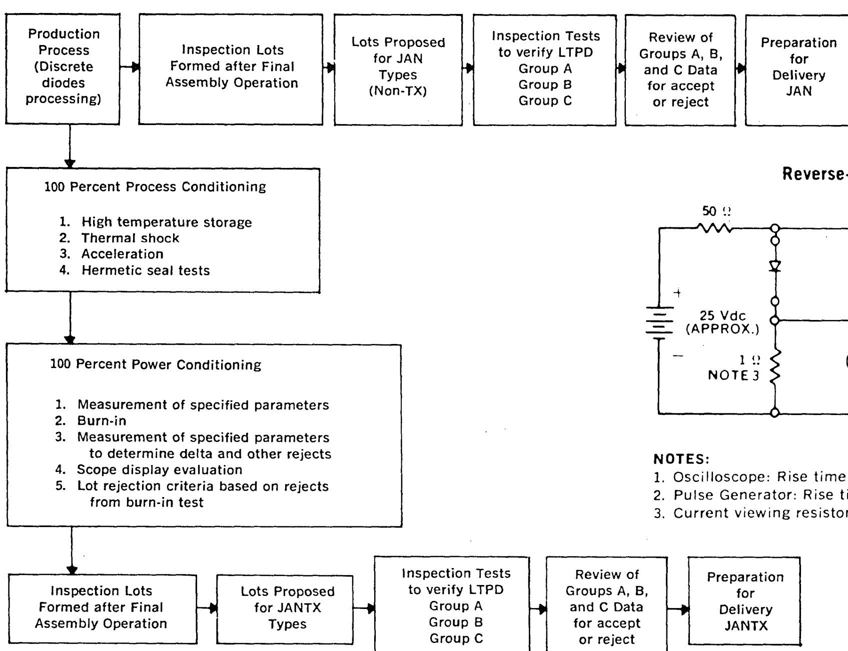


Typical Leakage Current vs. PIV

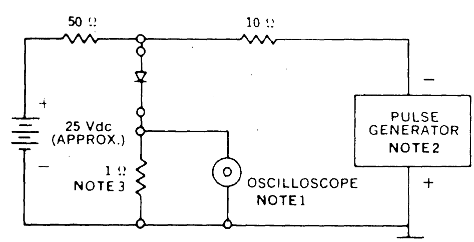


Current Derating Curve





Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

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RECTIFIER ASSEMBLIES

Three Phase Bridges, 25 Amp, Military Approved

JANTX 483-1
JANTX 483-2
JANTX 483-3

FEATURES

- Qualified to MIL-S-19500/483
- Current Rating: 25A
- PIV: from 200 to 600V
- Surge Ratings: 150A
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION

This military high-current three phase bridge series is assembled with diodes which have been subjected to TX type screening tests. This series of bridges offers the utmost in high reliability as normally required in military system design.

ABSOLUTE MAXIMUM RATINGS

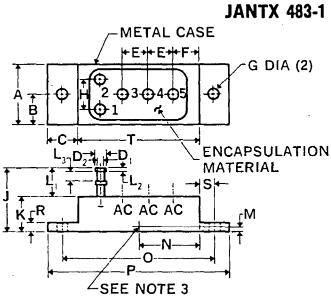
Peak Inverse Voltage	200 to 600V
Maximum Average D.C. Output Current	
@ $T_C = 55°C$	25A
@ $T_C = 100°C$	18.5A
Non-Repetitive Sinusoidal Surge (8.3ms)	
@ $T_C = 55°C$	150A
Operating and Storage Temperature Range	−65°C to +150°C
Thermal Resistance Junction to Ambient	20°C/W
Junction to Case	2.5°C/W

LTR	DIMENSIONS INCH MIN	INCH MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	.730	.770	18.54	19.56
B	.355	.395	9.02	10.03
C	.355	.395	9.02	10.03
D_1	.141	.151	3.58	3.84
D_2	.108	.118	2.74	3.00
E	.355	.395	9.02	10.03
F	.230	.270	5.84	6.86
G	.149	.189	3.78	4.80
H	.355	.395	9.02	10.03
J		.82		20.83
K	.39	.51	9.91	12.95
L_1	.240	.320	6.10	8.13
L_2	.015	.030	.38	.76
L_3	.100	.125	2.54	3.18
M	.040	.060	1.02	1.52
N	.72	.78	18.29	19.81
O	1.84	1.90	46.74	48.26
P	2.22	2.28	56.39	57.91
R	.09	.15	2.29	3.81
S	.168	.208	4.27	5.28
T	1.47	1.53	37.34	38.86

VIII

MECHANICAL SPECIFICATIONS

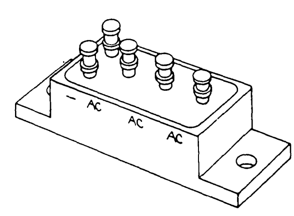
JANTX 483-1 JANTX 483-2 JANTX 483-3



See Table Above

Typical Weight — 1.0 ounces 30 grams

ME



NOTES:
1. Terminals shall be tinned.
2. Polarity shall be marked as shown on drawing.
3. Point at which T_C is read (shall be in metal part of case).

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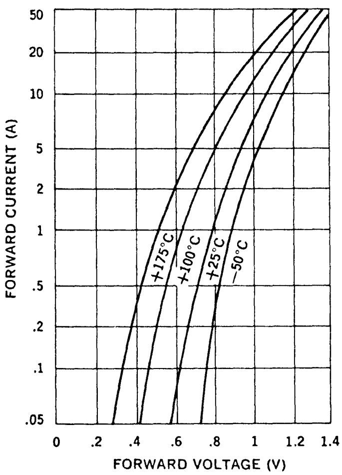
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

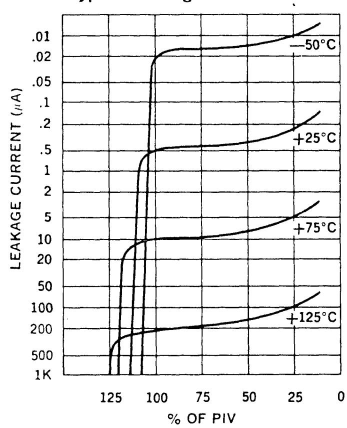
Type	PIV Per Leg	Breakdown Voltage Per Leg @ 50μA	Maximum Forward Voltage Drop Per Leg*	Maximum Leakage Current Per Leg @ PIV	
				$T_C = 25°C$	$T_C = 100°C$
	Volts	Volts		μA	μA
JAN 483-1	200	240	1.3V @ 39A (pk)	2	200
JAN 483-2	400	480			
JAN 483-3	600	660			

* Maximum forward voltage drop is measured at a pulse width of 8.3ms, duty cycle ≤2%.

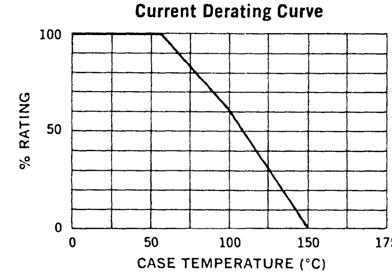
Typical Forward Voltage Per Leg vs. Forward Current

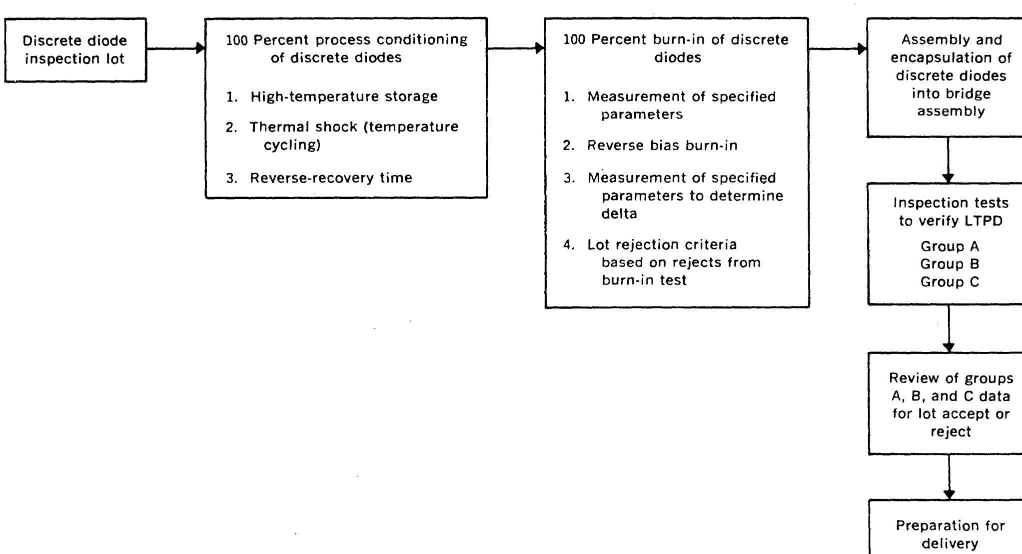


Typical Leakage Current vs. PIV



Current Derating Curve





RECTIFIER ASSEMBLIES

Single Phase Bridges, 1.5Amp, Standard and Fast Recovery

FEATURES
- Miniature Package
- Surge Ratings: to 25A
- PIV's: from 100 to 600V
- Recovery Times: to 500ns
- Controlled Avalanche Characteristics
- Only Fused-in-Glass Diodes Used

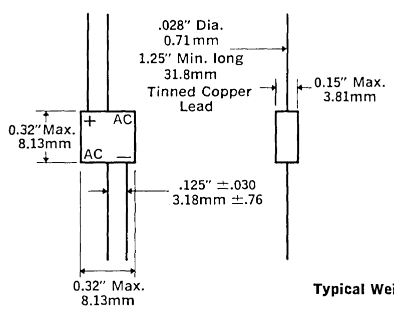
DESCRIPTION
These miniature transfer-molded single-phase power bridges are designed for universal application in power supplies. One basic bridge assembly comes in a choice of lead configurations for mounting in wired chassis or on printed boards.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3mS)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient	50°C/W

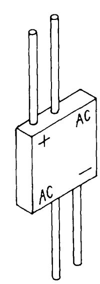
MECHANICAL SPECIFICATIONS

673, 676 SERIES

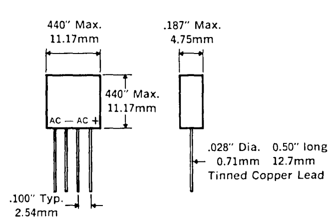


Typical Weight G: 0.05 ounces 1.4 grams

G BODY



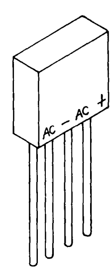
673, 676 SERIES



When specifying S body, add suffix S i.e., 673-1S

Typical Weight S: 0.11 ounces 3.1 grams

S BODY



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

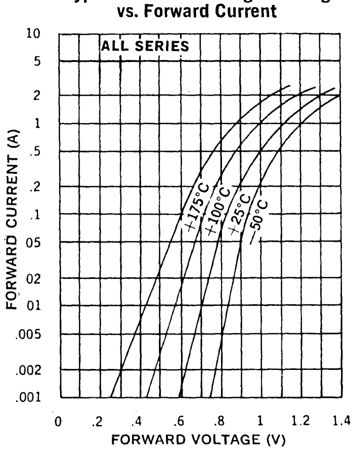
Part number is printed on the body.

UNITRODE

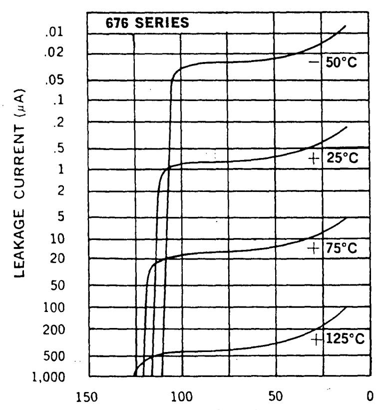
Electrical Specifications (at 25°C unless noted)							Maximum Ratings	
Type		PIV Per Leg	Maximum Forward Drop Per Leg	Leakage Current Per Leg		Maximum Reverse Recovery Time†	Maximum Average D.C. Output Current	Non-Repetitive Sinusoidal Surge (8.3mS)
				$T_A = 25°C$	$T_A = 100°C$		$T_A = 25°C$	
		Volts		μA	μA	ns	Amps	Amps
Standard Recovery	673-1	100	1.1V @ 1.0A	2	100	—	1.5	25
	673-2	200						
	673-3	300						
	673-4	400						
	673-5	500						
	673-6	600						
Fast Recovery	676-1	100	1.1V @ 0.5A	3	150	500	1.0	20
	676-2	200						
	676-3	300						
	676-4	400						
	676-5	500						
	676-6	600						

†Measured in a reverse recovery circuit switching from 10mA forward to 10mA reverse current recovering to 5mA.

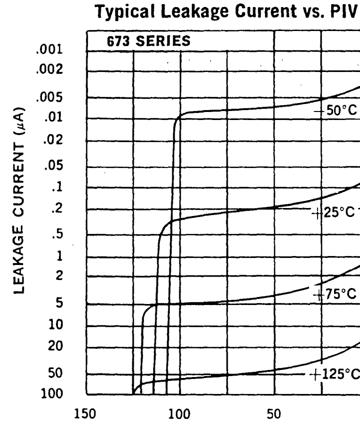
Typical Forward Voltage Per Leg vs. Forward Current



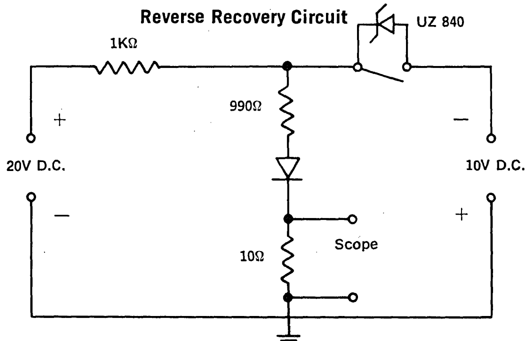
Typical Leakage Current vs. PIV



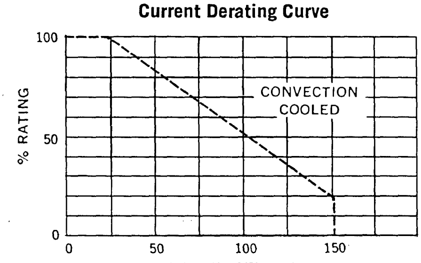
Typical Leakage Current vs. PIV



Reverse Recovery Circuit



Current Derating Curve



RECTIFIER ASSEMBLIES

Single Phase Bridges, High Voltage 0.125-0.6 Amp, Standard and Fast Recovery

673, 676 SERIES
(1200-5000V)

FEATURES

- Miniature High Voltage Bridges
- Continuous Ratings: to 0.6A
- Surge Ratings: to 15A
- PIV's: from 1200 to 5000V
- Recovery Times: to 500ns
- Controlled Avalanche Characteristics
- Only Fused in Glass Diodes Used

DESCRIPTION

These miniature molded high-voltage single phase bridges are designed for universal application in power supplies. The miniature package is shatterproof and is capable of handling extremes in temperature, vibration and shock. These bridges, therefore are ideally suited for miniaturized, tightly packaged equipment operating in extreme environments.

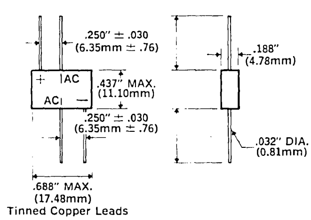
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	1200 to 5000V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	−65°C to +150°C
Thermal Resistance Junction-to-Ambient	50°C/W

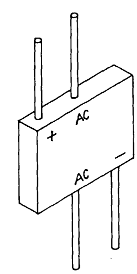
VIII

MECHANICAL SPECIFICATIONS

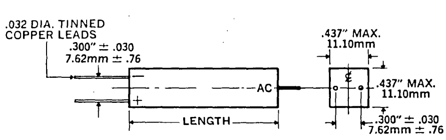
673-7



Body H



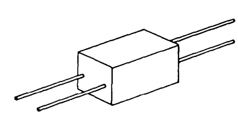
673, 676 SERIES



MAX. LENGTHS

J	K	L	M	N	O	P
.562" 14.27mm	.688" 17.48mm	.875" 22.23mm	1.125" 28.58mm	1.25" 31.75mm	1.375" 34.92mm	1.625" 41.28mm

BODY J through P



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative Output	—

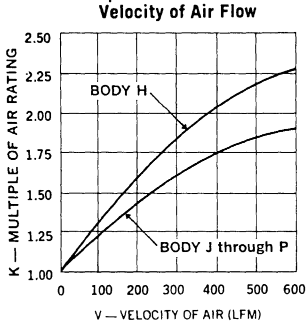
Part number is printed on the body.

UNITRODE

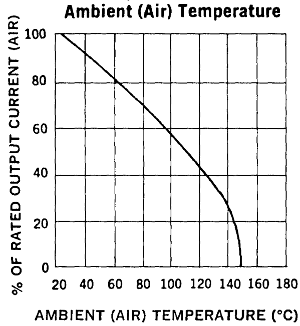
Type		Electrical Specifications at 25°C						Maximum Ratings		
		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time*	Body Size	Maximum Average D.C. Output Current		Non-repetitive Sinusoidal Surge (8.3ms)
				$T_A = 25°C$	$T_A = 100°C$			$T_A = 25°C$ Air	$T_A = 50°C$ Oil	
		Volts		μA	μA	ns		Amps	Amps	Amps
Standard Recovery	673-7	1200	2.2V @ 0.4A	2	100		H	0.6	1.5	15
	673-75	1800	3.3V @ 0.4A				J	0.5	1.25	
	673-8	2400	4.4V @ 0.4A				K	0.4	1.0	
	673-85	3000	5.5V @ 0.3A				L	0.3	0.75	
	673-9	3600	6.6V @ 0.2A				M	0.2	0.5	
	673-10	4200	7.7V @ 0.2A				N	0.18	0.45	
	673-11	4800	8.8V @ 0.15A				O	0.16	0.4	
	673-12	5000	9.0V @ 0.15A				O	0.16	0.4	
Fast Recovery	676-12	1200	3.3V @ 0.3A	5	150	500	J	0.4	1.0	10
	676-18	1800	4.4V @ 0.2A				K	0.35	0.85	
	676-24	2400	5.5V @ 0.2A				L	0.325	0.8	
	676-30	3000	7.7V @ 0.2A				M	0.25	0.625	
	676-36	3600	8.8V @ 0.15A				N	0.175	0.425	
	676-42	4200	9.9V @ 0.15A				O	0.15	0.375	
	676-48	4800	11V @ 0.15A				P	0.135	0.325	
	676-50	5000	11V @ 0.15A				P	0.125	0.3	

†Measured in a reverse recovery circuit switching from 10mA forward to 10mA reverse current recovering to 5mA.

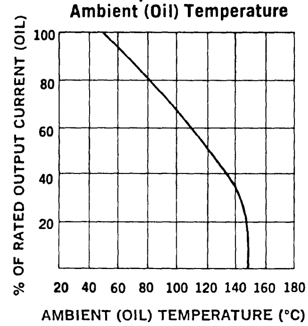
Output Current Ratio vs Velocity of Air Flow



Output Current vs Ambient (Air) Temperature

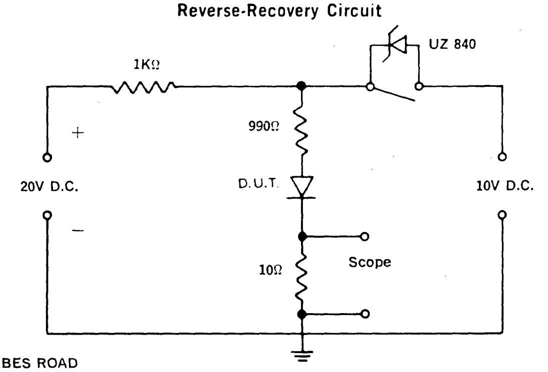


Output Current vs Ambient (Oil) Temperature



Application example: The rectifier is to be used in a cabinet at 60°C with ambient air moving at 400 LFM. The rating is reduced (Fig. 2) by a factor of 0.81 due to the elevated temperature, but is enhanced by 2.X (Fig. 1) due to the air flow. Hence the DC output current is 0.81 x 2, or 1.6 times the 25°C air rating.

Reverse-Recovery Circuit



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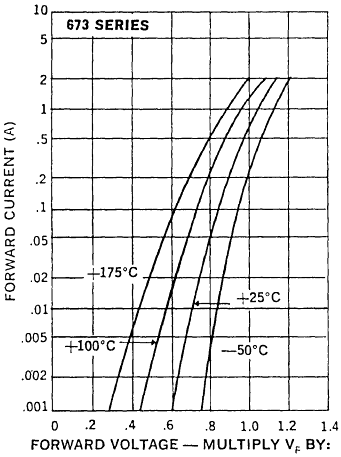
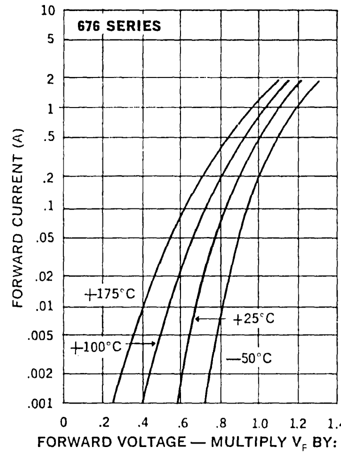
Typical Forward Voltage vs Forward Current

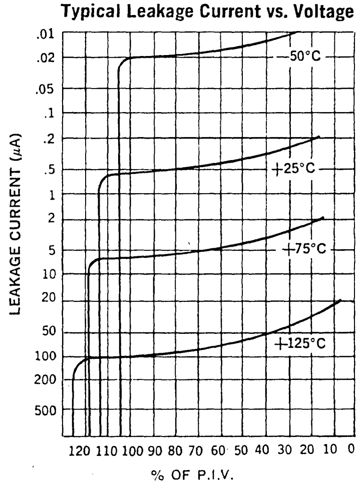


Typical Forward Voltage vs Forward Current



VIII

Typical Leakage Current vs. Voltage



RECTIFIER ASSEMBLIES

Three Phase Bridges, 15-25 Amp, Standard and Fast Recovery Magnum®

678, 682, 695 696 SERIES

FEATURES
- Current Rating: to 25A
- PIVs: from 100 to 600V
- Only Fused-in-Glass Diodes Used
- Recovery Times: to 500ns
- Controlled Avalanche Characteristics
- Surge Ratings: to 150A
- Aluminum Heat Sink Case, Electrically Insulated

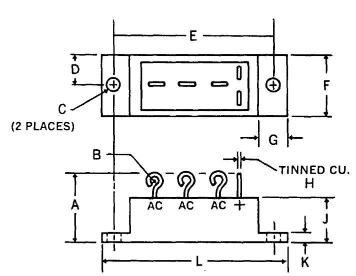
DESCRIPTION
This series of three phase MAGNUM® bridges offer the ultimate in high current power supply applications. The fast recovery series allows operation at full power at high frequencies (up to 40KHz squarewave), often used in choppers, inverters and converters in aircraft, missiles, etc., equipment.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient, All Series	20°C/W
Junction to Case, 678, 682 Series	1.5°C/W
Junction to Case, 695, 696 Series	3.0°C/W

MECHANICAL SPECIFICATIONS

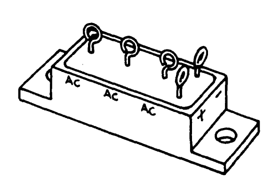
678, 682, 695, 696 SERIES



	ins.	mm.
A	.820 MAX.	20.83 MAX.
B	.09 DIA. TYP.	2.29 DIA. TYP.
C	.164-.174 DIA.	4.17-4.42 DIA.
D	.365-.385	9.27-9.78
E	1.870-1.880	47.50-47.75
F	.740-.760	18.80-19.30
G	.370-.390	9.40-9.91
H	.040 TYP.	1.02 TYP
J	.486-.506	12.34-12.85
K	.115-.135	2.92-3.43
L	2.240-2.260	56.90-57.40

Typical Weight — 30 grams

NC



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

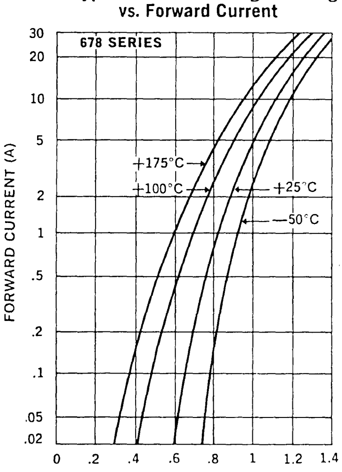
Part number is printed on the body.

UNITRODE

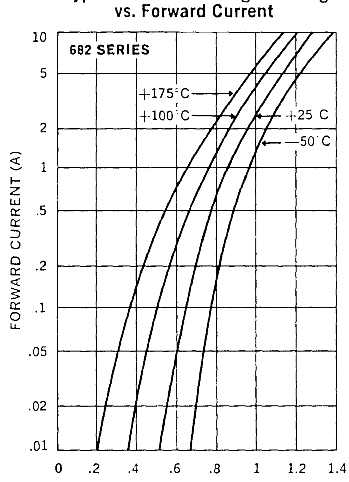
Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time*	Maximum Average D.C. Output Current		Non-Repetitive Sinusoidal Surge (8.3ms)
				$T_A = 25°C$	$T_A = 100°C$		$T_C = 55°C$	$T_C = 100°C$	$T_A = 100°C$
		Volts		µA	µA	ns	Amps	Amps	Amps
Standard Recovery	678-1	100	1.2V @ 10A	10	200	—	25	18.5	150
	678-2	200							
	678-3	300							
	678-4	400							
	678-5	500							
	678-6	600							
Standard Recovery	695-1	100	1.2V @ 2A	5	150	—	15	9	80
	695-2	200							
	695-3	300							
	695-4	400							
	695-5	500							
	695-6	600							
Fast Recovery	682-1	100	1.2V @ 6A	10	200	500	20	14	150
	682-2	200							
	682-3	300							
	682-4	400							
	682-5	500							
	682-6	600							
Fast Recovery	696-1	100	1.2V @ 2A	5	150	500	15	9	60
	696-2	200							
	696-3	300							
	696-4	400							
	696-5	500							
	696-6	600							

*Measured in a reverse recovery circuit switching from 1.0A forward to 1.0A reverse current recovering to 0.5A.

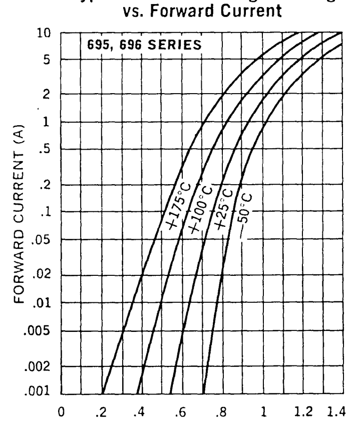
Typical Forward Voltage Per Leg vs. Forward Current



Typical Forward Voltage Per Leg vs. Forward Current



Typical Forward Voltage Per Leg vs. Forward Current



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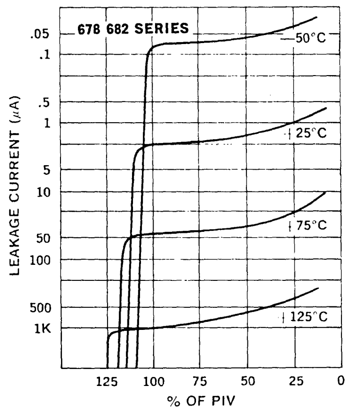
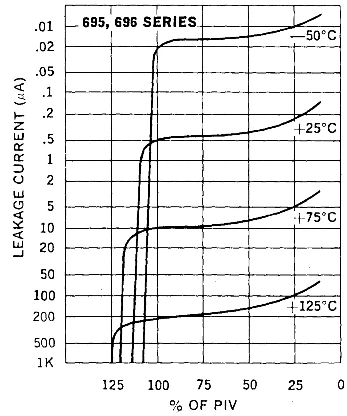
VIII

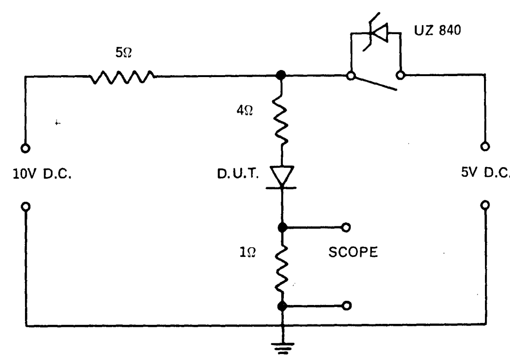
Typical Leakage Current vs. PIV



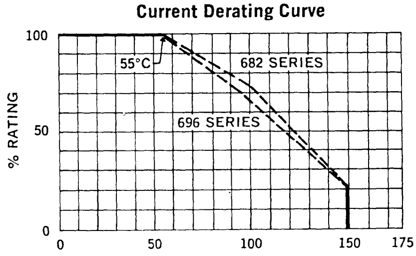
Typical Leakage Current vs. PIV



Reverse Recovery Circuit

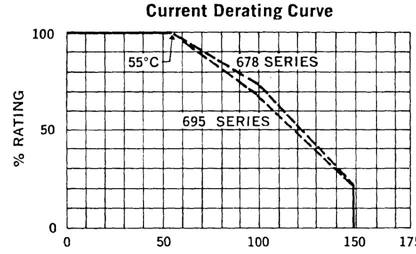


Current Derating Curve



Fast Recovery Series

Current Derating Curve



Standard Recovery Series

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RECTIFIER ASSEMBLIES

679, 680, 683, 684 SERIES

Single Phase Bridges, 10-25 Amp, Standard and Fast Recovery Magnum™

FEATURES
- Current Ratings: to 25A
- Recovery Time: to 500ns
- PIVs: from 100 to 600V
- Surge Ratings: to 150A
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION
This series of single phase MAGNUM™ bridge offers the designer the ultimate in high current power supply applications. The fast recovery series allows operation at full power at high frequencies, up to 40kHz square wave, which is often used in chopper, inverters and converters in aircraft, missiles, etc., equipment.

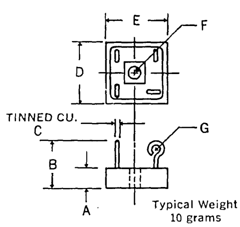
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient, 679, 683 Series	20°C/W
Junction to Ambient, 680, 684 Series	25°C/W
Junction to Case, 679, 683 Series	2.0°C/W
Junction to Case, 680, 684 Series	4.0°C/W

VIII

MECHANICAL SPECIFICATIONS

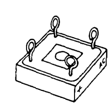
680, 684 SERIES



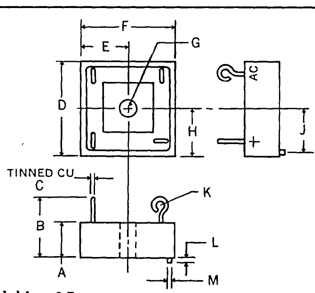
	ins.	mm.
A	.240 MAX.	6.10 MAX.
B	.57 MAX.	14.45 MAX.
C	.040 TYP.	1.02 TYP.
D	.750 MAX.	19.05 MAX.
E	.750 MAX.	19.05 MAX.
F	.140 DIA.	3.56 DIA.
G	.09 DIA. TYP.	2.29 DIA. TYP.

Typical Weight — 0.35 ounces
10 grams

NA



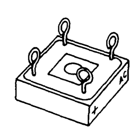
679, 683 SERIES



	ins.	mm.
A	.328 MAX.	8.33 MAX.
B	.750 MAX.	19.05 MAX.
C	.040 TYP.	1.02 TYP.
D	1.125 MAX.	28.58 MAX.
E	.562	14.27
F	1.125 MAX.	28.58 MAX.
G	.193	4.90
H	.562	14.27
J	.500	12.70
K	.09 DIA. TYP.	2.29 DIA. TYP.
L	.062	1.57
M	.062	1.57

Typical Weight — 0.7 ounces
20 grams

NB



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

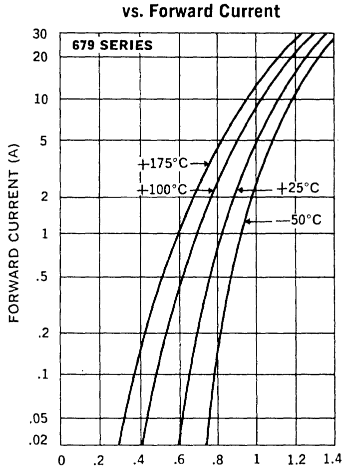
Part number is printed on the body.

UNITRODE

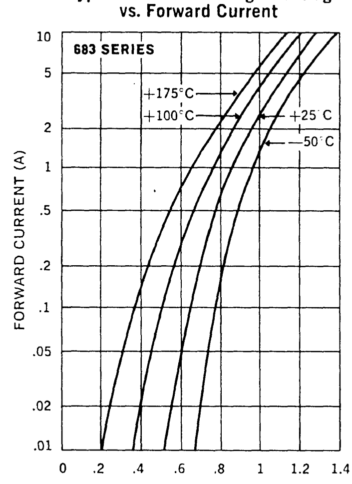
Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time*	Maximum Average D.C. Output Current		Non-Repetitive Sinusoidal Surge (8.3ms)
Electrical Specifications (at 25°C unless noted)							Maximum Ratings		
				$T_A = 25°C$	$T_A = 100°C$		$T_C = 55°C$	$T_C = 100°C$	$T_A = 100°C$
		Volts		μA	μA	ns	Amps	Amps	Amps
Standard Recovery	679-1	100	1.2V @ 10A	10	200	—	25	18.5	150
	679-2	200							
	679-3	300							
	679-4	400							
	679-5	500							
	679-6	600							
Standard Recovery	680-1	100	1.2V @ 2A	2	50	—	10	6	50
	680-2	200							
	680-3	300							
	680-4	400							
	680-5	500							
	680-6	600							
Fast Recovery	683-1	100	1.2V @ 6A	10	200	500	20	14	150
	683-2	200							
	683-3	300							
	683-4	400							
	683-5	500							
	683-6	600							
Fast Recovery	684-1	100	1.2V @ 2A	5	100	500	10	6	50
	684-2	200							
	684-3	300							
	684-4	400							
	684-5	500							
	684-6	600							

*Measured in a reverse recovery circuit switching from 1.0A forward to 1.0A reverse current recovering to 0.5A.

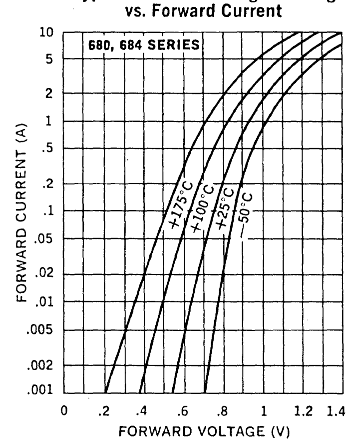
Typical Forward Voltage Per Leg vs. Forward Current



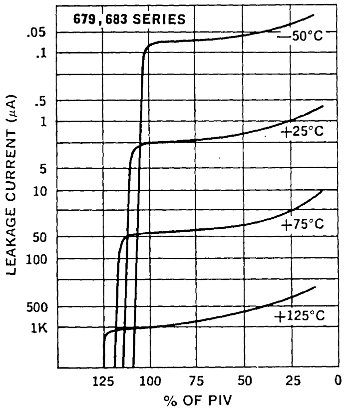
Typical Forward Voltage Per Leg vs. Forward Current



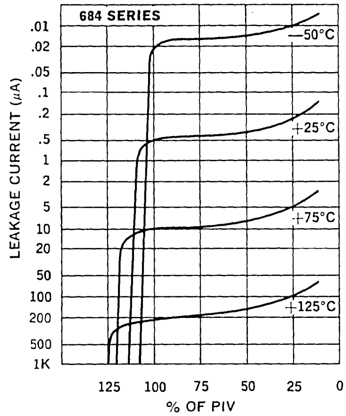
Typical Forward Voltage Per Leg vs. Forward Current



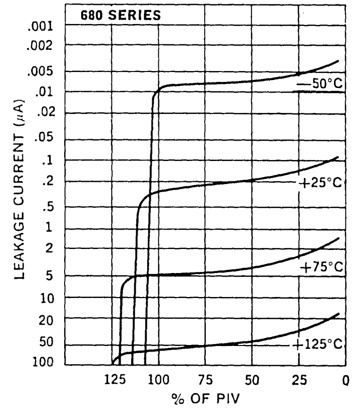
Typical Leakage Current vs. PIV



Typical Leakage Current vs. PIV

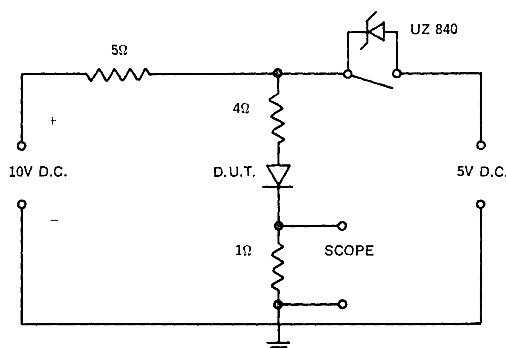


Typical Leakage Current vs. PIV

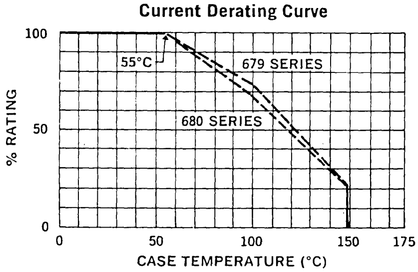


VIII

Reverse Recovery Circuit

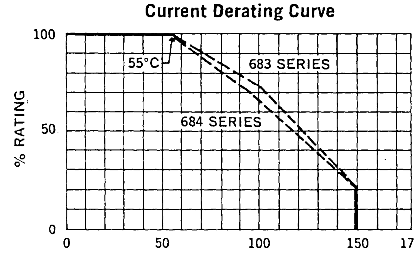


Current Derating Curve



Standard Recovery Series

Current Derating Curve



Fast Recovery Series

RECTIFIER ASSEMBLIES

Doubler and Center Tap, 15 Amp, Standard and Fast Recovery, Magnum®

FEATURES

- Current Ratings: to 15A
- Aluminum Heat Sink Case, Electrically Insulated
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- PIV: 100 to 600V
- Surge Ratings: to 150A

DESCRIPTION

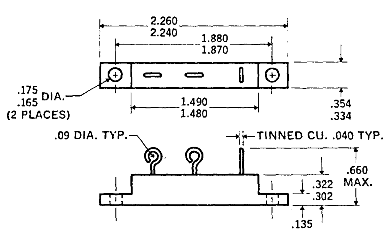
This series of MAGNUM® doublers and center tap rectifiers offers high current and high thermal conductivity needed in high current power supply applications. The MAGNUM® package is virtually indestructable and lends its use to high environmental stresses, as seen in aircraft, missile and satellite equipment.

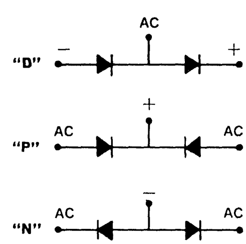
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltages	100 to 600V
Maximum Average D.C. Output Current	
@ $T_C = +55°C$	15A
@ $T_C = +100°C$	10A
Non-Repetitive Sinusoidal Surge (8.3ms)	
@ $T_A = +100°C$	150A
Operating and Storage Temperature Range	−65°C to +150°C
Thermal Resistance Junction to Ambient	20°C/W
Junction to Case	6.0°C/W

MECHANICAL SPECIFICATIONS

681, 689 SERIES

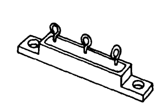




Orientation of terminals shown for "D". For "P" or "N" center terminal is at 90° from the AC terminals.

Typical Weight — 0.35 ounces 10 grams

ND



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

Part number is printed on the body.

† Add suffix P, N, or D for terminal configuration P, N, or D. For example, for center tap configuration, P, order 681-IP.

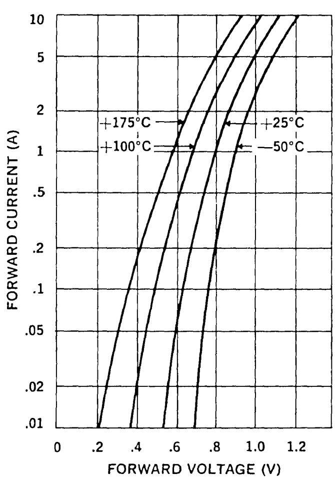
UNITRODE

Electrical Specifications (at 25°C unless noted)

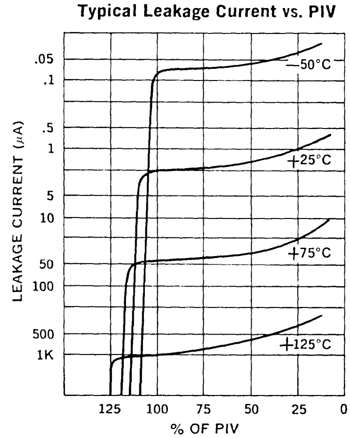
Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Reverse Recovery Time*	Maximum Leakage Current Per Leg @ PIV	
					$T_A = 25°C$	$T_A = 100°C$
		Volts		nS	μA	μA
Standard Recovery	681-1	100				
	681-2	200				
	681-3	300	1.2V @ 10A		10	200
	681-4	400				
	681-5	500				
	681-6	600				
Fast Recovery	689-1	100				
	689-2	200				
	689-3	300	1.2V @ 10A	500	10	200
	689-4	400				
	689-5	500				
	689-6	600				

*Measured in a reverse recovery circuit from 1A forward to 1A reverse current recovery to 0.5A.

Typical Forward Voltage Per Leg vs. Forward Current

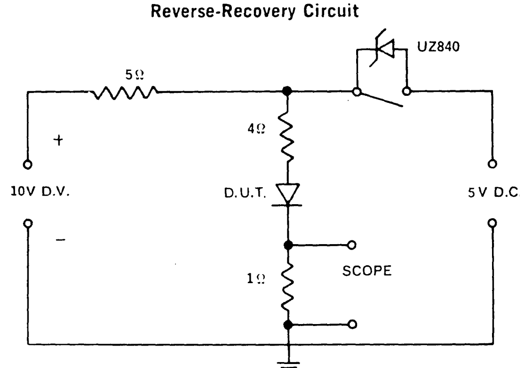


Typical Leakage Current vs. PIV

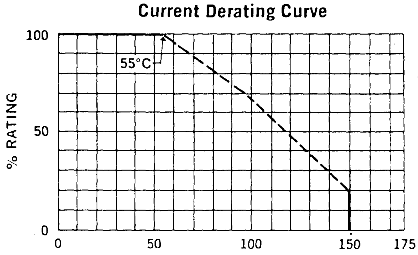


VIII

Reverse-Recovery Circuit



Current Derating Curve



RECTIFIER ASSEMBLIES

Single Phase Bridges, 7.5 Amp, Standard and Fast Recovery

FEATURES
- Miniature High Current Assemblies
- Continuous Ratings: to 7.5A
- Surge Ratings: to 80A
- PIV's: from 100V to 600V
- Recovery Times: to 500ns
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics

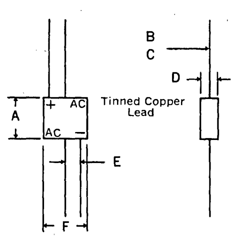
DESCRIPTION
These miniature molded high-current single-phase bridges are designed for universal application in power supplies. One basic bridge fills current requirements up to 7.5A, with PIV's from 100 to 600 volts and recovery times of standard, and 500ns max.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient	32°C/W
Junction to Case	10°C/W

MECHANICAL SPECIFICATIONS

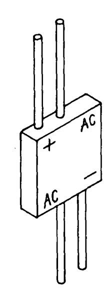
697, 698 SERIES



	ins.	mm.
A	0.50±.01	12.70±.25
B	.032 DIA.	0.81 DIA.
C	1.0 MIN.	25.4 MIN.
D	.250 MAX.	6.35 MAX.
E	.150 TYP.	3.81 TYP.
F	0.50±.01	12.70±.25

Typical Weight — 0.14 ounces
4.0 grams

GA



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

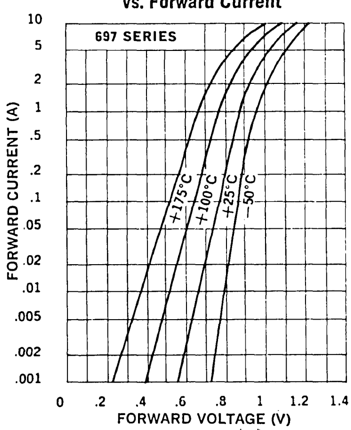
Part number is printed on the body.

UNITRODE

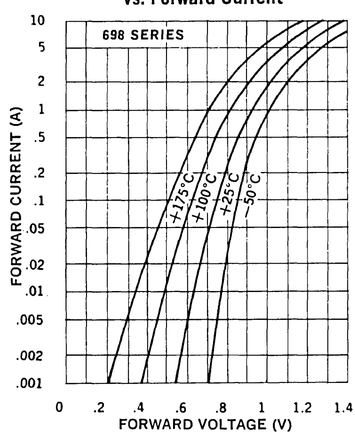
Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time†	Maximum Average D.C. Output Current		Non-Repetitive Sinusoidal Surge (8.3ms)
Electrical Specifications (at 25°C unless noted)							**Maximum Ratings**		
				$T_A = 25°C$	$T_A = 100°C$		$T_A = 25°C$	$T_C = 55°C$	
		Volts		μA	μA	ns	Amps	Amps	Amps
Standard Recovery	697-1	100	1.0V @ 2A	5	200		2.5	7.5	80
	697-2	200							
	697-3	300							
	697-4	400							
	697-5	500							
	697-6	600							
Fast Recovery	698-1	100	1.1V @ 2A	5	200	500	2.25	7.0	70
	698-2	200							
	698-3	300							
	698-4	400							
	698-5	500							
	698-6	600							

†Measured in a reverse recovery circuit switching from 1A forward to 1A reverse current recovering to .5A.

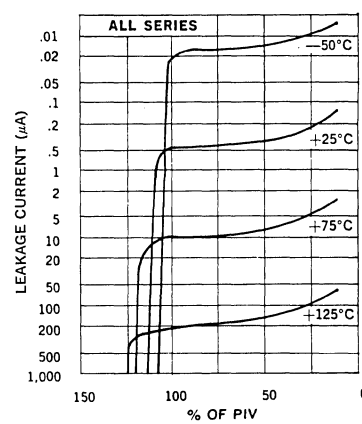
Typical Forward Voltage Per Leg vs. Forward Current



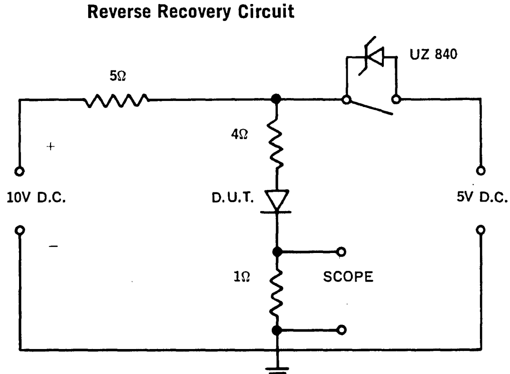
Typical Forward Voltage Per Leg vs. Forward Current



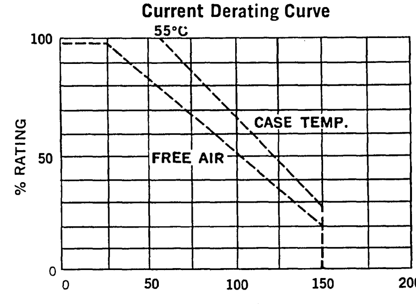
Typical Leakage Current vs. PIV



Reverse Recovery Circuit



Current Derating Curve



VIII

RECTIFIER ASSEMBLIES

Three Phase Bridges, 2.5 Amp, Standard and Fast Recovery

FEATURES
- Miniature Package
- Recovery Time: to 500ns
- Surge Ratings: to 25A
- PIV: from 100 to 600V
- Controlled Avalanche Characteristics
- Only Fused-in-Glass Diodes Used

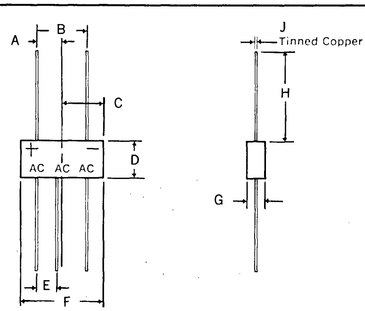
DESCRIPTION
These miniature transfer-molded high-voltage three-phase power bridges are designed for universal application in power supplies. One basic bridge fills current requirements up to 2.5A, with PIV's from 100 to 600 volts and recovery times of standard and 500ns.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction-to-Ambient	25°C/W

MECHANICAL SPECIFICATIONS

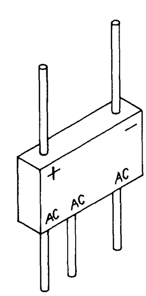
700, 701 SERIES



	ins.	mm.
A	.310	7.87
B	.621	15.77
C	.512 REF.	13.0 REF.
D	.460 MAX.	11.68 MAX.
E	.255	6.48
F	1.030 MAX.	26.16 MAX.
G	.220 MAX.	5.59 MAX.
H	.875	22.23
J	.028 DIA.	0.71 DIA.

Typical Weight — 0.12 ounces
3.5 grams

F



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

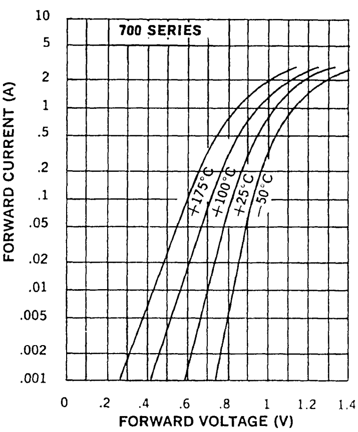
Part number is printed on the body.

UNITRODE

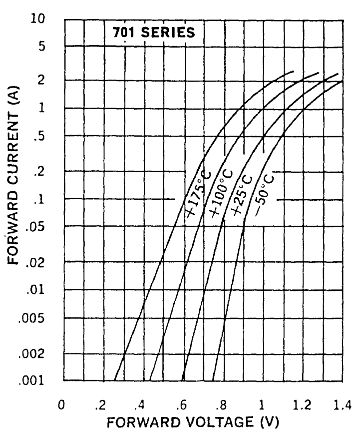
Type		Electrical Specifications (at 25°C unless noted)					Maximum Ratings	
		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time†	Maximum Average D.C. Output Current	Non-Repetitive Sinusoidal Surge (8.3ms)
				$T_A = 25°C$	$T_A = 100°C$		$T_A = 55°C$	
		Volts		μA	μA	ns	Amps	Amps
Standard Recovery	700-1 700-2 700-3 700-4 700-5 700-6	100 200 300 400 500 600	1.0V @ 0.5A	2	100		2.5	25
Fast Recovery	701-1 701-2 701-3 701-4 701-5 701-6	100 200 300 400 500 600	1.1V @ 0.5A	2	100	500	2.25	20

†Measured in a reverse recovery circuit switching from 10mA forward to 10mA reverse current recovering to 5mA.

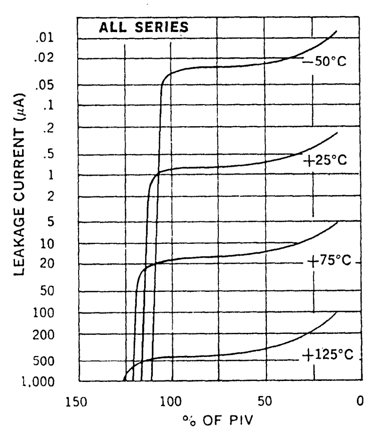
Typical Forward Voltage Per Leg vs. Forward Current



Typical Forward Voltage Per Leg vs. Forward Current

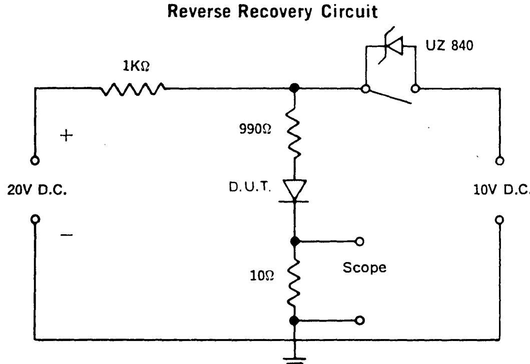


Typical Leakage Current vs. PIV

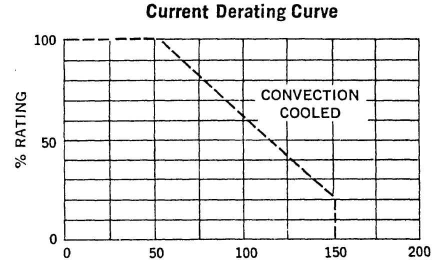


VIII

Reverse Recovery Circuit



Current Derating Curve



RECTIFIER ASSEMBLIES

Three Phase Bridges, 20-40 Amp, High Efficiency, ESP

FEATURES

- Current Ratings: to 40A
- Recovery Time: 50ns
- Surge Ratings: to 250A
- PIVs: from 50 to 150V
- Only Fused-in-Glass Diodes Used
- Exceptionally High Efficiency
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION

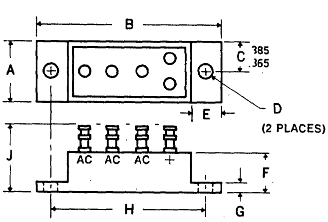
This series of three phase bridges offers the highest efficiency possible for applications where nothing else will do. The series allows operation at full power at high frequencies.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltages	50 to 150V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient, All Series	20°C/W
Junction to Case, 800 Series	2.5°C/W
Junction to Case, 801 Series	3.0°C/W

MECHANICAL SPECIFICATIONS

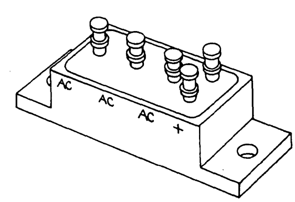
800, 801 SERIES



	ins.	mm.
A	.740-.760	18.80-19.30
B	2.240-2.260	56.90-57.40
C	.365-.385	9.27-9.78
D	.164-.174 DIA.	4.17-4.42 DIA.
E	.370-.390	9.40-9.91
F	.486-.506	12.34-12.85
G	.115-.135	2.92-3.43
H	1.870-1.880	47.50-47.75
J	.820 MAX.	20.83 MAX.

Typical Weight — 1.0 ounce
30 grams

ME



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

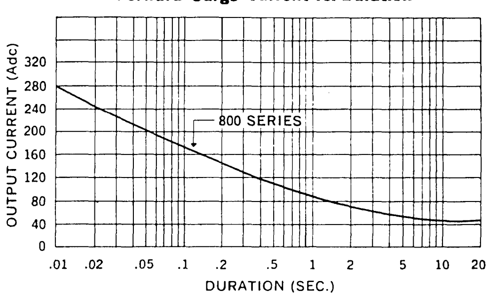
Part number is printed on the body.

UNITRODE

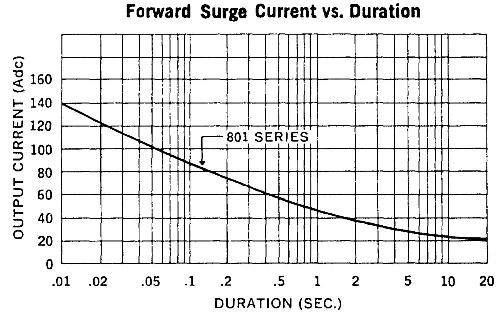
Type		Electrical Specifications (at 25°C unless noted) PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Reverse Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time*	Maximum Ratings: Maximum Average D.C. Output Current		Non-Repetitive Sinusoidal Surge (8.3ms)
				$T_A = 25°C$	$T_A = 100°C$		$T_C = 55°C$	$T_C = 100°C$	$T_A = 100°C$
		Volts		μA	μA	ns	Amps	Amps	Amps
ESP Recovery	800-1	50	.95V @ 10A	20	1000	50	40	25	250
	800-2	100							
	800-3	125							
	800-4	150							
ESP Recovery	801-1	50	.95V @ 6A	10	300	50	20	16	125
	801-2	100							
	801-3	125							
	801-4	150							

*Measured in a reverse recovery circuit switching from 1A forward to 1A reverse current recovering to 0.5A.

Forward Surge Current vs. Duration

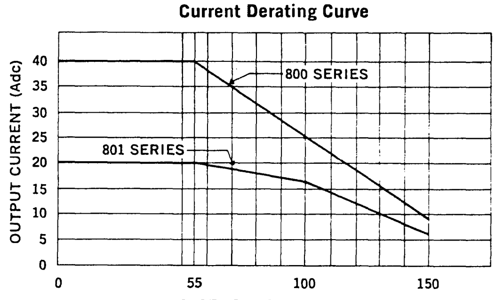


Forward Surge Current vs. Duration

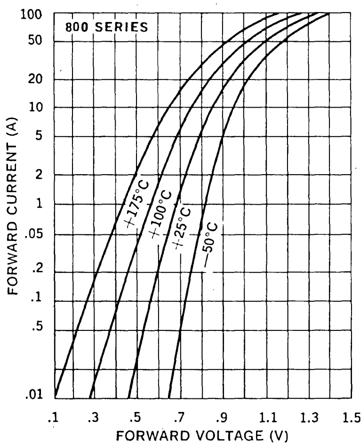


VIII

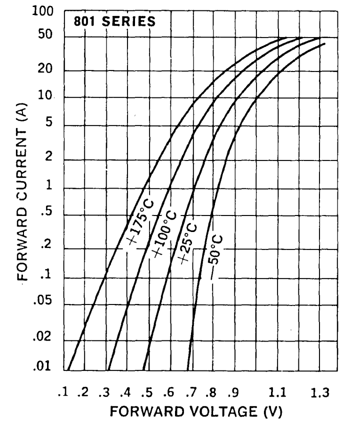
Current Derating Curve



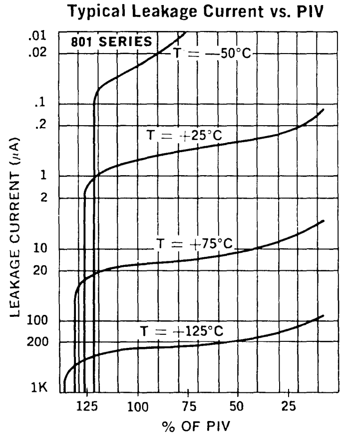
Typical Forward Voltage Per Leg vs. Forward Current



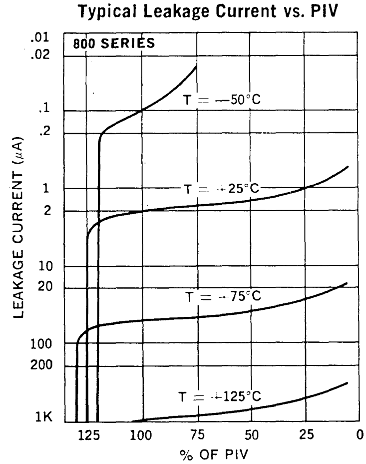
Typical Forward Voltage Per Leg vs. Forward Current



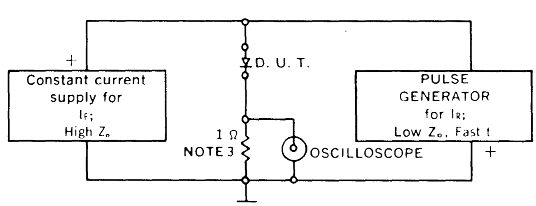
Typical Leakage Current vs. PIV



Typical Leakage Current vs. PIV

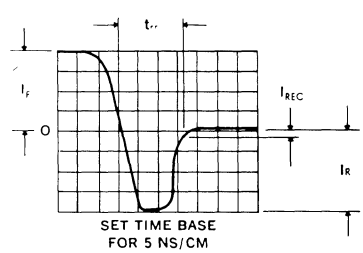


Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Characteristic Waveform



RECTIFIER ASSEMBLIES

802, 803 SERIES

Single Phase Bridges, 20-35 Amp, High Efficiency ESP Series

FEATURES

- Current Ratings: to 35A
- Recovery Time: 50ns
- Surge Ratings: to 250A
- PIVs: from 50 to 150V
- Only Fused-in-Glass Diodes Used
- Exceptional High Efficiency
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION

This series of single phase bridges offer the highest efficiency possible for applications where nothing else will do. The series allow operation at full power at very high frequency.

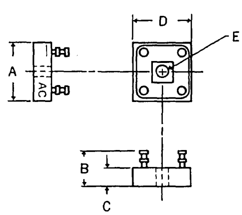
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	50 to 150V
Maximum Average D.C. Output Current	See Electrical Specifications
Non-Repetitive Sinusoidal Surge (8.3ms)	See Electrical Specifications
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient, 802 Series	20°C/W
803 Series	25°C/W
Junction to Case, 802 Series	2.0°C/W
803 Series	4.0°C/W

VIII

MECHANICAL SPECIFICATIONS

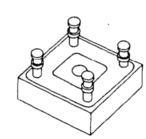
803 SERIES



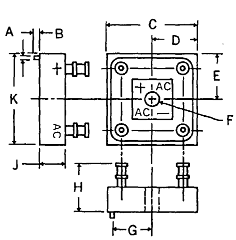
	ins.	mm.
A	.735-.755	18.67-19.18
B	.570 MAX.	14.48 MAX.
C	.226-.246	5.74-6.25
D	.735-.755	18.67-19.18
E	.130-.150 DIA.	3.30-3.81

Typical Weight — 0.35 ounces
10 grams

MB



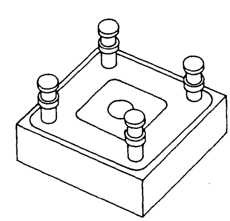
802 SERIES



	ins.	mm.
A	.056-.066	1.42-1.68
B	.052-.072	1.32-1.83
C	1.115-1.135	28.32-28.83
D	.552-.572	14.02-14.53
E	.552-.572	14.02-14.53
F	.180-.200 DIA.	4.57-5.08 DIA.
G	.490-.510	12.45-12.95
H	.750 MAX.	19.05 MAX.
J	.302-.322	7.67-8.18
K	1.115-1.135	28.32-28.83

Typical Weight — 0.70 ounces
20 grams

MA

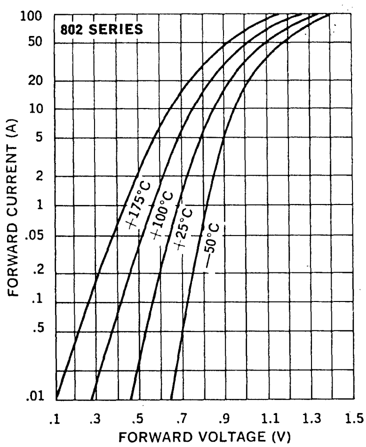


Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Reverse Leakage Current Per Leg @ PIV		Maximum Reverse Recovery Time*	Maximum Average D.C. Output Current		Non-Repetitive Sinusoidal Surge (8.3ms)
				$T_A = 25°C$	$T_A = 100°C$		$T_C = 55°C$	$T_C = 100°C$	$T_A = 100°C$
		Volts		μA	μA	ns	Amps	Amps	Amps
ESP Recovery	802-1	50	.95V @ 10A	20	1000	50	35	22.5	250
	802-2	100							
	802-3	125							
	802-4	150							
ESP Recovery	803-1	50	.95V @ 6A	10	300	50	20	16	125
	803-2	100							
	803-3	125							
	803-4	150							

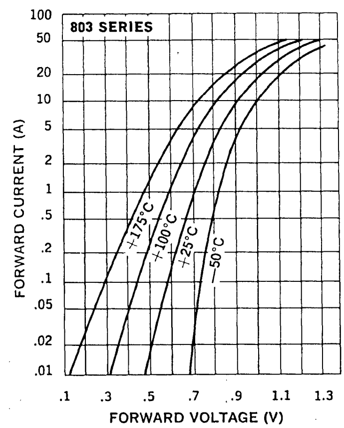
Electrical Specifications (at 25°C unless noted) / Maximum Ratings

*Measured in a reverse recovery circuit switching from 1A forward to 1A reverse current recovering to 0.5A.

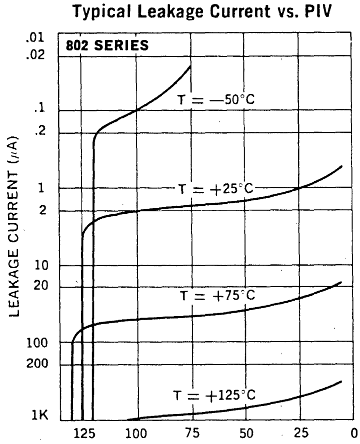
Typical Forward Voltage Per Leg vs. Forward Current



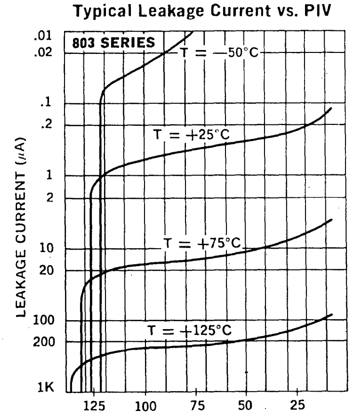
Typical Forward Voltage Per Leg vs. Forward Current



Typical Leakage Current vs. PIV



Typical Leakage Current vs. PIV



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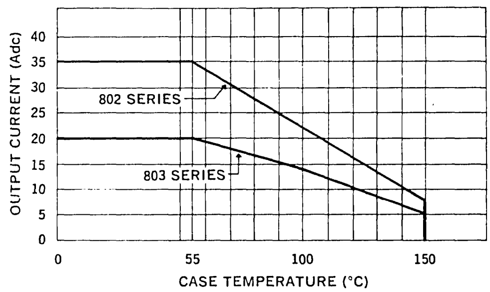
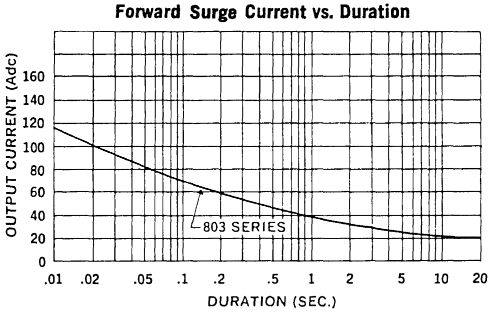
Current Derating Curve

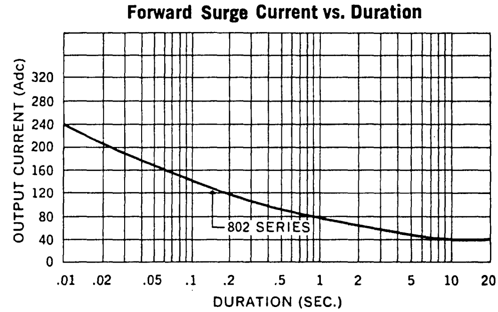


VIII

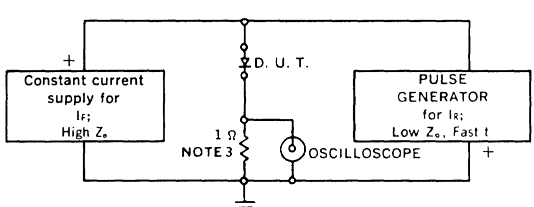
Forward Surge Current vs. Duration



Forward Surge Current vs. Duration



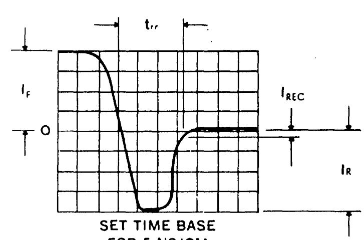
Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Characteristic Waveform



SET TIME BASE
FOR 5 NS/CM

RECTIFIER ASSEMBLIES

Doublers and Center Tap, 20 Amp, High Efficiency, ESP

FEATURES

- Current Rating: to 20A
- Aluminum Heat Sink Case, Electrically Insulated
- Recovery Time: 50ns
- Surge Rating: to 250A
- PIVs: from 50 to 150V
- Only Fused-in-Glass Diodes Used
- Exceptional High Efficiency

DESCRIPTION

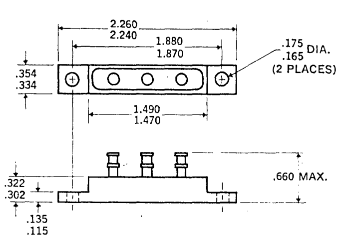
This series of doublers and center tap rectifiers offer the ultimate in high efficiency application. The rectifiers are particularly suited to switching regulator supplies where very fast recovery time and low forward drop are of prime importance.

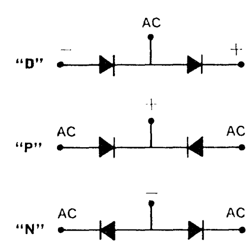
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	50 to 150V
Maximum Average D.C. Output Current	
@ $T_C = +55°C$	20A
@ $T_C = +100°C$	14A
Non-Repetitive Sinusoidal Surge (8.3ms)	
@ $T_A = +100°C$	250A
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient	20°C/W
Junction to Case	6.0°C/W

MECHANICAL SPECIFICATIONS

804 SERIES

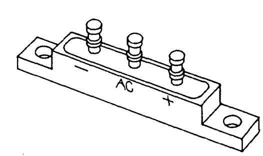




Dimensions in inches.

Typical Weight — 0.35 ounces
10 grams

MF



MARKING

Alternating Current Input	A.C.
Cathode — Positive Output	+
Anode — Negative	—

Part number is printed on the body.

† Add suffix P, N, or D for terminal configuration P, N, or D. For example, for center tap configuration, P, order 804-IP

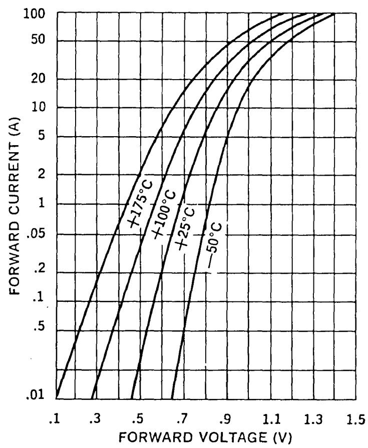
UNITRODE

Electrical Specifications (at 25°C unless noted)

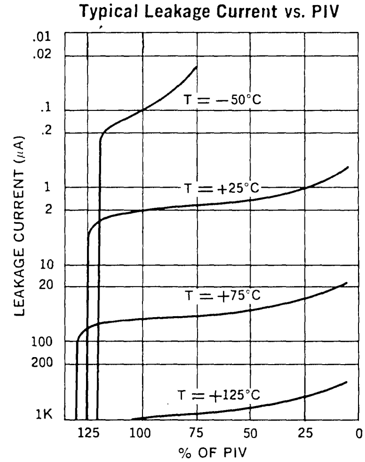
Type		PIV Per Leg	Maximum Forward Voltage Drop Per Leg	Maximum Leakage Current (μA) Per Leg @ PIV		Maximum Reverse Recovery Time*
				$T_A = 25°C$	$T_A = 100°C$	
		Volts		μA	μA	ns
ESP	804-1	50	.95V @ 10A	10	500	50
Recovery	804-2	100				
	804-3	125				
	804-4	150				

*Measured in a reverse recovery circuit switching from 1A forward to 1A reverse current recovering to 0.5A.

Typical Forward Voltage Per Leg vs. Forward Current

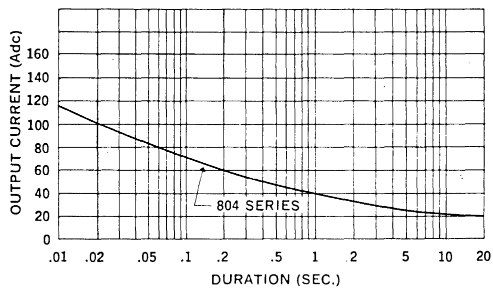


Typical Leakage Current vs. PIV

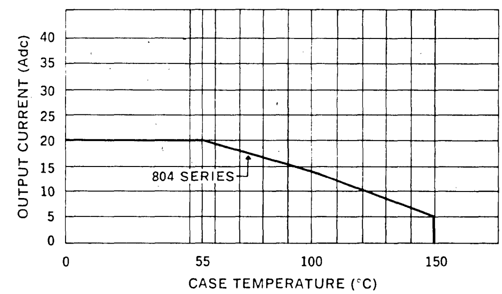


VIII

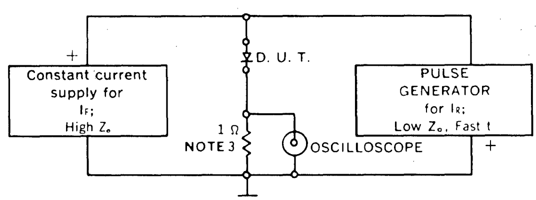
Forward Surge Current vs. Duration



Current Derating Curve

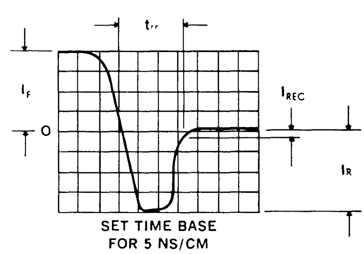


Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

Characteristic Waveform



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RECTIFIER ASSEMBLIES

Doubler and Center-Tap PMB Power Modules High Voltage, High Current

PMB101–PMB107
PMB101X–PMB107X
PMB201–PMB205
PMB201X–PMB205X

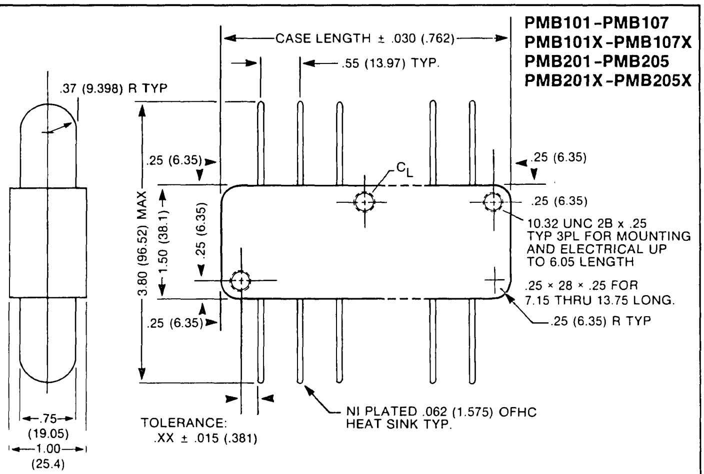
FEATURES
- PIV: From 2.5kV to 30kV
- 6A in Oil
- 300A Surge Current
- Dense Packaging
- Convenient Mounting

DESCRIPTION
The PMB POWER MODULE is available as a high voltage doubler or center tap with either a positive or negative tap. The high current capabilities suggest such applications as high power TWT amplifiers, power supplies and precipitators. The molded heat sunk configuration allows operation in oil and air.

VIII

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage .... 2.5kV to 30kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −65°C to +150°C

MECHANICAL SPECIFICATIONS



PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
PMB101, 101X	1.65	41.91
PMB102, 102X	2.75	69.85
PMB103, 103X	3.85	97.79
PMB104, 104X	4.95	125.73
PMB105, 105X	7.15	181.61
PMB106, 106X	9.35	237.49
PMB107, 107X	13.75	349.25

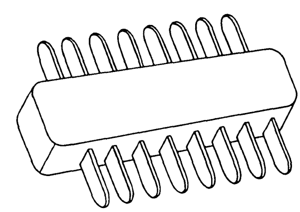
PART NUMBER	CASE LENGTH	
	INCHES	MILLIMETERS
PMB201, 201X	2.75	69.85
PMB202, 202X	4.95	125.73
PMB203, 203X	7.15	181.61
PMB204, 204X	9.35	237.49
PMB205, 205X	13.75	349.25

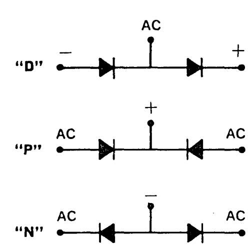
NOTE:
Add "P" to P/N for positive center-tap.
Add "N" to P/N for negative center-tap.
Add "D" to P/N for doubler configuration.

Polarity indicated by −, +, AC near terminals

Dimensions in inches and (millimeters)

PMA





Typical Weight — 0.35 ounces
10 grams

UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS					
Maximum Reverse Recovery Time		Peak Inverse Voltage	Maximum Reverse Current @ PIV		Maximum Forward Voltage	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS	Case Length	
T_{RR}*		PIV	I_R		V_F	I_O @ 50°C			I_F(surge)		
Type	Type	kV	25°C	100°C	@ 3.0A Peak	NC	FA	Oil			
2µS	250nS		µA	µA	V	A**	A***	A	A	Inches	MM
PMB101	PMB101X	2.5	2	100	5	1.0	2.4	3.0	150	1.65	41.91
PMB102	PMB102X	5	2	100	10	1.0	2.4	3.0	150	2.75	69.85
PMB103	PMB103X	7.5	2	100	15	1.0	2.4	3.0	150	3.85	97.79
PMB104	PMB104X	10	2	100	20	1.0	2.4	3.0	150	4.95	125.73
PMB105	PMB105X	15	2	100	30	1.0	2.4	3.0	150	7.15	181.61
PMB106	PMB106X	20	2	100	40	1.0	2.4	3.0	150	9.35	237.49
PMB107	PMB107X	30	2	100	50	1.0	2.4	3.0	150	13.75	349.25
					@ 6.0A Peak						
PMB201	PMB201X	2.5	2	100	5	2.0	4.8	6.0	300	2.75	69.85
PMB202	PMB202X	5	2	100	10	2.0	4.8	6.0	300	4.95	125.73
PMB203	PMB203X	7.5	2	100	15	2.0	4.8	6.0	300	7.15	181.61
PMB204	PMB204X	10	2	100	20	2.0	4.8	6.0	300	9.35	237.49
PMB205	PMB205X	15	2	100	30	2.0	4.8	6.0	300	13.75	349.25

* Reverse recovery test conditions for each cell prior to assembly $I_F = 400mA$, $I_R = 800mA$, $I_{RR} = 200mA$.
** For natural air convection operation unit must by mounted horizontally with no air restrictions.
*** Forced air ratings are with a minimum air flow of 600 linear feet per minute.

Notes:
1. Junction to heat sink thermal resistance 2.5°C per watt.
2. Consult factory for series and/or parallel applications for special matching.
3. I_O ratings @ 50°C linearly derate to 0 @ 150°C.
4. Oil and forced air operation any position.
5. Heat sinks are electrrically "hot".

RECTIFIER ASSEMBLIES

Single Phase Full Wave Bridges
PMC Power Modules
High Voltage, High Current

PMC101–PMC105
PMC101X–PMC105X
PMC201–PMC203
PMC201X–PMC203X

FEATURES
- PIV: From 2.5kV to 60kV
- 12A in Oil
- 300A Surge Current
- Fast Recovery
- Low Leakage

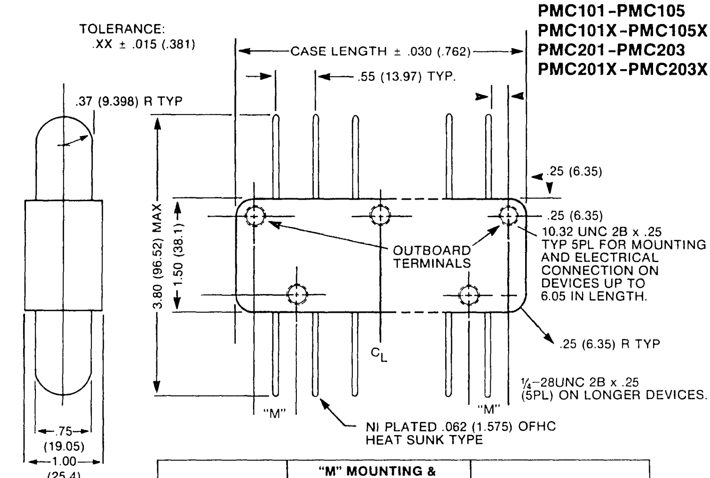
DESCRIPTION
The PMC POWER MODULE is a densely packaged single phase high voltage bridge rectifier assembly. Typical applications include high power transmitters, cable fault detectors, and shipboard radar systems, to name a few.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage .... 2.5kV to 15kV
Maximum Average Rectified Current .... See Electrical Specifications
Maximum One Cycle Surge 8.3mS .... See Electrical Specifications
Operating and Storage Temperature Range .... −65°C to +150°C

VIII

MECHANICAL SPECIFICATIONS

PMC101-PMC105
PMC101X-PMC105X
PMC201-PMC203
PMC201X-PMC203X



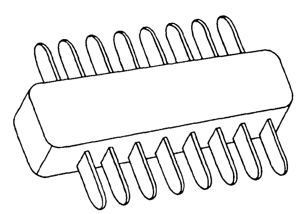
PART NUMBER	"M" MOUNTING & ELECTRICAL SPACING		CASE LENGTH	
	INCHES	MM	INCHES	MM
PMC101, 101X	.58	14.73	2.75	69.85
PMC102, 102X	1.13	28.70	4.95	125.73
PMC103, 103X	1.68	42.67	7.15	181.61
PMC104, 104X	2.23	56.64	9.35	237.49
PMC105, 105X	3.33	84.58	13.75	349.25
PMC201, 201X	1.13	28.70	4.95	125.73
PMC202, 202X	2.23	56.64	9.35	237.49
PMC203, 203X	3.33	84.58	13.75	349.25

NOTE: SINGLE PHASE FWB REQUIRES EXTERNAL CONNECTION BETWEEN BOTH OUTBOARD TERMINALS. DEVICE IS AVAILABLE WITH OUTPUT FROM THESE TERMINALS EITHER POSITIVE OR NEGATIVE BY ADDING SUFFIX P OR N, RESPECTIVELY TO THE PART NUMBER.

Polarity indicated by −, +, AC near terminals

Dimensions in inches and (millimeters)

PMA



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS							
Maximum Reverse Recovery Time		Peak Inverse Voltage	Maximum Reverse Current @ PIV		Maximum Forward Voltage	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS	"M" Mounting & Electrical Spacing		Case Length	
T_{RR}*		PIV	I_R		V_F	I_O @ 50°C			I_F(surge)				
Type	Type	kV	25°C	100°C	@ 3.0A Peak	NC	FA	Oil					
2µS	250nS		µA	µA	V	A**	A***	A	A	Inches	MM	Inches	MM
PMC101	PMC101X	2.5	2	100	5	2	4.8	6	150	.58	14.73	2.75	69.85
PMC102	PMC102X	5	2	100	10	2	4.8	6	150	1.13	28.70	4.95	125.73
PMC103	PMC103X	7.5	2	100	15	2	4.8	6	150	1.68	42.67	7.15	181.61
PMC104	PMC104X	10	2	100	20	2	4.8	6	150	2.23	56.64	9.35	237.49
PMC105	PMC105X	15	2	100	30	2	4.8	6	150	3.33	84.58	13.75	349.25
					@ 6.0A Peak								
PMC201	PMC201X	2.5	2	100	5	4	9.6	12	300	1.13	28.70	4.95	125.73
PMC202	PMC202X	5	2	100	10	4	9.6	12	300	2.23	56.64	9.35	237.49
PMC203	PMC203X	7.5	2	100	15	4	9.6	12	300	3.33	84.58	13.75	349.25

* Reverse recovery test conditions for each cell prior to assembly $I_F = 400mA$, $I_R = 800mA$, $I_{RR} = 200mA$.
** For natural air convection operation unit must by mounted horizontally with no air restrictions.
*** Forced air ratings are with a minimum air flow of 600 linear feet per minute.

Notes:
1. Junction to heat sink thermal resistance 2.5°C per watt.
2. Consult factory for series and/or parallel applications for special matching.
3. I_o ratings @ 50°C linearly derate to 0 @ 150°C.
4. Oil and forced air operation any position.
5. Heat sinks are electrrically "hot".

RECTIFIER ASEMBLIES

Three Phase Full Wave Bridges
PMD Power Modules
High Voltage, High Current

PMD101–PMD104
PMD101X–PMD104X
PMD201–PMD202
PMD201X–PMD202X

FEATURES
- PIV: From 2.5kV to 10kV
- 18A in Oil
- 300A Surge Current
- High Density Packaging
- Low Leakage
- Fast Recovery

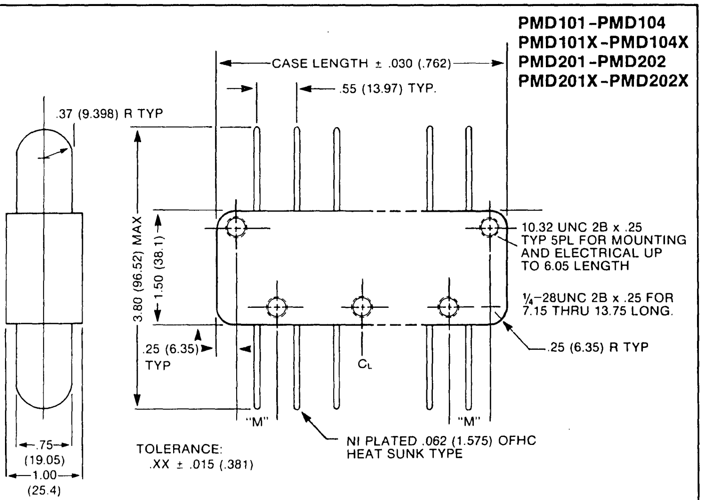
DESCRIPTION
The PMD POWER MODULE is a high density three phase high voltage bridge rectifier assembly. This package combines the low ripple and high efficiency characteristics with the high current capabilities to enhance the design of microwave systems, high current power supplies and transmitters of all types where high power is a key factor.

ABSOLUTE MAXIMUM RATINGS

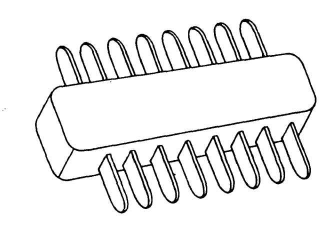
Peak Inverse Voltage	2.5kV to 10kV
Maximum Average Rectified Current	See Electrical Specifications
Maximum One Cycle Surge 8.3mS	See Electrical Specifications
Operating and Storage Temperature Range	−65°C to +150°C

VIII

MECHANICAL SPECIFICATIONS



PMA



PART NUMBER	"M" MOUNTING & ELECTRICAL SPACING INCHES	MM	CASE LENGTH INCHES	MM
PMD101, 101X	.58	14.73	3.85	97.79
PMD102, 102X	1.13	28.70	7.15	181.61
PMD103, 103X	1.68	42.67	10.45	265.43
PMD104, 104X	2.23	56.64	13.75	349.25
PMD201, 201X	1.13	28.70	7.15	181.61
PMD202, 202X	2.23	56.64	13.75	349.25

Polarity indicated by −, +, AC near terminals.
Dimensions in inches and (millimeters)

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)						MAXIMUM RATINGS							
Maximum Reverse Recovery Time		Peak Inverse Voltage	Maximum Reverse Current @ PIV		Maximum Forward Voltage	Maximum Average Rectified Current†			Maximum One Cycle Surge 8.3mS	"M" Mounting & Electrical Spacing		Case Length	
T_{RR}*		PIV	I_R		V_F	I_O @ 50°C			I_F(surge)				
Type	Type	kV	25°C	100°C	@ 3.0A Peak	NC	FA	Oil					
2µS	250nS		µA	µA	V	A**	A***	A	A	Inches	MM	Inches	MM
PMD101	PMD101X	2.5	2	100	5	3	7.2	9	150	.58	14.73	3.85	97.79
PMD102	PMD102X	5	2	100	10	3	7.2	9	150	1.13	28.70	7.15	181.61
PMD103	PMD103X	7.5	2	100	15	3	7.2	9	150	1.68	42.67	10.45	265.43
PMD104	PMD104X	10	2	100	20	3	7.2	9	150	2.23	56.64	13.75	349.25
					@ 6.0A Peak								
PMD201	PMD201X	2.5	2	100	5	6	14.4	18	300	1.13	28.70	7.15	181.61
PMD202	PMD202X	5	2	100	10	6	14.4	18	300	2.23	56.64	13.75	349.25

* Reverse recovery test conditions for each cell prior to assembly $I_F = 400mA$, $I_R = 800mA$, $I_{RR} = 200mA$.
** For natural air convection operation unit must by mounted horizontally with no air restrictions.
*** Forced air ratings are with a minimum air flow of 600 linear feet per minute.

Notes: 1. Junction to heat sink thermal resistance 2.5°C per watt.
2. Consult factory for series and/or parallel applications for special matching.
3. I_O ratings @ 50°C linearly derate to 0 @ 150°C.
4. Oil and forced air operation any position.
5. Heat sinks are electrrically "hot".

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RECTIFIERS

SES5401C–SES5403C

High Efficiency, 16A Center-Tap

FEATURES
- Low Forward Voltage
- Fast Recovery Times
- Economical, Convenient TO-220AB Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION

The SES5401C Series in the economical, convenient TO-220AB package, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The series combines two high efficiency devices into one package, simplifying installation, reducing heatsink requirements and the need to purchase matched components.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5401C 50V
Peak Inverse Voltage, SES5402C 100V
Peak Inverse Voltage, SES5403C 150V
Maximum Average D.C. Output Current
@ T_C = 125°C 16A
@ T_A = 25°C 3A
@ T_A = 25°C (Note 1) 10A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 70A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 1.75°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... −55°C to +150°C

VIII

NOTE 1. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

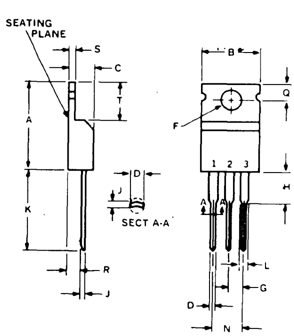
ELECTRICAL SPECIFICATIONS

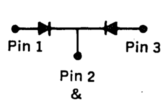
Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @1A t_r = 8nS
		T_J = 25°C	T_J = 100°C	@ T_J = 25°C	@ T_J = 100°C		
SES5401C SES5402C SES5403C	50V 100V 150V	1.025V @ 8A	0.945V @ 8A	5μA	150μA	100nS	1.4V

*Measured in circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

MECHANICAL SPECIFICATIONS

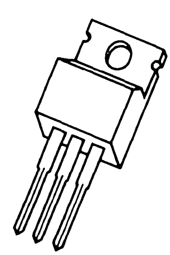
SES5401C-SES5403C



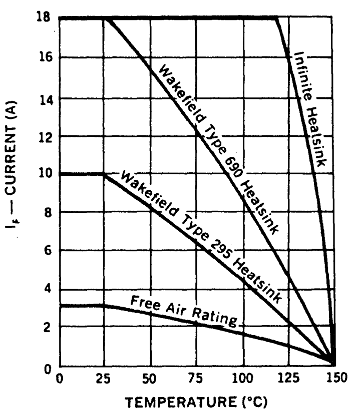


DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

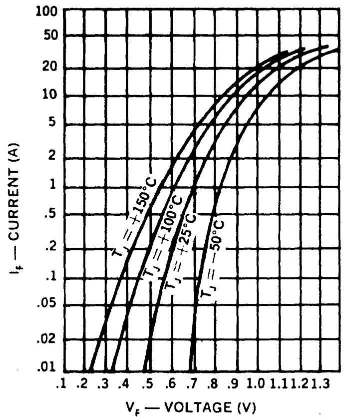
TO-220AB



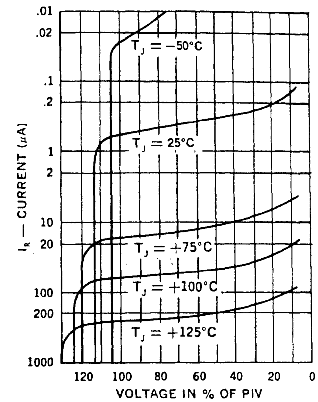
Output Current vs. Temperature



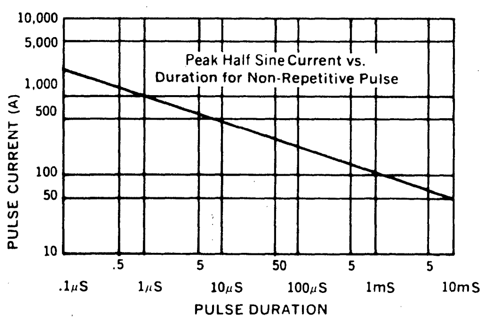
Typical Forward Current vs. Forward Voltage



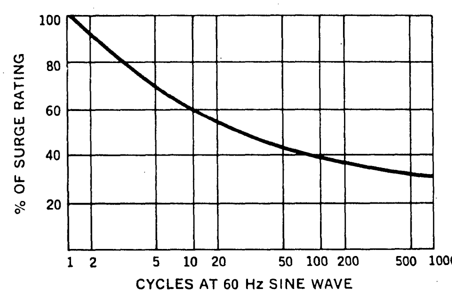
Typical Reverse Current vs. Voltage



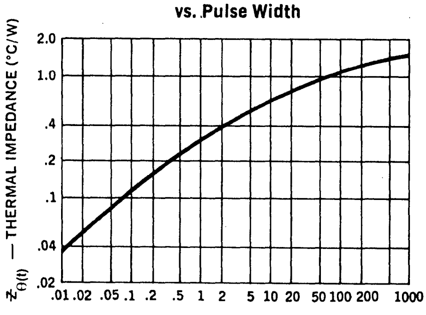
Forward Pulse Current vs. Duration



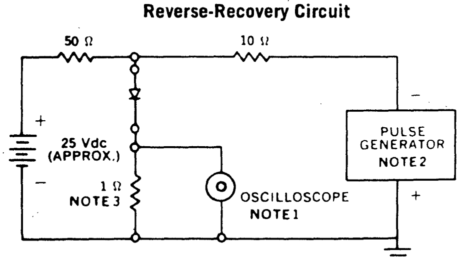
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 25A Center-Tap

SES5601C
SES5602C
SES5603C

FEATURES

- Low Forward Voltage
- Fast Switching Speed
- Convenient Package
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged TO-3 Package
- Available as Positive or Negative Center-Tap

DESCRIPTION

The SES, super-fast recovery, rectifiers are specifically designed for operation in power switching circuits. Their super-fast recovery time and very low forward voltage make them particularly efficient in most switching applications.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, SES5601C 50V
Peak Inverse Voltage, SES5602C 100V
Peak Inverse Voltage, SES5603C 150V
Maximum Average D.C. Output Current at $T_c = 100°C$ 25A
Non-Repetitive Sinusoidal Surge Current 8.3 mS 400A
Thermal Resistance, Junction to Case .... 1 °C/W
Operating and Storage Temperature Range .... −55 °C to +175 °C

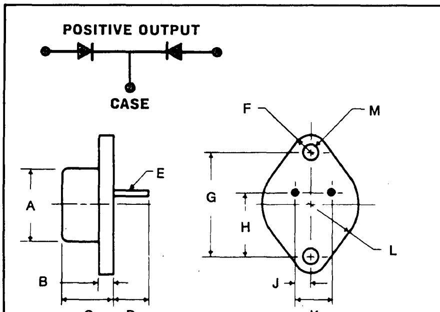
VIII

ELECTRICAL SPECIFICATIONS PER DIODE

Type	PIV	Maximum Forward Voltage (V_F) @		Maximum Reverse Current (I_R) @PIV		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	@$T_C = 25°C$	@$T_C = 125°C$	
SES5601C SES5602C SES5603C	50V 100V 150V	0.990V @ 12.5A $t_p = 300\mu S$	0.830V @ 12.5A $t_p = 300\mu S$	20μA	4mA	100nS

*Measured in circuit $I_F = 0.5A$, $I_R = 1.0A$, $I_{REC} = 0.25A$

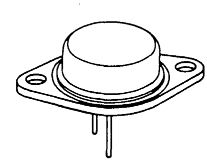
MECHANICAL SPECIFICATIONS



SES5601C-SES5603C

	Ins.	mm
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.00-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA	3.84-4.09 DIA.

TO-3

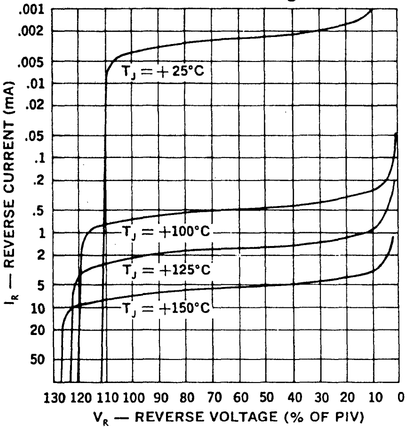


NOTES:

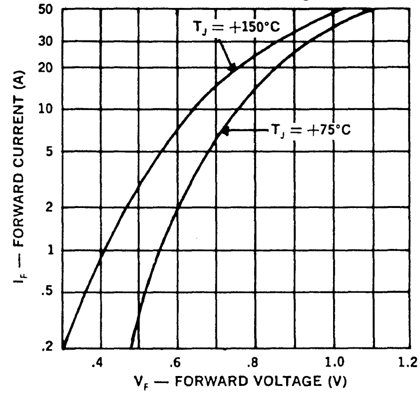
1. Standard polarity is positive output.
   For reverse polarity (negative output) add suffix "R", ie, SES5601CR.
2. All metal surfaces tin plated.

UNITRODE

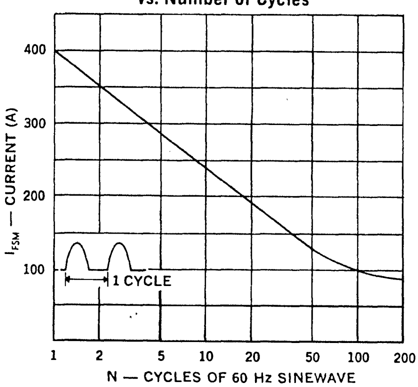
Typical Reverse Current vs. Reverse Voltage



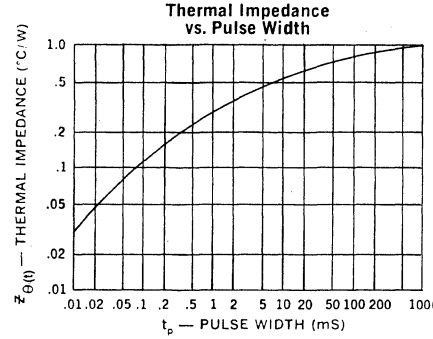
Typical Forward Current vs. Forward Voltage



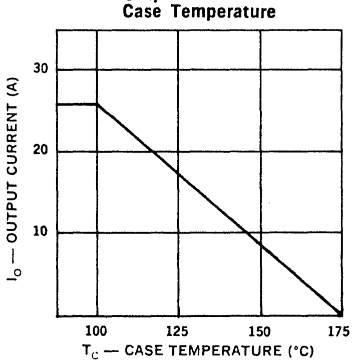
Maximum Forward Surge vs. Number of Cycles



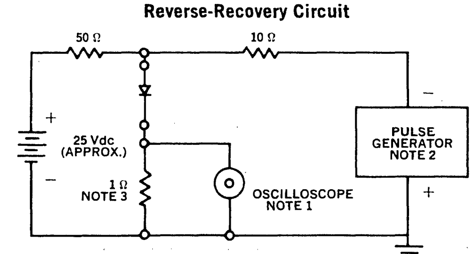
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:

1. Oscilloscope: Rise time ⩽ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIER ASSEMBLIES
Single Phase Bridges, 25 Amp, Military Approved

JAN SPA25
JAN SPB25
JAN SPC25
JAN SPD25

FEATURES
- Qualified to MIL-S-19500/446
- Current Rating: to 25A
- PIV: from 100 to 600V
- Surge Ratings: to 150A
- Only Fused-in-Glass Diodes Used
- Controlled Avalanche Characteristics
- Aluminum Heat Sink Case, Electrically Insulated

DESCRIPTION
This series of military high-current single-phase bridges offer the utmost in reliability as required in military system designs. This series is assembled with diodes which have been subjected to 100% screening tests.

VIII

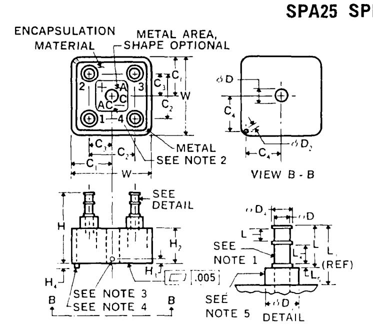
ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage	100 to 600V
Maximum Average D.C. Output Current	
@ $T_C = 55°C$	25A
@ $T_C = 100°C$	15A
Non-Repetitive Sinusoidal Surge (8.3ms)	
@ $T_C = 55°C$	150A
Operating and Storage Temperature Range	—65°C to +150°C
Thermal Resistance Junction to Ambient	20°C/W
Junction to Case	2.5°C/W

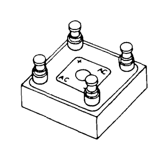
Ltr	Dimensions			
	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
C_1	.552	.572	14.02	14.53
C_2	.624	.760	15.85	19.30
C_3	.312	.380	7.92	9.65
C_4	.495	.512	12.57	13.00
ϕD_1	.189	.195	4.80	4.95
ϕD_2	.057	.067	1.45	1.70
ϕD_3	.108	.118	2.74	3.00
ϕD_4	.141	.151	3.58	3.84
ϕD_5	.225	.235	5.72	5.97
H_1	.669	1.060	17.53	26.92
H_2	.300	.500	7.62	12.70
H_3	.040	.060	1.02	1.52
H_4	.042	.062	1.07	1.57
L_1	.370	.560	9.40	14.22
L_2	.307	.365	7.80	9.27
L_3	.089	.099	2.26	2.49
L_4	.132	.142	3.35	3.61
L_5	.026	.036	.66	.91
W	1.104	1.144	28.04	29.06

MECHANICAL SPECIFICATIONS

SPA25 SPB25 SPC25 SPD25



MC



NOTES:
1. Terminals shall be hot tin dipped or silver plated.
2. Polarity shall be marked on terminal side of device.
3. Point at which T_C is read (must be in metal part of case).
4. Locating pin shall be adjacent to positive terminal.
5. Insulating sleeve shall be alumina (AL_2O_3) or equivalent.

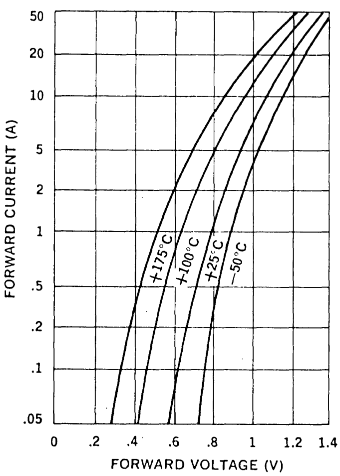
UNITRODE

Electrical Specifications (at 25°C unless noted)

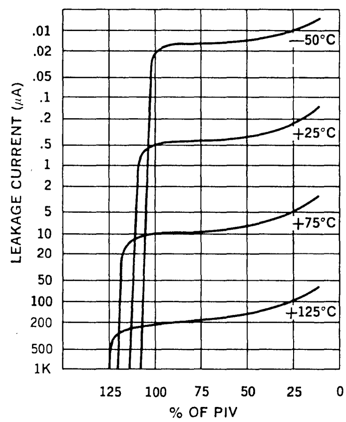
Type	PIV Per Leg	Peak Forward Voltage Drop*		Maximum Reverse Recovery Time†	Maximum Leakage Current Per Leg @ PIV	
					$T_C = 25°C$	$T_C = 150°C$
	Volts	Minimum	Maximum	μS	μA	μA
JAN SPA25 JAN SPB25 JAN SPC25 JAN SPD25	100 200 400 600	0.9V	1.4V @ 39A(pk)	2	2	250

*Peak forward voltage drop is measured at a pulse width of 8.3ms.
†Measured in a reverse recovery circuit switching from 0.5A forward to 1.0A reverse current recovery to 0.5A.

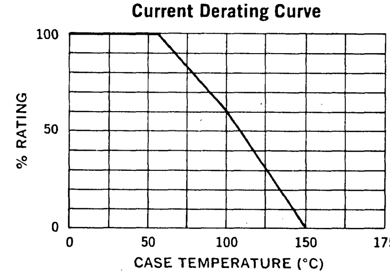
Typical Forward Voltage Per Leg vs. Forward Current

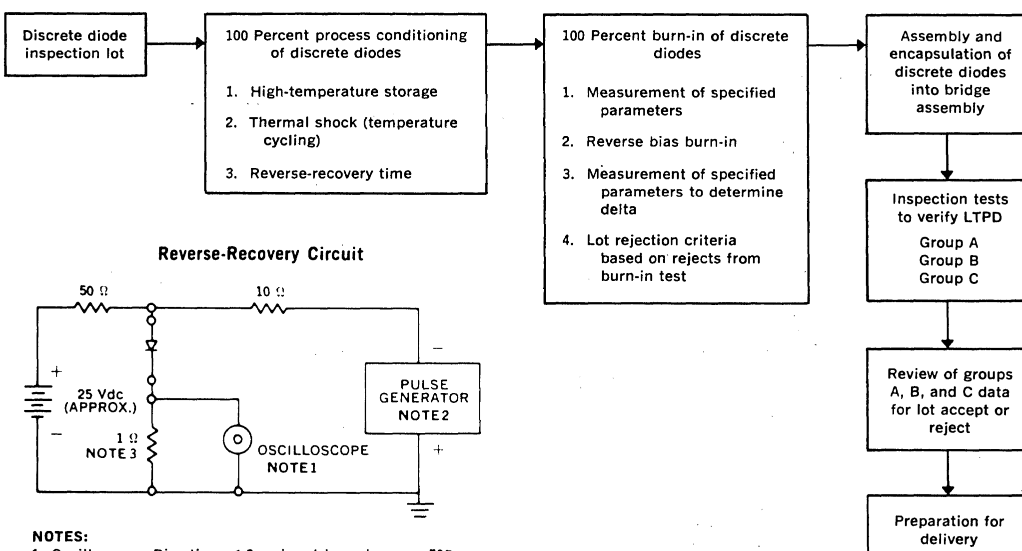


Typical Leakage Current vs. PIV



Current Derating Curve





NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 16A Center-Tap

UES2401-UES2403

FEATURES
- Very Low Forward Voltage
- Very Fast Recovery Times
- Economical, Convenient TO-220AB Package
- Low Thermal Resistance
- Mechanically Rugged

DESCRIPTION
The UES2401 Series in the economical, convenient TO-220AB package, is specifically designed for operation in power switching circuits to frequencies in excess of 100KHz. The series combines two high efficiency devices into one package, simplifying installation, reducing heatsink requirements and the need to purchase matched components.

VIII

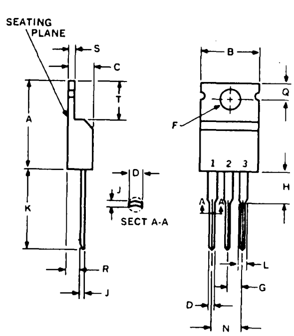
ABSOLUTE MAXIMUM RATINGS

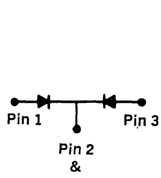
Peak Inverse Voltage, UES2401 .... 50V
Peak Inverse Voltage, UES2402 .... 100V
Peak Inverse Voltage, UES2403 .... 150V
Maximum Average D.C. Output Current
@ T_C = 125°C (Note 1) 16A
@ T_A = 25°C 3A
@ T_A = 25°C (Note 2) 10A
Non-Repetitive Sinusoidal Surge Current, 8.3mS 80A
Thermal Resistance, Junction to Case, $\Theta_{J\text{-}C}$ .... 1.75°C/W
Thermal Resistance, Junction to Ambient, $\Theta_{J\text{-}A}$ .... 60°C/W
Operating and Storage Temperature Range .... —55°C to +150°C

Note 1. Above 8A use the tab for electrical connection.
Note 2. Using Wakefield Type 295 heatsink with convection cooling. For more definitive data refer to the Output Current vs. Temperature Curves on this datasheet.

MECHANICAL SPECIFICATIONS

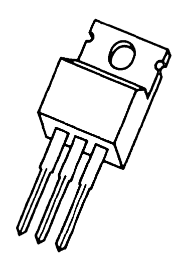
UES2401-2403





DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

TO-220AB

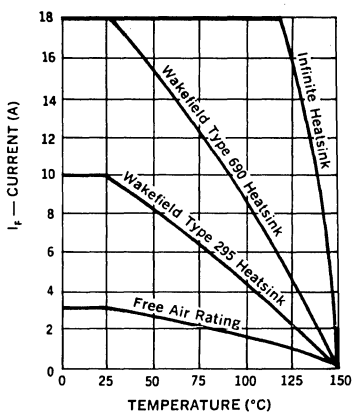


ELECTRICAL SPECIFICATIONS

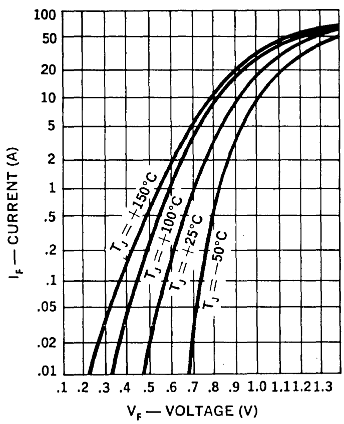
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current @ PIV		Maximum Reverse Recovery Time*	Typical Forward Recovery Voltage @ 1A t_r = 8nS
		T_J = 25°C	T_J = 100°C	T_J = 25°C	T_J = 100°C		
UES2401 UES2402 UES2403	50V 100V 150V	0.9V @ 4A 0.975V @ 8A tp = 300μS	0.8V @ 4A 0.895V @ 8A	5μA	150μA	35nS	1.4V

*Measured in circuit I_F = 0.5A, I_R = 1.0A, I_{REC} = 0.25A

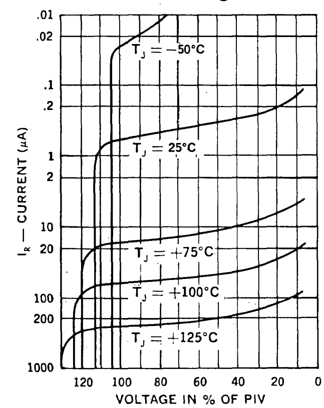
Output Current vs. Temperature



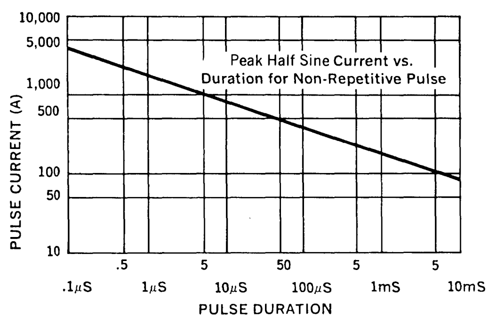
Typical Forward Current vs. Forward Voltage



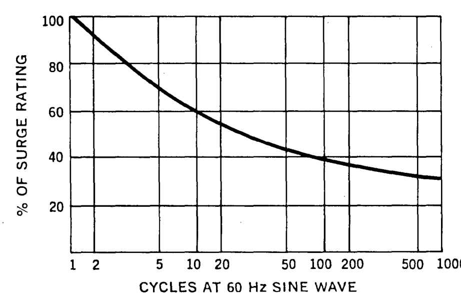
Typical Reverse Current vs. Voltage



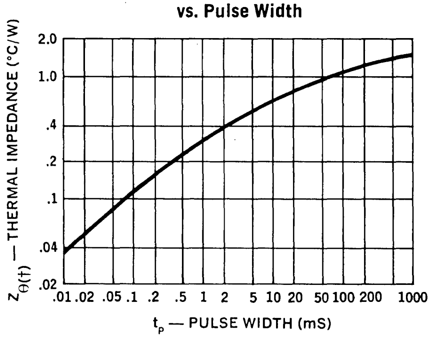
Forward Pulse Current vs. Duration



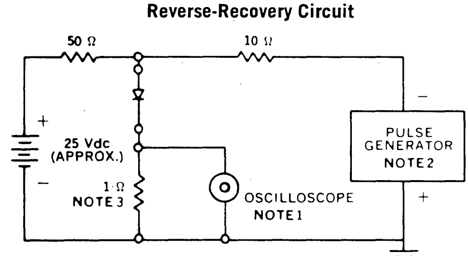
Multiple Surge Current vs. Duration



Thermal Impedance vs. Pulse Width



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3nS; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8nS; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS
High Efficiency, 30A Center-Tap

UES2601–UES2603

FEATURES
- Very Low Forward Voltage
- Very Fast Switching Speed
- Convenient Package
- High Surge
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION
This series combines two high efficiency devices into one package, simplifying installation, reducing heat sink requirements and the need to purchase matched components.

ABSOLUTE MAXIMUM RATINGS
Peak Inverse Voltage, UES2601 .... 50V
Peak Inverse Voltage, UES2602 .... 100V
Peak Inverse Voltage, UES2603 .... 150V
Maximum Average D.C. Output Current at $T_C = 100°C$ 30A
Non-Repetitive Sinusoidal Surge Current 8.3 ms 400A
Thermal Resistance, Junction to Case .... 1°C/W
Operating and Storage Temperature Range .... −55°C to +175°C

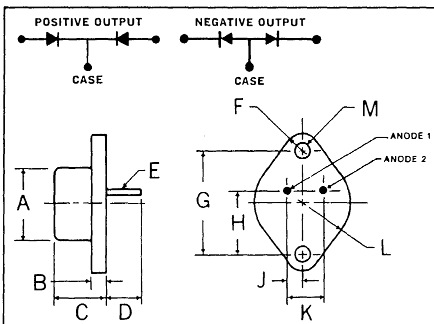
VIII

POWER CYCLING
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS
The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

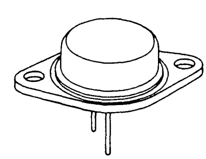
MECHANICAL SPECIFICATIONS



UES2601-UES2603

	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



Note:
Standard polarity is positive output.
For reverse polarity (negative output) add suffix "R", ie. UES2601R.

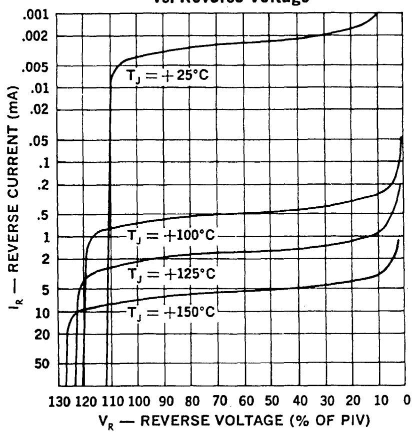
UNITRODE

ELECTRICAL SPECIFICATIONS

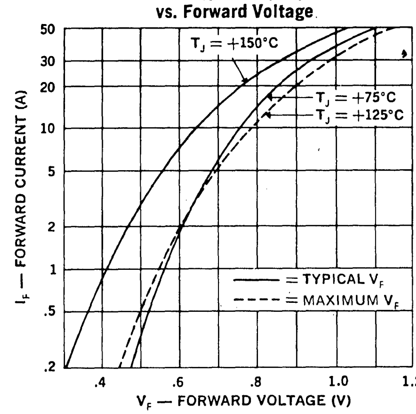
Type	PIV	Maximum Forward Voltage @		Maximum Reverse Current @		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES2601 UES2602 UES2603	50V 100V 150V	.930V @ 15A $t_p = 300\mu S$	.825V @ 15A $t_p = 300\mu S$	20μA	4mA	35nS

* Measured in circuit $I_F = 0.5A$, $I_R = 1A$, $I_{REC} = 0.25A$

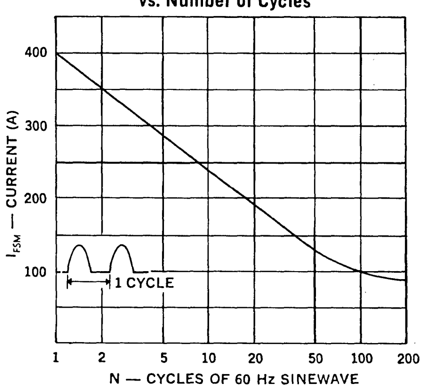
Typical Reverse Current vs. Reverse Voltage



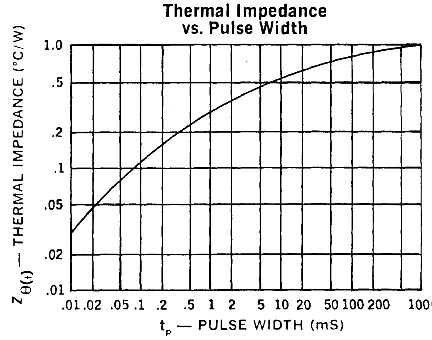
Forward Current vs. Forward Voltage



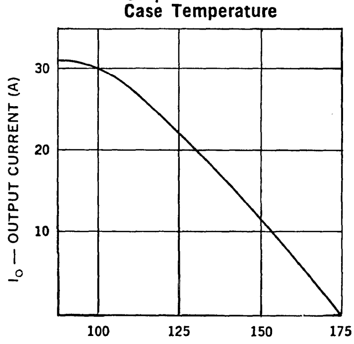
Maximum Forward Surge vs. Number of Cycles



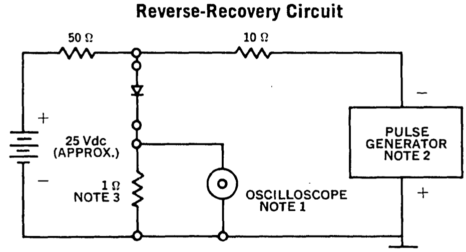
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ⩽ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ⩽ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

RECTIFIERS

High Efficiency, 30A Center-Tap

FEATURES

- Very Low Forward Voltage (1.15V)
- Very Fast Recovery Times (50nSec)
- Low Profile Package
- High Surge Capability
- Low Thermal Resistance
- Mechanically Rugged
- Both Polarities Available

DESCRIPTION

The UES2604 series is specifically designed for operation in power switching circuits operating at frequencies of at least 20 KHz.
This series combines two high efficiency devices into one package, simplifying installation, reducing heat sink requirements and the need to purchase matched components.

ABSOLUTE MAXIMUM RATINGS

Peak Inverse Voltage, UES2604 .... 200V
Peak Inverse Voltage, UES2605 .... 300V
Peak Inverse Voltage, UES2606 .... 400V
Maximum Average D.C. Output Current @ $T_C = 100°C$ 30A
Surge Current, 8.3mSec 300A
Thermal Resistance, Junction to Case .... 1°C/W
Operating and Storage Temperature Range .... —55°C to +150°C

POWER CYCLING

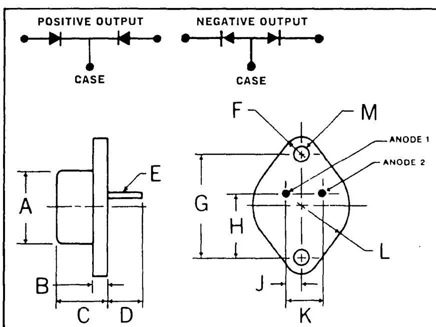
These devices possess the unique ability to pass many thousands of cycles of a stress test designed to evaluate the integrity of the bonding systems used in the construction of power rectifiers.

In this stress test, the case of the device is not heat sunk. Full rated forward current is supplied to force a case temperature increase at least 75°C, at which time, the current is removed and the case allowed to cool. The cycle is repeated a minimum of 5,000 times to simulate equipment being turned on and off. Extended power cycling tests demonstrate a product capability in excess of 25,000 cycles.

SWITCHING CHARACTERISTICS

The switching times of these ultra-fast rectifiers increase relatively little, with temperature or at different currents. Even in severe applications, such as catch diodes for switching regulators and output rectifiers for high frequency square wave inverters, these devices switch many times faster than the fastest associated transistors. Thus, the stresses on and powers dissipated in the switching transistors are substantially less than when using other rectifiers.

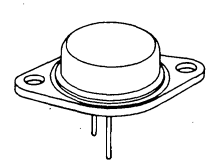
MECHANICAL SPECIFICATIONS



UES2604-UES2606

	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.	0.97-1.09 DIA.
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

TO-3



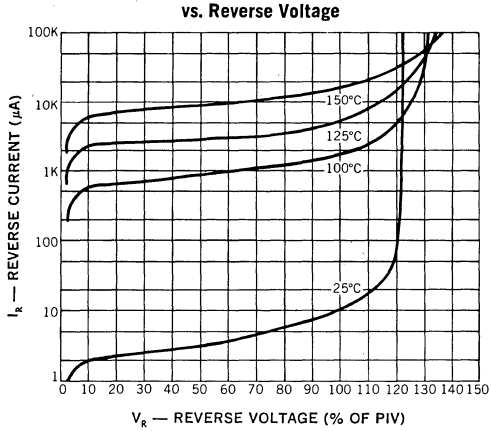
Note:
Standard polarity is positive output.
For reverse polarity (negative output) add suffix "R", ie. UES2604R.

ELECTRICAL SPECIFICATIONS, PER LEG

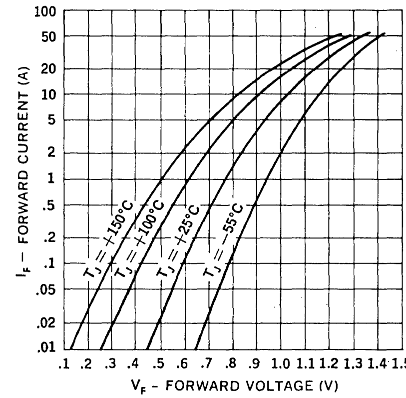
Type	PIV	Maximum Forward Voltage		Maximum Reverse Current		Maximum Reverse Recovery Time*
		$T_C = 25°C$	$T_C = 125°C$	$T_C = 25°C$	$T_C = 125°C$	
UES2604 UES2605 UES2606	200V 300V 400V	1.25V @ 15A $t_p = 300\mu S$	1.15V @ 15A $t_p = 300\mu S$	50μA	10mA	50nS

*Measured in circuit $I_F = .5A$, $I_R = 1A$, $I_{REC} = .25A$

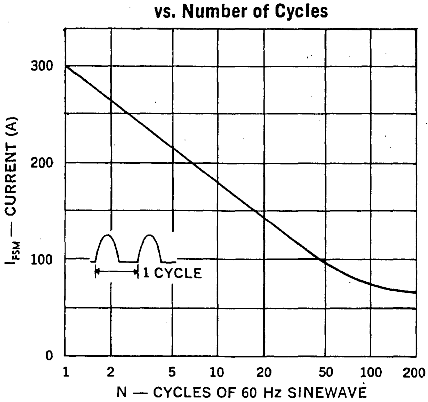
Typical Reverse Current vs. Reverse Voltage



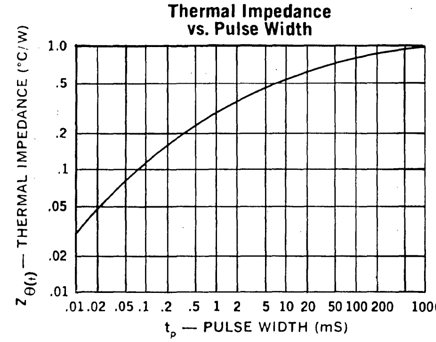
Forward Current vs. Forward Voltage



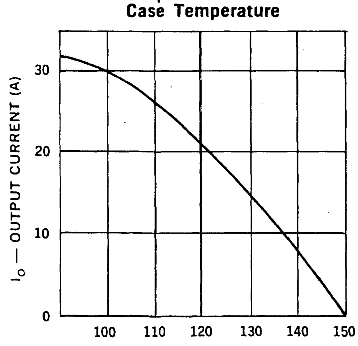
Maximum Forward Surge vs. Number of Cycles



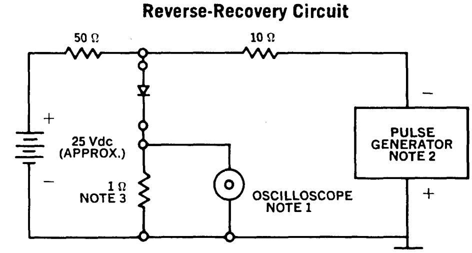
Thermal Impedance vs. Pulse Width



Output Current vs. Case Temperature



Reverse-Recovery Circuit



NOTES:
1. Oscilloscope: Rise time ≤ 3ns; input impedance = 50Ω.
2. Pulse Generator: Rise time ≤ 8ns; source impedance 10Ω.
3. Current viewing resistor, non-inductive, coaxial recommended.

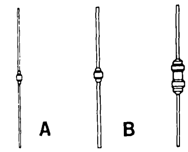
POWER ZENERS & TRANSIENT VOLTAGE SUPPRESSORS IX

POWER ZENERS AND TRANSIENT VOLTAGE SUPPRESSORS

Transient Voltage Suppressors

Package Style	Part No.	Stand-Off Voltage V_R (V)	Min. Breakdown Voltage $BV_{(min)}$ @ 1mA (V)	Max. Peak Pulse Current I_{PP} (A)	Max. Clamping Voltage* V_C @ I_{PP} (V)	Peak Power for lmS (W)
A Body	TVS305	5.0	6.0	17	8.7	150
	TVS310	10.0	11.1	8.9	16.8	
	TVS312	12.0	13.8	7.1	21.0	
	TVS315	15.0	16.7	5.9	25	
	TVS318	18.0	20.4	4.9	31	
	TVS324	24.0	28.4	3.6	42	
	TVS328	28.0	30.7	3.2	46	
	TVS348	48.0	54	1.7	82	
	TVS360	60.0	67	1.4	105	
	TVS410	100.0	111	.91	160	
	TVS420	200.0	234	.42	360	
	TVS430	300.0	342	.28	520	
B Body	TVS5-1	5.0	—	45	7.5	500
	TVS5-2	5.0	—	48	8.5	
	TVS5-3	5.0	—	53.7	9.3	
	TVS505	5.0	6.0	53.7	9.3	500
	TVS510	10.0	11.1	30.3	16.5	
	TVS512	12.0	13.8	23.8	21.0	
	TVS515	15.0	16.7	19.8	25.2	
	TVS518	18.0	20.4	16.3	30.5	
	TVS524	24.0	28.4	11.9	42.0	
	TVS528	28.0	30.7	10.7	46.5	
	1N6461**	5.0	5.6 @ 25mA	56	9	500
	1N6462**	6.0	6.5 @ 20mA	46	11	
	1N6463**	12.0	13.6 @ 5mA	22	22.6	
	1N6464**	15.0	16.4 @ 5mA	19	26.5	
	1N6465**	24.0	27.0 @ 2mA	12	41.4	
	1N6466**	30.5	33.0 @ 1mA	11	47.5	
	1N6467**	40.3	43.7 @ 1mA	8	63.5	
	1N6468**	51.6	54.0 @ 1mA	6	78.5	
CCL Body	1N5610*		33.0	32.0	47.5	1500
	1N5611*		43.7	24.0	63.5	
	1N5612*		54.0	19.0	79.5	
	1N5613*		191.0	5.7	265.0	

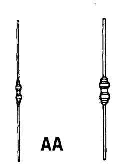
*Available in JAN & JANTX
**Available in JAN, JANTX and JANTXV



A B CCL

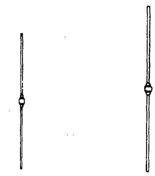
Bi-directional Zeners

Power	1W	3W	5W
Package Style	AA	AA	BB
Voltage, V (10% Tolerance) 7.5	UDZ8807	UDZ807	UDZ5807
8.2	UDZ8808	UDZ808	UDZ5808
9.1	UDZ8809	UDZ809	UDZ5809
10	UDZ8810	UDZ810	UDZ5810
12	UDZ8812	UDZ812	UDZ5812
15	UDZ8815	UDZ815	UDZ5815
18	UDZ8818	UDZ818	UDZ5818
20	UDZ8820	UDZ820	UDZ5820
24	UDZ8824	UDZ824	UDZ5824
27	UDZ8827	UDZ827	UDZ5827
30	UDZ8830	UDZ830	UDZ5830
33	UDZ8833	UDZ833	UDZ5833
36	UDZ8836	UDZ836	UDZ5836
40	UDZ8840	UDZ840	UDZ5840
45	UDZ8845	UDZ845	UDZ5845
60	UDZ8860	UDZ860	UDZ5860



AA BB

POWER ZENERS AND TRANSIENT VOLTAGE SUPPRESSORS



A B

Power Zeners

Power	1W	1.5W	3W	5W	5W	6W	10W
Package Style	**A**	**A**	**A**	**B**	**B**	**CL**	**C**
VOLTAGE V_Z (5% Tolerance)†							
5.6V					1N5968*		
6.2V					1N5969*		
6.8V	UZ8706	1N4461*	1N5063	UZ4706	1N4954*	UZ7706L	UZ7706
7.5V	UZ8707	1N4462*	1N5064	UZ4707	1N4955*	UZ7707L	UZ7707
8.2V	UZ8708	1N4463*	1N5065	UZ4708	1N4956*	UZ7708L	UZ7708
9.1V	UZ8709	1N4464*	1N5066	UZ4709	1N4957*	UZ7709L	UZ7709
10V	UZ8710	1N4465*	1N5067	UZ4710	1N4958*	UZ7710L	UZ7710
11V	UZ8711	1N4466*	1N5068		1N4959*	UZ7711L	UZ7711
12V	UZ8712	1N4467*	1N4883	UZ4712	1N4960*	UZ7712L	UZ7712
13V	UZ8713	1N4468*	1N5069	UZ4713	1N4961*	UZ7713L	UZ7713
14V	UZ8714		1N5070		1N5118	UZ7714L	UZ7714
15V	UZ8715	1N4469*	1N5071	UZ4715	1N4962*	UZ7715L	UZ7715
16V	UZ8716	1N4470*	1N5072	UZ4716	1N4963*	UZ7716L	UZ7716
18V	UZ8718	1N4471*	1N5073	UZ4718	1N4964*	UZ7718L	UZ7718
20V	UZ8720	1N4472*	1N4884	UZ4720	1N4965*	UZ7720L	UZ7720
22V	UZ8722	1N4473*	1N5074	UZ4722	1N4966*	UZ7722L	UZ7722
24V	UZ8724	1N4474*	1N5075	UZ4724	1N4967*	UZ7724L	UZ7724
27V	UZ8727	1N4475*	1N5076	UZ4727	1N4968*	UZ7727L	UZ7727
30V	UZ8730	1N4476*	1N5077	UZ4730	1N4969*	UZ7730L	UZ7730
33V	UZ8733	1N4477*	1N5078	UZ4733	1N4970*	UZ7733L	UZ7733
36V	UZ8736	1N4478*	1N5079	UZ4736	1N4971*	UZ7736L	UZ7736
39V		1N4479*	1N5080	UZ4739	1N4972*		
40V	UZ8740		1N5081		1N5119	UZ7740L	UZ7740
43V		1N4480*	1N5082	UZ4743	1N4973*		
45V	UZ8745		1N5083		1N5120	UZ7745L	UZ7745
47V		1N4481*	1N5084	UZ4747	1N4974*		
50V	UZ8750		1N5085		1N5121	UZ7750L	UZ7750
51V		1N4482*	1N5086	UZ4751	1N4975*		
56V	UZ8756	1N4483*	1N5087	UZ4756	1N4976*	UZ7756L	UZ7756
60V	UZ8760		1N5088		1N5122	UZ7760L	UZ7760
62V		1N4484*	1N5089	UZ4762	1N4977*		
68V		1N4485*	1N5090	UZ4768	1N4978*		
PULSE POWER **	100W	140W	230W	720W	900W	2000W	2000W

* Available as JAN, JANTX, & JANTXV
** For 100 μsec pulse width
† 10% and 20% tolerance also available.

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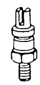
CL



C

IX

Power	1W	1.5W	3W	5W	5W	6W	10W
Package Style	**A**	**A**	**A**	**B**	**B**	**CL**	**C**
VOLTAGE Vz (5% Tolerance)†							
70V	UZ8770		1N5091		1N5123	UZ7770L	UZ7770
75V	UZ8775	1N4486*	1N5092	UZ4775	1N4979*	UZ7775L	UZ7775
80V	UZ8780		1N5093		1N5124	UZ7780L	UZ7780
82V		1N4487*	1N5094	UZ4782	1N4980*		
90V	UZ8790		1N4096		1N5125	UZ7790L	UZ7790
91V		1N4488*	1N4095	UZ4791	1N4981*		
100V	UZ8110	1N4489*	1N4097	UZ4110	1N4982*	UZ7110L	UZ7110
110V	UZ8111	1N4490*	1N5096	UZ4111	1N4983*		
120V	UZ8112	1N4491*	1N5097	UZ4112	1N4984*		
130V	UZ8113	1N4492*	1N5098	UZ4113	1N4985*		
140V	UZ8114		1N5099				
150V	UZ8115	1N4493*	1N5098	UZ4115	1N4986*		
160V	UZ8116	1N4494*	1N5100	UZ4116	1N4987*		
170V	UZ8117		1N5101		1N5127		
180V	UZ8118	1N4495*	1N5102	UZ4118	1N4988*		
190V	UZ8119		1N5103		1N5128		
200V	UZ8120	1N4496*	1N5104	UZ4120	1N4989*		
220V			1N5105		1N4990*		
240V			1N5106		1N4991*		
260V			1N5107		1N5129		
270V			1N5108		1N4992*		
280V			1N5109		1N5130		
300V			1N5110		1N4993*		
320V			1N5111		1N5131		
330V			1N5112		1N4994*		
340V			1N5113		1N5132		
360V			1N5114		1N4995*		
380V			1N5115		1N5133		
390V			1N5116		1N4996		
400V			1N5117		1N5134		
PULSE POWER **	100W	140W	230W	720W	900W	2000W	2000W

* Available as JAN, JANTX, & JANTXV
** For 100 μsec pulse width
† 10% and 20% tolerance also available.

POWER ZENERS
1.5 Watt, Military

1N4461-1N4496
JAN, JANTX & JANTXV

FEATURES
- 5 Times Greater Surge Rating than JAN1N3016 Series
- Low Reverse Current: to 50nA
- ¼ Size of Conventional 1 Watt Zeners

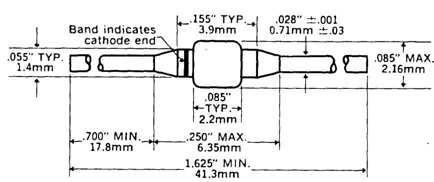
DESCRIPTION
Fused-in-glass, metallurgically bonded 1.5 watt zeners, qualified to MIL-S-19500/406.

ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 200V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	−65°C to +175°C

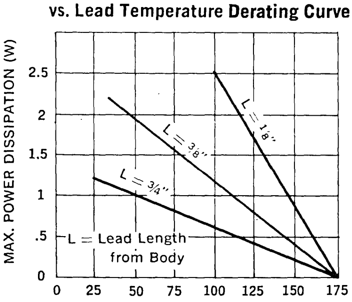
MECHANICAL SPECIFICATIONS

JAN, JANTX & JANTXV 1N4461-1N4496

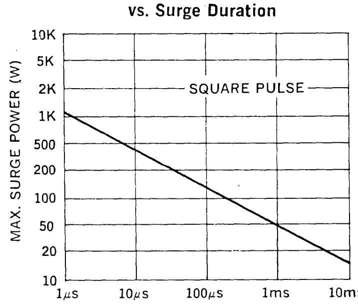


BODY A

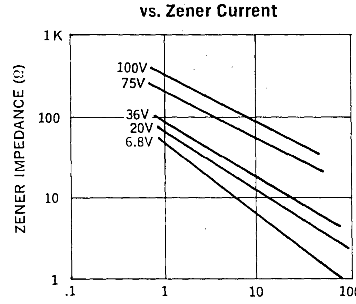
Power Dissipation vs. Lead Temperature Derating Curve



Max. Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



1/79

UNITRODE

Type	Nominal Zener Voltage † V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Impedance § Z_Z @ I_{ZT}	Z_{ZK} @ I_{ZK}	I_{ZK}	Voltage ** Regulation ΔBV Max	Maximum Reverse Leakage Current I_R @ V_R	V_R	Maximum Cont. Current I_{ZM}	Maximum Surge Current ‡ I_S
	Electrical Specifications at 25°C								Maximum Ratings	
±5% Tolerance	Volts	mA	Ohms	Ohms	mA	Volts	µA	Volts	mA	Amps
1N4461	6.8	37	2.5	200	1.0	.30	5.0	4.08	210	5.0
1N4462	7.5	34	2.5	400	.5	.35	1.0	4.50	191	4.5
1N4463	8.2	31	3.0	400	.5	.40	.50	4.92	174	3.9
1N4464	9.1	28	4.0	500	.5	.45	.30	5.46	157	3.4
1N4465	10	25	5.0	500	.25	.50	.30	8.0	143	3.0
1N4466	11	23	6.0	550	.25	.55	.30	8.8	130	2.6
1N4467	12	21	7.0	550	.25	.60	.20	9.6	119	2.4
1N4468	13	19	8.0	550	.25	.65	.10	10.4	110	2.2
1N4469	15	17	9.0	600	.25	.75	.05	12.0	95	1.8
1N4470	16	15.5	10.0	600	.25	.80	.05	12.8	90	1.6
1N4471	18	14	11.0	650	.25	.83	.05	14.4	79	1.4
1N4472	20	12.5	12.0	650	.25	.95	.05	16.0	71	1.2
1N4473	22	11.5	14	650	.25	1.0	.05	17.6	65	1.1
1N4474	24	10.5	16	700	.25	1.1	.05	19.2	60	.90
1N4475	27	9.5	18	700	.25	1.3	.05	21.6	53	.80
1N4476	30	8.5	20	750	.25	1.4	.05	24.0	48	.75
1N4477	33	7.5	25	800	.25	1.5	.05	26.4	43	.66
1N4478	36	7.0	27	850	.25	1.7	.05	28.8	40	.60
1N4479	39	6.5	30	900	.25	1.8	.05	31.2	37	.54
1N4480	43	6.0	40	950	.25	1.9	.05	34.4	33	.48
1N4481	47	5.5	50	1000	.25	2.1	.05	37.6	30	.45
1N4482	51	5.0	60	1100	.25	2.3	.05	40.8	28	.42
1N4483	56	4.5	70	1300	.25	2.5	.05	44.8	26	.39
1N4484	62	4.0	80	1500	.25	2.7	.05	49.6	23	.35
1N4485	68	3.7	100	1700	.25	3.0	.05	54.4	21	.32
1N4486	75	3.3	130	2000	.25	3.3	.05	60.0	19	.29
1N4487	82	3.0	160	2500	.25	3.6	.05	65.6	17	.26
1N4488	91	2.8	200	3000	.25	4.0	.05	72.8	16	.23
1N4489	100	2.5	250	3100	.25	4.4	.25	80.0	14	.20
1N4490	110	2.0	300	4000	.25	5.0	.25	88.0	13	.19
1N4491	120	2.0	400	4500	.25	5.5	.25	96.0	12	.18
1N4492	130	1.9	500	5000	.25	6.0	.25	104	11	.16
1N4493	150	1.7	700	6000	.25	7.0	.25	120	9.5	.14
1N4494	160	1.6	1000	6500	.25	8.0	.25	128	8.9	.12
1N4495	180	1.4	1300	7000	.25	10.0	.25	144	7.9	.10
1N4496	200	1.2	1500	8000	.25	12.0	.25	160	7.2	.08

† All Zener voltages are measured with an automated test set using a 35 millisecond test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§ Zener impedance is derived from the 60 cycle AC Voltage created when AC current with RMS value of 10% of DC Zener test current is superimposed on the test current.

** ΔBV is obtained by measuring the voltage change when the test current is changed from 10% to 50% of Iz max under DC conditions. During this measurement the leads are heat sunk .375 inch from the body and maintained at 25°C.

‡ **Ratings shown are for peak sinusoidal surge current of 8.3 ms duration, non-repetitive. The 8.3 ms square pulse rating is 71% of the value shown. Rating exceeds JEDEC Registered Specification.**

IX

POWER ZENERS
5 Watt, Military

1N4954-1N4995
1N5968-1N5969
JAN, JANTX & JANTXV
1N4996

FEATURES
- 2 Times Greater Surge Rating than Conventional 10 Watt Zeners
- Small Physical Size

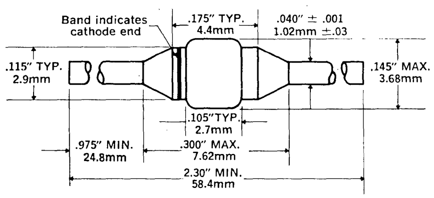
DESCRIPTION
Fused-in-glass, metallurgically-bonded 5 watt zeners, qualified to MIL-S-19500/356.

ABSOLUTE MAXIMUM RATINGS

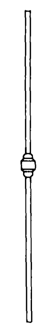
Zener Voltage, V_Z	5.6 to 390V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	−65°C to +175°C

MECHANICAL SPECIFICATIONS

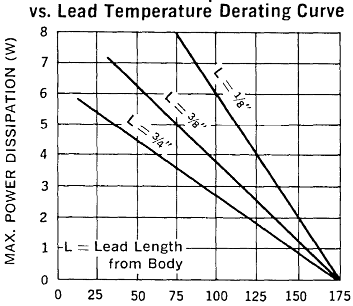
J, JTX, JTXV 1N4954-1N4995
J, JTX, JTXV 1N5968-1N5969
1N4996



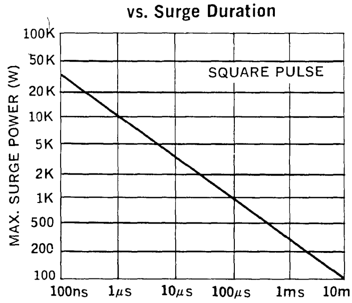
BODY B



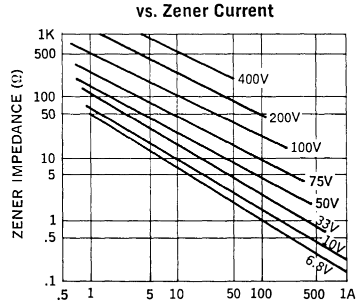
Power Dissipation vs. Lead Temperature Derating Curve



Max. Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



UNITRODE

Electrical Specifications at 25°C										Maximum Ratings	
Type	Nominal Zener Voltage† V_Z @ I_{ZT}	Test Current I_{ZT}	Maximum Zener Impedance § Z_Z @ I_{ZT}	Maximum Zener Impedance § Z_{ZK}†† @ I_{ZK} = 1mA	Voltage Regulation ΔBV §§	Maximum Reverse Leakage Current I_R††	Maximum Reverse Leakage Current I_R	Maximum Reverse Leakage Current V_R	Maximum Temperature Coeff. T_C @ I_{ZT}	Maximum Continuous Current ★ I_{ZM}	Maximum Surge Current‡ I_S
±5% Tolerance	Volts	mA	Ohms	Ohms	Volts	μA	μA	Volts	%/°C	mA	Amps
1N5968*	5.6	220	1.0	400	0.4	5000	5000	4.28	.04	865	20
1N5969*	6.2	220	1.0	1000	0.5	1000	1000	4.74	.04	765	20
1N4954*	6.8	175	1.0	1000	0.7	150	300	5.2	.05	700	40
1N4955*	7.5	175	1.5	800	0.7	100	200	5.7	.06	630	32
1N4956*	8.2	150	1.5	600	0.7	50	100	6.2	.06	580	24
1N4957*	9.1	150	2.0	400	0.7	25	50	6.9	.06	520	22
1N4958*	10.0	125	2.0	125	0.8	25	25	7.6	.07	475	20
1N4959*	11	125	2.5	130	0.8	10	15	8.4	.07	430	19
1N4960*	12	100	2.5	140	0.8	10	10	9.1	.07	395	18
1N4961*	13	100	3.0	145	0.8	10	10	9.9	.08	365	16
1N4962*	15	75	3.5	150	1.0	5	5	11.4	.08	315	12
1N4963*	16	75	3.5	155	1.1	5	5	12.2	.08	294	10
1N4964*	18	65	4.0	160	1.2	5	5	13.7	.085	264	9.0
1N4965*	20	65	4.5	165	1.5	2	2	15.2	.085	237	8.0
1N4966*	22	50	5.0	170	1.8	2	2	16.7	.085	216	7.0
1N4967*	24	50	5.0	175	2.0	2	2	18.2	.090	198	6.5
1N4968*	27	50	6.0	180	2.0	2	2	20.6	.090	176	6.0
1N4969*	30	40	8	190	2.5	2	2	22.8	.090	158	5.5
1N4970*	33	40	10	200	2.8	2	2	25.1	.095	144	5.0
1N4971*	36	30	11	220	3.0	2	2	27.4	.095	132	4.5
1N4972*	39	30	14	230	3.0	2	2	29.7	.095	122	4.0
1N4973*	43	30	20	240	3.3	2	2	32.7	.095	110	3.5
1N4974*	47	25	25	250	3.5	2	2	35.8	.095	100	3.2
1N4975*	51	25	27	270	4.0	2	2	38.8	.095	92	3.0
1N4976*	56	20	35	320	4.4	2	2	42.6	.095	84	2.8
1N4977*	62	20	42	400	5.0	2	2	47.1	.100	76	2.5
1N4978*	68	20	50	500	5.5	2	2	51.7	.100	70	2.2
1N4979*	75	20	55	620	6.0	2	2	56.0	.100	63.0	2.0
1N4980*	82	15	80	720	6.6	2	2	62.2	.100	58.0	1.8
1N4981*	91	15	90	760	7.5	2	2	69.2	.100	52.5	1.6
1N4982*	100	12	110	800	8.0	2	2	76.0	.100	47.5	1.4
1N4983*	110	12	125	1000	9.0	2	2	83.6	.100	43.0	1.2
1N4984*	120	10	170	1150	10	2	2	91.2	.100	39.5	1.00
1N4985*	130	10	190	1250	11	2	2	98.8	.105	36.6	0.80
1N4986*	150	8	330	1500	13	2	2	114.0	.105	31.6	0.75
1N4987*	160	8	350	1650	14	2	2	121.6	.105	29.4	0.70
1N4988*	180	5	450	1750	16	2	2	136.8	.110	26.4	0.60
1N4989*	200	5	500	1850	18	2	2	152	.110	23.6	0.50
1N4990*	220	5	550	2000	19	2	2	167	.115	21.6	0.50
1N4991*	240	5	650	2050	22	2	2	182	.115	19.8	0.40
1N4992*	270	5	800	2100	25	2	2	206	.120	17.5	0.35
1N4993*	300	4	950	2150	28	2	2	228	.120	15.6	0.30
1N4994*	330	4	1175	2200	32	2	2	251	.120	14.4	0.25
1N4995*	360	3	1400	2300	35	2	2	274	.120	13.0	0.22
1N4996	390	3	1800	2500	40	2	2	297	.120	12.0	0.20

* Available as JAN, JANTX & JANTXV.
† All zener voltages are measured with an automated test set using a 35 msec test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.
§ Zener impedance is derived from the 60-cycle voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.
§§ ΔBV is obtained by measuring the voltage change when the test current is changed from 10% to 50% of Iz max under DC conditions. During this measurement the leads are heat sunk .375 inch from the body and maintained at 25°C.
★ Maximum current based on 5 Watt Rating. See lead temperature derating curves for proper mounting methods.
‡ Figures shown are for peak sinusoidal surge current of 8.3 msec duration, non-repetitive. The 8.3 ms square pulse rating is 71% of the value shown.
†† These specifications apply only to JAN and JANTX

IX

POWER ZENERS

Transient Suppressor Diodes

FEATURES

- 1500 Watts for 1ms Pulse Power Capability
- Small Physical Size
- Designed to be Used in Mil-Std-704A Applications

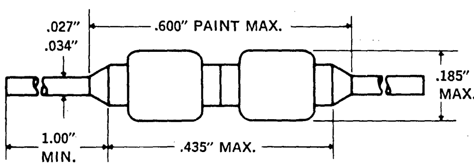
DESCRIPTION

Zener diodes with high surge capability qualified to MIL-S-19500/434. 1N5555 series in DO-13 package and 1N5610 series on double C body for ultimate reliability in repetitive surge applications.

ABSOLUTE MAXIMUM RATINGS (at 25°C except where otherwise noted)

	1N5610	1N5611	1N5612	1N5613
Zener Voltage	See Electrical Specifications			
Forward Surge Current	200A	200A	200A	200A
Zener Surge Current, at 25°C	32.0A	24.0A	19.0A	5.7A
Surge Current, at 150°C	5.5A	4.8A	3.2A	1.0A
Surge Power	See Graph			
Storage and Operating Temperature	—65°C to +175°C			

JAN & JANTX 1N5610-1N5613



Polarity: Cathode indicated by band.
Weight: 1.5 gram (approximate).
Mounting Position: Any. **Leads:** Tinned Copper.
Marking: Type number marked on unit.

Double C BODY

UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Min. Zener Voltage § Vz @ ImA	Max. Zener Voltage† Vz @ Is		Max. Reverse Leakage Current I_R @ V_R		Max. Forward Voltage‡ @ 100 Amps	Typical Temperature Coefficient
	Volts	Volts	Amps	μA	Volts	Volts	%/°C
1N5610*	33.0	47.5	32.0	5.0	30.5	4.8	.093
1N5611*	43.7	63.5	24.0	5.0	40.3	4.8	.094
1N5612*	54.0	79.5	19.0	5.0	49.0	4.8	.096
1N5613*	191.0	265.0	5.7	5.0	175.0	4.8	.100

Notes: * Available as JAN and JANTX.
§ Duration of applied current ⩽ 300ms, duty cycle ⩽ 2%.
† Utilizing a pulse which decays exponentially to 50% of the peak value in 1ms. See graph entitled "Pulse Waveform."
‡ Peak Sinusoidal surge current of 8.3ms duration, non-repetitive.

APPLICATIONS

Voltage transients can be suppressed with series elements, shunt elements, or a combination of both. These elements may be passive or active. For low and medium power applications, a series resistor and zener clamp offer several attractive features:

1. Simplicity of design
2. High reliability
3. Fast response time

The 1N5610 series of surge suppressors will suppress the following transients defined by *MIL-S-704A* without the use of any series limiting resistance beyond that provided by the source:

1. All 600V transients (category #1 on chart below)
2. All 80V transients except those generated by the main voltage regulator (category #2 on chart below)
3. The overvoltage transients generated by the *main voltage regulator* (category #3 on chart below) will also be suppressed by the 1N5610 series if:
   a. A 20 ohm series limiting resistor is used, or
   b. No series resistance is used but the zener is protected within 500 μs by using, for example, an SCR crowbar

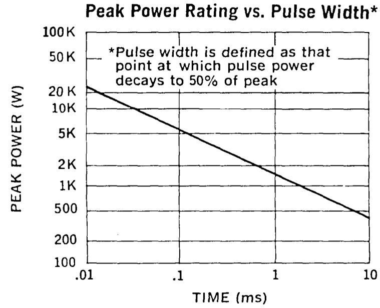
The above statements are based on the source impedances and dv/dt characteristics as given in ARINC* Specification #413. This report entitled "Guidance for Aircraft Electrical Power Utilization and Transient Protection" serves to further define *MIL-STD-704A* for large aircraft electrical systems.

Category	Source of Transient	Maximum Amplitude	Duration	Min. Source Impedance	dv/dt
1.	Inductive Switching	600 V	⩽ 10 μs	50 ohms	
2.	BUS Switching	80 V	⩽ 10 ms	15 ohms	
3.	Main Voltage Regulator	80 V	⩾ 10 ms	0.2 ohms	50V/ms

These Surge Suppressors are useful in a variety of other applications where semiconductor devices must function reliably in an environment subject to extremely high but short term surges.

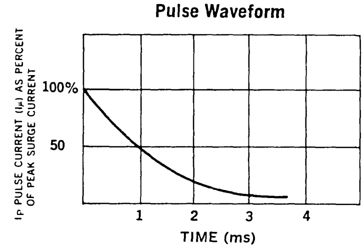
* ARINC stands for Aeronautical Radio, Inc. (Annapolis, Maryland 21401)

Peak Power Rating vs. Pulse Width*

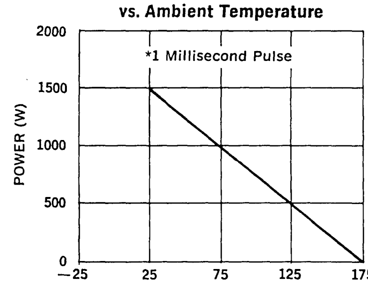


IX

Pulse Waveform



Peak Power Rating* vs. Ambient Temperature



TRANSIENT VOLTAGE SUPPRESSORS
500W, Military

1N6461-1N6468
JAN, JANTX & JANTXV

FEATURES
- 500W Power Capability for 1ms pulse
- Glass Encapsulated Device
- Clamping Time in Picoseconds

DESCRIPTION
Transient voltage suppressor of noncavity design and qualified to MIL-S-19500/551. Metallurgically bonded for high reliabilty.

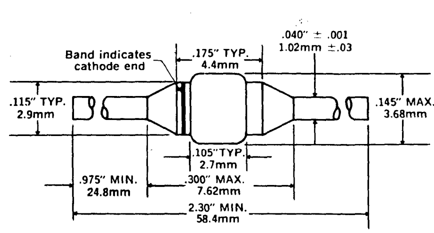
ABSOLUTE MAXIMUM RATINGS @ 25°C

Stand-off Voltage, V_R	5.0V to 51.6V
Peak Pulse Power (1ms)*, P_{PR}	500W
Forward Surge Current @ tp = 8.33ms, I_{FSM}	80A(pk)
Peak Pulse Current	see table
Breakdown Voltage	see table
Power, Continuous (Derate @ 16.7mW/°C above T_A = 25°C), P_R	2.5W
Storage Temperature	−55°C to +200°C
Operating Temperature	−55°C to +175°C

*See Figure 2 for Peak Pulse Power vs. Pulse Duration.

MECHANICAL SPECIFICATIONS

J, JTX & JTXV 1N6461-1N6468



BODY B

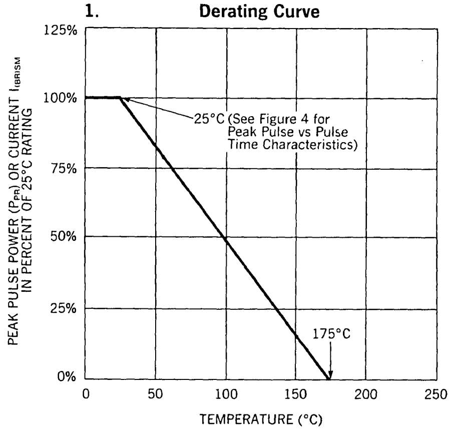
UNITRODE

ELECTRICAL SPECIFICATIONS @ 25°C

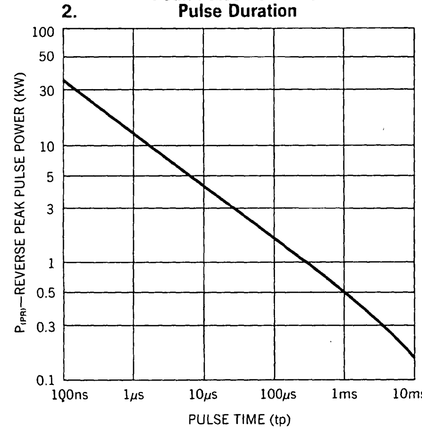
Part No.	Stand-off Voltage V_R	Min. Breakdown Voltage @ I_{BR}	Test Current I_{BR} @ tp = 300ms Duty Cycle ≤ 2%	Max. Leakage Current I_R @ V_R	Max. Peak Pulse Current I_{pp} tp = 1ms tr = 10μs (Fig. 3)	Max. Peak Pulse Current I_{pp} tp = 20μs tr = 8μs (Fig. 4)	Max. Clamping Voltage ($V_{C\ MAX.}$) @ Ipp for tp = 1ms	Max. Clamping Voltage @ Ipp (tp = 1ms) Inverse Voltage $-V_{C\ Max.}$	Max. Temperature Coefficient ∝ $V_{(BR)}$
	V	V	mA	μA	A(pk)	A(pk)	V	V	%/°C
1N6461	5.0	5.6	25	3000	56	315	9.0	-3.5	0.040
1N6462	6.0	6.5	20	2500	46	258	11.0	-3.2	0.040
1N6463	12.0	13.6	5	500	22	125	22.6	-3.8	0.050
1N6464	15.0	16.4	5	500	19	107	26.5	-3.8	0.060
1N6465	24.0	27.0	2	50	12	69	41.4	-3.6	0.084
1N6466	30.5	33.0	1	3	11	63	47.5	-3.6	0.093
1N6467	40.3	43.7	1	2	8	45	63.5	-3.5	0.094
1N6468	51.6	54.0	1	2	6	35	78.5	-3.4	0.096

IX

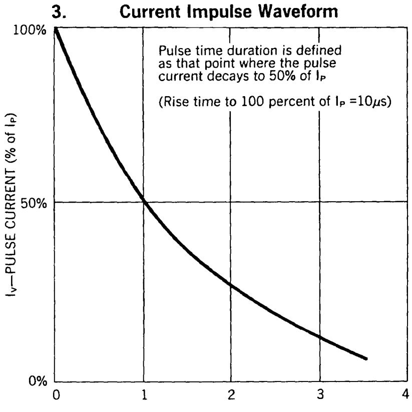
1. Derating Curve



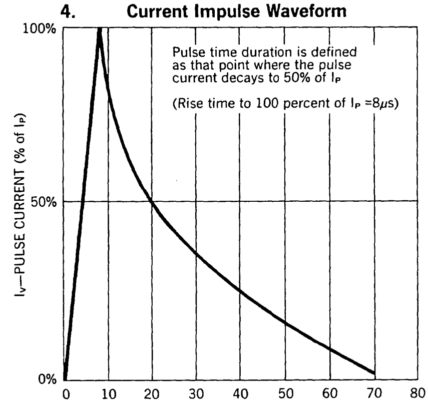
2. Peak Pulse Power vs. Pulse Duration



3. Current Impulse Waveform



4. Current Impulse Waveform



TRANSIENT VOLTAGE SUPPRESSORS

5V Protection for Logic and Memory

TVS5-1
TVS5-2
TVS5-3

FEATURES
- Clamping Time in Picoseconds
- Metallurgically Bonded Construction
- Small Size-Miniature Glass Hermetic Package
- Clamping Voltage Specified at Maximum Current
- Can be Taped and Reeled for Automatic Insertion

DESCRIPTION
Unitrode's TVS5 series is specially designed for clamping and protecting 5V logic lines. High energy pulses can be absorbed repeatedly with negligible degradation while protecting any voltage sensitive components from damage.

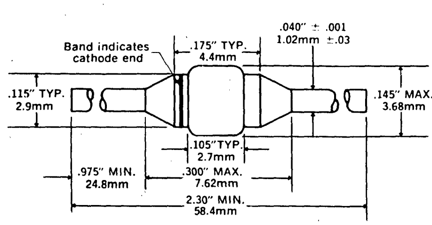
ABSOLUTE MAXIMUM RATINGS @ 25°C

Stand-off Voltage, V_R	5.0V
Peak Pulse Power (1ms)*, P_{PR}	$I_{pp} \times V_C$ @ I_{pp} 1ms
Forward Surge Current (8.3ms Half Sinewave), I_{FSM}	50A
Peak Pulse Current	see table
Breakdown Voltage	see table
Power, Continuous, P_R	5W
Storage and Operating Temperature	−65°C to +175°C

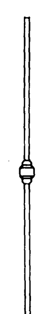
*See Figure 3 for Peak Pulse Power vs. Pulse Duration

MECHANICAL SPECIFICATIONS

TVS5-1 TVS5-2 TVS5-3



BODY B



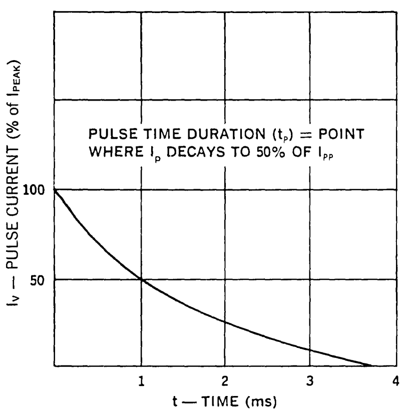
UNITRODE

ELECTRICAL SPECIFICATIONS @ 25°C

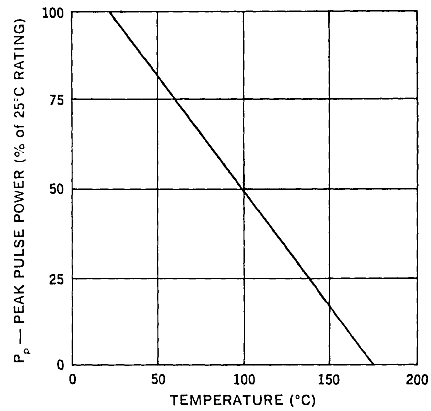
Part No.	Stand-off Voltage V_R	Max. Leakage I_R @ 5V	Min. Impedance Z_Z @ 5V	Max. Peak Pulse Current I_{PP}*	Max. Clamping Voltage V_C @ I_{PP}*	Max. Current To Clamp* @		
						6.8V	7V	7.2V
	V	mA	kΩ	A	V	A	A	A
TVS5-1	5.0	1.0	0.5	45.0	7.5	10	18	32
TVS5-2	5.0	0.7	0.8	48.0	8.5	4	12	20
TVS5-3	5.0	0.3	3.0	53.7	9.3	2	5	12

*For 1ms pulse, see Figure 1

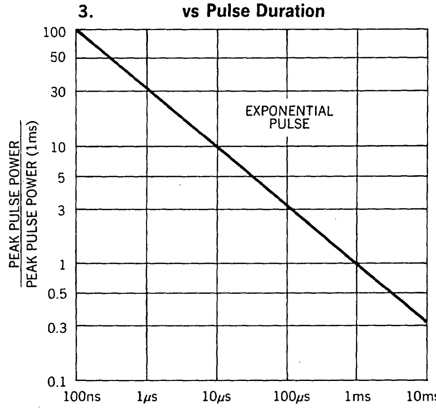
1. Pulse Waveform



2. Derating Curve



3. Normalized Peak Pulse Power vs Pulse Duration



IX

TRANSIENT VOLTAGE SUPPRESSORS

TVS305-TVS430
TVS505-TVS528

FEATURES
- Up to 500W for 1mS Pulse Power Capability
- Clamping Time in Picoseconds
- Direct Applicability for all popular Microprocessors and IC families
- Metallurgically bonded assembly system to assure long term reliability
- Miniature glass encased hermetically sealed package

DESCRIPTION
Unitrode's TVS series of transient voltage suppressors feature oxide passivated zener type chips with full-faced metallurgical bonds on both sides to achieve high surge capability and negligible electrical degradation under repeated surge conditions. The series is especially useful in protecting microprocessor, MOS, CMOS, TTL, Schottky TTL, ECL, I^2L and linear integrated circuits from spurious transient disturbances.

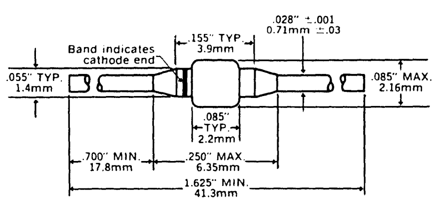
ABSOLUTE MAXIMUM RATINGS @ 25°C

	TVS305-TVS430	TVS505-TVS528
Stand-off Voltage, V_R	5 to 300V	5.0V to 28.0V
Peak Pulse Power (1mS)*	150W	500W
Forward Surge Current (8.3mS half sinewave)	15A	50A
Peak Pulse Current	See Table	See Table
Breakdown Voltage	See Table	See Table
Power, Continuous	3W	5W
Storage and Operating Temperature	−65 to +175°C	−65 to +175°C

*See Figures 3 and 4 for Peak Pulse Power vs Pulse Duration.

MECHANICAL SPECIFICATIONS

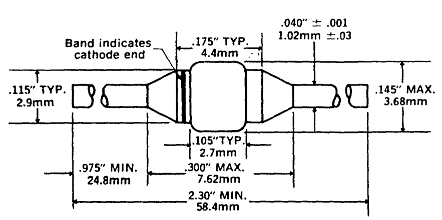
TVS305 Series



BODY A

MECHANICAL SPECIFICATIONS

TVS505 Series



BODY B

UNITRODE

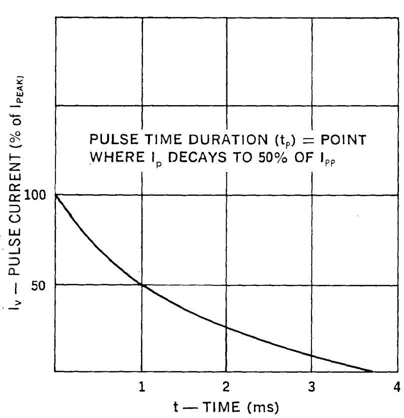
ELECTRICAL SPECIFICATIONS @ 25°C

TVS Part No.	Stand -Off Voltage V_R	Min. Breakdown Voltage $BV_{(min)}$ @ 1mA	Max. Leakage Current I_R @ V_R	Max. Peak Pulse Current* I_{pp}	Max. Clamping Voltage* V_C @ I_{pp}	Max. Clamping Voltage* V_C @ 1A	Max. Clamping Voltage* V_C @ 5A	10A
	V	V	μA	A	V	V	V	
TVS305	5.0	6.0	50	17	8.7	—	—	—
TVS310	10.0	11.1	2	8.9	16.8	—	—	—
TVS312	12	13.8	1	7.1	21.0	—	—	—
TVS315	15	16.7	1	5.9	25	—	—	—
TVS318	18	20.4	1	4.9	31	—	—	—
TVS324	24	28.4	1	3.6	42	—	—	—
TVS328	28	30.7	1	3.2	46	—	—	—
TVS348	48	54	1	1.7	82	—	—	—
TVS360	60	67	1	1.4	105	—	—	—
TVS410	100	111	1	.91	160	—	—	—
TVS420	200	234	1	.42	360	—	—	—
TVS430	300	342	1	.28	520	—	—	—
TVS505	5.0	6.0	300	53.7	9.3	7.4	—	7.9
TVS510	10.0	11.1	5	30.3	16.5	13.2	—	14.4
TVS512	12.0	13.8	5	23.8	21.0	16.5	—	18.5
TVS515	15.0	16.7	5	19.8	25.2	19.7	—	22.2
TVS518	18.0	20.4	5	16.3	30.5	23.8	26.0	—
TVS524	24.0	28.4	5	11.9	42.0	32.4	37.0	—
TVS528	28.0	30.7	5	10.7	46.5	35.9	41.0	—

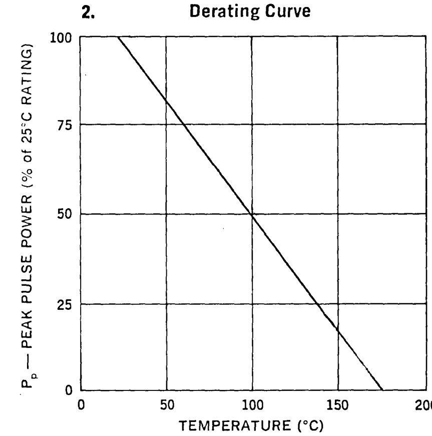
*For 1mS pulse: see Figure 1.

IX

1. Pulse Waveform



2. Derating Curve



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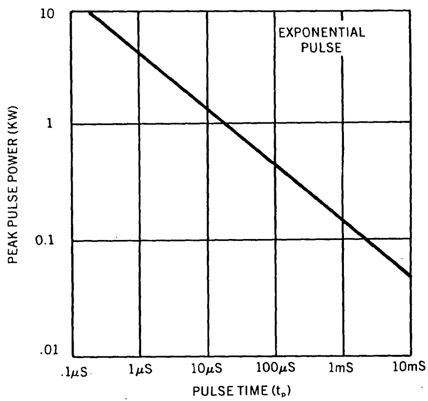
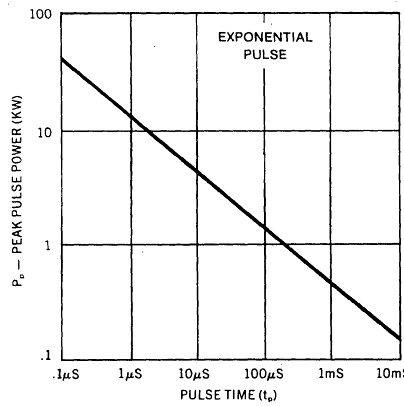
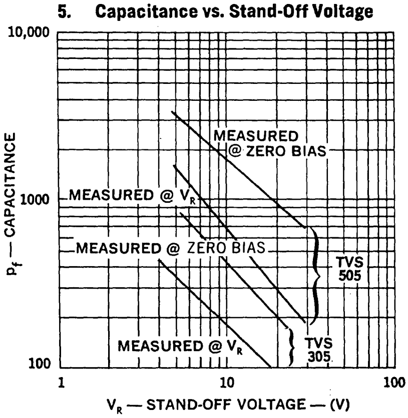
3. Peak Pulse Power vs. Pulse Duration



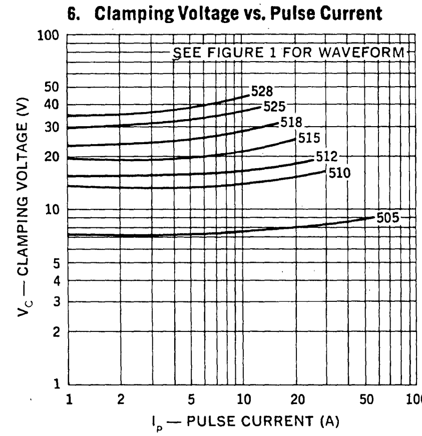
4. Peak Pulse Power vs. Pulse Duration



5. Capacitance vs. Stand-Off Voltage



6. Clamping Voltage vs. Pulse Current



CHOOSING AND SPECIFYING THE PROPER TVS

The following terms are generally used in specifying Transient Voltage Suppressors (TVS):

1. Stand-off Voltage (V_R) is the highest reverse voltage at which the TVS will be non-conducting.
2. Minimum Breakdown Voltage (BV min) is the reverse voltage at which the TVS conducts 1 milli-amp. This is the point where the TVS begins to limit the transient.
3. Maximum Clamping Voltage (V_C max) is the maximum voltage the TVS will allow during a transient "spike."

Figure 7 graphically shows all three terms.

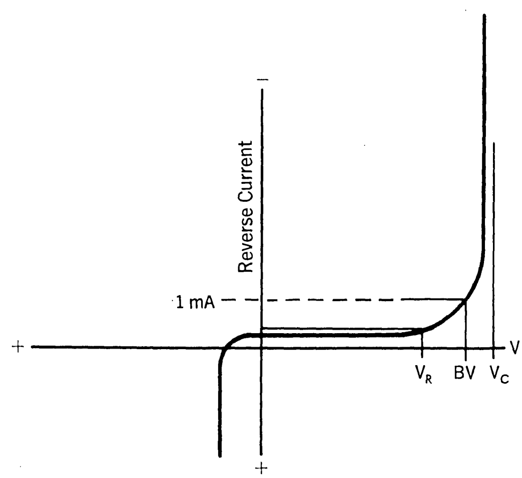


Figure 7

The three most important factors in choosing the appropriate TVS for an application in their order of importance are:

1. Pulse power (P_P) — Choose the TVS series that will handle the Transient Pulse Power. Transient Pulse Power is equal to the clamping voltage (V_C) times the peak pulse current (i_{PP}). The pulse duration vs. pulse power graph on the TVS data sheet can then be used to determine the maximum allowable pulse duration. (Figure 3 or 4).
2. Standoff voltage (V_R) — From the TVS series selected, choose the device with the stand-off voltage equal to or greater than the normal circuit operating voltage.
3. Maximum Clamping Voltage (V_{CMAX}) — Determine the clamping voltage of the device chosen for the transient given and be sure it is below the voltage that might damage any components.

For further information see Unitrode Application Note U-79, "Guidelines for Using Transient Voltage Suppressors."

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AC POWER ZENERS
1, 3 and 5 Watt Types

UDZ807 SERIES
UDZ5807 SERIES
UDZ8807 SERIES

FEATURES
- Zener Characteristics in Both Directions
- 7.5 to 60V
- High Surge Ratings
- Small Physical Size

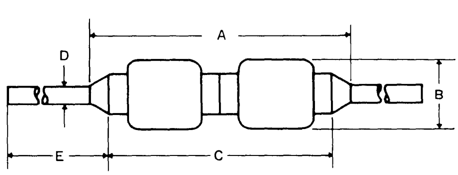
DESCRIPTION
These devices consist of two fused-in-glass zeners brazed anode-to-anode to provide zener action in both directions.

ABSOLUTE MAXIMUM RATINGS

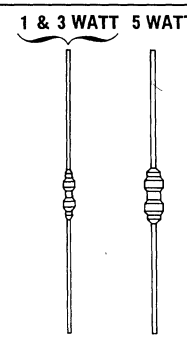
Zener Voltage	7.5 to 60V
Continuous Current	See Tables
Surge Current (8.3ms)	See Tables
Surge Power	See Graph
Power	See Data Sheets for Related Series (UZ8807, UZ807 and UZ5807)
Storage and Operating Temperature	—65°C to +175°C

MECHANICAL SPECIFICATIONS

UDZ807 SERIES UDZ5807 SERIES UDZ8807 SERIES



MARKING: "D," followed by last 3 to 4 digits and part number. *Example: 7.5 volt ±10%, 1 watt type would be marked: "D8807".*



Dimensions

1 Watt UDZ8807 Series

	ins.	mm
A	.450 MAX.	11.43 MAX.
B	.085 MAX.	2.16 MAX.
C	.275 TYP.	6.99 TYP.
D	.028 ± .001	.71 ± .03
E	.700 MIN.	17.78 MIN.

3 Watt UDZ807 Series

	ins.	mm
A	.450 MAX.	11.43 MAX.
B	.085 MAX.	2.16 MAX.
C	.275 TYP.	6.99 TYP.
D	.028 ± .001	.71 ± .03
E	.700 MIN.	17.78 MIN.

5 Watt UDZ5807 Series

	ins.	mm
A	.500 MAX.	12.70 MAX.
B	.145 MAX.	3.68 MAX.
C	.325 TYP.	8.26 TYP.
D	.040 ± .001	1.02 ± .03
E	.975 MIN.	24.77 MIN.

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Type	Electrical Specifications at 25°C						Maximum Ratings**	
	Nominal Zener Voltage† V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Imped § Z_Z @ I_{ZT}	Maximum Leakage Current	@ Reverse Voltage ±10%	±5%	Maximum Cont. Current I_{ZM}	Maximum Surge Current‡ I_S
±10% Tolerance*	Volts	mA	Ohms	μA	Volts	Volts	mA	Amps
1 WATT ZENERS — Specifications apply for both directions.								
UDZ8807	7.5	34	6	50	4.9	5.2	125	5
UDZ8808	8.2	31	7	30	5.4	5.7	115	4.5
UDZ8809	9.1	28	8	10	5.9	6.2	105	3.9
UDZ8810	10	25	8.5	3	6.6	6.9	95	3.37
UDZ8812	12	23	9	1	8.6	9.1	85	2.25
UDZ8815	15	17	14	0.5	10.8	11.4	63	1.65
UDZ8818	18	14	20	0.5	12.9	13.7	52	1.12
UDZ8820	20	12.5	23	0.5	14.4	15.2	47	1.12
UDZ8824	24	10.5	25	0.5	17.3	18.2	40	0.825
UDZ8827	27	9.5	35	0.5	19.4	20.6	35	0.825
UDZ8830	30	8.5	40	0.5	21.6	22.8	31	0.825
UDZ8833	33	7.5	45	0.5	23.7	25.1	28	0.675
UDZ8836	36	7.0	50	0.5	25.9	27.4	26	0.562
UDZ8840	40	6.5	62	0.5	28.8	30.4	24	0.562
UDZ8845	45	6	75	0.5	32.4	34.2	22	0.450
UDZ8860	60	4	125	0.5	43.2	45.6	15	0.337
3 WATT ZENERS — Specifications apply for both directions.								
UDZ807	7.5	75	3	500	4.9	5.2	400	10
UDZ808	8.2	75	4	300	5.4	5.7	360	8
UDZ809	9.1	75	4	200	5.9	6.2	330	7
UDZ810	10	75	5	100	6.6	6.9	300	5
UDZ812	12	65	5	10	8.6	9.1	250	4
UDZ815	15	50	6	10	10.8	11.4	200	3
UDZ818	18	40	8	5	12.9	13.7	170	2
UDZ820	20	40	9	5	14.4	15.2	150	2
UDZ824	24	30	10	5	17.3	18.2	125	1.5
UDZ827	27	25	12	1	19.4	20.6	110	1.5
UDZ830	30	25	15	1	21.6	22.8	100	1.5
UDZ833	33	20	21	1	23.7	25.1	90	1.2
UDZ836	36	20	21	1	25.9	27.4	85	1
UDZ840	40	20	27	1	28.8	30.4	75	1
UDZ845	45	15	37	1	32.4	34.7	65	0.8
UDZ860	60	10	70	1	43.2	45.6	50	0.6

*For ±5% voltage tolerance change the 3rd number from the right from 8 to 7 i.e. UDZ8807 to UDZ8707, etc.

†All zener voltages are measured with an automated test set using a 35ms test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

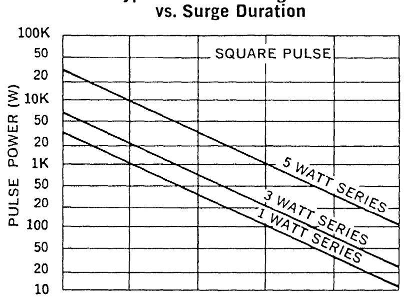
§Zener impedance is derived from the 60-cycle voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

**D.C. Ratings are based on the lead temperature conditions shown in the data sheets covering the UDZ8807, UDZ807, and UDZ5807 series devices. Other conditions will affect the power ratings of all the families except the 1 watt zener family. However, the surge values given apply for any mounting conditions including printed circuit board mounting.

‡Figures shown are for peak sinusoidal surge current of 8.3ms duration using 60 cycle AC. The 8.3ms square pulse rating is 71% of the value shown.

IX

Typical Reverse Surge Power vs. Surge Duration



For Sinusoidal Pulse, Peak Value is 1.4 Times Value Shown

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Type	Electrical Specifications at 25°C						Maximum Ratings**	
	Nominal Zener Voltage† V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Imped § Z_Z @ I_{ZT}	Maximum Leakage Current	@ Reverse Voltage ±10%	±5%	Maximum Cont. Current I_{ZM}	Maximum Surge Current‡ I_S
±10% Tolerance*	Volts	mA	Ohms	μA	Volts	Volts	mA	Amps
5 WATT ZENERS — Specifications apply for both directions.								
UDZ5807	7.5	175	1.8	500	4.9	5.2	620	40
UDZ5808	8.2	150	1.8	400	5.4	5.7	570	32
UDZ5809	9.1	150	2.5	200	5.9	6.2	510	24
UDZ5810	10	125	2.5	100	6.6	6.9	470	22
UDZ5812	12	100	2.5	50	8.6	9.1	385	18
UDZ5815	15	75	3.5	15	10.8	11.4	300	12
UDZ5818	18	65	4	10	12.9	13.7	255	9
UDZ5820	20	65	4.5	10	14.4	15.2	220	8
UDZ5824	24	50	5	10	17.3	18.2	180	6.5
UDZ5827	27	50	6	10	19.4	20.6	155	6
UDZ5830	30	40	8	10	21.6	22.8	140	5.5
UDZ5833	33	40	10	5	23.7	25.1	130	5
UDZ5836	36	30	11	5	25.9	27.4	120	4.5
UDZ5840	40	30	14	5	28.8	30.4	105	4
UDZ5845	45	30	20	5	32.4	34.2	95	3.5
UDZ5860	60	20	40	5	43.2	45.6	75	2.5

*For ±5% voltage tolerance change the 3rd number from the right from 8 to 7 i.e. UDZ8807 to UDZ8707, etc.

†All zener voltages are measured with an automated test set using a 35ms test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§Zener impedance is derived from the 60-cycle voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

**D.C. Ratings are based on the lead temperature conditions shown in the data sheets covering the UDZ8807, UDZ807, and UDZ5807 series devices. Other conditions will affect the power ratings of all the families except the 1 watt zener family. However, the surge values given apply for any mounting conditions including printed circuit board mounting.

‡Figures shown are for peak sinusoidal surge current of 8.3ms duration using 60 cycle AC. The 8.3ms square pulse rating is 71% of the value shown.

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POWER ZENERS
3 Watt

UZ706 SERIES
UZ806 SERIES

FEATURES
- 10 Times Greater Surge Rating than Conventional 1 Watt Types
- Small Physical Size

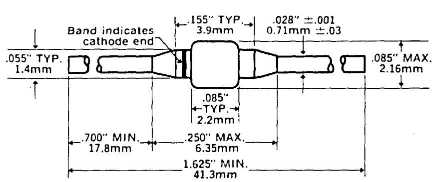
DESCRIPTION
Fused-in-glass metallurgically bonded 3 watt zener diodes.

ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 400V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	—65°C to +175°C

MECHANICAL SPECIFICATIONS

UZ706 SERIES UZ806 SERIES

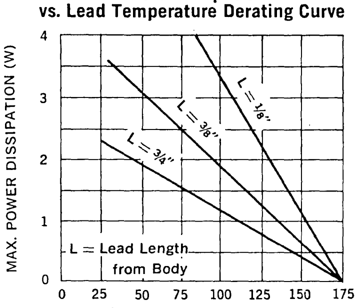


UZ Prefix is identified by a Blue or Red Cathode Band

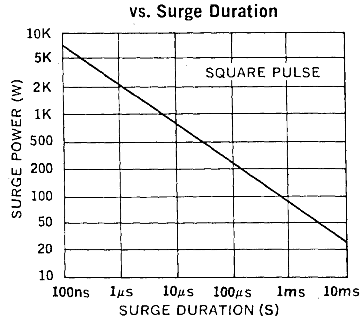
BODY A

IX

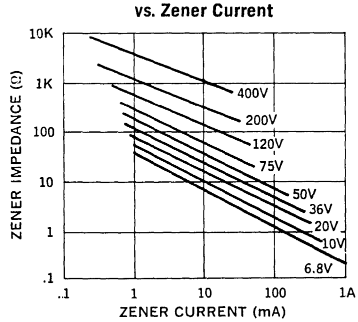
Power Dissipation vs. Lead Temperature Derating Curve



Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



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Type*		Electrical Specifications at 25°C							Maximum Ratings	
		Nominal Zener Voltage † V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Impedance § Z_Z @ I_{ZT}	Maximum Reverse Leakage Current I_R @ V_R	± 5% V_R	± 10% V_R	Typ. Temp. Coefficient T_C @ I_{ZT}	Maximum Continuous Current ★ I_{ZM}	Maximum Surge Current‡ I_S
±5% Tolerance	Jedec** Registration	Volts	mA	Ohms	μA	Volts	Volts	%/°C	mA	Amps
UZ706	1N5063	6.8	75	2	500	5.2	4.9	.04	440	10.0
UZ707	1N5064	7.5	75	2	300	5.7	5.4	.04	400	8.0
UZ708	1N5065	8.2	75	3	200	6.2	5.9	.05	360	7.0
UZ709	1N5066	9.1	75	3	100	6.9	6.6	.05	330	6.0
UZ710	1N5067	10.0	75	4	40	7.6	7.2	.06	300	5.0
UZ712	1N4883	12	65	5	10	9.1	8.6	.07	250	4.0
UZ713	1N5069	13	50	6	10	9.9	9.3	.07	230	4.0
UZ714	1N5070	14	50	6	10	10.6	10.1	.07	210	4.0
UZ715	1N5071	15	50	6	10	11.4	10.8	.07	200	3.0
UZ716	1N5072	16	50	7	5	12.2	11.5	.07	185	3.0
UZ718	1N5073	18	40	8	5	13.7	12.9	.08	170	2.0
UZ720	1N4884	20	40	9	5	15.2	14.4	.08	150	2.0
UZ722	1N5074	22	30	10	5	16.7	15.8	.08	135	2.0
UZ724	1N5075	24	30	10	5	18.2	17.3	.08	125	1.5
UZ727	1N5076	27	25	12	1	20.6	19.4	.09	110	1.5
UZ730	1N5077	30	25	15	1	22.8	21.6	.090	100	1.5
UZ733	1N5078	33	20	21	1	25.1	23.7	.090	90	1.2
UZ736	1N5079	36	20	21	1	27.4	25.9	.090	85	1.0
UZ740	1N5081	40	20	27	1	30.4	28.8	.095	75	1.0
UZ745	1N5083	45	15	37	1	34.2	32.4	.095	65	0.8
UZ750	1N5085	50	15	50	1	38.0	36.0	.095	60	0.8
UZ756	1N5087	56	10	70	1	42.6	40.3	.095	55	0.7
UZ760	1N5088	60	10	70	1	45.7	43.2	.095	50	0.6
UZ770	1N5091	70	10	90	1	53.3	50.5	.095	45	0.6
UZ775	1N5092	75	10	100	1	56.0	54.0	.095	40	0.5
UZ780	1N5093	80	10	115	1	60.8	57.7	.095	35	0.4
UZ790	1N4096	90	8.0	150	1	68.5	64.8	.095	30	0.4
UZ110	1N4097	100	5.0	175	1	76.0	72.0	.100	30	0.4
UZ111	1N5096	110	5.0	250	1	83.6	79.2	.100	25	0.3
UZ112	1N5097	120	5.0	325	1	91.2	86.4	.100	25	0.2
UZ113	1N5098	130	5.0	375	1	98.8	93.6	.100	20	0.20
UZ114	1N5099	140	5.0	550	1	106	101	.100	20	0.20
UZ115	1N4098	150	5.0	650	1	114	108	.100	20	0.20
UZ116	1N5100	160	4.0	700	1	122	115	.100	20	0.15
UZ117	1N5101	170	4.0	750	1	129	122	.100	18	0.15
UZ118	1N5102	180	4.0	850	1	137	129	.100	18	0.10
UZ119	1N5103	190	4.0	900	1	144	137	.100	15	0.10
UZ120	1N5104	200	4.0	950	1	152	144	.100	15	0.10
UZ122	1N5105	220	3.0	1100	1	167	158	.100	15	0.09
UZ124	1N5106	240	3.0	1300	1	182	173	.105	12	0.09
UZ126	1N5107	260	3.0	1500	1	198	187	.105	12	0.08
UZ128	1N5109	280	3.0	1700	1	213	202	.105	10	0.08
UZ130	1N5110	300	3.0	1900	1	228	216	.105	10	0.07
UZ132	1N5111	320	2.0	2100	1	243	230	.105	9	0.07
UZ134	1N5113	340	2.0	2400	1	258	245	.110	9	0.06
UZ136	1N5114	360	2.0	2700	1	274	259	.110	8	0.06
UZ138	1N5115	380	2.0	3000	1	289	274	.110	8	0.06
UZ140	1N5117	400	2.0	3500	1	304	288	.110	7	0.06

* Specify 20% voltage tolerance by changing first numeral of type number from 7 to 9. (UZ709 becomes UZ909) or from 1 to 3 (UZ111 becomes UZ311).
Specify 10% voltage tolerance by changing first numeral of type number from 7 to 8. (UZ709 becomes UZ809) or from 1 to 2 (UZ111 becomes UZ211).

** Jedec registration applies to ±5% tolerance zeners only.

† All zener voltages are measured with an automated test set using a 35 ms test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§ Zener impedance is derived from the 60-cycle AC voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

★ Maximum current based on 3 watt rating. See lead temperature derating curves for proper mounting methods.

‡ Figures shown are for a peak sinusoidal surge current of 8.3ms duration using 60 cycle AC. The 8.3ms square pulse rating is 71% of the value shown.

POWER ZENERS
5 Watt, Industrial

UZ4706 SERIES
UZ4806 SERIES

FEATURES
- 2 Times Greater Surge Rating than Plastic Types
- Small Physical Size
- Impervious to Moisture

DESCRIPTION

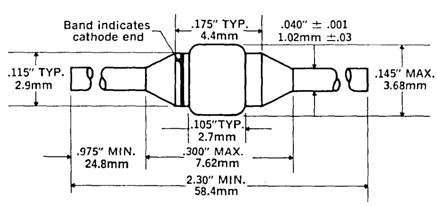
Fused-in-glass 5 watt zeners with the same electrical specs as the 1N5342-1N5388 series.

ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 200V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	−65°C to +175°C

MECHANICAL SPECIFICATIONS

UZ4706 SERIES UZ4806 SERIES

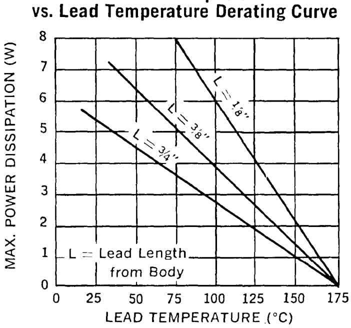


UZ Prefix is identified by a Blue or Red Cathode Band

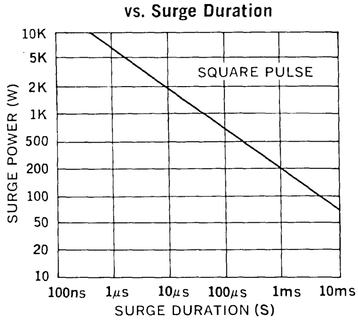
BODY B

IX

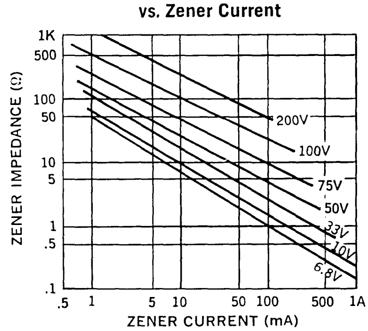
Power Dissipation vs. Lead Temperature Derating Curve



Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



UNITRODE

Type		Electrical Specifications at 25°C							Maximum Ratings	
		Nominal Zener Voltage † V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Impedance §		Reverse Voltage			Maximum Cont. Current I_{ZM}	Maximum Surge Current ‡ I_S
				Z_Z @ I_{ZT}	Z_{ZK} @ I_{ZK} = ImA	Maximum Leakage Current	@ Reverse Voltage ±10%	±5%		
±5% Tolerance	±10% Tolerance	Volts	mA	Ohms	Ohms	µA	Volts	Volts	mA	Amps
UZ4706	UZ4806	6.8	175	1	1000	500	4.9	5.2	675	32
UZ4707	UZ4807	7.5	175	1.5	800	400	5.4	5.7	620	26.5
UZ4708	UZ4808	8.2	150	1.5	600	200	5.9	6.2	570	19.2
UZ4709	UZ4809	9.1	150	2	400	100	6.6	6.9	510	17.6
UZ4710	UZ4810	10	125	2	125	75	7.2	7.6	470	16
UZ4712	UZ4812	12	100	2.5	140	50	8.6	9.1	385	14.4
UZ4713	UZ4813	13	100	3	145	25	9.3	9.9	350	12.8
UZ4715	UZ4815	15	75	3.5	150	15	10.8	11.4	300	9.6
UZ4716	UZ4816	16	75	3.5	155	10	11.5	12.2	275	8
UZ4718	UZ4818	18	65	4	160	10	12.9	13.7	255	7.2
UZ4720	UZ4820	20	65	4.5	165	10	14.4	15.2	220	6.4
UZ4722	UZ4822	22	50	5	170	10	15.8	16.7	195	5.6
UZ4724	UZ4824	24	50	5	175	10	17.3	18.2	180	5.2
UZ4727	UZ4827	27	50	6	180	10	19.4	20.6	155	4.8
UZ4730	UZ4830	30	40	8	190	10	21.6	22.8	140	4.4
UZ4733	UZ4833	33	40	10	200	5	23.7	25.1	130	4.0
UZ4736	UZ4836	36	30	11	220	5	25.9	27.4	120	3.6
UZ4739	UZ4839	39	30	14	230	5	28.1	29.7	105	3.2
UZ4743	UZ4843	43	30	20	240	5	31	32.7	100	2.8
UZ4747	UZ4847	47	25	25	250	5	33.8	35.8	96	2.6
UZ4751	UZ4851	51	25	27	270	5	36.7	38.8	85	2.4
UZ4756	UZ4856	56	20	35	320	5	40.3	42.6	81	2.2
UZ4762	UZ4862	62	20	42	400	5	44.6	47.1	73	2.0
UZ4768	UZ4868	68	20	50	500	5	49.0	51.7	61	1.8
UZ4775	UZ4875	75	20	55	620	5	54.0	56	60	1.6
UZ4782	UZ4882	82	15	80	720	5	59.0	62.2	55	1.4
UZ4791	UZ4891	91	15	90	760	5	65.5	69.2	50	1.3
UZ4110	UZ4210	100	12	100	800	5	72.0	76.0	45	1.1
UZ4111	UZ4211	110	12	125	1000	5	79.2	83.6	40	1.0
UZ4112	UZ4212	120	10	170	1150	5	86.4	91.2	38	.8
UZ4113	UZ4213	130	10	190	1250	5	93.6	98.8	35	.64
UZ4115	UZ4215	150	8	330	1500	5	108	114.0	31	.60
UZ4116	UZ4216	160	8	350	1650	5	115	121.6	30	.56
UZ4118	UZ4218	180	5	450	1750	5	129	136.8	25	.48
UZ4120	UZ4220	200	5	500	1850	5	144	152.0	22	.40

Maximum V_F @ 1.0 Amp = 1.2 Volts for all types

†All zener voltages are measured with an automated test set using a 35 ms test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§Zener impedance is derived from the 60-cycle voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

‡Figures shown are for peak sinusoidal surge current of 8.3 ms duration using 60 cycle AC. The 8.3ms square pulse rating is 71% of the value shown.

POWER ZENERS
5 Watt

UZ5706 SERIES
UZ5806 SERIES

FEATURES
- 2 Times Greater Surge Rating than Conventional 10 Watt Zeners
- Small Physical Size

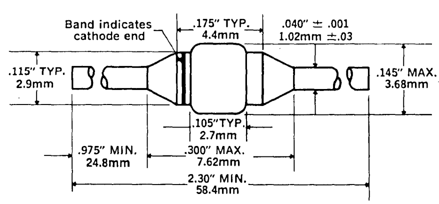
DESCRIPTION
Fused-in-glass, metallurgically-bonded 5 watt zeners.

ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 400V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	—65°C to +175°C

MECHANICAL SPECIFICATIONS

UZ5706 SERIES UZ5806 SERIES

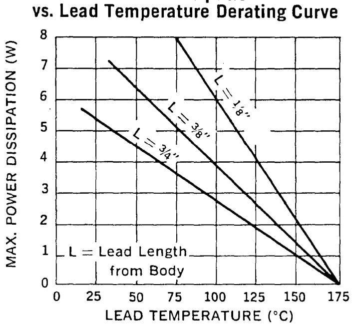


UZ Prefix is identified by a Blue or Red Cathode Band

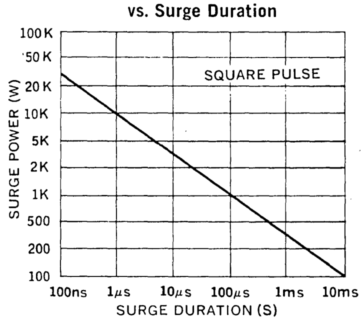
BODY B

IX

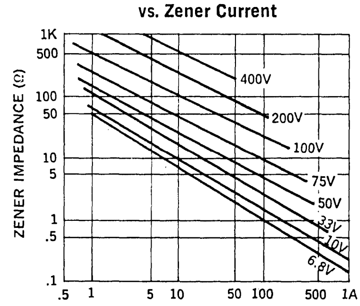
Power Dissipation vs. Lead Temperature Derating Curve



Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



UNITRODE

Type *		Electrical Specifications at 25°C							Maximum Ratings	
		Nominal Zener Voltage † V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Impedance § Z_Z @ I_{ZT}	Maximum Reverse Leakage Current I_R	± 5% V_R	± 10% V_R	Typ. Temp. Coeff. T_C @ I_{ZT}	Maximum Continuous Current ★ I_{ZM}	Maximum Surge Current ‡ I_S
±5% Tolerance	±10% Tolerance	Volts	mA	Ohms	µA	Volts	Volts	%/°C	mA	Amps
UZ5706	UZ5806	6.8	175	1.0	500	5.2	4.9	.05	675	40
UZ5707	UZ5807	7.5	175	1.5	400	5.7	5.4	.06	620	32
UZ5708	UZ5808	8.2	150	1.5	200	6.2	5.9	.06	570	24
UZ5709	UZ5809	9.1	150	2.0	100	6.9	6.6	.06	510	22
UZ5710	UZ5810	10.0	125	2.0	75	7.6	7.2	.07	470	20
UZ5712	UZ5812	12	100	2.5	50	9.1	8.6	.07	385	18
UZ5713	UZ5813	13	100	3.0	25	9.9	9.3	.08	350	16
UZ5714	UZ5814	14	100	3.0	20	10.6	10.1	.08	320	14
UZ5715	UZ5815	15	75	3.5	15	11.4	10.8	.08	300	12
UZ5716	UZ5816	16	75	3.5	10	12.2	11.5	.08	275	10
UZ5718	UZ5818	18	65	4.0	10	13.7	12.9	.085	255	9.0
UZ5720	UZ5820	20	65	4.5	10	15.2	14.4	.085	220	8.0
UZ5722	UZ5822	22	50	5.0	10	16.7	15.8	.085	195	7.0
UZ5724	UZ5824	24	50	5.0	10	18.2	17.3	.090	180	6.5
UZ5727	UZ5827	27	50	6.0	10	20.6	19.4	.090	155	6.0
UZ5730	UZ5830	30	40	8	10	22.8	21.6	.09	140	5.5
UZ5733	UZ5833	33	40	10	5	25.1	23.7	.09	130	5.0
UZ5736	UZ5836	36	30	11	5	27.4	25.9	.095	120	4.5
UZ5740	UZ5840	40	30	14	5	30.4	28.8	.095	105	4.0
UZ5745	UZ5845	45	30	20	5	34.2	32.4	.095	95	3.5
UZ5750	UZ5850	50	25	25	5	38.0	36.0	.095	85	3.0
UZ5756	UZ5856	56	20	35	5	42.6	40.3	.095	80	2.8
UZ5760	UZ5860	60	20	40	5	45.7	43.2	.100	75	2.5
UZ5770	UZ5870	70	20	50	5	53.3	50.5	.100	65	2.3
UZ5775	UZ5875	75	15	55	5	56.0	54.0	.100	60	2.0
UZ5780	UZ5880	80	15	80	5	60.8	57.7	.100	55	1.8
UZ5790	UZ5890	90	15	90	5	68.5	64.8	.100	50	1.6
UZ5110	UZ5210	100	10	100	5	76.0	72.0	.100	45	1.4
UZ5111	UZ5211	110	10	125	5	83.6	79.2	.100	40	1.2
UZ5112	UZ5212	120	10	170	5	91.2	86.4	.100	38	1.0
UZ5113	UZ5213	130	10	190	5	98.8	93.6	.105	35	0.80
UZ5114	UZ5214	140	8	230	5	106.0	101.0	.105	33	0.80
UZ5115	UZ5215	150	8	330	5	114.0	108.0	.105	31	0.75
UZ5116	UZ5216	160	8	350	5	122.0	115.0	.105	30	0.70
UZ5117	UZ5217	170	8	380	5	129.0	122.0	.105	27	0.65
UZ5118	UZ5218	180	5	450	5	137	129	.110	25	0.60
UZ5119	UZ5219	190	5	470	5	144	137	.110	24	0.55
UZ5120	UZ5220	200	5	500	5	152	144	.110	22	0.50
UZ5122	UZ5222	220	5	550	5	167	158	.115	20	0.45
UZ5124	UZ5224	240	5	650	5	182	173	.115	18	0.40
UZ5126	UZ5226	260	5	750	5	198	187	.120	17	0.35
UZ5128	UZ5228	280	4	850	5	213	202	.120	16	0.30
UZ5130	UZ5230	300	4	950	5	228	216	.120	15	0.25
UZ5132	UZ5232	320	4	1100	5	243	230	.120	14	0.24
UZ5134	UZ5234	340	4	1200	5	258	245	.120	13	0.23
UZ5136	UZ5236	360	3	1400	5	274	259	.120	12	0.22
UZ5138	UZ5238	380	3	1500	5	289	274	.120	12	0.21
UZ5140	UZ5240	400	3	1800	5	304	288	.120	11	0.20

Temperature Range: Operating and Storage −65°C to +175°C.

* Specify 20% tolerance by changing the second numeral of type number from 8 to 9 (UZ5809 becomes UZ5909) or from 2 to 3 (UZ5211 becomes UZ5311).

† All zener voltages are measured with an automated test set using a 35 millisecond test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§ Zener impedance is derived from the 60-cycle AC voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

★ Maximum current based on 5 watt rating. See lead temperature derating curves for proper mounting methods.

‡ Figures shown are for a peak sinusoidal surge current of 8.3ms duration using 60 cycle AC. The 8.3ms square pulse rating is 71% of the value shown.

Several of the above types now have JEDEC 1N type numbers. The following cross-reference table lists the appropriate 1N numbers; specifications are same as above.

JEDEC #	UNITRODE TYPE	JEDEC #	UNITRODE TYPE	JEDEC #	UNITRODE TYPE
1N5118	UZ5714	1N5124	UZ5780	1N5130	UZ5128
1N5119	UZ5740	1N5125	UZ5790	1N5131	UZ5132
1N5120	UZ5745	1N5126	UZ5114	1N5132	UZ5134
1N5121	UZ5750	1N5127	UZ5117	1N5133	UZ5138
1N5122	UZ5760	1N5128	UZ5119	1N5134	UZ5140
1N5123	UZ5770	1N5129	UZ5126		

UNITRODE CORPORATION • 5 FORBES ROAD
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TWX (710) 326-6509 • TELEX 95-1064

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POWER ZENERS
6 Watt, Military, 10 Watt Military

UZ7706L and UZ7806L SERIES
UZ7706 and UZ7806 SERIES

FEATURES
- High Surge Rating
- Small Physical Size
- Leaded and Stud Packages Available

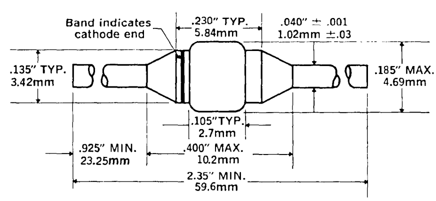
DESCRIPTION
Fused-in-glass, metallurgically bonded 6 watt leaded zeners and 10 watt stud-type zeners.

ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 100V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power — UZ7706L & UZ7806L	See Lead Temperature Derating Curve
UZ7706 & UZ7806 @100°C Case	10W
Storage and Operating Temperature	—65°C to +175°C

MECHANICAL SPECIFICATIONS

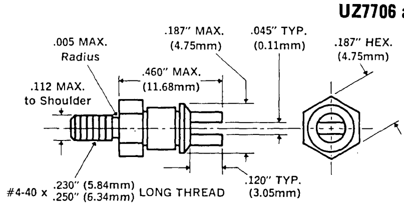
UZ7706L and UZ7806L SERIES



UZ Prefix is identified by a Blue or Red Cathode Band

BODY C — Lead Mount

UZ7706 and UZ7806 SERIES



POLARITY: Cathode to Stud is standard. Reverse polarity denoted by "R" suffix.

FINISH: Metal parts gold plated per MIL-G-45204, Type II.

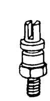
WEIGHT: 1.5 grams (max.)

INSTALLATION PRECAUTIONS: Maximum unlubricated stud torque: 28 inch-ounces. Do not use a screwdriver in the turret slot for installation purposes, or damage may result.

UZ Prefix is identified by a Blue or Red Cathode Band

Also available with insulated stud. Reference Design Note-17.

BODY C — Stud Mount



IX

UNITRODE

Type *		Electrical Specifications at 25°C							Maximum Ratings	
		Nominal Zener Voltage † V_Z @ I_{ZT}	Test Current I_{ZT}	Max. Zener Impedance § Z_Z @ I_{ZT}	Maximum Reverse Leakage Current			Typ. Temp. Coeff. T_C @ I_{ZT}	Maximum Continuous Current ★ I_{ZM}	Maximum Surge Current ‡ I_S
					I_R @ V_R	± 5% V_R	± 10% V_R			
±5% Tolerance	±10% Tolerance	Volts	mA	Ohms	μA	Volts	Volts	%/°C	mA	Amps
UZ7706	UZ7806	6.8	350	0.6	1000	5.2	4.9	.04	1350	50
UZ7707	UZ7807	7.5	325	0.7	800	5.7	5.4	.04	1250	41
UZ7708	UZ7808	8.2	300	0.8	200	6.2	5.9	.05	1150	31
UZ7709	UZ7809	9.1	275	1.0	150	6.9	6.6	.05	1020	29
UZ7710	UZ7810	10.0	250	1.0	100	7.6	7.2	.06	950	26
UZ7712	UZ7812	12	200	1.3	75	9.1	8.6	.07	770	23
UZ7713	UZ7813	13	200	1.5	50	9.9	9.3	.07	700	21
UZ7714	UZ7814	14	175	1.5	40	10.6	10.1	.07	640	20
UZ7715	UZ7815	15	150	2.0	30	11.4	10.8	.07	600	17
UZ7716	UZ7816	16	150	2.5	20	12.2	11.5	.07	550	15
UZ7718	UZ7818	18	130	3.5	20	13.7	12.9	.08	500	13
UZ7720	UZ7820	20	120	4.0	20	15.2	14.4	.08	440	12
UZ7722	UZ7822	22	100	4.5	20	16.7	15.8	.08	390	11
UZ7724	UZ7824	24	100	5.0	20	18.2	17.3	.08	360	10
UZ7727	UZ7827	27	90	6.0	20	20.6	19.4	.09	310	9
UZ7730	UZ7830	30	80	8	20	22.8	21.6	.090	280	8.5
UZ7733	UZ7833	33	70	10	10	25.1	23.7	.090	260	7.5
UZ7736	UZ7836	36	60	12	10	27.4	25.9	.090	240	7.0
UZ7740	UZ7840	40	60	15	10	30.4	28.8	.095	210	6.4
UZ7745	UZ7845	45	50	20	10	34.2	32.4	.095	180	5.5
UZ7750	UZ7850	50	50	22	10	38.0	36.0	.095	170	4.6
UZ7756	UZ7856	56	40	30	10	42.6	40.3	.095	160	4.1
UZ7760	UZ7860	60	40	35	10	45.6	43.2	.095	150	3.7
UZ7770	UZ7870	70	35	40	10	53.2	50.4	.095	130	3.3
UZ7775	UZ7875	75	30	45	10	56.0	54.0	.095	120	3.1
UZ7780	UZ7880	80	30	60	10	60.8	57.6	.095	110	2.9
UZ7790	UZ7890	90	25	75	10	68.4	64.8	.095	100	2.6
UZ7110	UZ7210	100	20	90	10	76.0	72.0	.100	90	2.3

Power Rating: Stud Mounted: 10 Watts at 100°C Case derate linerally to zero at 175°C Case.
Lead Mounted: See lead temperature derating curve.
Temperature Range: Operating and storage −65°C to 175°C.

★ Specify 20% tolerance by changing the second numeral of type number from 8 to 9 (UZ7809 becomes UZ7909) or from 2 to 3 (UZ7210 becomes UZ7310). Specify leaded version by adding an L suffix (UZ7809 becomes UZ7809L).

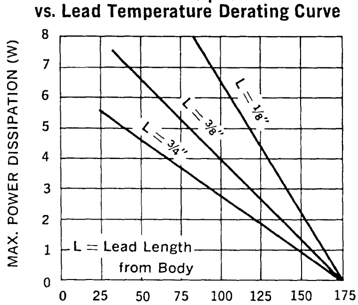
† All zener voltages are measured with an automated test set using a 35 msec test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§ Zener impedance is derived from the 60-cycle voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

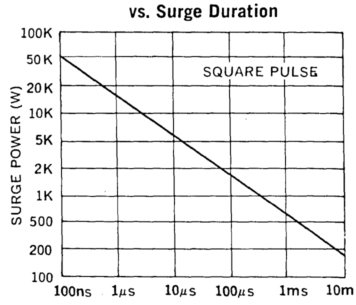
★ Ratings Based on 100°C Case temperature; for leaded devices multiply by 0.6.

‡ Figures shown are for a peak sinusoidal surge current of 8.3ms duration, non-repetitive. The 8.3ms square pulse rating is 71% of the value shown.

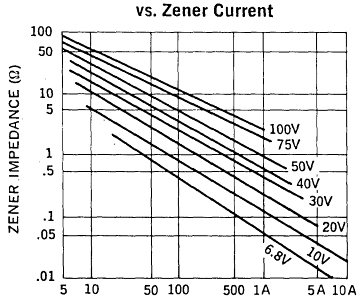
Power Dissipation vs. Lead Temperature Derating Curve



Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



POWER ZENERS
1 Watt, Industrial

UZ8706 SERIES
UZ8806 SERIES

FEATURES
- High Surge Ratings
- A Quarter the Size of Conventional 1 Watt Zeners
- Impervious to Moisture

DESCRIPTION
One watt zener diodes, hermetically sealed in glass.

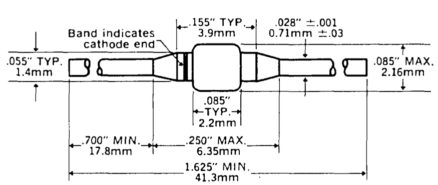
ABSOLUTE MAXIMUM RATINGS

Zener Voltage, V_Z	6.8 to 200V
Continuous Current	See Table
Surge Current (8.3ms)	See Table
Surge Power	See Graph
Power	See Lead Temperature Derating Curve
Storage and Operating Temperature	—65°C to +175°C

IX

MECHANICAL SPECIFICATIONS

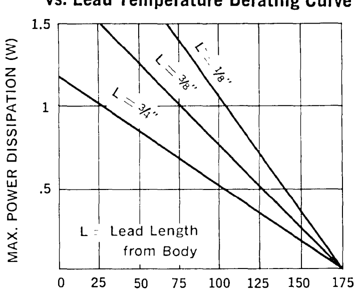
UZ8706 SERIES UZ8806 SERIES



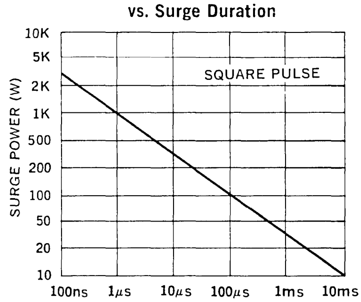
UZ Prefix is identified by a Blue or Red Cathode Band

BODY A

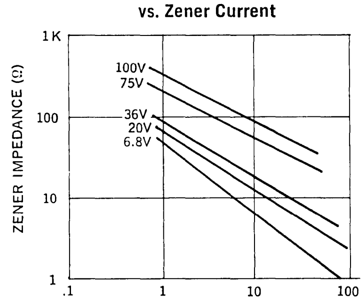
Power Dissipation vs. Lead Temperature Derating Curve



Surge Power vs. Surge Duration



Typical Zener Impedance vs. Zener Current



UNITRODE

Type		Electrical Specifications at 25°C							Maximum Ratings	
		Nominal Zener Voltage †	Test Current	Max. Zener Impedance §	Maximum Reverse Leakage Current			Typ. Temp. Coefficient	Maximum Continuous Current ★	Maximum Surge Current ‡
						± 5%	± 10%			
		V_Z @ I_{ZT}	I_{ZT}	Z_Z @ I_{ZT}	I_R @ V_R	V_R	V_R	T.C. @ I_{ZT}	I_{ZM}	I_S
± 5% Tolerance	± 10% Tolerance	Volts	mA	Ohms	µA	Volts	Volts	%/°C	mA	Amps
UZ 8706	UZ 8806	6.8	37	3.5	50	5.2	4.9	0.04	140	5.00
UZ 8707	UZ 8807	7.5	34	4.0	30	5.7	5.4	0.04	125	4.50
UZ 8708	UZ 8808	8.2	31	4.5	10	6.2	5.9	0.05	115	3.90
UZ 8709	UZ 8809	9.1	28	5.0	3.0	6.9	6.6	0.05	105	3.37
UZ 8710	UZ 8810	10	25	7.0	2.0	7.6	7.2	0.06	95	2.77
UZ 8712	UZ 8812	12	23	9.0	1.0	9.1	8.6	0.07	85	2.25
UZ 8713	UZ 8813	13	21	10	0.5	9.9	9.3	0.07	80	2.25
UZ 8714	UZ 8814	14	19	12	0.5	10.6	10.1	0.07	74	2.25
UZ 8715	UZ 8815	15	17	14	0.5	11.4	10.8	0.07	63	1.65
UZ 8716	UZ 8816	16	15.5	16	0.5	12.1	11.5	0.07	60	1.65
UZ 8718	UZ 8818	18	14.0	20	0.5	13.7	12.9	0.08	52	1.12
UZ 8720	UZ 8820	20	12.5	22	0.5	15.2	14.4	0.08	47	1.12
UZ 8722	UZ 8820	22	11.5	23	0.5	16.7	15.8	0.08	43	1.12
UZ 8724	UZ 8824	24	10.5	25	0.5	18.2	17.3	0.08	40	0.825
UZ 8727	UZ 8827	27	9.5	35	0.5	20.5	19.4	0.09	35	0.825
UZ 8730	UZ 8830	30	8.5	40	0.5	22.8	21.6	0.09	31	0.825
UZ 8733	UZ 8833	33	7.5	45	0.5	25.1	23.7	0.09	28	0.675
UZ 8736	UZ 8836	36	7.0	50	0.5	27.3	25.9	0.09	26	0.562
UZ 8740	UZ 8840	40	6.5	62	0.5	30.4	28.8	0.095	24	0.562
UZ 8745	UZ 8845	45	6.0	75	0.5	34.2	32.4	0.095	22	0.450
UZ 8750	UZ 8850	50	5.0	85	0.5	38.0	36.0	0.095	20	0.450
UZ 8756	UZ 8856	56	4.5	110	0.5	42.5	40.3	0.095	17	0.390
UZ 8760	UZ 8860	60	4.0	125	0.5	45.6	43.2	0.095	15	0.337
UZ 8770	UZ 8870	70	3.7	150	0.5	53.2	50.4	0.095	14	0.337
UZ 8775	UZ 8875	75	3.3	175	0.5	57.0	54.0	0.095	12	0.277
UZ 8780	UZ 8880	80	3.0	200	0.5	60.8	57.6	0.095	11	0.225
UZ 8790	UZ 8890	90	2.8	250	0.5	68.4	64.8	0.095	10	0.225
UZ 8110	UZ 8210	100	2.5	350	0.5	76.0	72.0	0.10	9.5	0.225
UZ 8111	UZ 8211	110	2.3	450	0.5	83.6	79.2	0.10	8.5	0.165
UZ 8112	UZ 8212	120	2.0	550	0.5	91.2	86.4	0.10	8.0	0.112
UZ 8113	UZ 8213	130	1.9	700	0.5	98.8	93.6	0.10	7.2	0.112
UZ 8114	UZ 8214	140	1.8	850	0.5	106	100	0.10	6.8	0.112
UZ 8115	UZ 8215	150	1.7	1000	0.5	114	108	0.10	6.3	0.112
UZ 8116	UZ 8216	160	1.6	1100	0.5	121	115	0.10	5.9	0.082
UZ 8117	UZ 8217	170	1.5	1200	0.5	129	122	0.10	5.6	0.082
UZ 8118	UZ 8218	180	1.4	1300	0.5	137	129	0.10	5.2	0.056
UZ 8119	UZ 8219	190	1.3	1400	0.5	144	137	0.10	5.0	0.056
UZ 8120	UZ 8220	200	1.2	1500	0.5	152	144	0.10	4.7	0.056

†All zener voltages are measured with an automated test set using a 35 millisecond test time. Longer or shorter test times will have a corresponding effect on the measured value due to heating effects.

§Zener impedance is derived from the 60-cycle AC voltage created when AC current with RMS value of 10% of DC zener test current is superimposed on the test current.

★Ratings are based on free air. T_A is 25°C. For use at 1.5 watts see derating curve.

‡Figures shown are for a peak sinusoidal surge current of 8.3 ms duration using 60 cycle AC. The 8.3 ms square pulse rating is 71% of the value shown.

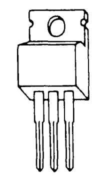
THYRISTORS (SCRs, Triacs, PUTs) X

TRIACs

8-20A/200-800V

Features:
- Diffused design
- Center gate construction
- Isolated and non-isolated
- Hard glass passivation
- High dv/dt
- Low power dissipation
- High surge capability

PACKAGE



TO-220AB

$I_{T(RMS)}$		8A	
		Part Number	
		Isolated	Non-Isolated
Repetitive Peak Off-State Voltage V_{DRM} (V)	200	USC1420-2	USC1470-2
	400	USC1420-4	USC1470-4
	600	USC1420-6	USC1470-6
	800	USC1420-8	USC1470-8
I_{GT}		Quadrant 1, 3	30mA
		Quadrant 2, 4	50mA
I_H		30mA	

$I_{T(RMS)}$		10A	
		Part Number	
		Isolated	Non-Isolated
Repetitive Peak Off-State Voltage V_{DRM} (V)	200	USC1440-2	USC1490-2
	400	USC1440-4	USC1490-4
	600	USC1440-6	USC1490-6
	800	USC1440-8	USC1490-8
I_{GT}		Quadrant 1, 3	50mA
		Quadrant 2, 4	80mA
I_H		50mA	

$I_{T(RMS)}$		15A	
		Part Number	
		Isolated	Non-Isolated
Repetitive Peak Off-State Voltage V_{DRM} (V)	200	USC2120-2	USC2250-2
	400	USC2120-4	USC2250-4
	600	USC2120-6	USC2250-6
	800	USC2120-8	USC2250-8
I_{GT}		Quadrant 1, 3	30mA
		Quadrant 2, 4	50mA
I_H		60mA	

$I_{T(RMS)}$		20A	
		Part Number	
		Isolated	Non-Isolated
Repetitive Peak Off-State Voltage V_{DRM} (V)	200	USC2140-2	USC2270-2
	400	USC2140-4	USC2270-4
	600	USC2140-6	USC2270-6
	800	USC2140-8	USC2270-8
I_{GT}		Quadrant 1, 3	50mA
		Quadrant 2, 4	80mA
I_H		90mA	

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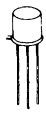
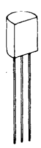
THYRISTORS (SCRs, TRIACs & PUTs)



TO-18

SCR

$I_{T(RMS)}$	.5A			
V_{DRM} (V) 30		2N3027*	2N3030*	ID100
60	AA114	2N3028*	2N3031*	ID101
100		2N3029*	2N3032*	ID102
150				ID103
200	AA116			ID104
300	AA110			ID105
400	AA111			ID106
I_{GT}	200μA	200μA	20μA	200μA
I_H	2mA	5mA	4mA	5mA



TO-92

SCR

$I_{T(RMS)}$	.8A	
V_{DRM} (V) 30	2N5060	IP100
60	2N5061	IP101
100	2N5062	IP102
150	2N5063	IP103
200	2N5064	IP104
300	2N6564	IP105
400	2N6565	IP106
I_{GT}	.2μA TYP.	.2μA TYP.
I_H	5mA	5mA

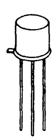
SCR (High Voltage)

$I_{T(RMS)}$	1.0A	
V_{DRM} (V) 100	2N6681	IP200
200	2N6682	IP202
400	2N6683	IP204
600	2N6684	IP206
800	2N6685	IP208
I_{GT}	30μA (TYP) 200μA	
I_H	5mA	

TO-9

SCR

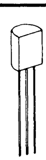
$I_{T(RMS)}$	1.25A	
V_{DRM} (V) 30	2N1876	2N1870A**
60	2N1877	2N1871A**
100	2N1878	2N1872A**
150	2N1879	2N1873A
200	2N1880	2N1874A**
I_{GT}	20μA	200μA
I_H	3mA	5mA



TO-39

SCR

$I_{T(RMS)}$	1.6A			
V_{DRM} (V) 30			2N2322	
60	AD100	2N2323A***	2N2323***	ID200
100	AD101	2N2324A***	2N2324***	ID201
150		2N2325A	2N2325	ID202
200	AD102	2N2326A***	2N2326***	ID203
300	AD103	2N2328A***	2N2328***	ID300
400	AD104		2N2329***	ID301
I_{GT}	2μA	20μA	200μA	200μA
I_H	2mA	2mA	2mA	3mA



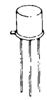
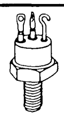
TO-92

TRIAC

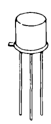
$I_{T(RMS)}$	.8A
V_{DRM} (V) 200	IB202
400	IB204
600	IB206
I_{GT}	Quadrant 1,3 5mA†
	Quadrant 2,4 10mA
I_H	15mA

*Available as JAN and JANTX types.
**Available as JAN type.
***Available as JAN, JANTX, JANTXV types.
†3mA available from factory

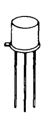
ULTRAFAST SWITCHING

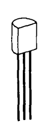
Package	Type				
 TO-18	SCR	V_{DRM} (V)	$I_{T(RMS)}$	.4A	
			60V	GA200 GA300	GA200A GA300A
			100V	GA201 GA301	GA201A GA301A
			t_{on}	20ns (TYP.)	20nS (TYP.)
			t_q	2.0μS	.5μS
 TO-59	SCR	V_{DRM} (V)	$I_{T(RMS)}$	6A	
			60V	GB200 GB300	GB200A GB300A
			100V	GB201 GB301	GB201A GB301A
			t_{on}	20ns (TYP.)	20nS (TYP.)
			t_q	2.0μS	.5μS

RADIATION HARDENED SCRs

Package			
 TO-18	On-State Current $I_{T(RMS)}$		0.4A
	Package Style		**TO-18**
	REPETITIVE PEAK OFF-STATE VOLTAGE, V_{DRM} and REVERSE VOLTAGE, V_{RRM}	30V	GA100
		60V	GA101
		80V	GA102
	Key Parameters		I_{GT} (Post 3X10[14] NVT) 20mA
			I_H (Post 3X10[14] NVT) 30mA

PUTs — PROGRAMMABLE UNIJUNCTION TRANSISTORS

Package				
 TO-18	Peak Recurrent Forward Current		8A	
	Package Style		**TO-18**	
	MIN. VALLEY CURRENT, I_V MAX. PEAK POINT CURRENT, I_P	$I_V = 25\mu A$ @ $R_G = 10K$ $I_P = .15\mu A$ @ $R_G = 1Meg$	U13T2	CONSULT FACTORY
		$I_V = 70\mu A$ @ $R_G = 10K$ $I_P = 2\mu A$ @ $R_G = 1Meg$	U13T1	
		$I_V = ImA$ @ $R_G = 200\Omega$ $I_P = .15\mu A$ @ $R_G = 1Meg$	2N6120	
		$I_V = 1.5mA$ @ $R_G = 200\Omega$ $I_P = 2\mu A$ @ $R_G = 1Meg$	2N6119 2N6137*	
	Forward and Reverse Voltage; V_{AK}, V_{AKR}		40V	100V

Package				
 TO-92	Peak Recurrent Forward Current		5A	2A
	Package Style		**TO-92**	**TO-92**
	MIN. VALLEY CURRENT, I_V MAX. PEAK POINT CURRENT, I_P	$I_V = 25\mu A$ @ $R_G = 10K$ $I_P = .15\mu$ @ $R_G = 1Meg$	P13T2	
		$I_V = 70\mu$ @ $R_G = 10K$ $I_P = 2\mu A$ @ $R_G = 1Meg$	P13T1	
		$I_V = 1mA$ @ $R_G = 200\Omega$ $I_P = .15\mu$ @ $R_G = 1Meg$		2N6028
		$I_V = 1.5mA$ @ $R_G = 200\Omega$ $I_P = 2\mu A$ @ $R_G = 1Meg$		2N6027
	Forward and Reverse Voltage; V_{AK}, V_{AKR}		40V	

* Available as JAN and JANTX types.

X

SCRs

1.25 Amp, Planar

FEATURES

- Available as Either "JAN" or Standard Types
- Operating D.C. Current Range: 5 to 1250mA
- Pulse Currents: to 30A
- Voltage Ratings: to 200V
- Maximum Trigger Current: 0.2mA
- Maximum Trigger Voltage: 0.8V
- All Leads Isolated from Case
- Maximum Θ_{J-C}: 20°C/W

DESCRIPTION

These are premium PNPN controlled switches intended for use in applications requiring a high degree of reliability assurance. The JAN types are specified under MIL-S-19500/198, and are included in MIL-STD-701 as recommended types for military usage.

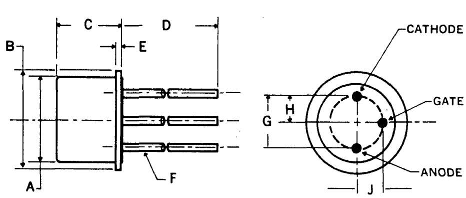
This series is useful in a wide variety of applications including: safety, arming and detonating circuits; timing and programming circuits; protective and warning circuits; driving relays; driving indicator lamps, encoding and decoding circuits; replacing relays, thyratrons, and magamps; servo motor control; pulse generation; plus many others.

ABSOLUTE MAXIMUM RATINGS

	2N1870A JAN2N1870A	2N1871A JAN2N1871A	2N1872A JAN2N1872A	2N1873A —	2N1874A JAN2N1874A
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V	150V	200V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V	150V	200V
D.C. On-State Current, I_T					
100°C Ambient			250mA		
100°C Case			1.25A		
Repetitive Peak On-State Current, I_{TRM}			up to 30A		
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}			15A		
Peak Gate Current, I_{GM}			250mA		
Average Gate Current, $I_{G(AV)}$			25mA		
Reverse Gate Voltage, V_{GR}			5V		
Thermal Resistance, Junction to Case, $R\Theta_{J-C}$			20°C/W		
Operating and Storage Temperature Range			−65°C to +150°C		

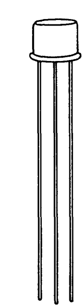
MECHANICAL SPECIFICATIONS

2N1870A-2N1874A



	ins.	mm.
A	.275-.335	6.99-7.75
B	..290-.370	7.37-9.40
C	.200-.260	5.08-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.25-.76
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.100	2.54

TO-9



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Subgroup 1 (Visual and Mechanical)						
Subgroup 2 (25°C Tests)						
Off-State Current	I_{DRM}	—	0.5	10	μA	$R_{GK} = 1K$, $V_{DRM} = +$ Rating
Reverse Current	I_{RRM}	—	0.5	10	μA	$R_{GK} = 1K$, $V_{RRM} = -$ Rating
Gate Trigger Voltage	V_{GT}	0.4	0.55	0.8	V	$R_{GS} = 100$ ohms, $V_D = 5V$
Gate Trigger Current	I_{GT}	—	30	200	μA	$R_{GS} > 10K$ ohms, $V_D = 5V$
On-State Voltage	V_{TM}	—	1.8	2.5	V	$I_{TM} = 2A$ (pulse test)
Off-State Voltage — Critical of Rise	dv_c/dt	100	—	—	V/μs	Specified test circuit
Reverse Gate Current	I_{GR}	—	0.5	10	μA	$V_{GRM} = 5V$, anode open
Holding Current	I_H	0.3	—	5.0	mA	$I_G = -150\mu A$, $V_D = 5V$
Subgroup 3 (125°C Tests)						
High Temp. Off-State Current	I_{DRM}	—	15	100	μA	$R_{GK} = 1K$, $V_{DRM} = +$ Rating
High Temp. Reverse Current	I_{RRM}	—	15	100	μA	$R_{GK} = 1K$, $V_{RRM} = -$ Rating
High Temp. Gate Non-Trigger Voltage	V_{GD}	0.2	—	—	V	$R_{GS} = 100$ ohms, $V_D = 5V$
High Temp. Holding Current	I_H	0.2	—	—	mA	$I_G = -150\mu A$, $V_D = 5V$
Subgroup 4 (−65°C Tests)						
Low Temp. Gate Trigger Voltage	V_{GT}	—	—	1.0	V	$R_{GK} = 100$ ohms, $V_D = 5V$
Low Temp. Gate Trigger Current	I_{GT}	—	—	500	μA	$R_{GK} > 10K$ ohms, $V_D = 5V$
Low Temp. Holding Current	I_H	—	—	15	mA	$I_G = -150\mu A$, $V_{AA} = 5V$

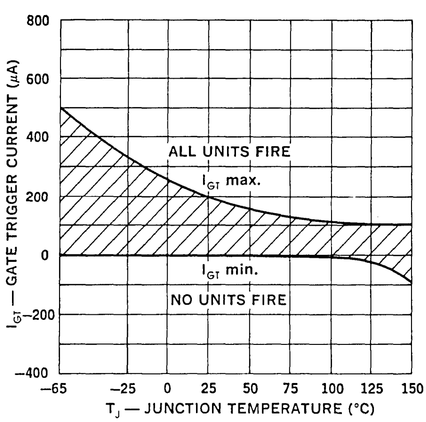
†All values in this table are JEDEC registered.

Note: Voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1 K or smaller, or other adequate gate bias is used.

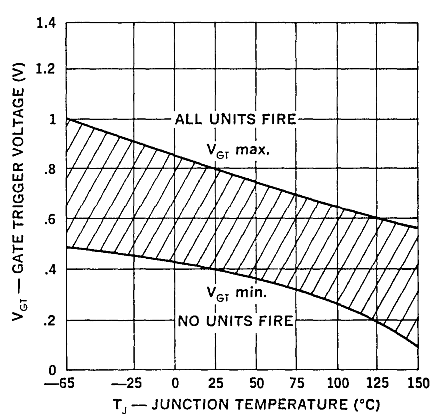
X

Triggering and Bias Stabilization

1. Gate Trigger Current

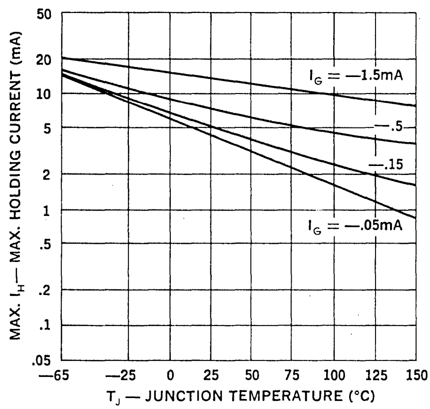


2. Gate Trigger Voltage

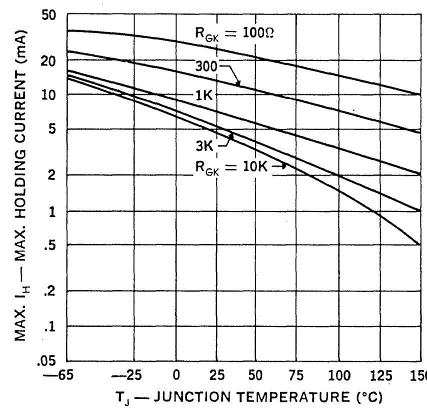


Holding Current

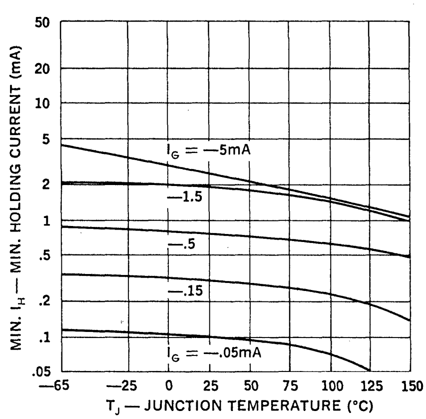
1. Max. Holding Current (Current Bias)



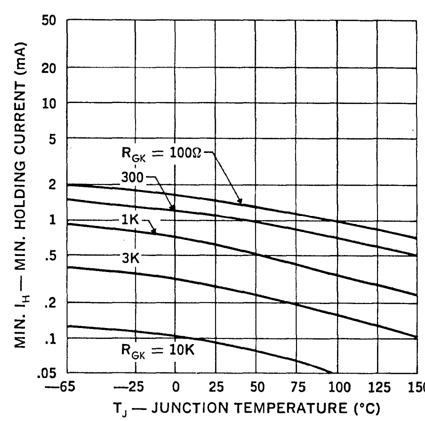
2. Max. Holding Current (Resistor Bias)



3. Min. Holding Current (Current Bias)

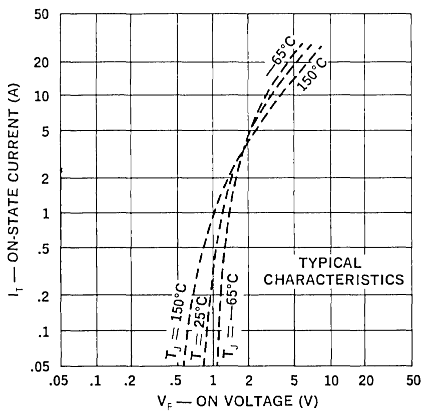


4. Min. Holding Current (Resistor Bias)

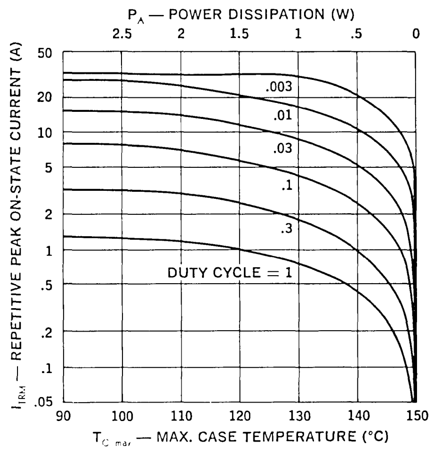


Current Ratings — Thermal Design

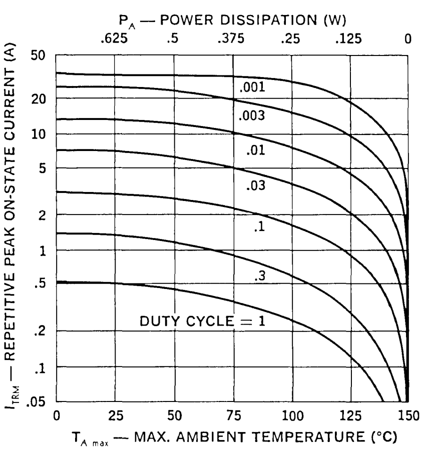
1. On-State Current vs. Voltage



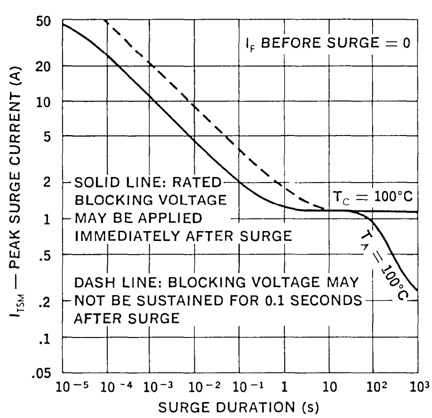
2. Peak Current vs. Case Temperature



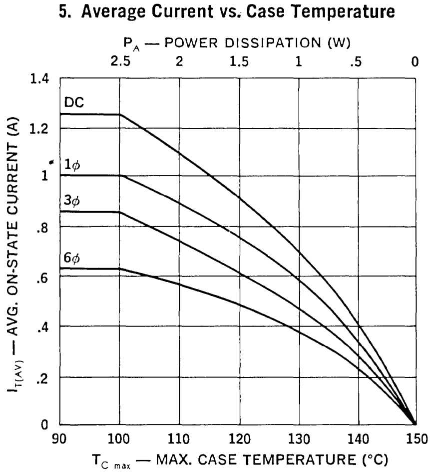
3. Peak Current vs. Ambient Temperature



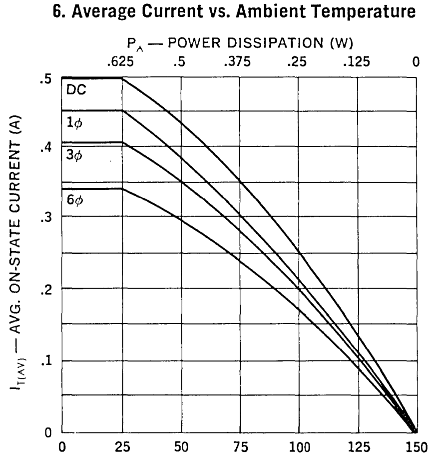
4. Surge Current vs. Time



5. Average Current vs. Case Temperature



6. Average Current vs. Ambient Temperature



SCRs
1.25 Amp, Planar

FEATURES
- Operating D.C. Current Range: 10-1250mA
- Peak Pulse Current: to 30A
- Maximum Gate Current to Fire: 20μA
- Firing Voltage: .52±.08V
- Voltage Ratings: to 200V
- "Turn-on" Time: Typically 0.1μs
- Low On Voltage: 2.5V Maximum at 2A

DESCRIPTION
This high sensitivity series, featuring very precise control of triggering characteristics, is particularly useful for timing and time delay circuits, voltage limit detectors, high gain static switching, logic circuits, pulse and sweep generators, and related applications.

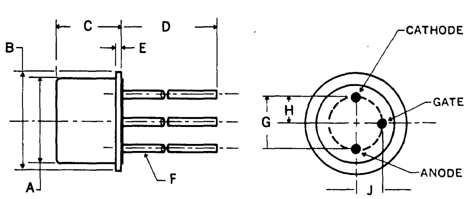
This series is available in a TO-9 package, with all leads isolated from the case, providing a maximum thermal resistance of 20°C/Watt between junction and case.

ABSOLUTE MAXIMUM RATINGS

	2N1875	2N1876	2N1877	2N1878	2N1879	2N1880
Repetitive Peak Off-State Voltage, V_{DRM}	15V	30V	60V	100V	150V	200V
Repetitive Peak Reverse Voltage, V_{RRM}	15V	30V	60V	100V	150V	200V
D.C. On-State Current, I_T						
100°C Ambient	250mA					
100°C Case	1.25A					
Repetitive Peak On-State Current, I_{TRM}	up to 30A					
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}	15A					
Peak Gate Current, I_{GM}	250mA					
Average Gate Current, $I_{G(AV)}$	25mA					
Reverse Gate Voltage, V_{GR}	5V					
Thermal Resistance, Junction to Case, $R\theta_{J-C}$	20°C/W					
Operating and Storage Temperature Range	−65°C to +150°C					

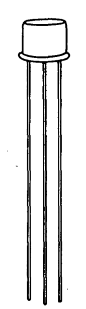
MECHANICAL SPECIFICATIONS

2N1875-2N1880



	ins.	mm.
A	.275-.335	6.99-7.75
B	..290-.370	7.37-9.40
C	.200-.260	5.08-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.25-.76
F	$.017 \pm ^{.002}_{.001}$	$.432 \pm ^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.100	2.54

TO-9



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Subgroup 1 (Visual and Mechanical)						
Subgroup 2 (25°C Tests)						
Off-State Current	I_{DRM}	—	0.5	5	μA	V_{DRM} = Rating, R_{GK} = 1K
Reverse Current	I_{RRM}	—	0.5	10	μA	V_{RRM} = Rating
Reverse Gate Current	I_{GR}	—	0.5	10	μA	$V_{GR} = 2V$
Gate Trigger Current	I_{GT}	—	5	20	μA	$V_D = 5V$, $R_{GS} = 10K$
Gate Trigger Voltage	V_{GT}	.44	.52	.60	V	$V_D = 5V$, $R_{GS} = 100\Omega$
Anode Trigger Current (Note 2)	I_{AT}	—	100	—	μA	$V_D = 5V$
On-State Voltage	V_T	0.8	1.8	2.5	V	$I_T = 2A$ (Pulse Test)
Holding Current	I_H	0.3	1.0	3	mA	$I_G = -150\mu A$, $V_{AA} = 5V$
Subgroup 3 (25°C Tests)						
Turn-on Time	t_{on}	—	0.1	—	μs	$I_G = 20mA$
Turn-off Time	t_{off}	—	0.5	—	μs	$I_T = .5A$
Gate Trigger — on Pulse Width	$t_{pg(on)}$	—	0.5	—	μs	$V_D = 30V$
Circuit Commutated Turn-off Time	t_q	—	10	—	μs	$I_T = .5A$, $i_R = .5A$, $R_{GK} = 1K$
Subgroup 4 (125°C Tests)						
High Temp. Off-State Current	I_{DRM}	—	5	20	μA	V_D = Rating, R_{GK} = 1K
High Temp. Reverse Current	I_{RRM}	—	15	100	μA	V_{RRM} = Rating

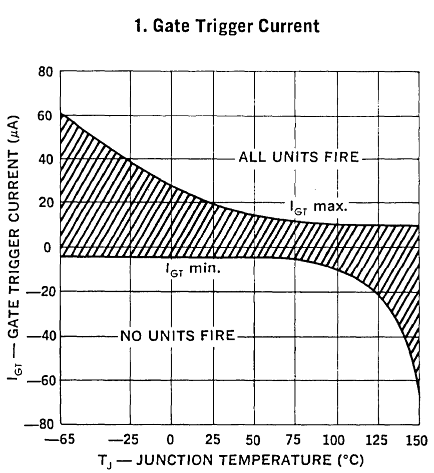
Note: 1. Voltage ratings apply over the operating temperature range, provided the gate is connected to the cathode through an appropriate resistor, or adequate gate bias is used.

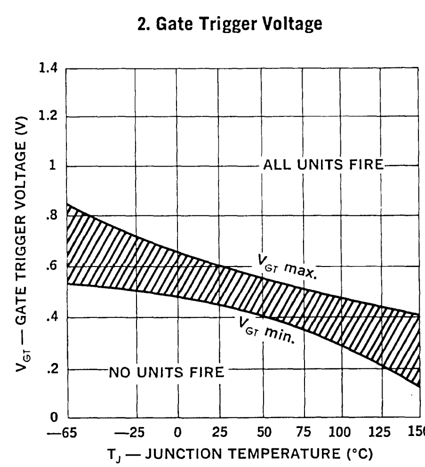
2. For a maximum limit of 50μA, use suffix "—1" and drop "2N". Example: 1877-1.

† All values in this table are JEDEC registered.

X

TRIGGERING AND BIAS STABILIZATION





SCRs

1 Amp, Planar

FEATURES

- One Cycle Surge Current: 15A
- Voltage Ratings: to 200V
- Low "On-Voltage": 2V Max. at 1A
- Operation: to 150°C Junction Temperature
- All Leads Isolated for Design Flexibility

DESCRIPTION

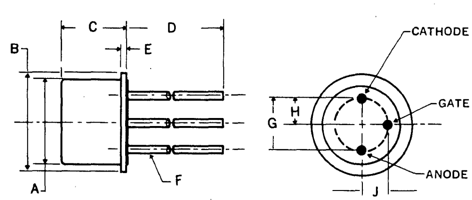
These types are useful in AC and DC static switching, proportioning control, relay and thyratron replacement, DC to AC converters, servo motor driving, protective circuits, and related applications.
This series is available in a TO-9 package, with all leads isolated from the case, providing a maximum thermal resistance of 20°C/Watt between junction and case.

ABSOLUTE MAXIMUM RATINGS

	2N1881	2N1882	2N1883	2N1884	2N1885
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V	150V	200V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V	150V	200V
D.C. On-State Current, I_T					
100°C Ambient			250mA		
100°C Case			1.0A		
Repetitive Peak On-State Current, I_{TRM}			up to 30A		
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}			15A		
Peak Gate Current, I_{GM}			250mA		
Average Gate Current $I_{G(AV)}$			25mA		
Reverse Gate Voltage, V_{GR}			3V		
Thermal Resistance, Junction to Case, $R\Theta_{J-C}$			20°C/W		
Operating and Storage Temperature Range			−65°C to +150°C		

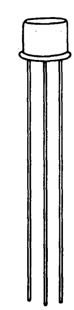
MECHANICAL SPECIFICATIONS

2N1881-2N1885



	ins.	mm.
A	.275-.335	6.99-7.75
B	.290-.370	7.37-9.40
C	.200-.260	5.08-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.25-.76
F	$.017 \pm ^{.002}_{.001}$	$.432 \pm ^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.100	2.54

TO-9



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Subgroup 1 (Visual and Mechanical)						
Subgroup 2 (25°C Tests)						
Off-State Current	I_{DRM}	—	0.5	10	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	0.5	10	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Reverse Gate Current	I_{GR}	—	0.5	10	μA	$V_{GRM} = 2V$
Gate Trigger Current	I_{GT}	—	0.2	2	mA	$R_{GS} = 10K$, $V_D = 5V$
Gate Trigger Voltage	V_{GT}	0.40	1	2	V	$R_{GS} = 100\Omega$, $V_D = 5V$
On-State Voltage	V_T	—	1.5	2	V	$I_T = 1A$ (pulse test)
Holding Current	I_H	—	2	—	mA	$I_G = -150\mu A$, $V_D = 5V$
Anode Trigger Current	I_{AT}	—	0.5	—	mA	$R_{GS} = 10K$, $V_D = 5V$
Subgroup 3 (25°C Tests)						
Turn-on Time	t_{on}	—	0.2	—	μs	$I_G = 20mA$, $I_T = 0.5A$, $V_D = 30V$
Gate Trigger — on Pulse Width	t_{pg} (on)	—	1	—	μs	$I_G = 20mA$, $I_T = 0.5A$, $V_D = 30V$
Turn-off Time	t_{off}	—	1	—	μs	$I_T = 1A$, $I_R = IA$, $R_{GK} = IK$
Circuit Commutated Turn-off Time	t_q	—	10	—	μs	$I_T = 1A$, $I_R = IA$, $R_{GK} = IK$
Subgroup 3 (125°C Tests)						
High Temp. Off-State Current	I_{DRM}	—	15	200	μA	$R_{GK} = 1K$, V_{DRM} = Rating
High Temp. Reverse Current	I_{RRM}	—	15	200	μA	$R_{GK} = 1K$, V_{RRM} = Rating

† All values in this table are JEDEC registered.

Note: Voltage ratings apply over the operating temperature range, provided the gate is connected to the cathode through an appropriate resistor, or adequate gate bias is used.

X

SCRs
1.6 Amp, Planar

FEATURES
- Available as JAN, JANTXV & JANTXV Types
- 1.6A D.C. Current
- Peak Currents: to 30A
- Voltage Ratings: to 400V
- 20μA Max. Trigger Current ("A" types)
- 0.6V Max. Trigger Voltage ("A" types)

DESCRIPTION
These are premium thyristor switches intended for use in high performance industrial, military and space applications requiring a high degree of reliability assurance. This series is useful in a wide variety of applications including timing and programming circuits, protective and warning circuits, driving relays, driving indicator lamps, encoding and decoding circuits, replacing relays, thyratrons, and magamps, servo motor control, pulse generation, plus many others. The high surge current rating (15A - 1 cycle) makes this series particularly useful for squib firing.

The following JAN, JANTX and JANTXV types are specified under Mil-S-19500/276A and are included in Mil-STD-701 as recommended types for military usage:

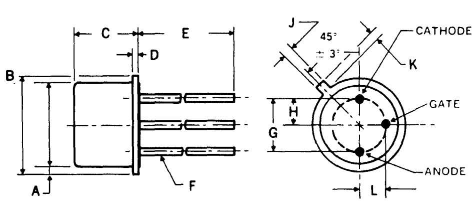
ABSOLUTE MAXIMUM RATINGS

	2N2322	2N2323 JAN2N2323 JANTX2N2323 JANTXV2N2323 / 2N2323A JAN2N2323A JANTX2N2323A JANTXV2N2323A	2N2324 JAN2N2324 JANTX2N2324 JANTXV2N2324 / 2N2324A JAN2N2324A JANTX2N2324A JANTXV2N2324A	2N2325 / 2N2325A	2N2326 JAN2N2326 JANTX2N2326 JANTXV2N2326 / 2N2326A JAN2N2326A JANTX2N2326A JANTXV2N2326A	2N2327 / 2N2327A	2N2328 JAN2N2328 JANTX2N2328 JANTXV2N2328 / 2N2328A JAN2N2328A JANTX2N2328A JANTXV2N2328A	2N2329 JAN2N2329 JANTX2N2329 JANTXV2N2329
Repetitive Peak Off-State Voltage, V_{DRM}	25V	50V	100V	150V	200V	250V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	25V	50V	100V	150V	200V	250V	300V	400V
Non-Repetitive Peak Reverse Voltage, V_{RSM} (< 5ms)	40V	75V	150V	225V	300V	350V	400V	500V

D.C. On-State Current, I_T 80°C Ambient	300mA
85°C Case	1.6A
One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}	15A
Repetitive Peak On-State Current, I_{TM}	30A
Gate Power Dissipation, P_{GM}	0.1W
Gate Power Dissipation, $P_{GM(AV)}$	0.01W
Peak Gate Current, I_{GM}	100mA
Peak Gate Voltage, Forward and Reverse	6V
Reverse Gate Current, I_{GR}	3mA
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−65°C to +125°C

MECHANICAL SPECIFICATIONS

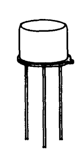
2N2322-2N2329 2N2323A-2N2328A



	ins.	mm.
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.35-6.60
D	.010-.030	.25-.76
E	.5 MIN.	12.70 MIN.
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.79±.08
K	.029-.045	.74-1.14
L	.100	2.54

TO-5 has 1.5" (38.10mm) lead length

TO-39



JAN types available in TO-5 package upon request.

UNITRODE

ELECTRICAL SPECIFICATIONS

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Visual and Mechanical						MIL-STD-750, Method 2071
25°C						
Off-State Current	I_{DRM}	—	0.1	10	μA	V_{DRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Reverse Current	I_{RRM}	—	0.1	10	μA	V_{RRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Gate Trigger Current	I_{GT}					
"A" Types		—	2	20	μA	V_D = 6V, R_L = 100Ω
non-"A" Types		—	50	200	μA	V_D = 6V, R_L = 100Ω
Gate Trigger Voltage	V_{GT}					
"A" Types		0.35	0.52	0.60	V	V_D = 6V, R_{GK} = 2K, R_L = 100Ω
non-"A" Types		0.35	0.55	0.80	V	V_D = 6V, R_{GK} = 1K, R_L = 100Ω
On-State Voltage	V_{TM}	—	2.0	2.2	V	I_{TM} = 4A (pulse test)
Holding Current	I_H	—	0.3	2.0	mA	V_D = 6V, R_{GK} = 1K (2K for "A" Types)
Reverse Gate Current	I_{GR}	—	1	200*	μA	V_{GR} = 6V
Delay Time	t_d	—	0.6	—	μs	I_G = 10mA, I_T = 1A, V_D = 30V
Rise Time	t_r	—	0.4	—	μs	I_G = 10mA, I_T = 1A, V_D = 30V
Circuit Commutated Turn-Off Time	t_q	—	20	—	μs	I_T = 1A, I_R = 1A, R_{GK} = 1K
125°C						
Off-State Current	I_{DRM}	—	1	100	μA	V_{DRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Reverse Current	I_{RRM}	—	1	100	μA	V_{RRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Gate Trigger Voltage	V_{GT}	0.1	0.3	—	V	V_D = Rated V_D, R_{GK} = 1K (2K for "A" Types)
Holding Current	I_H					
"A" Types		0.1†	—	—	mA	V_D = 6V, R_{GK} = 2K
non-"A" Types		0.15†	—	—	mA	V_D = 6V, R_{GK} = 1K
Off-State Voltage — Critical Rate of Rise	dv/dt					
"A" Types		0.7*			V/μs	V_D = Rating, R_{GK} = 2K
non-"A" Types		1.8*			V/μs	V_D = Rating, R_{GK} = 1K
−65°C						
Off-State Current	I_{DRM}	—	.05	5.0*	μA	V_{DRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Reverse Current	I_{RRM}	—	.05	5.0*	μA	V_{RRM} = Rating, R_{GK} = 1K (2K for "A" Types)
Gate Trigger Current	I_{GT}					
"A" Types		—	50	75	μA	V_D = 6V, R_L = 100Ω
non-"A" Types		—	100	350	μA	V_D = 6V, R_L = 100Ω
Gate Trigger Voltage	V_{GT}					
"A" Types		—	0.7	0.8*	V	V_D = 6V, R_{GK} = 2K, R_L = 100Ω
				0.9†	V	V_D = 6V, R_{GK} = 2K, R_L = 100Ω
non-"A" Types		—	0.75	1.0	V	V_D = 6V, R_{GK} = 1K, R_L = 100Ω
Holding Current	I_H	—	—	3.0†	mA	V_D = 6V, R_{GK} = 1K (2K for "A" Types)

* JAN and JANTX Types only.
† Industrial Types only.

JAN and JANTX Acceptance Tests

100% Screening TX-Types

High Temperature Storage
Temperature Cycling
Constant Acceleration
Fine & Gross Hermetic Seal
Electrical Test
Burn-in
Electrical Test

Group B Tests

Subgroup 1 — Reverse Gate Current
Surge Current
Non-Repetitive Reverse Voltage

Subgroup 2 — Low Temp. Reverse Blocking Current
Low Temp. Forward Blocking Current
Low Temp. Gate Trigger Voltage
Low Temp. Gate Trigger Current

Subgroup 3 — Temperature Cycling
Thermal Shock
Moisture Resistance
Solderability

Subgroup 4 — Blocking Life Test

Group C Tests

Subgroup 1 — Physical Dimensions

Subgroup 2 — Shock
Constant Acceleration
Vibration, Variable Frequency

Subgroup 3 — Barometric Pressure, Reduced

Subgroup 4 — Salt Atmosphere

Subgroup 5 — Terminal Strength

Subgroup 6 — Intermittent Operating Life Test

X

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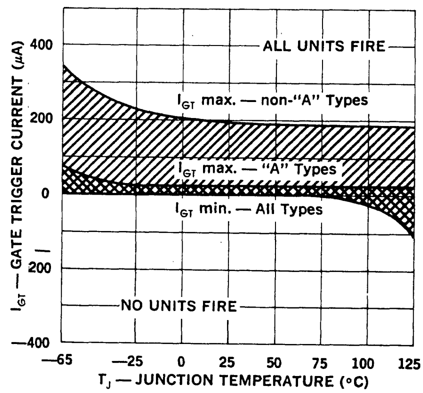
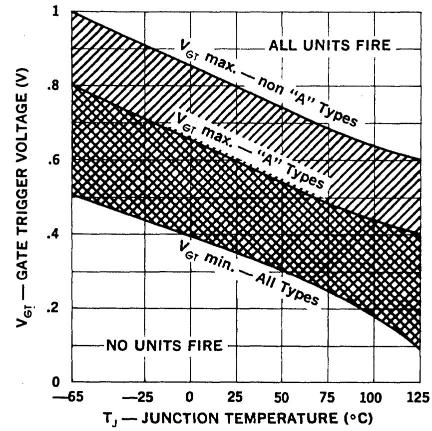
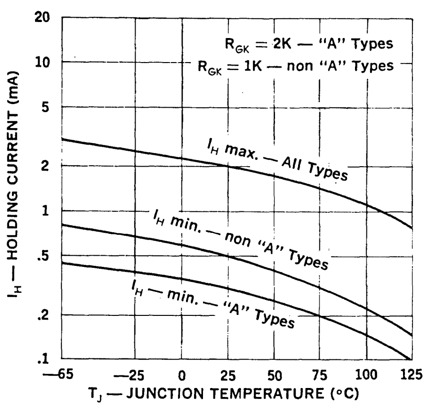
Gate Trigger Current



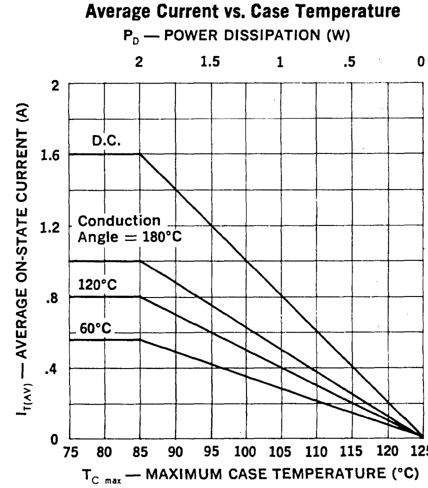
Gate Trigger Voltage



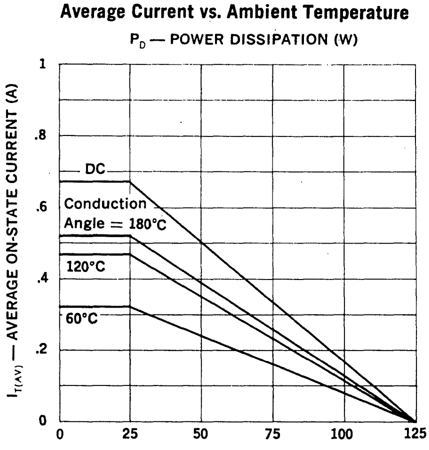
Holding Current



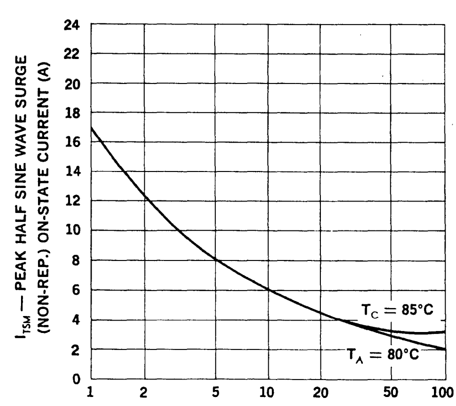
Average Current vs. Case Temperature



Average Current vs. Ambient Temperature



Surge Current



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SCRs
0.5 Amp, Planar

FEATURES
- JAN and JANTX Types Available
- Fully Characterized for "Worst Case" Design
- Passivated Planar Construction for Maximum Reliability and Parameter Uniformity
- Low On-State Voltage and Fast Switching at High Current Levels
- Typical Turn-On Time: 0.12μs
- Typical Recovery Time: 0.7μs
- Pulse Currents: to 30A

DESCRIPTION
The 2N3027 series of planar SCRs (controlled switches) are intended for use in military and space applications requiring a high degree of reliability. They offer a unique combination of extremely fast switching, precise triggering, high pulse power, small size, intrinsic parameter stability, and high radiation tolerance.

The JAN and JANTX types are specified under MIL-S-19500/419, and are included in MIL-STD-701 as recommended types for military usage.

ABSOLUTE MAXIMUM RATINGS

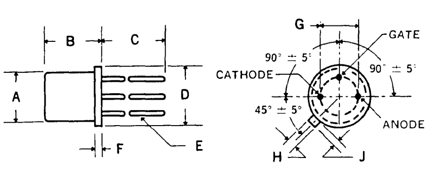
	JAN & JANTX 2N3027 JAN & JANTX 2N3030	JAN & JANTX 2N3028 JAN & JANTX 2N3031	JAN & JANTX 2N3029 JAN & JANTX 2N3032
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V
D.C. On-State Current, I_T			
100°C Case		500mA	
75°C Ambient		250mA	
Repetitive Peak On-State Current, I_{TRM}		30A	
Surge (Non-Rep.) On-State Current, I_{TSM}			
50ms		5A	
8ms		8A	
Peak Gate Current, I_{GM}		250mA	
Average Gate Current, $I_{G(AV)}$		25mA	
Reverse Gate Voltage		5V	
Reverse Gate Current		3mA	
Storage Temperature Range		−65°C to +200°C	
Operating Temperature Range		−65°C to +150°C	

Note: Blocking voltage ratings apply over the operating temperature range, provided the gate is connected to the cathode through an appropriate resistor, or adequate gate bias is used. (See section on bias stabilization.)

X

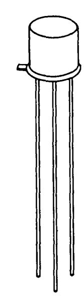
MECHANICAL SPECIFICATIONS

JAN & JANTX 2N3027-2N3032



	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	$.017 \pm ^{.002}_{.001}$ DIA.	$.432 \pm ^{.051}_{.025}$
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N3027 — 2N3028 — 2N3029

Parameter	Symbol	Min.	Typical	Max.	Units	Test Conditions
SUBGROUP 1 Visual and Mechanical	—	—	—	—	—	MIL-STD-750 Method 2071
SUBGROUP 2 (25°C Tests)						
Off-State Current	I_{DRM}	—	.002	0.1	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	.002	0.1	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Reverse Gate Voltage	V_{GR}	5	8	—	V	$I_{GR} = 0.1mA$
Gate Trigger Current	I_{GT}	−5	8	200	μA	$R_{GS} = 10K$, $V_D = 5V$
Gate Trigger Voltage	V_{GT}	.40	.55	.80	V	$R_{GS} = 100\Omega$, $V_D = 5V$
On-State Voltage	V_T	0.8	1.2	1.5	V	$i_T = 1A$ (pulse test)
Holding Current	I_H	0.3	0.7	5.0	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 3 (25°C Tests)						
Off-State Voltage — Critical Rate of Rise	dv_c/dt	30	60	—	v/μs	$R_{GK} = 1K$, $V_D = 30V$
Gate Trigger–on Pulse Width	$t_{pg\,(on)}$	—	.07	0.2	μs	$I_G = 10mA$, $I_T = 1A$, $V_{DM} = 30V$
Delay Time	t_d	—	.08	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Rise Time	t_r	—	.04	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Circuit Commutated Turn-off Time	t_q	—	0.7	2.0	μs	$I_T = 1A$, $i_R = 1A$, $R_{GK} = 1K$
SUBGROUP 4 (150°C Tests)						
High Temp. Off-State Current	I_{DRM}	—	2	20	μA	$R_{GK} = 1K$, V_{DRM} = Rating
High Temp. Reverse Current	I_{RRM}	—	20	50	μA	$R_{GK} = 1K$, V_{RRM} = Rating
High Temp. Gate Trigger Voltage	V_{GT}	.10	.15	0.6	V	$R_{GS} = 100\Omega$, $V_D = 5V$
High Temp. Holding Current	I_H	.05	.20	1.0	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 5 (−65°C Tests)						
Low Temp. Gate Trigger Voltage	V_{GT}	0.6	0.75	1.1	V	$R_{GS} = 100\Omega$, $V_D = 5V$
Low Temp. Gate Trigger Current	I_{GT}	0	150	1.2	mA	$R_{GS} = 10K$, $V_D = 5V$
Low Temp. Holding Current	I_H	0.5	3.5	10	mA	$R_{GK} = 1K$, $V_D = 5V$

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)
2N3030 — 2N3031 — 2N3032

Parameter	Symbol	Min.	Typical	Max.	Units	Test Conditions
SUBGROUP 1 Visual and Mechanical	—	—	—	—	—	MIL-STD-750 Method 2071
SUBGROUP 2 (25°C Tests)						
Off-State Current	I_{DRM}	—	.002	0.1	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	.002	0.1	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Reverse Gate Voltage	V_{GR}	5	8	—	V	$I_{GR} = 0.1mA$
Gate Trigger Current	I_{GT}	−5		20	μA	$R_{GS} = 10K$, $V_D = 5V$
Gate Trigger Voltage	V_{GT}	0.44		0.6	V	$R_{GS} = 100\Omega$, $V_D = 5V$
On-State Voltage	V_T	0.8	1.2	1.5	V	$i_T = 1A$ (pulse test)
Holding Current	I_H	0.3	1.0	4.0	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 3 (25°C Tests)						
Off-State Voltage — Critical Rate of Rise	dv_c/dt	30	60	—	v/μs	$R_{GK} = 1K$, $V_D = 30V$
Gate Trigger–on Pulse Width	t_{pg} (on)	—	.05	0.1	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Delay Time	t_d	—	0.1	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Rise Time	t_r	—	.05	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Circuit Commutated Turn-off Time	t_q	—	0.7	2.0	μs	$I_T = 1A$, $i_R = 1A$, $R_{GK} = 1K$
SUBGROUP 4 (150°C Tests)						
High Temp. Off-State Current	I_{DRM}	—	2	20	μA	$R_{GK} = 1K$, V_{DRM} = Rating
High Temp. Reverse Current	I_{RRM}	—	20	50	μA	$R_{GK} = 1K$, V_{RRM} = Rating
High Temp. Gate Trigger Voltage	V_{GT}	.10	.15	0.4	V	$R_{GS} = 100\Omega$, $V_D = 5V$
High Temp. Holding Current	I_H	.05	.30	2.0	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 5 (−65°C Tests)						
Low Temp. Gate Trigger Voltage	V_{GT}	0.44	0.8	0.95	V	$R_{GS} = 100\Omega$, $V_D = 5V$
Low Temp. Gate Trigger Current	I_{GT}	0	0.4	0.5	mA	$R_{GS} = 10K$, $V_D = 5V$
Low Temp. Holding Current	I_H	0.5	5.0	8	mA	$R_{GK} = 1K$, $V_D = 5V$

High Reliability Processing

The 2N3027-2N3032 series provides a complete range of high reliability processing from the standard devices that undergo extensive electrical testing, through JAN and JANTX levels. 100% processing, Group B, and Group C tests for JAN and JANTX devices is shown below. For further details, see MIL-S-19500/419(EL).

100% Screening TX-Types

High Temperature Storage
Temperature Cycling
Constant Acceleration
Fine & Gross Hermetic Seal
Electrical Test
Burn-in
Electrical Test

Group B Tests

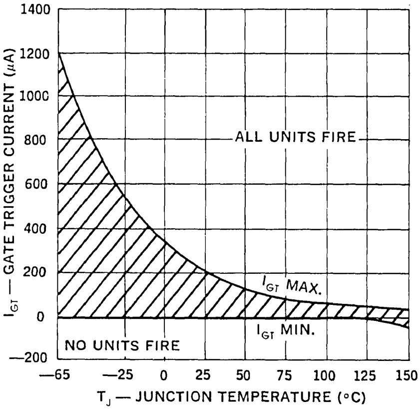
Subgroup 1 — Physical Dimensions
Subgroup 2 — Solderability
Temperature Cycling
Thermal Shock
Constant Acceleration
Moisture Resistance
Subgroup 3 — Surge Current
Subgroup 4 — Blocking Life Test
Subgroup 5 — Storage Life Test
Subgroup 6 — Operating Life Test

Group C Tests

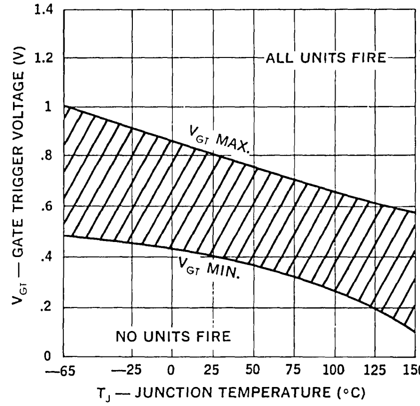
Subgroup 1 — Shock
Vibration, Variable Frequency
Subgroup 2 — Salt Atmosphere
Subgroup 3 — Terminal Strength
Subgroup 4 — High Temp. Anode Voltage — Critical rate or rise
Subgroup 5 — Storage Life Test
Subgroup 6 — Operating Life Test

TYPICAL CHARACTERISTICS
2N3027 — 2N3028 — 2N3029

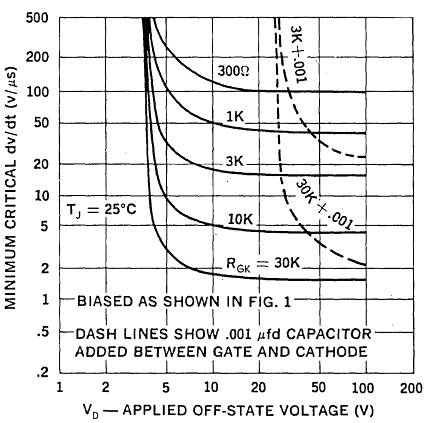
1 Gate Trigger Current



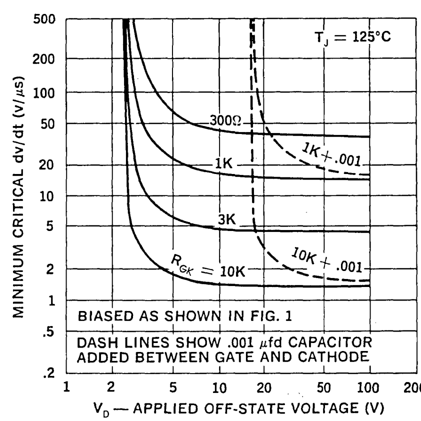
2 Gate Trigger Voltage



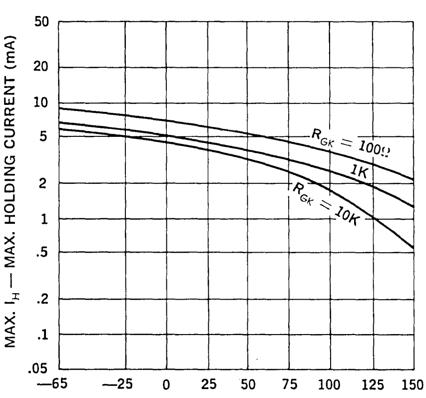
3 Min. Critical dv/dt (25°C — R Bias)



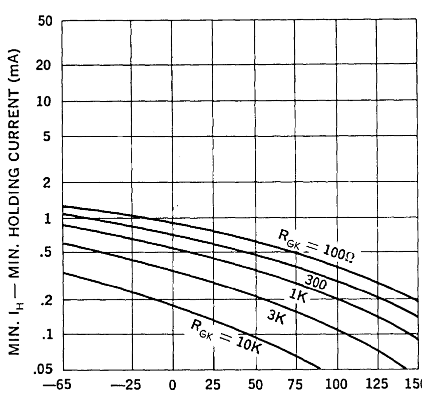
4 Min. Critical dv/dt (125°C — R Bias)



5 Max. Holding Current (Resistor Bias)

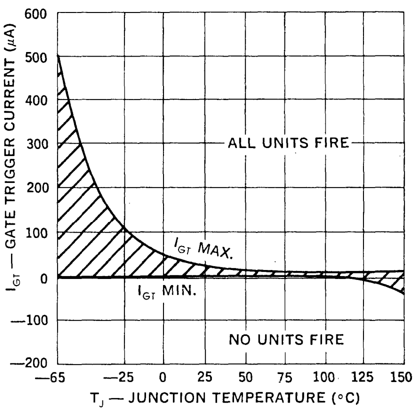


6 Min. Holding Current (Resistor Bias)

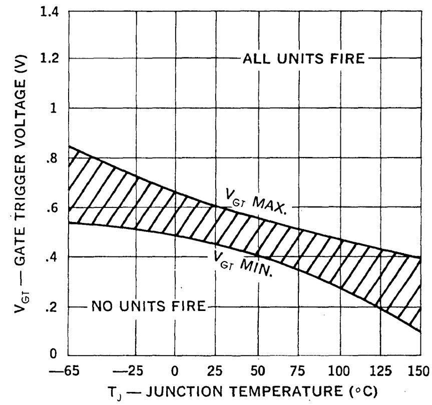


TYPICAL CHARACTERISTICS
2N3030 — 2N3031 — 2N3032

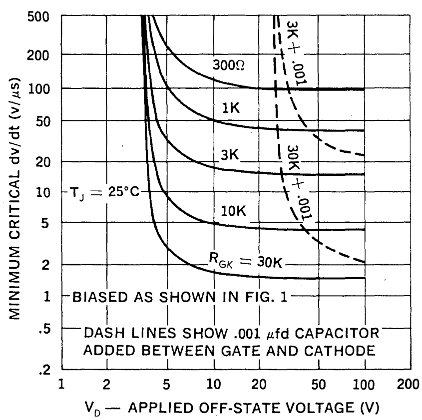
1 Gate Trigger Current



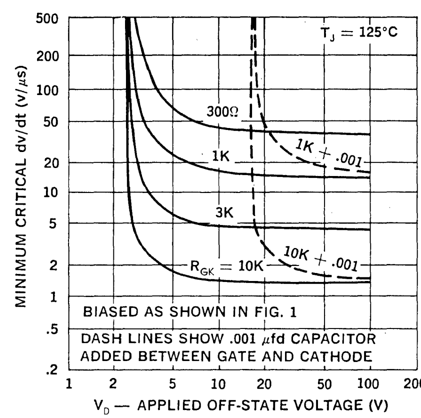
2 Gate Trigger Voltage



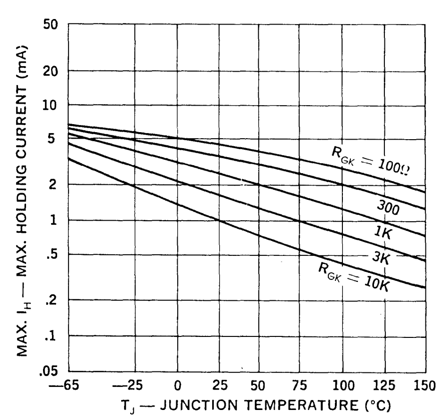
3 Min. Critical dv/dt (25°C — R Bias)



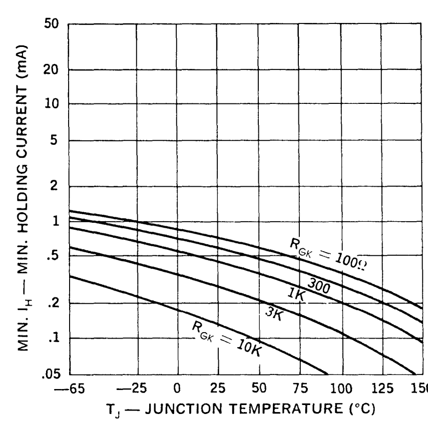
4 Min. Critical dv/dt (125°C — R Bias)



5 Max. Holding Current (Resistor Bias)

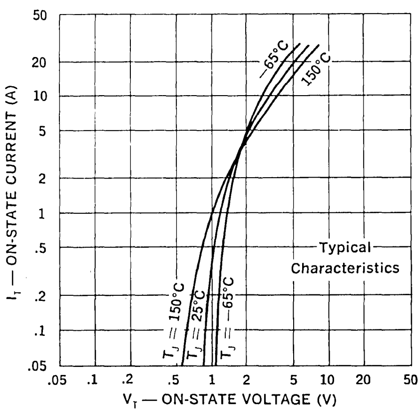


6 Min. Holding Current (Resistor Bias)

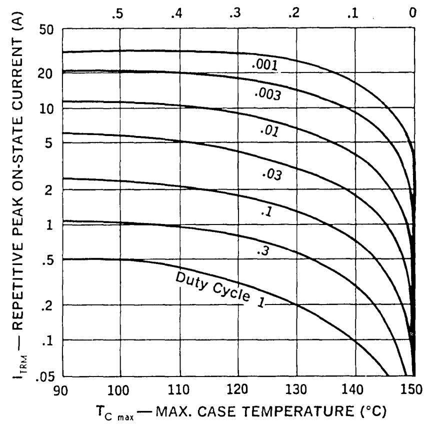


CURRENT RATINGS

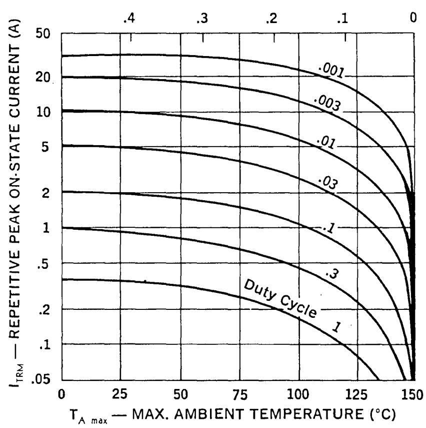
C1 Forward on Current vs. Voltage



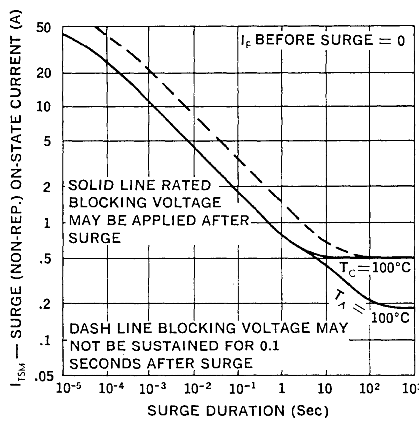
C2 Peak Current vs. Case Temperature



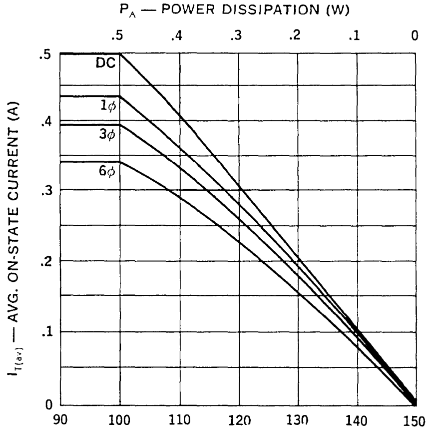
C3 Peak Current vs. Ambient Temperature TO-18 Ratings (see note)



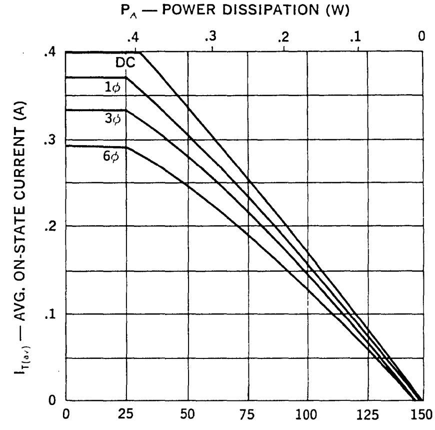
C4 Surge Current vs. Time



C5 Average Current vs. Case Temperature



C6 Average Current vs. Ambient Temperature TO-18 Ratings (see note)



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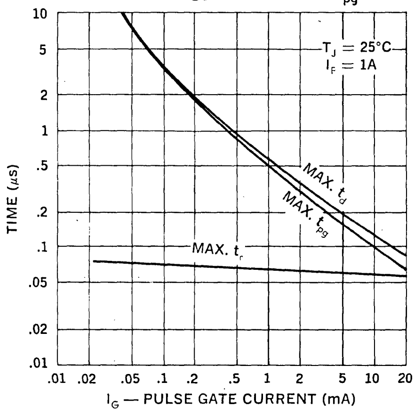
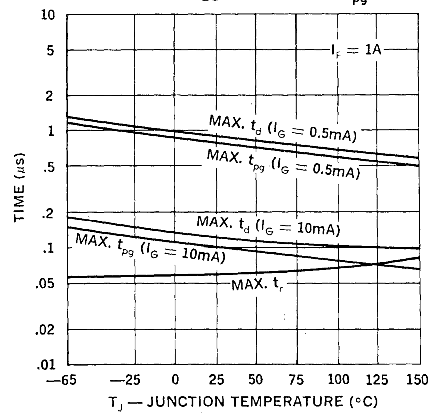
SWITCHING SPEEDS

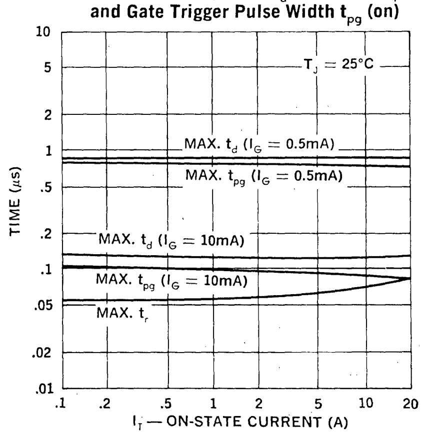
S1 Maximum Delay Time t_d, Rise Time t_r, and Gate Trigger Pulse Width t_{pg} (on)



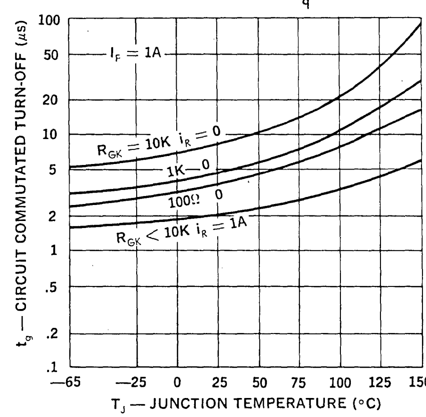
S2 Maximum Delay Time t_d, Rise Time t_r, and Gate Trigger Pulse Width t_{pg} (on)



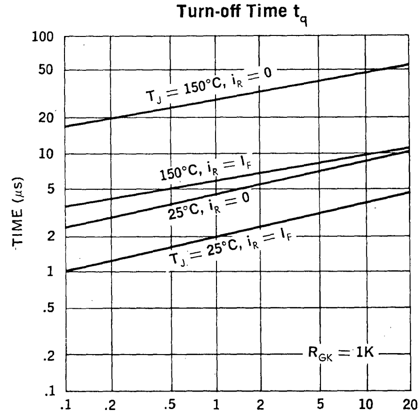
S3 Maximum Delay Time t_d, Rise Time t_r, and Gate Trigger Pulse Width t_{pg} (on)



S4 Maximum Circuit Commutated Turn-off Time t_q



S5 Maximum Circuit Commutated Turn-off Time t_q



SCRs
.8 Amp RMS, Plastic

FEATURES
- Voltage Ratings: to 200V
- Forward Current: 0.8A RMS
- Surge Current: 6A, 8ms
- Gate Sensitivity: 200μa max.
- Planar Passivated Process
- TO-92 Plastic Package

DESCRIPTION
This plastic series features very fast switching performance, low forward voltage drop and a high degree of reliability and parameter stability. All units are fully planar passivated and are packaged in a rugged TO-92 case, constructed from a special epoxy compound that features excellent moisture resistance providing stable performance under high humidity conditions and good thermal transfer characteristics.

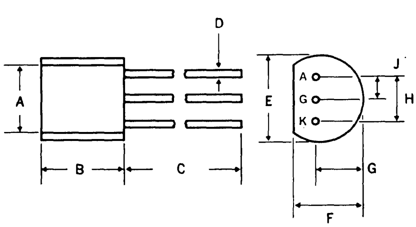
TYPICAL APPLICATIONS
Lamp Driving	Process Controls	Remote Controls
Relay Driving	Pressure Controls	High Current SCR Driving
Relay Replacement	Display Systems	Timers
Alarm Systems	Touch Switches	Temperature Controls
Counters	and many other current sensing and control applications.	

X

ABSOLUTE MAXIMUM RATINGS
	2N5060	2N5061	2N5062	2N5063	2N5064
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V	150V	200V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V	150V	200V
On-State Current, $I_{T(RMS)}$			0.8A		
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}			6A		
Peak Gate Current, I_{GM}			1.0A		
Peak Gate Power, P_{GM}			1W		
Average Gate Power $P_{G(AV)}$			0.01W		
Reverse Gate Voltage, V_{GR}			6V		
Storage Temperature Range			−65°C to +150°C		
Operating Temperature Range			−65°C to +125°C		

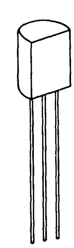
MECHANICAL SPECIFICATIONS

2N5060-2N5064



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92



UNITRODE

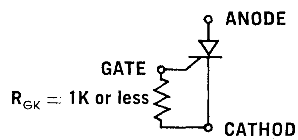
ELECTRICAL SPECIFICATIONS (at 25°C unless noted

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	0.1	1.0	μA	V_{DRM} = Rating R_{GK} = 1KΩ
		—	—	50	μA	V_{DRM} = Rating, T = 125°C
Reverse Current	I_{RRM}	—	0.1	1.0	μA	V_{RRM} = Rating R_{GK} = 1KΩ
		—	—	50	μA	V_{RRM} = Rating, T = 125°C
Gate Trigger Current	I_{GT}	—	—	200	μA	V_D = 7V, R_L = 100 ohms R_{GS} = 10KΩ
		—	—	350	μA	V_D = 7V, R_L = 100 ohms, T = −65°C
Gate Trigger Voltage	V_{GT}	—	0.6	0.8	V	V_D = 7V, R_L = 100 ohms R_{GS} = 10KΩ
		—	—	1.2	V	V_D = 7V, R_L = 100 ohms, T = −65°C
		0.1	—	—	V	V_D = Rating, R_L = 100 ohms, T = 125°C
Peak On-State Voltage	V_{TM}	—	1.2	1.7	V	I_{TM} = 1 Amp Pulse
Holding Current	I_H	—	0.7	5.0	mA	V_D = 7V, T = 25°C
		—	—	10.0	mA	V_D = 7V, T = −65°C
Critical Rate of Rise — Off-State Voltage	dv/dt	—	75	—	V/μs	V_D = Rated
Turn-on Time	t_{on}	—	.25	—	μs	I_G = 10mA, I_T = 1A, V_D = 30V
Circuit Commutated Turn-off Time	t_q	—	20	—	μs	I_{TM} = I_R = 1A

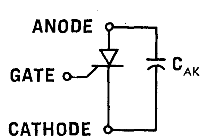
Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

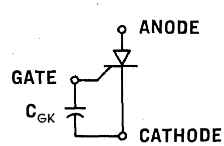
DESIGN CONSIDERATIONS

1. The 2N5060 Series SCRs are guaranteed to block their rated voltage over the rated operating temperature when a resistance of 1000 ohms or less is connected from gate to cathode as shown.

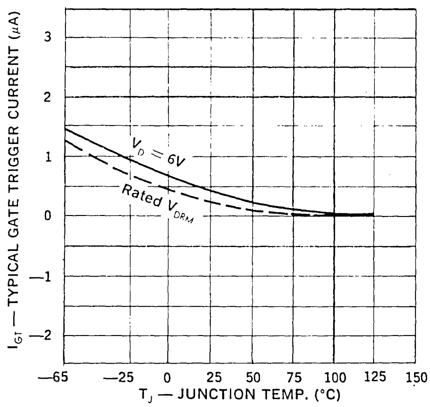


2. In cases where the SCR may be subjected to fast rising anode voltages a capacitor can be connected between anode or gate and cathode as shown, to serve as protection against dv/dt firing.

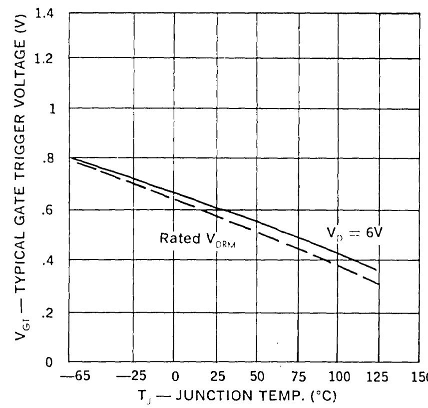




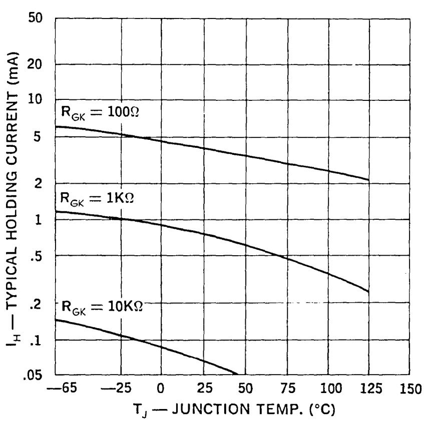
Gate Trigger Current vs. Junction Temp.



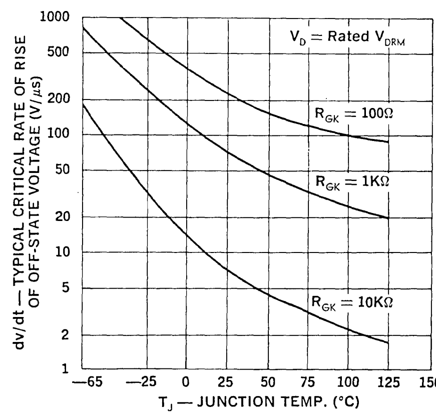
Gate Trigger Voltage vs. Junction Temp.



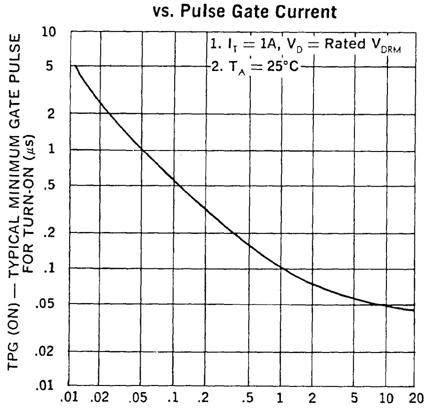
Holding Current vs. Junction Temp.



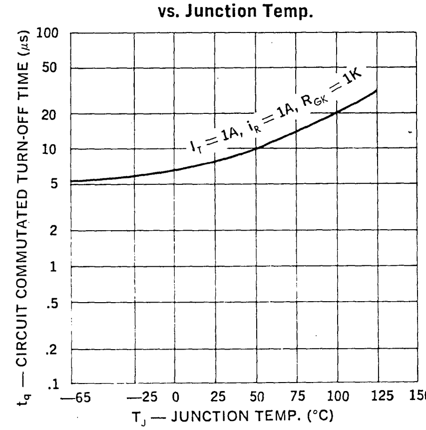
dv/dt vs. Junction Temp.



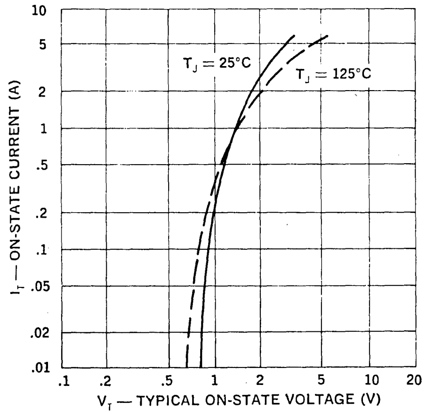
Gate Pulse For Turn-On vs. Pulse Gate Current



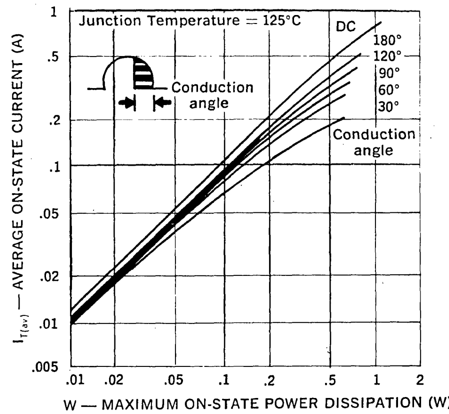
Forward Blocking Recovery Time vs. Junction Temp.



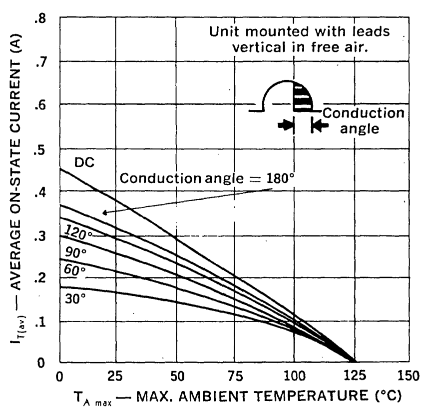
Current vs. On-State Voltage



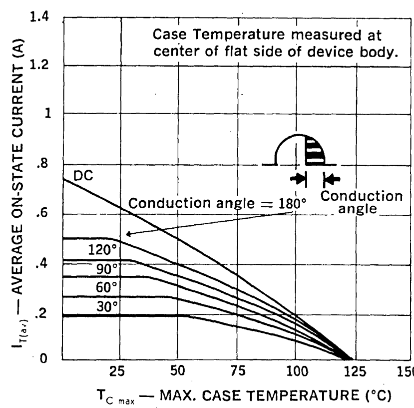
Current vs. Power Dissipation



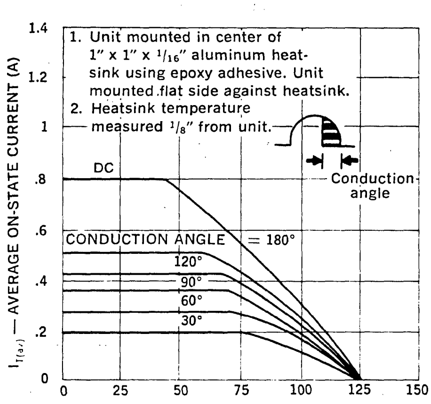
Current vs. Ambient Temp.



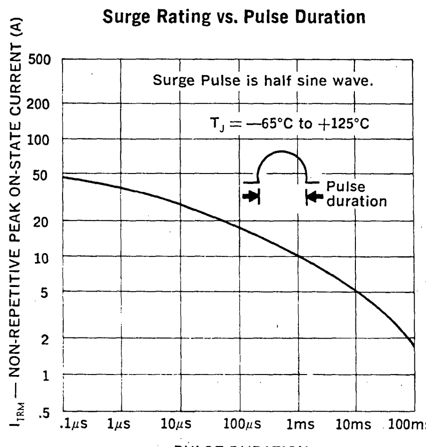
Current vs. Case Temp.



Current vs. Heatsink Temp.



Surge Rating vs. Pulse Duration



UNITRODE CORPORATION • 5 FORBES ROAD
LEXINGTON, MA 02173 • TEL. (617) 861-6540
TWX (710) 326-6509 • TELEX 95-1064

SCRs
1.6 Amp, Planar

FEATURES

- Maximum Gate Trigger Current: 20μA
- Closely Controlled Gate Trigger Voltage: .44 to .6V
- Operating Current Range: 2mA to 1.6A
- Voltage Ratings: to 400V
- Low On-State Voltage
- Specified for dv/dt and Switching Time

DESCRIPTION

These devices are intended for general purpose usage in Military/aerospace or severe industrial environments. Major design parameters are specified at the temperature extremes, thus permitting worst case design on the basis of guaranteed values. These devices undergo 100% preconditioning, which includes high temperature storage and temperature cycling followed by a fine leak test as a regular part of the manufacturing procedure.

The high voltage types of the 2N5724 series are especially useful as pulse modulator switches in low to medium power pulse modulator applications. Specific parameters such as rise time, delay time, holding current, and recovery time can be selected for optimum performance in a pulse modulator circuit.

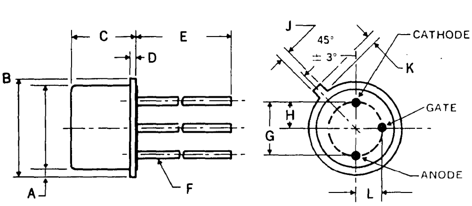
ABSOLUTE MAXIMUM RATINGS

	2N5724	2N5725	2N5726	2N5727	2N5728
Repetitive Peak Off-State Voltage, V_{DRM}	60V	100V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	60V	100V	200V	300V	400V
Non-Repetitive Peak Off-State Voltage, V_{DSM}	500V				
D.C. On-State Current, I_T					
75°C Ambient	450mA				
85°C Case	1.6A				
Repetitive Peak On-State Current, I_{TRM}	up to 30A				
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}	15A				
Peak Gate Current, I_{GM}	250mA				
Average Gate Current, $I_{G(AV)}$	25mA				
Reverse Gate Current, I_{GR}	3mA				
Reverse Gate Voltage, V_{GR}	6V				
Operating and Storage Temperature Range	−65°C to +150°C				

X

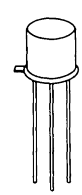
MECHANICAL SPECIFICATIONS

2N5724-2N5728



	ins.	mm.
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.35-6.60
D	.010-.030	.25-.76
E	.5 MIN.	12.70 MIN.
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.79±.08
K	.029-.045	.74-1.14
L	.100	2.54

TO-39



UNITRODE

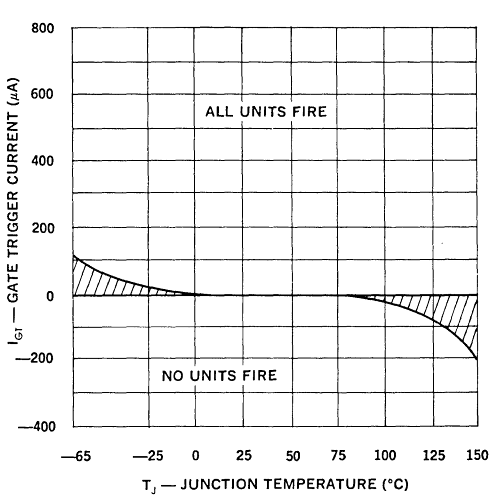
ELECTRICAL SPECIFICATIONS

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
SUBGROUP 1						
Visual and Mechanical	—	—	—	—	—	
SUBGROUP 2 (25°C TESTS)						
Off-State Current	I_{DRM}	—	.05	0.1	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	.05	0.1	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Reverse Gate Voltage	V_{GR}	5	8	—	V	$I_{GR} = 0.1mA$
Gate Trigger Current	I_{GT}	—	2	20	μA	$R_{GS} = 10K$, $V_D = 5V$
Gate Trigger Voltage	V_{GT}	0.44	0.5	0.6	V	$R_{GS} = 100\Omega$, $V_D = 5V$
On-State Voltage	V_T	—	2.3	2.5	V	$I_T = 5A$ (pulse test)
Holding Current	I_H	0.3	0.8	2.0	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 3 (25°C TESTS)						
Off-State Voltage — Critical Rate of Rise	dv/dt	100	150	—	v/μs	$R_{GK} = 1K$, $V_D = 30V$
Gate Trigger — on Pulse Width	t_{pg} (on)	—	0.1	0.5	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Delay Time	t_d	—	0.1	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Rise Time	t_r	—	0.3	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Circuit Commutated Turn-off Time						
2N5724, 2N5725, 2N5726,	t_q	—	15	30	μs	$I_T = 1A$, $i_R = 1A$, $R_{GK} = 1K$
2N5727, 2N5728		—	30	50	μs	
SUBGROUP 4 (150°C TESTS)						
High Temp. Off-State Current	I_{DRM}	—	50	200	μA	$R_{GK} = 1K$, V_{DRM} = Rating
High Temp. Reverse Current	I_{RRM}	—	80	200	μA	$R_{GK} = 1K$, V_{RRM} = Rating
High Temp. Gate Trigger Voltage	V_{GT}	0.10	0.15	—	V	$R_{GS} = 100\Omega$, $V_D = 5V$
High Temp. Holding Current	I_H	0.10	0.15	—	mA	$R_{GK} = 1K$, $V_D = 5V$
SUBGROUP 5 (—65°C TESTS)						
Low Temp. Gate Trigger Voltage	V_{GT}	—	0.7	0.9	V	$R_{GS} = 100\Omega$, $V_D = 5V$
Low Temp. Gate Trigger Current	I_{GT}	—	50	125	μA	$R_{GS} = 10K$, $V_D = 5V$
Low Temp. Holding Current	I_H	—	1.2	3.0	mA	$R_{GK} = 1K$, $V_D = 5V$

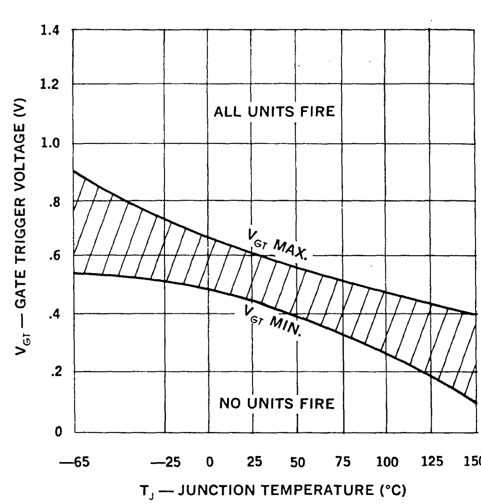
Note 1 See rating curves for full rating information.

Note 2 Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1K or smaller, or other adequate gate bias is used.

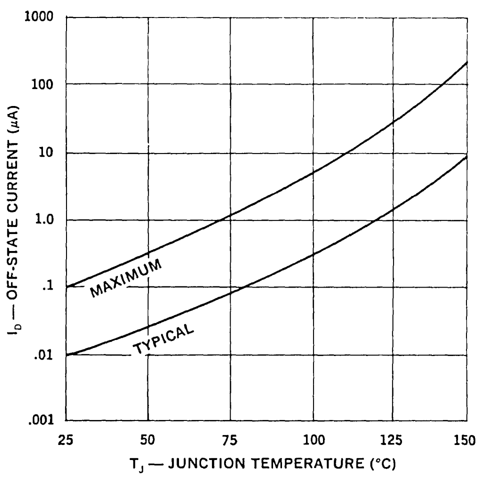
Gate Trigger Current



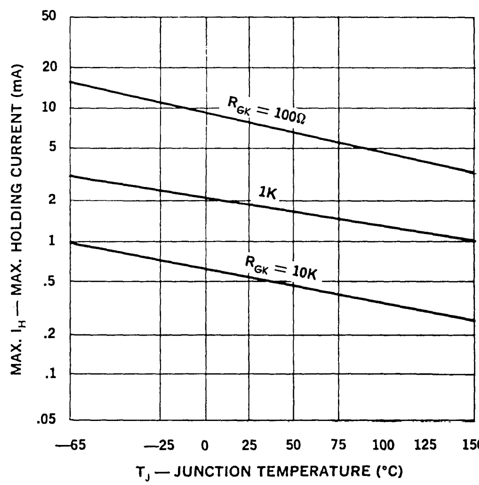
Gate Trigger Voltage



Off-State Current



Max. Holding Current



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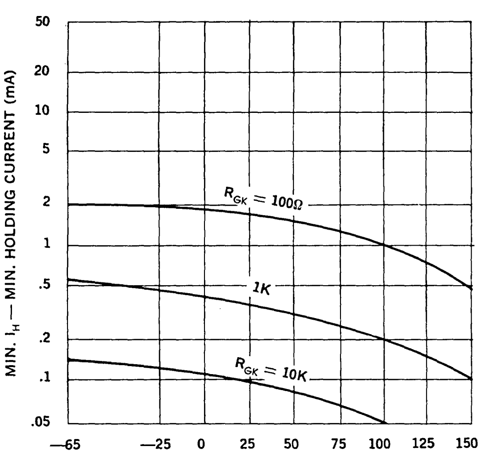
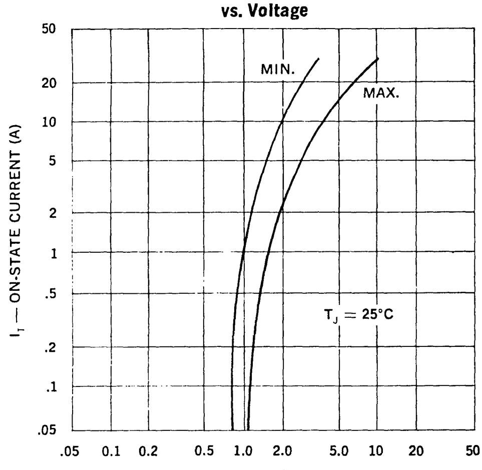
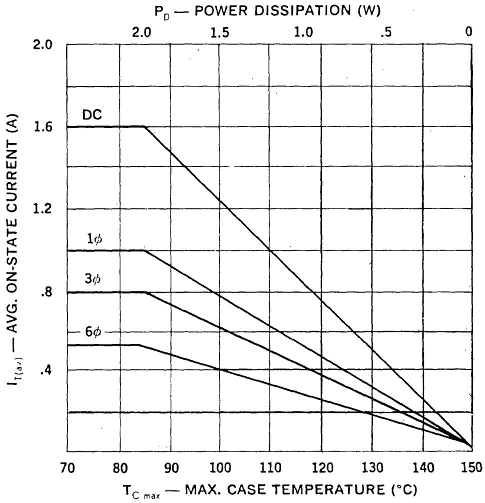
Min. Holding Current



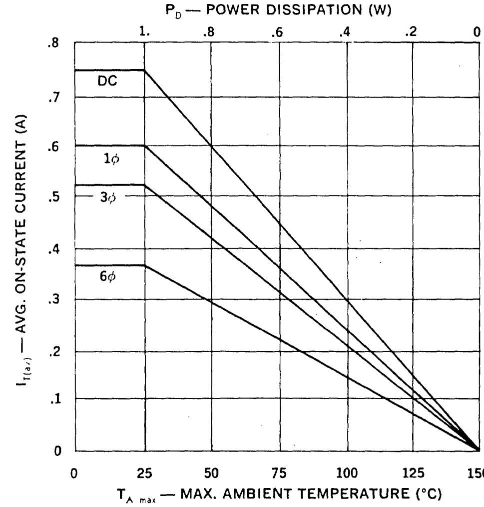
On-State Current vs. Voltage



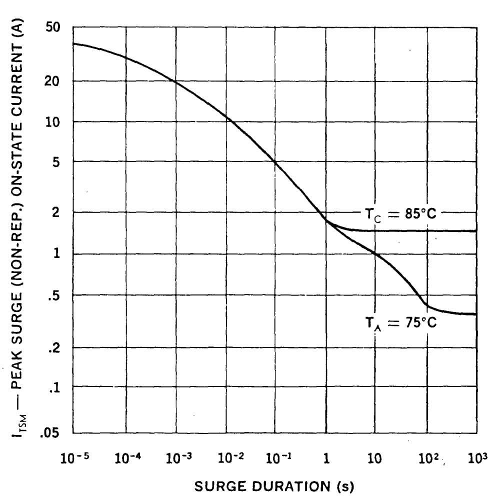
Avg. Current vs. Case Temperature



Avg. Current vs. Ambient Temperature



Surge Current



PUTs

2N6027-2N6028

Planar, TO-92 Plastic

FEATURES
- TO-92 Plastic Package
- Maximum Peak Current: 150nA
- Minimum Valley Current: 1.5mA
- Peak Forward Current: 5A
- Programmable Eta, R_{BB}, I_P and I_V
- Planar Passivated Construction for Maximum Reliability and Parameter Uniformity

DESCRIPTION
The Unitrode Programmable Unijunction Transistor is today's preferred device for low cost timing circuits, oscillators, sensing circuits and a wide range of other applications where a variable voltage level threshold is desired. Functionally equivalent to standard unijunction transistors, the Unitrode PUT offers the distinct advantage of versatile programming. External resistors can be added to meet the designer's needs in programming the Eta, R_{BB}, I_P, and I_V functions. For additional information see Unitrode Application Note U-66.

TYPICAL FEATURES
Programmable Turn-on
Programmable Turn-off
Low Leakage Current
High Output Pulse

TYPICAL APPLICATIONS

SCR Triggers	Delay Circuits
Timing Circuits	Sampling Circuits
Oscillators	Relay Drivers
Sweep Circuits	Smoke Detectors

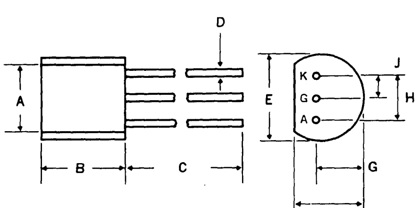
ABSOLUTE MAXIMUM RATINGS

Anode-to-Cathode Voltage, V_{AK}	±40V
Gate-to-Cathode Forward Voltage, V_{GK}	40V
Gate-to-Anode Reverse Voltage, V_{GAR}	40V
Gate-to-Cathode Reverse Voltage, V_{GKR}	−5V
Peak Recurrent Forward Current	
20μs, 1% Duty Cycle	2A
100μs, 1% Duty Cycle	1A
Peak Non-recurrent Forward Current, 10μs	5A
Power Dissipation	
25°C Ambient	375mW
Derating Factor	5mW/°C
Storage Temperature	−55°C to +125°C
Operating Temperature Range	−55°C to +100°C

X

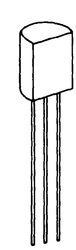
MECHANICAL SPECIFICATIONS

2N6027-2N6028



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

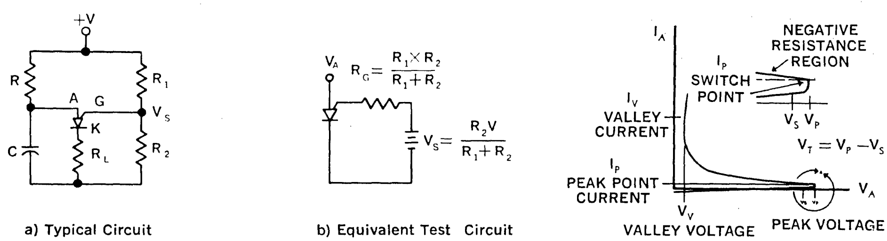
TO-92



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Fig.	2N6027 Min.	2N6027 Max.	2N6028 Min.	2N6028 Max.	Units	Test Conditions
Peak Current	I_P	1	—	2	—	0.15	μA	$R_G = 1M\Omega$, $V_S = 10V$
			—	5	—	1.0	μA	$R_G = 10k\Omega$, $V_S = 10V$
Valley Current	I_V	1	—	50	—	25	μA	$R_G = 1M\Omega$, $V_S = 10V$
			70	—	25	—	μA	$R_G = 10k\Omega$, $V_S = 10V$
			1.5	—	1.0	—	mA	$R_G = 200\Omega$, $V_S = 10V$
Offset Voltage	V_T	1	0.2	0.6	0.2	0.6	V	$R_G = 10k\Omega$, $V_S = 10V$
			0.2	1.6	0.2	0.6	V	$R_G = 1M\Omega$, $V_S = 10V$
Gate-to-Anode Leakage	I_{GAO}	2	—	10	—	10	nA	$T = 25°C$, $V_S = 40V$
			—	100	—	100	nA	$T = 75°C$, $V_S = 40V$
Gate-to-Cathode Leakage	I_{GKS}	3	—	100	—	100	nA	$V_S = 40V$
Forward Voltage	V_F	4	—	1.5	—	1.5	V	$I_F = 50mA$
Pulse Output Voltage	V_O	5	6	—	6	—	V	
Pulse Output Rise Time	t_r	5	—	80	—	80	ns	



a) Typical Circuit b) Equivalent Test Circuit

Figure 1

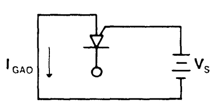


Figure 2

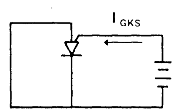


Figure 3

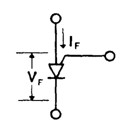


Figure 4

Note: Conditions for oscillation

$$\frac{V_{BB} - V_P}{R} > I_P$$

$$\frac{V_{BB} - V_V}{R} < I_V$$

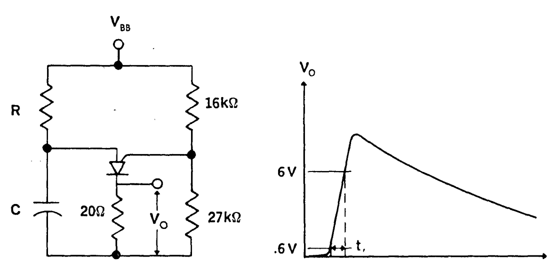
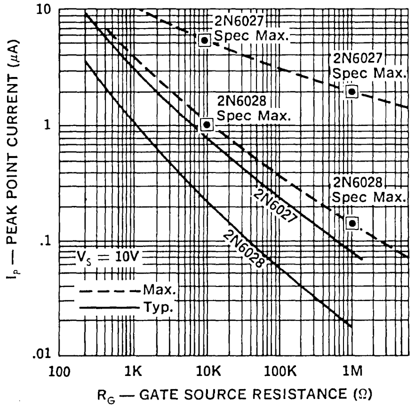
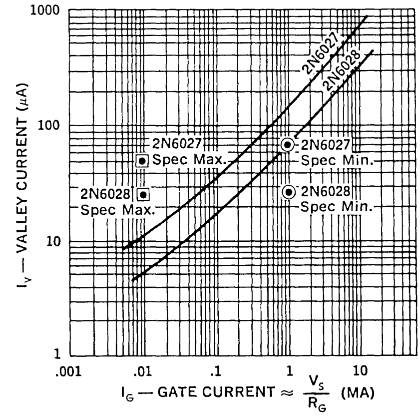


Figure 5

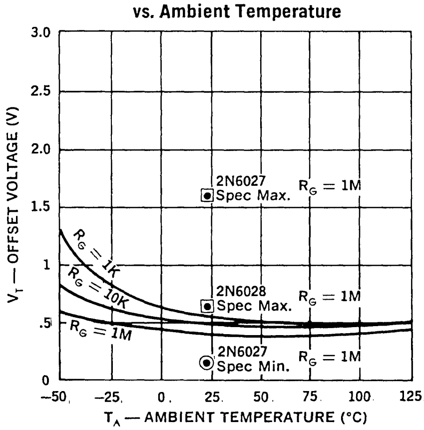
Peak Point Current vs. Gate Source Resistance



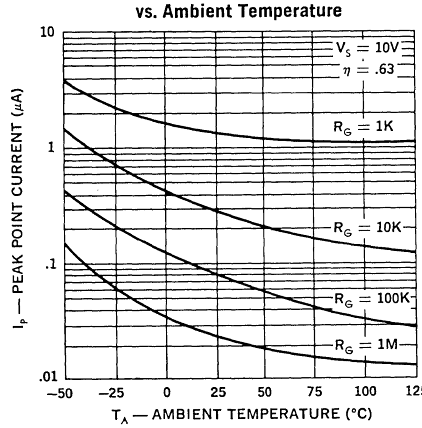
Valley Current vs. Gate Current



Offset Voltage vs. Ambient Temperature



Peak Point Current vs. Ambient Temperature



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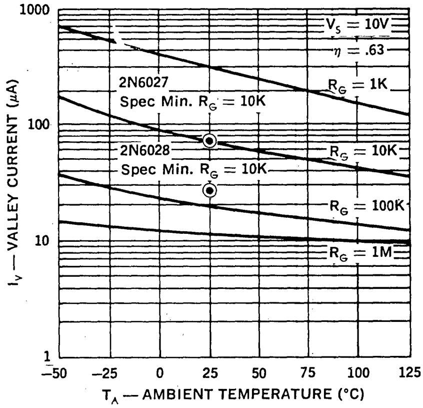
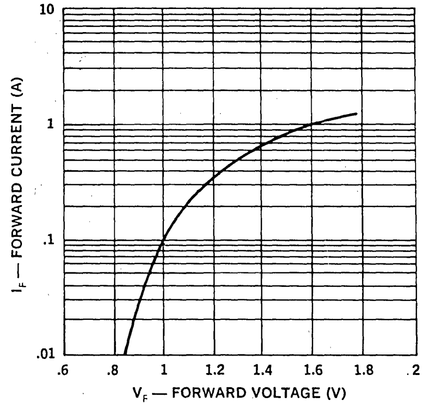
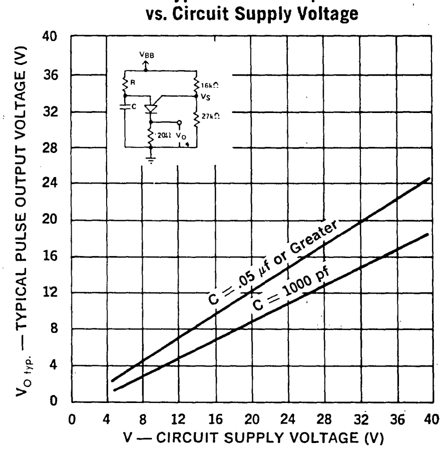
Valley Current vs. Ambient Temperature



Forward Current vs. Forward Voltage



Typical Pulse Output vs. Circuit Supply Voltage



PUTs

Planar, TO-18, Hermetic

2N6119-2N6120

FEATURES

- Hermetically Sealed TO-18 Metal Can
- Programmable Eta, R_{BB}, I_P and I_V
- Maximum Peak Point Current: 150nA
- Minimum Valley Current to 1.5mA
- Nano-Amp Leakage
- Passivated Planar Construction for Maximum Reliability and Parameter Uniformity

DESCRIPTION

Functionally equivalent to standard unijunction transistors, Unitrode's Programmable Unijunction Transistors offer the distinct advantage of versatile programming. External resistors can be added to meet the designer's needs in programming Eta, R_{BB}, I_P and I_V functions. This series also features a hermetically sealed TO-18 package for optimum reliability in all environmental conditions. Applications include pulse and timing circuits, SCR trigger circuits, relaxation oscillators and sensing circuits. For additional information see Unitrode Application Note U-66.

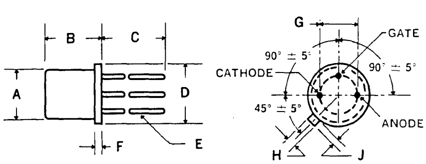
ABSOLUTE MAXIMUM RATINGS

Anode-to-Cathode Voltage, V_{AK}	±40V
Gate-to-Cathode Forward Voltage, V_{GK}	40V
Gate-to-Anode Reverse Voltage, V_{GAR}	40V
Gate-to-Cathode Reverse Voltage, V_{GKR}	−5V
Peak Recurrent Forward Current	
10μs, 1% Duty Cycle	8A
100μs, 1% Duty Cycle	5A
Power Dissipation	
25°C Ambient	400mW
Derating Factor	3.2mW/°C
Storage Temperature	−55°C to +125°C
Operating Temperature Range	−55°C to +125°C

X

MECHANICAL SPECIFICATIONS

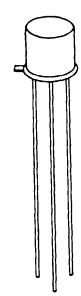
2N6119-2N6120



GATE CONNECTED TO CASE

	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA. / .001 DIA.	.432 ± .051 / .025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

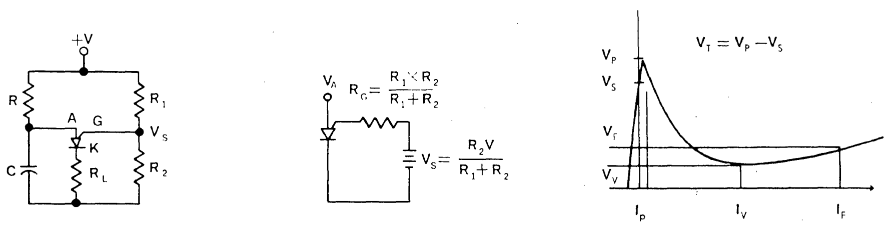
TO-18



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Fig.	2N6119 Min.	2N6119 Max.	2N6120 Min.	2N6120 Max.	Units	Test Conditions
Peak Current	I_P	1	—	5	—	1.0	μA	$R_G = 10k$, $V_S = 10V$
			—	2	—	0.15	μA	$R_G = 1$ Meg.
Valley Current	I_V	1	70	—	25	—	μA	$R_G = 10k$, $V_S = 10V$
			—	50	—	25	μA	$R_G = 1$ Meg.
			1.5	—	1.0	—	mA	$R_G = 200\Omega$
Offset Voltage	V_T	1	0.2	0.6	0.2	0.6	V	$R_G = 10k$, $V_S = 10V$
			0.2	1.6	0.2	0.6	V	$R_G = 1$ Meg.
Gate-to-Anode Leakage	I_{GAO}	2	—	10	—	10	nA	$T = 25°C$, $V_S = 40V$
			—	100	—	100	nA	$T = 75°C$
Gate-to-Cathode Leakage	I_{GKS}	3	—	100	—	100	nA	$V_S = 40V$
Forward Voltage	V_F	4	—	1.0	—	1.0	V	$I_F = 50mA$
Pulse Output Voltage	V_o	5	9	—	9	—	V	
Pulse Output Rate of Rise	t_r	5	—	80	—	80	ns	



a) Typical Circuit

b) Equivalent Test Circuit

c) Characteristic Curve

Figure 1

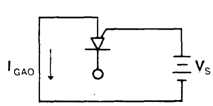


Figure 2

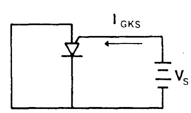


Figure 3

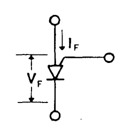


Figure 4

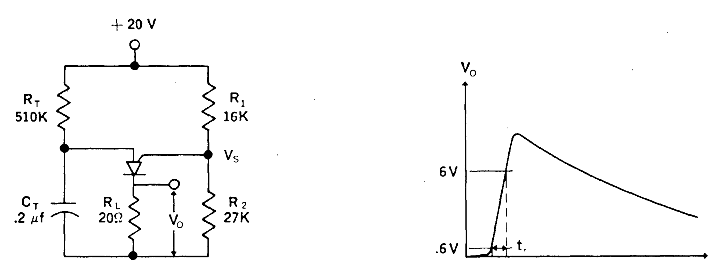


Figure 5

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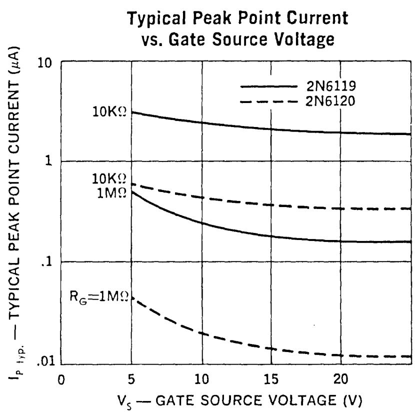
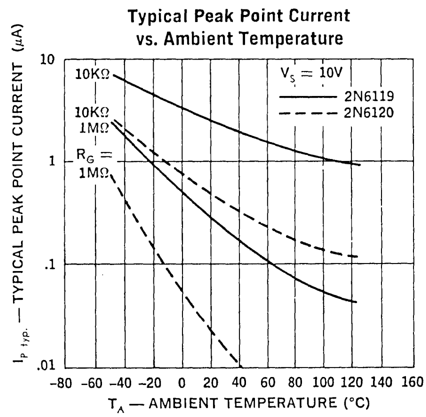
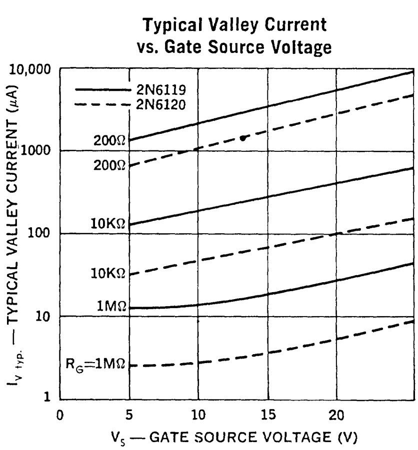


Typical Peak Point Current
vs. Gate Source Voltage
2N6119
2N6120
10KΩ
10KΩ
1MΩ
RG=1MΩ
10
1
.1
.01
0
5
10
15
20
IP typ. — TYPICAL PEAK POINT CURRENT (μA)
VS — GATE SOURCE VOLTAGE (V)

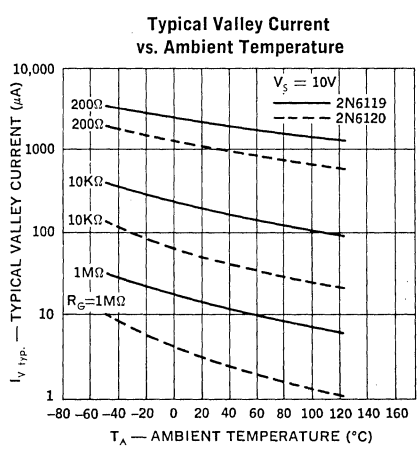


Typical Peak Point Current
vs. Ambient Temperature
VS = 10V
2N6119
2N6120
10KΩ
10KΩ
1MΩ
RG =
1MΩ
10
1
.1
.01
-80 -60 -40 -20 0 20 40 60 80 100 120 140 160
IP typ. — TYPICAL PEAK POINT CURRENT (μA)
TA — AMBIENT TEMPERATURE (°C)

X

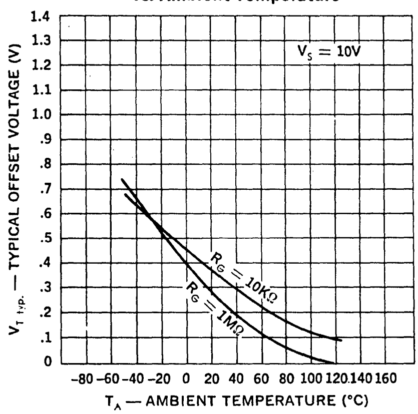


Typical Valley Current
vs. Gate Source Voltage
2N6119
2N6120
200Ω
200Ω
10KΩ
10KΩ
1MΩ
RG=1MΩ
10,000
1000
100
10
1
0
5
10
15
20
IV typ. — TYPICAL VALLEY CURRENT (μA)
VS — GATE SOURCE VOLTAGE (V)

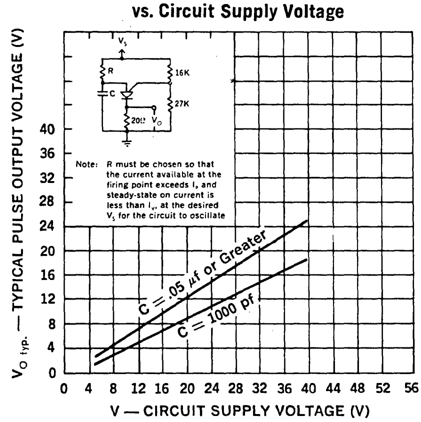


Typical Valley Current
vs. Ambient Temperature
VS = 10V
2N6119
2N6120
200Ω
200Ω
10KΩ
10KΩ
1MΩ
RG=1MΩ
10,000
1000
100
10
1
-80 -60 -40 -20 0 20 40 60 80 100 120 140 160
IV typ. — TYPICAL VALLEY CURRENT (μA)
TA — AMBIENT TEMPERATURE (°C)

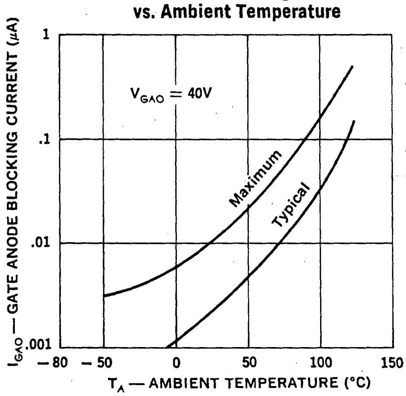
Typical Offset Voltage vs. Ambient Temperature



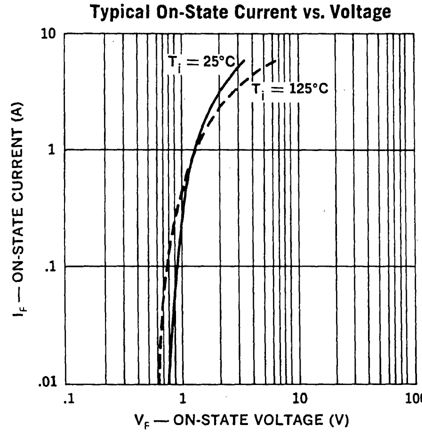
Typical Pulse Output vs. Circuit Supply Voltage



Gate-Anode Blocking Current vs. Ambient Temperature



Typical On-State Current vs. Voltage



PUTs
2N6137

Military, Planar, TO-18, Hermetic

FEATURES

- Available as JAN and JANTX types per MIL standard 19500/493
- −55°C to +125°C Temperature Range for Timing and Oscillator Circuits
- $I_P \leqslant 10\mu A$ at $T = -55°C$
  $I_V \geqslant 40\mu A$ at $T = +125°C$
- Programmable η, R_{BB}, I_P and I_V
- Peak Recurrent Current: of 5A
- Low On-State Voltage Drop
- Hermetically Sealed Metal Case and Planar Passivated Construction for Maximum Reliability and Parameter Stability.

DESCRIPTION

The Programmable Unijunction Transistor is functionally equivalent to a standard unijunction transistor with the advantage that external resistors can be used to program η, R_{BB}, I_P, and I_V, depending upon the designer's needs. The Unitrode device, in addition to allowing programmable versatility, is completely planar passivated and packaged in a TO-18 hermetically sealed package, which offers an order of magnitude improvement in inherent reliability over many similar devices. Applications include pulse and timing circuits, SCR trigger circuits, relaxation oscillators, and sensing circuits. For further application information see Unitrode Application Note U-66.

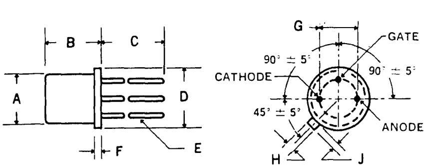
ABSOLUTE MAXIMUM RATINGS

Anode-to-Cathode Forward Voltage, V_{AK} 40V
Anode-to-Cathode Reverse Voltage, V_{AKR} 40V
Gate-to-Cathode Forward Voltage, V_{GK} 40V
Gate-to-Anode Reverse Voltage, V_{GAR} 40V
Gate-to-Cathode Reverse Voltage, V_{GKR} 5V
Peak Recurrent Forward Current, 10μs 1% Duty Cycle 5A
Peak Gate Current, I_{GM} 250mA
Average Gate Current, $I_{G(AV)}$ 50mA
Power Dissipation
25°C Ambient 300mW
Derating Factor .... 2.4mW/°C
Storage Temperature Range .... −55°C to +125°C
Operating Temperature Range .... −55°C to +125°C

X

MECHANICAL SPECIFICATIONS

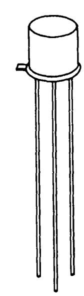
2N6137



GATE CONNECTED TO CASE

	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA. / .001 DIA.	.432 ± .051 / .025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18

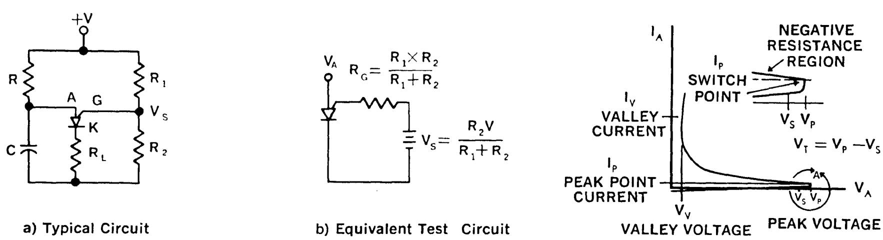


UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)†

Test	Symbol	Figure	Minimum	Typical	Maximum	Units	Test Conditions
SUBGROUP 1 Visual and Mechanical	—	—	—	—	—	—	—
SUBGROUP 2							
Gate-anode blocking current	I_{GAO}	2	—	2	10	nA	V_{GA} = Rating
Gate-cathode blocking current	I_{GKS}	3	—	5	100	nA	V_{GK} = Rating
SUBGROUP 3							
Peak-point anode current	I_P	1	— —	1 2.5	2 5	μA μA	R_G = 1 Meg R_G = 10K } V_S = 10V
Peak-point offset voltage	V_T	1	0.2 0.2	0.26 0.35	1.6 0.6	V V	R_G = 1 Meg R_G = 10K } V_S = 10V
Valley-point anode current	I_V	1	— 70 1.5	15 200 2	50 — —	μA μA mA	R_G = 1 Meg R_G = 10K R_G = 200Ω } V_S = 10V
SUBGROUP 4							
Forward on-state voltage	V_F	4	—	0.85	1.0	V	I_F = 50mA
Peak pulse voltage	V_o	5	9	12	—	V	
Peak pulse voltage rise time	t_r	5	—	50	80	ns	
SUBGROUP 5							
Gate-anode blocking current (125°C Test)	I_{GAO}	2	—	150	500	nA	V_{GA} = Rating
Valley-point anode current (125°C Test)	I_V	1	40	100	—	μA	R_G = 10K, V_S = 10V
Peak-point anode current (—55°C Test)	I_P	1	—	7.5	10	μA	R_G = 10K, V_S = 10V

† All values in table are JEDEC registered



a) Typical Circuit

b) Equivalent Test Circuit

Figure 1

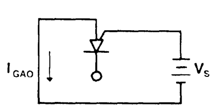


Figure 2

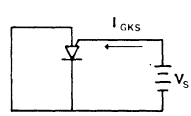


Figure 3

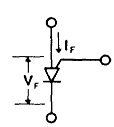


Figure 4

Note: Conditions for oscillation

$$\frac{V_{BB} - V_P}{R} > I_P$$

$$\frac{V_{BB} - V_V}{R} < I_V$$

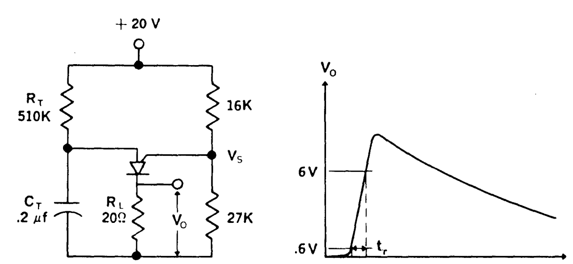
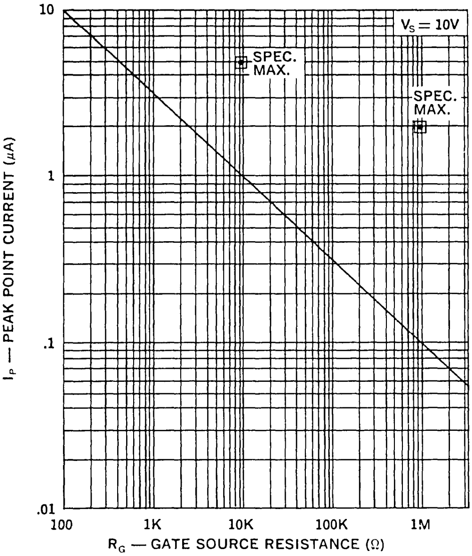
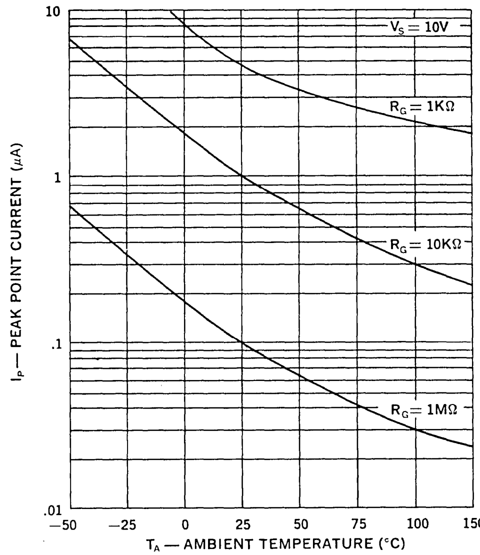


Figure 5

Peak Point Current vs. Gate Source Resistance



Peak Point Current vs. Ambient Temperature



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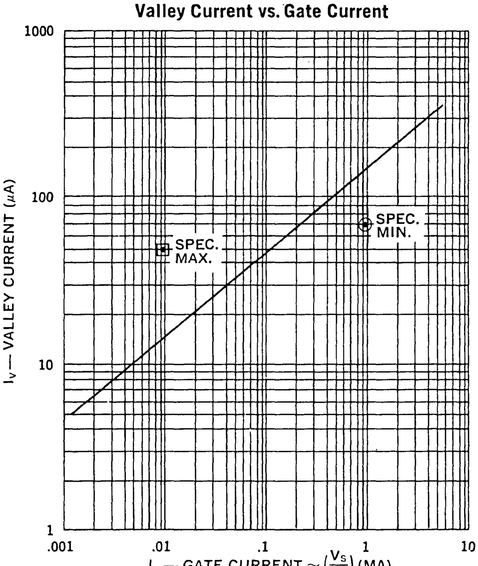
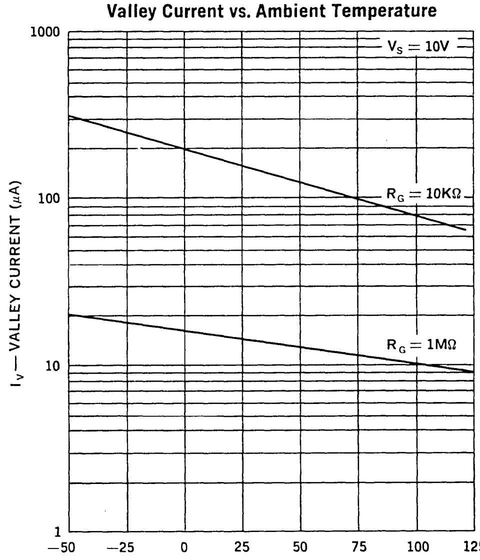
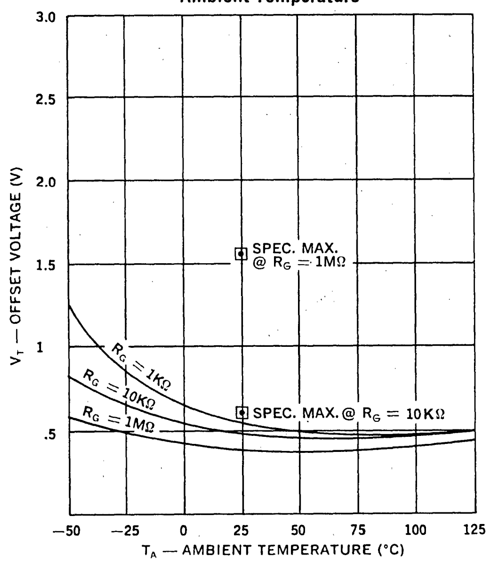
Valley Current vs. Gate Current



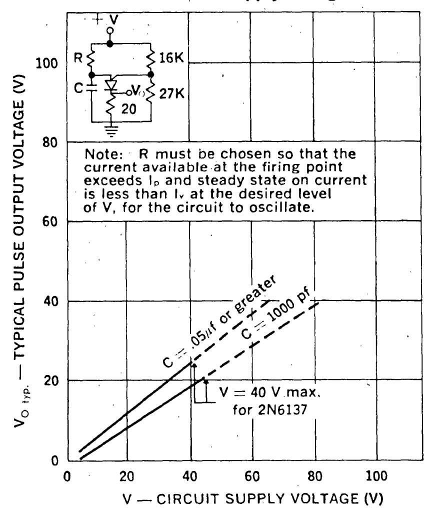
Valley Current vs. Ambient Temperature



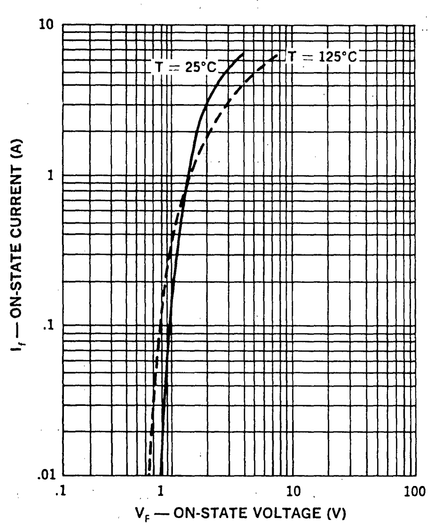
Offset Voltage vs. Ambient Temperature



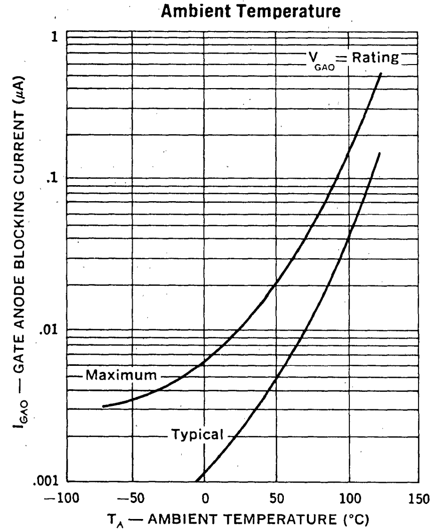
Typical Pulse Output Voltage vs. Circuit Supply Voltage



Typical Current vs. On-State Voltage



Gate-Anode Blocking Current vs. Ambient Temperature



SCRs
.8 Amp RMS, Plastic

2N6564-2N6565

FEATURES
- Voltage Ratings: to 400V
- Forward Current: 0.8A RMS
- Surge Current: 6A, 8ms
- Gate Sensitivity: 200μa max.
- Planar Passivated Process
- TO-92 Plastic Package

DESCRIPTION
This plastic series features very fast switching performance, low forward voltage drop and a high degree of reliability and parameter stability. All units are fully planar passivated and are packaged in a rugged TO-92 case, constructed from a special epoxy compound that features excellent moisture resistance providing stable performance under high humidity conditions and good thermal transfer characteristics.

TYPICAL APPLICATIONS

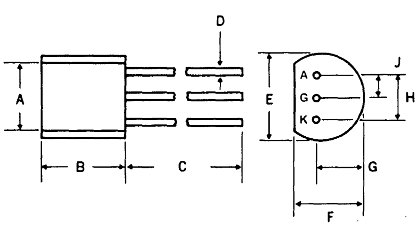
Lamp Driving	Process Controls	Remote Controls
Relay Driving	Pressure Controls	High Current SCR Driving
Relay Replacement	Display Systems	Timers
Alarm Systems	Touch Switches	Temperature Controls
Counters	and many other current sensing and control applications.	

ABSOLUTE MAXIMUM RATINGS

	2N6564	2N6565
Repetitive Peak Off-State Voltage, V_{DRM}	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	300V	400V
On-State Current, $I_{T(RMS)}$ @ $T_C = 70°C$	0.8A	
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}	6A	
Peak Gate Current, I_{GM}	1.0A	
Peak Gate Power, P_{GM}	1W	
Average Gate Power $P_{G(AV)}$	0.01W	
Reverse Gate Voltage, V_{GR}	6V	
Storage Temperature Range	−65°C to +150°C	
Operating Temperature Range	−65°C to +125°C	

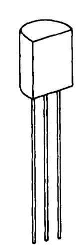
MECHANICAL SPECIFICATIONS

2N6564-2N6565



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92



X

UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted, R_{GK} = 1000 ohms)

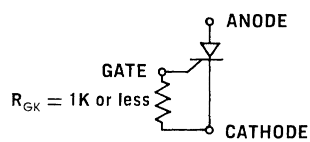
Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	0.1	1.0	μA	V_{DRM} = Rating
		—	—	100	μA	V_{DRM} = Rating, T = 125°C*
Reverse Current	I_{RRM}	—	0.1	1.0	μA	V_{RRM} = Rating
		—	—	100	μA	V_{RRM} = Rating, T = 125°C*
Gate Trigger Current	I_{GT}	—	—	200	μA	V_D = 6V, R_L = 100 ohms
		—	—	350	μA	V_D = 6V, R_L = 100 ohms, T = −65°C*
Gate Trigger Voltage	V_{GT}	—	0.6	0.8	V	V_D = 6V, R_L = 100 ohms
		—	—	1.2	V	V_D = 6V, R_L = 100 ohms, T = −65°C*
		0.1	—	—	V	V_D = Rating, R_L = 100 ohms, T = 125°C*
Peak On-State Voltage	V_{TM}	—	1.0	1.7	V	I_{TM} = 1.2 Amp Pulse*
Holding Current	I_H	—	0.7	5.0	mA	V_D = 6V, T = 25°C
		—	—	10.0	mA	V_D = 6V, T = −65°C*
Critical Rate of Rise — Off-State Voltage	dv/dt	—	75	—	V/μs	V_D = Rating
Turn-on Time	t_{on}	—	0.5	1.5	μs	I_G = 10mA, I_T = 1A, V_D = Rating*
Circuit Commutated Turn-off Time	t_q	—	15	—	μs	I_T = I_R = 1A

Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

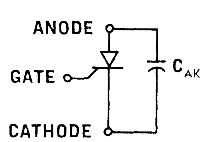
*Indicates JEDEC Registered data.

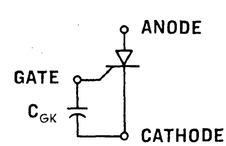
DESIGN CONSIDERATIONS

1. The 2N6564 Series SCRs are guaranteed to block their rated voltage over the rated operating temperature when a resistance of 1000 ohms or less is connected from gate to cathode as shown.



2. In cases where the SCR may be subjected to fast rising anode voltages a capacitor can be connected between anode or gate and cathode as shown, to serve as protection against dv/dt firing.





SCRs
1.0 Amp RMS, Plastic
800V

2N6681
2N6682
2N6683
2N6684
2N6685

FEATURES:
- Forward Current: 1.0A RMS
- Voltage Ratings: to 800V
- High Surge Current: 15A, 8mS
- Gate Sensitivity: 30μA Typical
- Hard Glass Passivated Junction
- Economical TO-92 Package

TYPICAL APPLICATIONS:

Ground fault interrupters
Photo flash circuits
Ignition/Ignitor circuits
Relay drivers
Relay replacement
Gate drivers for high current SCRs
Lamp driving
Off-line appliance controls

DESCRIPTION:
This plastic PNPN device is rated at 1.0 Amp RMS maximum on-state current, with rated voltages up to 800 volts. All units in this series offer full hard glass passivation with sensitivity especially targeted for good transient immunity. Supplied in an economical TO-92 package, this device is well suited for many high volume applications.

X

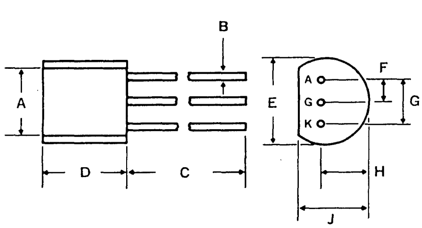
MAXIMUM RATINGS

	2N6681	2N6682	2N6683	2N6684	2N6685
Repetitive Peak Off-State Voltage, V_{DRM}	100V	200V	400V	600V	800V
Repetitive Peak Reverse Voltage, V_{RRM}	100V	200V	400V	600V	800V

On-State Current, I_T RMS At 60°C Case, 180° Conduction Sinewave	1.0A
Surge (Non-Rep.) On-State Current, I_{TSM}	15A
Peak Gate Current, I_{GM}	1.0A
Peak Gate Power, P_{GM}	1W
Average Gate Power P_G (AV.)	0.01W
Reverse Gate Voltage, V_{GR}	6V
Storage Temperature Range	−55°C to +150°C
Operating Temperature Range (2N6681-2N6683)	−55°C to +110°C
Operating Temperature Range (2N6684-2N6685)	−55°C to + 85°C

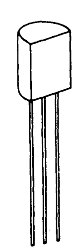
MECHANICAL SPECIFICATIONS

2N6681-5 SERIES



	inches	millimeters
A	.135 MIN.	3.43 MIN.
B	.019 - .016	.48 - .41
D	.210 - .170	5.33 - 4.32
C	.500 MIN.	12.7 MIN.
E	.205 - .175	5.21 - 4.45
J	.165 - .125	4.19 - 3.18
F	.055 - .045	1.40 - 1.14
G	.105 - .095	2.67 - 2.41
H	.105 - .080	2.67 - 2.03

TO-92

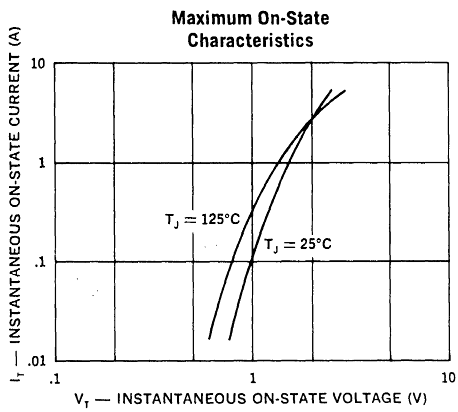


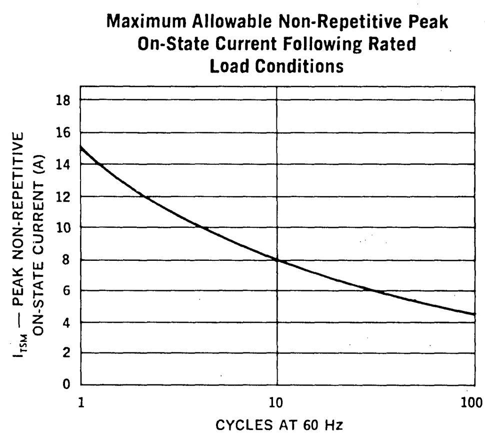
UNITRODE

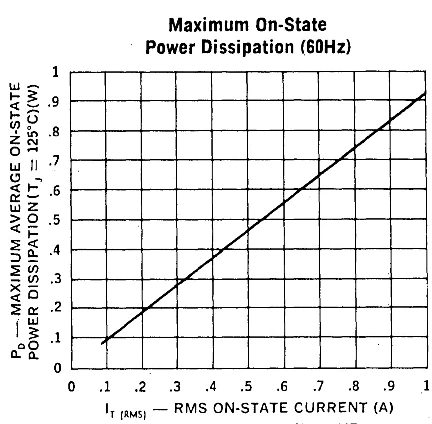
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

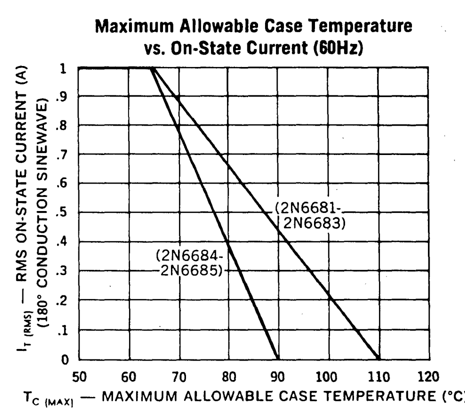
Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	—	100	μA	V_{DRM} = Rating, R_{GK}= 1K, T*= 110°C
Reverse Current	I_{RRM}	—	—	100	μA	V_{RRM} = Rating, R_{GK}= 1K, T* = 110°C
Gate Trigger Current	I_{GT}	—	30	200	μA	V_D = 6V, R_{GS} = 10K
Gate Trigger Voltage	V_{GT}	—	0.6	0.8	V	V_D = 6V, R_{GS} = 100Ω
		—	—	1.2	V	V_D = 6V, R_{GS} = 100Ω, T = − 55°C
		0.1	—	—	V	V_D = 6V, R_{GS} = 100Ω, T = 125°C
Peak On-State Voltage	V_{TM}	—	—	1.5	V	I_{TM} = 1 Amp Pulse
Holding Current	I_{HX}	—	0.7	5.0	mA	R_{GK} = 1K, T = 25°C
		—	—	10.0	mA	R_{GK} = 1K, T = −55°C
Critical Rate of Rise — Off-State Voltage	dv/dt	—	20	—	V/μs	V_D = Rating, R_{GK} = 1K, T = 100°C

*For 2N6684, 2N6685 T = 90°C









SCRs
.5A, Planar

AA100-AA104
AA107-AA111
AA114-AA118

FEATURES
- Maximum Gate Trigger Current: 2, 20 or 200μA
- Tight Gate Trigger Voltage Range: .44 to .6V
- Voltage Ratings: to 400V
- Specified for dv/dt and Switching Time

DESCRIPTION
This data sheet describes Unitrode's AA Series 0.5A SCRs designed for low-current sensing applications. Units are available in a complete range of blocking voltages from 60 to 400 volts.

The AA100 series offers a maximum gate trigger current of 2.0 microamps making it the most sensitive device of its type. The AA107 series has a maximum I_{GT} of 20μA while this parameter is specified at 200μA for the AA114 series.

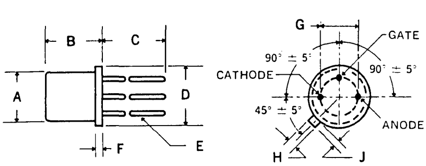
ABSOLUTE MAXIMUM RATINGS

	AA100 AA107 AA114	AA101 AA108 AA115	AA102 AA109 AA116	AA103 AA110 AA117	AA104 AA111 AA118
Repetitive Peak Off-State Voltage, V_{DRM}	60V	100V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	60V	100V	200V	300V	400V
Non-Repetitive Peak Reverse Voltage, V_{RSM}	80V	150V	300V	400V	500V
Non-Repetitive Peak Off-State Voltage, V_{DSM}			500V		
D.C. On-State Current, I_T					
75°C Ambient			250mA		
100°C Case			500mA		
Repetitive Peak On-State Current, I_{TRM}			up to 30A		
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}			5A		
Peak Gate Current, I_{GM}			250mA		
Average Gate Current, $I_{G(AV)}$			25mA		
Reverse Gate Voltage V_{GR}			6V		
Operating and Storage Temperature Range			−65°C to +150°C		

X

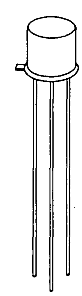
MECHANICAL SPECIFICATIONS

AA100-AA104 AA107-AA111 AA114-AA118



	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002/.001 DIA.	.432 ± .051/.025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



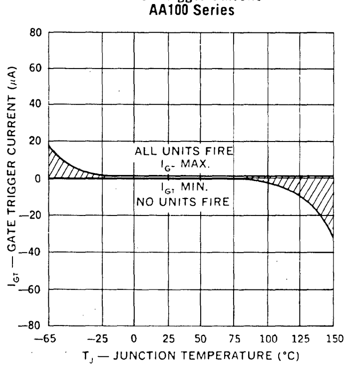
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

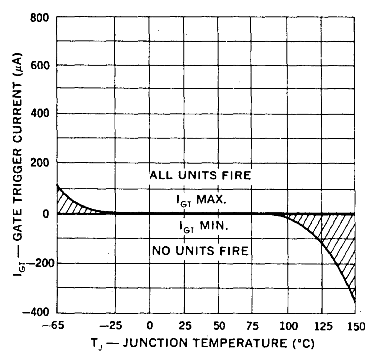
Parameter	Symbol	Min.	Typical	Max.	Units	Test Conditions
SUBGROUP 1						
Visual & Mechanical	—	—	—	—	—	—
SUBGROUP 2 (25°C TESTS)						
Off-State Current	I_{DRM}	—	.01	0.1	μA	$R_{GK} = 1K, V_{DRM}$ = Rating
Reverse Current	I_{RRM}	—	.01	0.1	μA	$R_{GK} = 1K, V_{RRM}$ = Rating
Reverse Gate Current	I_{GR}	—	0.1	0.2	μA	$V_{GR} = 2V$
Gate Trigger Current	I_{GT}					$R_{GS} = 10K, V_D = 5V$
AA100-104		—	0.2	2.0	μA	
AA107-111		—	2.0	20	μA	
AA114-118		—	20	200	μA	
Gate Trigger Voltage	V_{GT}	0.44	0.52	0.60	V	$R_{GS} = 100\Omega, V_D = 5V$
On-State Voltage	V_T	—	1.1	1.5	V	$I_T = 1.0$ A (pulse)
Holding Current	I_H	0.3	0.5	2.0	mA	$R_{GK} = 1K$
SUBGROUP 3 (25°C TESTS)						
Off-State Voltage — Critical Rate of Rise	dv/dt	50	100	—	V/μs	$R_{GK} = 1K, V_D = 30V$
Gate Trigger — on Pulse Width	t_{pg} (on)	—	0.5	2.0	μs	$I_G = 10mA, I_T = 1A, V_D = 30V$
Delay Time	t_d	—	0.6	—	μs	$I_G = 10mA, I_T = 1A, V_D = 30V$
Rise Time	t_r	—	0.4	—	μs	$I_G = 10mA, I_T = 1A, V_D = 30V$
Circuit Commutated Turn-off Time	t_q	—	20	50	μs	$I_T = 1A, I_R = 1A, R_{GK} = 1K$
SUBGROUP 4 (125°C TESTS)						
Off-State Current	I_{DRM}	—	10	20	μA	$R_{GK} = 1K, V_{DRM}$ = Rating
Reverse Current	I_{RRM}	—	30	100	μA	$R_{GK} = 1K, V_{RRM}$ = Rating
Gate Trigger Voltage	V_{GT}	0.15	0.2	—	V	$R_{GS} = 100\Omega, V_D = 5V$
Holding Current	I_H	0.2	0.4	1.5	mA	$R_{GK} = 1K$

Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

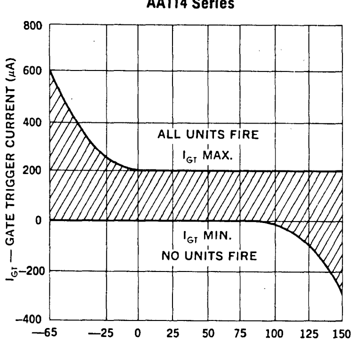
Gate Trigger Current
AA100 Series



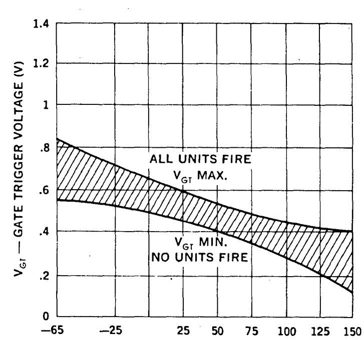
Gate Trigger Current
AA107 Series



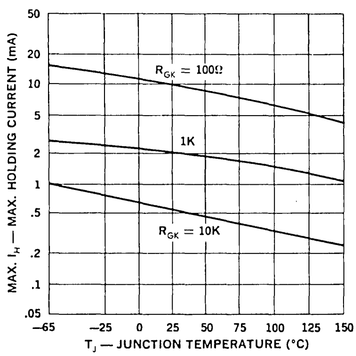
Gate Trigger Current
AA114 Series



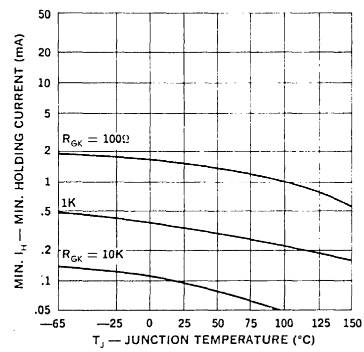
Gate Trigger Voltage



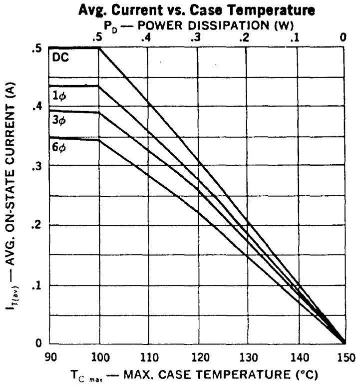
Max. Holding Current



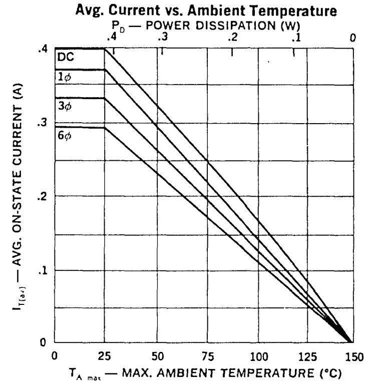
Min. Holding Current



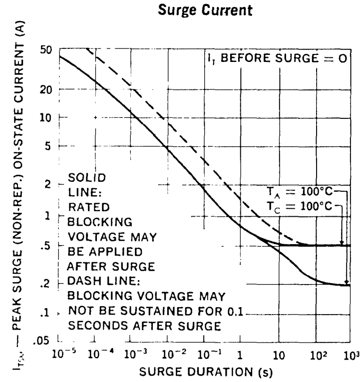
Avg. Current vs. Case Temperature



Avg. Current vs. Ambient Temperature



Surge Current



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SCRs
1.6 Amp, Planar

AD100-AD104
AD107-AD111
AD114-AD118

FEATURES
- Maximum Gate Trigger Current: 2, 20 or 200μA
- Tight Gate Trigger Voltage Range: .44 to .6V
- Voltage Ratings: to 400V
- Specified for dv/dt and Switching Time

DESCRIPTION
This data sheet describes Unitrode's AD Series 1.6A SCRs designed for medium-current control and sensing applications. Units are available in a complete range of blocking voltages from 60 to 400 volts.

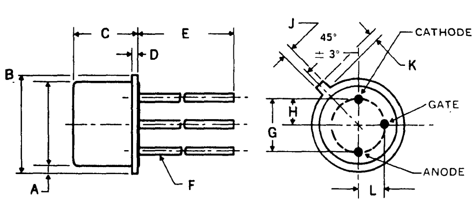
The AD100 series offers a maximum gate trigger current of 2.0 microamps making it the most sensitive device of its type. The AD107 series has a maximum I_{GT} of 20μA while this parameter is specified at 200μA for the AD114 series.

ABSOLUTE MAXIMUM RATINGS

	AD100 AD107 AD114	AD101 AD108 AD115	AD102 AD109 AD116	AD103 AD110 AD117	AD104 AD111 AD118
Repetitive Peak Off-State Voltage, V_{DRM}	60V	100V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	60V	100V	200V	300V	400V
Non-Repetitive Peak Reverse Voltage, V_{RSM}	80V	150V	300V	400V	500V
Non-Repetitive Peak Off-State Voltage, V_{DSM}			500V		
D.C. On-State Current, I_T					
75°C Ambient			450mA		
85°C Case			1.6A		
Repetitive Peak On-State Current, I_{TRM}			up to 30A		
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM}			15A		
Peak Gate Current, I_{GM}			250mA		
Average Gate Current, $I_{G(AV)}$			25mA		
Reverse Gate Voltage, V_{GR}			6V		
Operating and Storage Temperature Range			—65°C to +150°C		

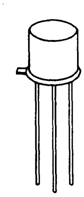
MECHANICAL SPECIFICATIONS

AD100-AD104 AD107-AD111 AD114-AD118



	ins.	mm.
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.35-6.60
D	.010-.030	.25-.76
E	.5 MIN.	12.70 MIN.
F	$.017 \pm {}^{.002}_{.001}$	$.432 \pm {}^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.79±.08
K	.029-.045	.74-1.14
L	.100	2.54

TO-39



UNITRODE

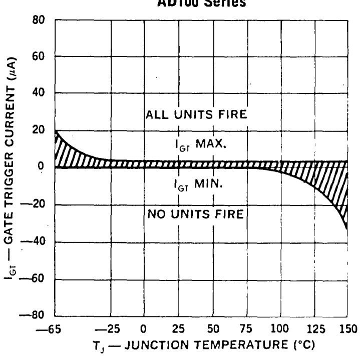
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Parameter	Symbol	Min.	Typical	Max.	Units	Test Conditions
SUBGROUP 1						
Visual & Mechanical	—	—	—	—	—	
SUBGROUP 2 (25°C TESTS)						
Off-State Current	I_{DRM}	—	.01	0.1	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	.01	0.1	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Reverse Gate Current	I_{GR}	—	0.1	0.2	μA	$V_{GR} = 2V$
Gate Trigger Current	I_{GT}					$R_{GS} = 10K$, $V_D = 5V$
AD100-104		—	0.2	2.0	μA	
AD107-111		—	2.0	20	μA	
AD114-118		—	20	200	μA	
Gate Trigger Voltage	V_{GT}	0.44	0.52	0.60	V	$R_{GS} = 100\Omega$, $V_D = 5V$
On-State Voltage	V_T	—	1.1	1.5	V	$I_T = 1.0$ Amp (pulse)
Holding Current	I_H	0.3	0.5	2.0	mA	$R_{GK} = 1K$
SUBGROUP 3 (25°C TESTS)						
On-State Voltage-Critical Rate of Rise	dv/dt	50	100	—	V/μs	$R_{GK} = 1K$, $V_D = 30V$
Gate Trigger-on Pulse Width	t_{pg} (on)	—	0.5	2.0	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Delay Time	t_d	—	0.6	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Rise Time	t_r	—	0.4	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 30V$
Circuit Commutated Turn-off Time	t_q	—	20	50	μs	$I_T = 1A$, $I_R = 1A$, $R_{GK} = 1K$
SUBGROUP 4 (125°C TESTS)						
Off-State Current	I_{DRM}	—	10	100	μA	$R_{GK} = 1K$, V_{DRM} = Rating
Reverse Current	I_{RRM}	—	30	100	μA	$R_{GK} = 1K$, V_{RRM} = Rating
Gate Trigger Voltage	V_{GT}	0.15	0.2	—	V	$R_{GS} = 100\Omega$, $V_D = 5V$
Holding Current	I_H	0.2	0.4	1.5	mA	$R_{GK} = 1K$

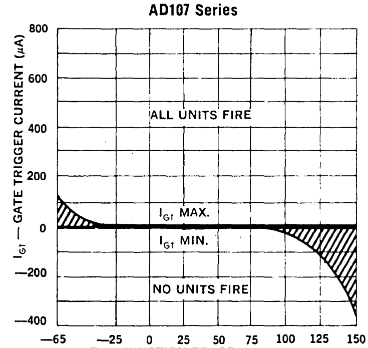
Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

X

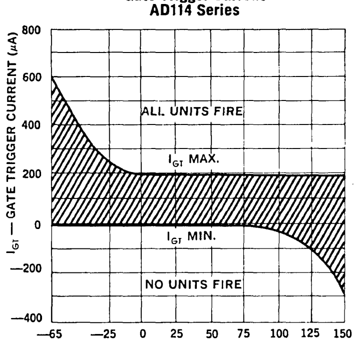
Gate Trigger Current AD100 Series



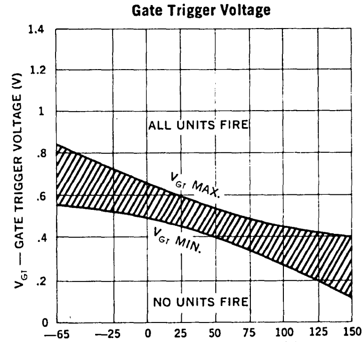
Gate Trigger Current AD107 Series

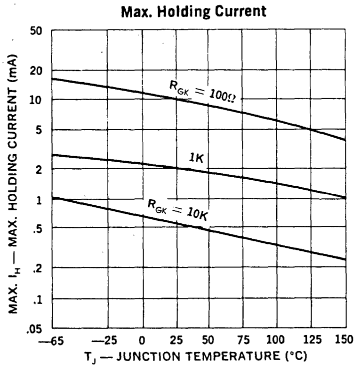


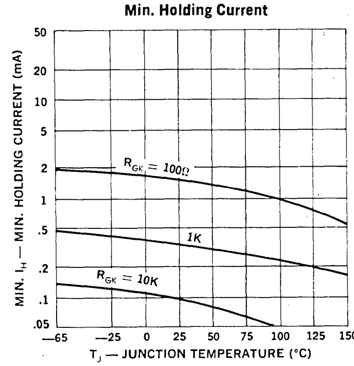
Gate Trigger Current AD114 Series

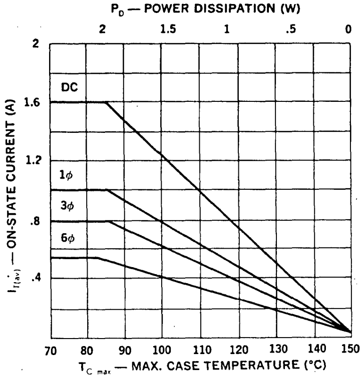


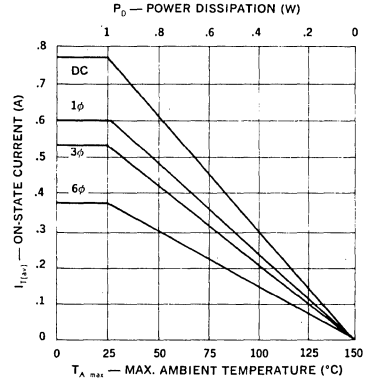
Gate Trigger Voltage

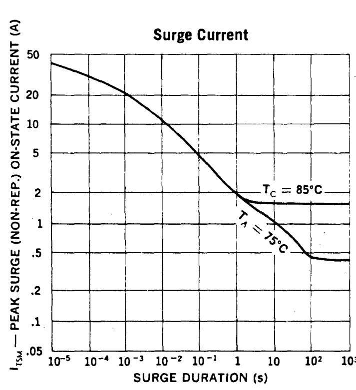



Max. Holding Current
MAX. I_H — MAX. HOLDING CURRENT (mA)
50
20
10
5
2
1
.5
.2
.1
.05
R_{GK} = 100Ω
1K
R_{GK} = 10K
—65 —25 0 25 50 75 100 125 150
T_J — JUNCTION TEMPERATURE (°C)


Min. Holding Current
MIN. I_H — MIN. HOLDING CURRENT (mA)
50
20
10
5
2
1
.5
.2
.1
.05
R_{GK} = 100Ω
1K
R_{GK} = 10K
—65 —25 0 25 50 75 100 125 150
T_J — JUNCTION TEMPERATURE (°C)


Avg. Current vs. Case Temperature
P_D — POWER DISSIPATION (W)
2 1.5 1 .5 0
$I_{T(av)}$ — ON-STATE CURRENT (A)
2
1.6
1.2
.8
.4
DC
1φ
3φ
6φ
70 80 90 100 110 120 130 140 150
$T_{C\ max}$ — MAX. CASE TEMPERATURE (°C)


Avg. Current vs. Ambient Temperature
P_D — POWER DISSIPATION (W)
1 .8 .6 .4 .2 0
$I_{T(av)}$ — ON-STATE CURRENT (A)
.8
.7
.6
.5
.4
.3
.2
.1
0
DC
1φ
3φ
6φ
0 25 50 75 100 125 150
$T_{A\ max}$ — MAX. AMBIENT TEMPERATURE (°C)


Surge Current
I_{TSM} — PEAK SURGE (NON-REP.) ON-STATE CURRENT (A)
50
20
10
5
2
1
.5
.2
.1
.05
T_C = 85°C
T_A = 75°C
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^2 10^3
SURGE DURATION (s)

SCRs

Nuclear Radiation Resistant, Planar

GA100
GA101
GA102

FEATURES

- Optimized for Radiation Resistance
- Fully Characterized for "Worst Case" Design
- Post Radiation Design Limits Specified
- Passivated Planar Construction for Maximum Reliability and Parameter Uniformity
- Pulse Currents: to 30A
- Max. Trigger Current 20mA after 3 X 10^{14} NVT
- Max. Holding Current 30mA after 3 X 10^{14} NVT

DESCRIPTION

The GA100 Series of Radiation Hard SCRs have been designed to provide significantly greater radiation tolerance than conventional SCRs or Transistors with the same current handling ability. This Series is capable of operation after exposure to 10^{15} NVT.

The radiation resistant characteristics of the GA100 series devices make them particularly desirable for use under radiation environments in squib firing circuits; inverters and converters; pulse generators; relay drivers; and modulator discharge switches.

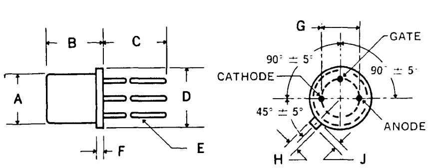
X

ABSOLUTE MAXIMUM RATINGS

	GA100	GA101	GA102
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	80V
D.C. On-State Current, I_T			
75°C Ambient		200mA	
100°C Case		400mA	
Repetitive Peak On-State Current, I_{TRM}		up to 30A	
Surge (non-rep.) On-State Current, I_{TSM} (Sq. Pulse-50ms)		5A	
Peak Gate Current, I_{GM}		250mA	
Average Gate Current, $I_{G(AV)}$		25mA	
Reverse Gate Voltage, V_{GR}		5V	
Reverse Gate Current, I_{GR}		3mA	
Storage Temperature Range		−65°C to +200°C	
Operating Temperature Range		−65°C to +150°C	

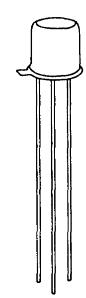
MECHANICAL SPECIFICATIONS

GA100 GA101 GA102



	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA. / .001 DIA.	.432 ± .051 / .025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

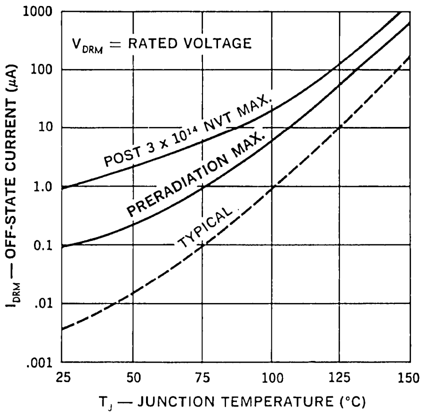
Test	Symbol	Preradiation Limits			Post 3 x 10^{14} NVT Design Limits		Units	Test Conditions
		Min.	Typ.	Max.	Min.	Max.		
SUBGROUP 1 Visual and Mechanical	—	—	—	—	—	—	—	MIL-STD-750 Method 2071
SUBGROUP 2 (25°C Tests)								
Off-State Current	I_{DRM}	—	.005	0.1	—	1.0	μA	R_{GK} = 220Ω, V_{DRM} = Rating
Reverse Gate Current	I_{GR}	—	.01	0.1	—	1.0	μA	V_{GR} = 2V
Input Trigger Current (Note 2)	I_{ST}	1.8	2.3	3.5	—	20	mA	R_{GK} = 220Ω, V_D = 5V
Gate Trigger Voltage	V_{GT}	0.4	0.5	0.7	—	1.5	V	R_{GK} = 220Ω, V_D = 5V
On-State Voltage	V_T	0.8	1.1	1.5	—	3.0	V	i_T = 1A (pulse test)
Holding Current	I_H	0.3	0.7	10	—	30	mA	R_{GK} = 220Ω
SUBGROUP 3 (25°C Tests)								
Off-State Voltage-Critical Rate of Rise	dv_c/dt	20	40	—	—	—	v/μs	R_{GK} = 220Ω, V_D = 30V
Gate Trigger-on Pulse Width	t_{pg} (on)	—	.02	.05	—	0.1	μs	I_G = 25mA, I_T = 1A, V_D = 30V
Delay Time	t_d	—	.02	—	—	—	μs	I_G = 25mA, I_T = 1A, V_D = 30V
Rise Time	t_r	—	.05	—	—	—	μs	I_G = 25mA, I_T = 1A, V_D = 30V
Circuit Commutated Turn-off Time	t_q	—	1.5	2.5	—	1.0	μs	I_T = 1A, i_R = 1A, R_{GK} = 220Ω
SUBGROUP 4 (125°C Tests)								
High Temp Off-State Current	I_{DRM}	—	10	100	—	100	μA	R_{GK} = 220Ω, V_{DRM} = Rating
High Temp Gate Trigger Voltage	V_{GT}	0.1	.17	—	0.1	—	V	R_{GK} = 220Ω, V_D = 5V

Notes: 1. Off-State voltage ratings apply over the operating temperature range provided the gate is connected to the cathode through an appropriate resistor, or other adequate bias is used.
2. Total Input Trigger Current, including current required by 220Ω gate bias resistance.

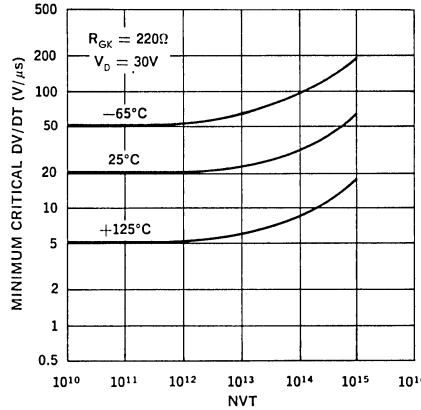
DESIGN CONSIDERATIONS

1. Curve 1 shows the off-state current, I_{DRM} of the SCR as a function of temperature. I_{DRM} is increased by radiation damage, but is not a design consideration at the recommended gate bias levels.
   In order to optimize for radiation tolerance, reverse blocking capability has not been retained as a design feature. Devices with reverse blocking capability can be provided.
2. Minimum critical dv/dt levels are defined in Curve 2. The dv/dt capability is improved after radiation because of reduced triggering sensitivity. dv/dt is therefore a design consideration only prior to radiation.
3. Curves 3 and 4 show the limits of Gate Trigger Voltage and Total Input Trigger Current prior to radiation. Maximum design limits after a total radiation dosage of 3 x 10^{14} NVT is also shown. Curves 5 and 6 show the maximum limits of Gate Trigger Voltage and Total Input Trigger Currents as a junction of neutron dosage. The minimum level of Trigger current prior to radiation is established by the shunting effect of a 220 ohm resistor between gate and cathode. After radiation the device is less sensitive and Total Trigger Current will increase to a level relatively independent of the bias resistance. The 220 ohm resistor is recommended since it raises the minimum preradiation trigger current to a level that is closer to the past radiation limit and minimizes the percentage change in this parameter.
4. Current ratings shown in Curves 10, 11, and 12 apply after the device has been subjected to 3 x 10^{14} NVT. Current ratings prior to radiation are greater than the values indicated.
5. Gamma radiation produces a reversible ionization (leakage) current within the device which is directly proportional to the Gamma flux level. When the Gamma flux level is in the range of 10 to 100 Roentgens per microsecond for burst durations greater than 1 microsecond, the device will self trigger ON. For the radiation bursts associated with nuclear explosions, the Gamma flux level will invariably cause device triggering at radiation levels significantly below the levels that would produce detectable permanent device damage due to cumulative neutron dosage. In applications where the burst effect triggering cannot be tolerated, it is necessary to reset the device after the radiation burst. Special circuit approaches such as additional SCRs to crowbar or otherwise cancel the output function may be used.

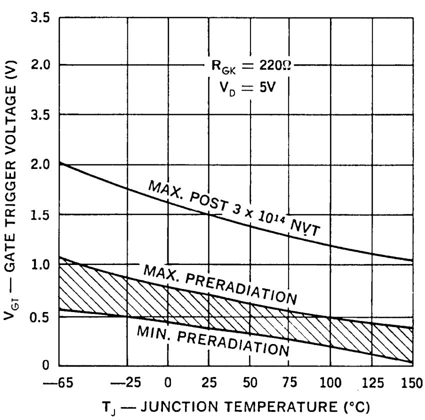
1. Off-State Current



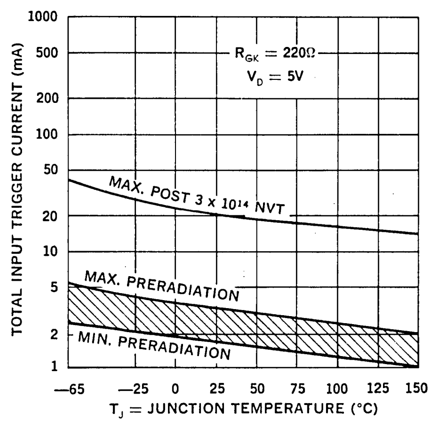
2. Minimum Critical DV/DT vs. Neutron Dosage



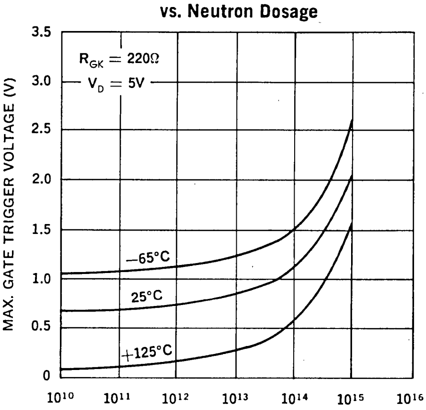
3. Gate Trigger Voltage



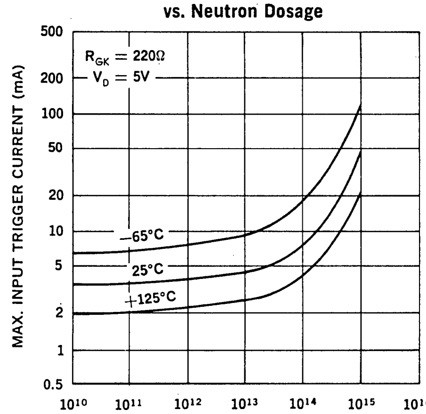
4. Input Trigger Current



5. Max. Gate Trigger Voltage vs. Neutron Dosage



6. Max. Input Trigger Current vs. Neutron Dosage



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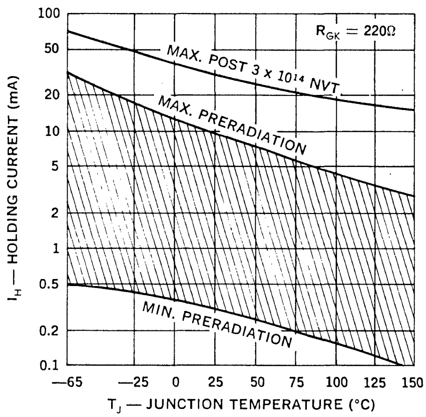
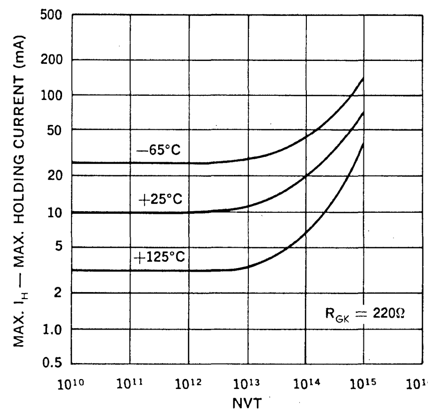
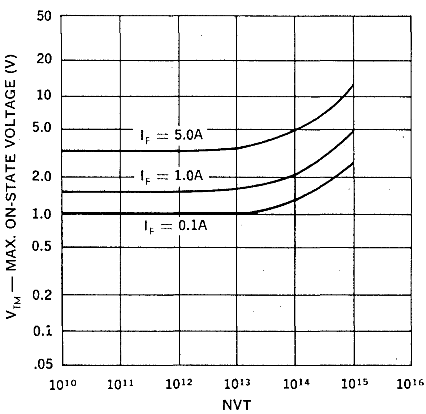
7. **Holding Current**



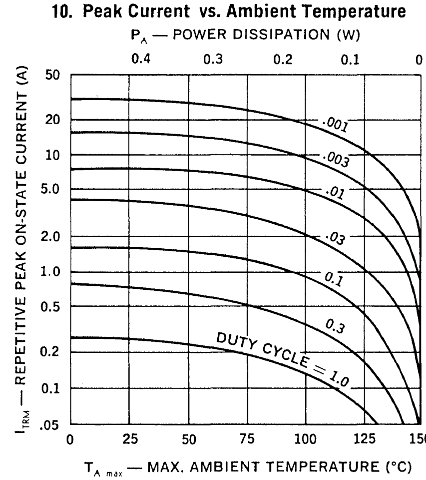
8. **Max. Holding Current vs. Neutron Dosage**



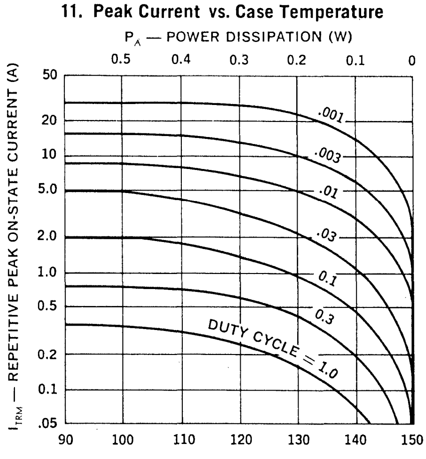
9. **Max. On-State Voltage vs. Neutron Dosage**



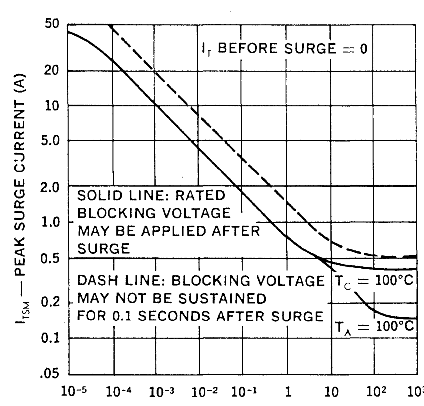
10. **Peak Current vs. Ambient Temperature**



11. **Peak Current vs. Case Temperature**



12. **Surge Current vs. Time**



SCRs
Nanosecond Switching, Planar

GA200 GB200
GA200A GB200A
GA201 GB201
GA201A GB201A

FEATURES
- Rise Time: 10ns
- Delay Time: 10ns
- Recovery Time: 0.5 μs
- Pulse Current: to 100A
- Turn-on with 20ns, 10 mA Gate Pulse

DESCRIPTION
The Unitrode Nanosecond Thyristor Switch combines the turn-on speed of logic level transistors with the high current switching capability inherent in SCRs. With this device engineers can now design circuits capable of switching pulse currents of 1A in less than 10ns or up to 30A in less than 20ns.

The GA/GB200 series is specifically designed for use as switching elements in high speed, low-to-medium power radar pulse modulators. Other applications include switching elements for phased array radars, laser pulse drivers, harmonic wave-form generators, line drivers and high current replacements for avalanche transistors. For applications requiring higher voltage levels, Unitrode has developed several "series string" circuits which allow the series connection of virtually an unlimited number of devices for voltages as high as 2000V with no significant decrease in speed. These circuits are described in Unitrode's Design Note #14.

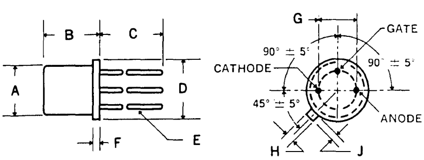
ABSOLUTE MAXIMUM RATINGS

	GA200 GA200A	GA201 GA201A	GB200 GB200A	GB201 GB201A
Repetitive Peak Off-State Voltage, V_{DRM}	60V	100V	60V	100V
Repetitive Peak On-State Current, I_{TRM}	up to 100A		up to 100A	
D.C. On-State Current, I_T				
70°C Ambient	200mA		—	
70°C Case	400mA		6A	
Peak Gate Current, I_{GM}	250mA		250mA	
Average Gate Current, $I_{G(AV)}$	25mA		50mA	
Reverse Gate Current, I_{GR}	3mA		3mA	
Reverse Gate Voltage, V_{GR}	5V		5V	
Storage Temperature Range	—65°C to +200°C			
Operating Temperature Range	—65°C to +150°C			

X

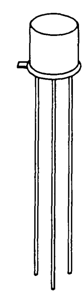
MECHANICAL SPECIFICATIONS

GA200 GA200A GA201 GA201A

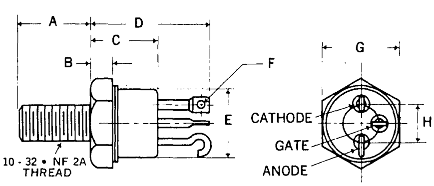


	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA. / .001 DIA.	.432 ± .051 / .025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



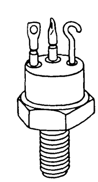
GB200 GB200A GB201 GB201A



	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	.055 ± .010 / .015	1.40 ± .254 / .381
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

NOTE: Anode connected to case.

TO-59



UNITRODE

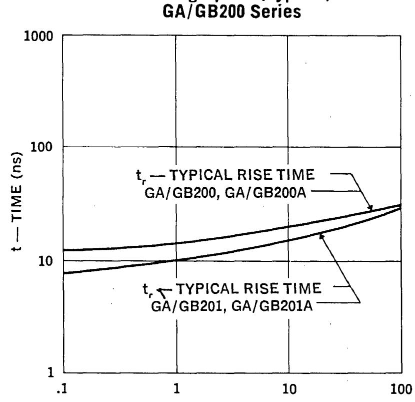
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Delay Time	t_d	—	20	30	ns	$I_G = 20mA$, $I_T = 1A$
		—	10	—	ns	$I_G = 30mA$, $I_T = 1A$
Rise Time GA200, 200A, GB200, 200A	t_r	—	15	25	ns	$V_D = 60V$, $I_T = 1A$ (1)
		—	25	—	ns	$V_D = 60V$, $I_T = 30A$ (1)
Rise Time GA201, 201A, GB201, 201A	t_r	—	10	20	ns	$V_D = 100V$, $I_T = 1A$ (1)
		—	20	—	ns	$V_D = 100V$, $I_T = 30A$ (1)
Gate Trigger on Pulse Width	$t_{pg(on)}$	—	.02	.05	μs	$I_G = 10mA$, $I_T = 1A$
Circuit Commutated Turn-off Time GA200, 201, GB200, 201	t_q	—	0.8	2.0	μs	$I_T = 1A$, $I_R = 1A$, $R_{GK} = 1K$
GA200A, 201A, GB200A, 201A	t_q	—	0.3	0.5	μs	
Off-State Current	I_{DRM}	—	.01	0.1	μA	V_{DRM} = Rating, $R_{GK} = 1K$
		—	20	100	μA	V_{DRM} = Rating, $R_{GK} = 1K$, 150°C
Reverse Current	I_{RRM}	—	1.0	10	mA	$V_{RRM} = 30V$, $R_{GK} = 1K$ (2)
Reverse Gate Current	I_{GR}	—	.01	0.1	mA	$V_{GRM} = 5V$
Gate Trigger Current	I_{GT}	—	10	200	μA	$V_D = 5V$, $R_{GS} = 10K$
Gate Trigger Voltage	V_{GT}	0.4	.06	0.75	V	$V_D = 5V$, $R_{GS} = 100\Omega$, $T = 25°C$
		0.10	0.2	—	V	$T = +150°C$
On-State Voltage	V_T	—	1.1	1.5	V	$I_T = 2A$
Holding Current	I_H	0.3	2.0	5.0	mA	$V_D = 5V$, $R_{GS} = 100\Omega$, $T = 25°C$
		0.05	0.2	—	mA	$T = +150°C$
Off-State Voltage-Critical Rate of Rise	dv/dt	20	40	—	V/μs	$V_D = 30V$, $R_{GK} = 1K$

Notes: 1. $I_G = 10mA$; Pulse Test, Duty Cycle <1%.

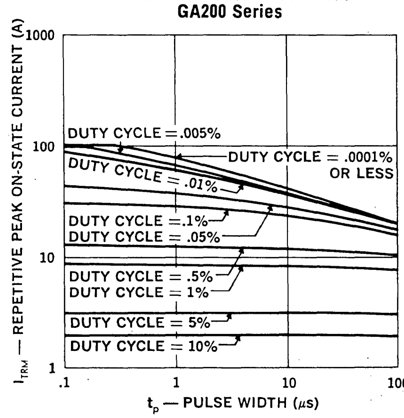
2. Pulse test intended to guarantee reverse anode voltage capability for pulse commutation. Device should not be operated in the Reverse blocking mode on a continuous basis.

Switching Speed (Typical) GA/GB200 Series



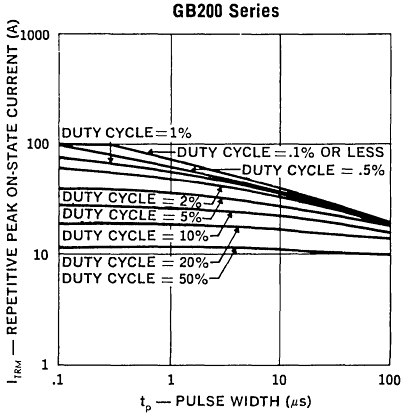
NOTES: 1. V_D = Rated V_{DRM}
2. $T_A = 25°C$
3. $I_G = 20mA$
4. t_d = 20ns TYPICALLY FOR ALL TYPES INDEPENDENT OF ANODE CURRENT

Peak Current vs. Pulse Width GA200 Series



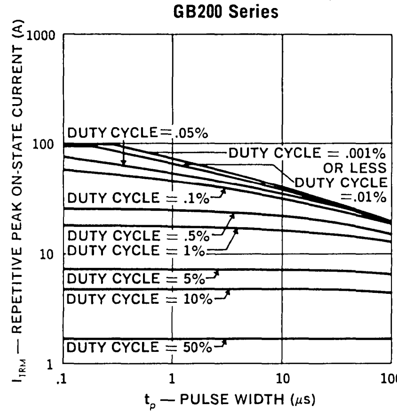
NOTES: 1. DATA BASED ON ON-STATE VOLTAGE GRAPH AT $T_j = 150°C$. BLOCKING VOLTAGE MAY BE APPLIED IMMEDIATELY AFTER TERMINATION OF CURRENT PULSE.
2. $T_A = 75°C$

**Peak Current vs. Pulse Width
GB200 Series**



NOTES: 1. DATA BASED ON ON-STATE VOLTAGE GRAPH AT $T_j = 150°C$. BLOCKING VOLTAGE MAY BE APPLIED IMMEDIATELY AFTER TERMINATION OF CURRENT PULSE.
2. $T_C = 75°C$

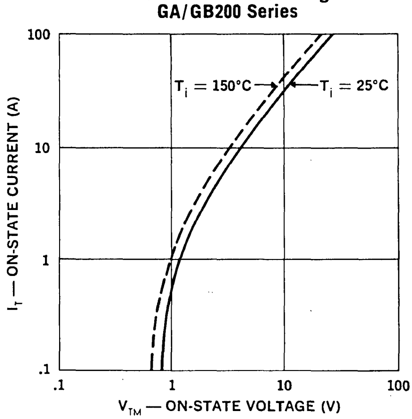
**Peak Current vs. Pulse Width
GB200 Series**



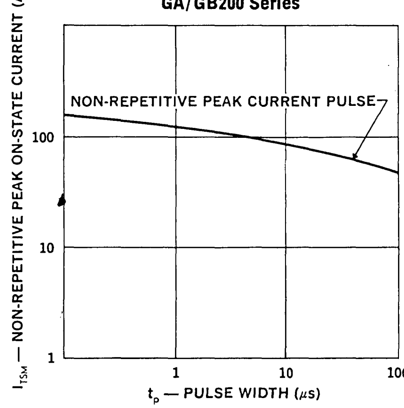
NOTES: 1. DATA BASED ON ON-STATE VOLTAGE GRAPH AT $T_j = 150°C$. BLOCKING VOLTAGE MAY BE APPLIED IMMEDIATELY AFTER TERMINATION OF CURRENT PULSE.
2. $T_A = 75°C$

X

**On-State Current vs. Voltage
GA/GB200 Series**



**Surge Rating Maximum
GA/GB200 Series**



NOTES: 1. BLOCKING VOLTAGE MAY NOT BE APPLIED FOR .001 SEC. AFTER TERMINATION OF SURGE PULSE AS JUNCTION TEMPERATURE WILL EXCEED 150°C.
2. $T_C = 75°C$

SCRs
Commercial Nanosecond Switching Planar

GA300 GB300
GA300A GB300A
GA301 GB301
GA301A GB301A

FEATURES
- Rise Time: 10ns
- Delay Time: 10ns
- Recovery Time: 0.5μs
- Pulse Current: to 100A
- Turn-on with 20ns, 10mA gate pulse

DESCRIPTION
Unitrode's Nanosecond Thyristor Switch combines the turn-on speed of logic level transistors with the high current switching capability inherent in SCRs. With this device, engineers can now design circuits capable of switching pulse currents of 1A in less than 10ns or up to 30A in less than 20ns.

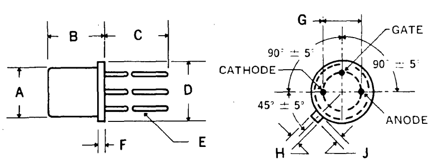
The GA300, GB300 Series is specifically designed for use as the switching element in high speed laser diode pulse drivers. Other applications include electronic crowbars, harmonic wave-form generators, line drivers and general purpose replacements for avalanche transistors. For applications requiring higher voltage levels, Unitrode has developed several "series string" circuits which allow the series connection of an unlimited number of devices for voltages as high as 2000V with no significant decrease in speed. These circuits are described in Unitrode's Design Note #14.

ABSOLUTE MAXIMUM RATINGS

	GA300 GA300A	GA301 GA301A	GB300 GB300A	GB301 GB301A
Repetitive Peak Off-State Voltage, V_{DRM}	60V	100V	60V	100V
Repetitive Peak On-State Current, I_{TRM}	up to 100A		up to 100A	
Peak Gate Current, I_{GM}	250mA		250mA	
Average Gate Current, $I_{G(AV)}$	25mA		50mA	
Reverse Gate Current, I_{GR}	3mA		3mA	
Reverse Gate Voltage, V_{GR}	5V		5V	
Storage Temperature Range	−65°C to +150°C			
Operating Temperature Range	0°C to +125°C			

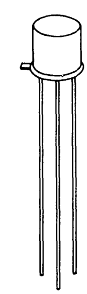
MECHANICAL SPECIFICATIONS

GA300 GA300A GA301 GA301A

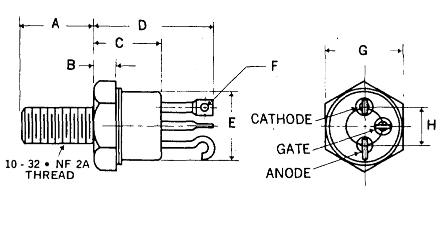


	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002/.001 DIA.	.432 ± .051/.025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



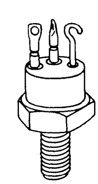
GB300 GB300A GB301 GB301A



	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	.055 ± .010/.015	1.40 ± .254/.381
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

NOTE: Anode connected to case.

TO-59



UNITRODE

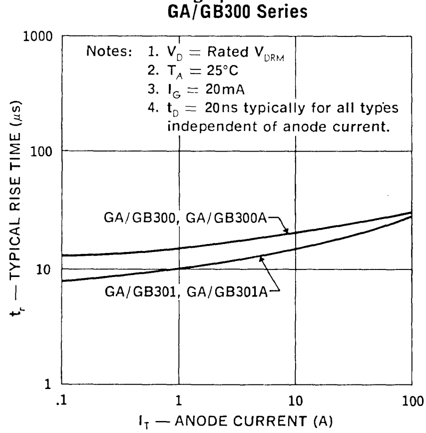
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Delay Time	t_d	—	20 10	30 —	ns	$I_G = 20mA, I_T = 1A$ $I_G = 30mA, I_T = 1A$
Rise Time (Note 1) GA300, 300A, GB300, 300A	t_r	—	15 25	25 —	ns	$V_D = 60V, I_T = 1A$ $V_D = 60V, I_T = 30A$ (Note 1)
Rise Time (Note 1) GA301, 301A, GB301, 301A	t_r	—	10 20	20 —	ns	$V_D = 100V, I_T = 1A$ $V_D = 100V, I_T = 30A$ (Note 1)
Circuit Commutated Turn-off Time GA300, 301, GB300, 301	t_q	—	0.8	2.0	μs	$I_T = 1A, I_R = 1A, R_{GK} = 1K$
GA300A, 301A, GB300A, 301A			0.3	0.5	μs	$I_T = 1A, I_R = 1A, R_{GK} = 1K$
Gate Trigger-on Pulse Width	$t_{pg\ (on)}$	—	0.02	0.05	μs	$I_G = 10mA, I_T = 1A$
Off-state Current	I_{DRM}	— —	0.01 20	0.1 100	μA μA	V_{DRM} = Rating, $R_{GK} = 1K, T = 25°C$ V_{DRM} = Rating, $R_{GK} = 1K, T = 125°C$
Reverse Current (Note 2)	I_{RRM}	—	1.0	10	mA	$V_{RRM} = 30V, R_{GK} = 1K$ (Note 2)
Gate Trigger Voltage	V_{GT}	0.4 0.10	0.6 0.2	0.75 —	V V	$V_D = 5V, R_{GS} = 100\Omega, T = 25°C$ $V_D = 5V, R_{GS} = 100\Omega, T = 125°C$
Gate Trigger Current	I_{GT}	—	10	200	μA	$V_D = 5V, R_{GS} = 10K$
On-state Voltage	V_T	—	1.1	1.5	V	$I_T = 2A$
Off-state Voltage — Critical Rate of Rise	dv/dt	15	30	—	V/μs	$V_D = 30V, R_{GK} = 1K$
Reverse Gate Current	I_{GR}	—	0.01	0.1	mA	$V_{GR} = 5V$
Holding Current	I_H	0.3 0.05	2.0 0.4	5.0 —	mA mA	$V_D = 5V, R_{GK} = 1K, T = 25°C$ $V_D = 5V, R_{GK} = 1K, T = 125°C$

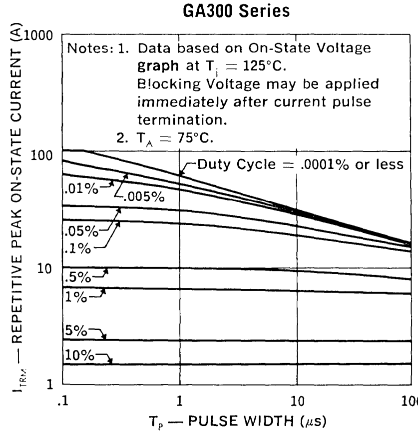
Notes: 1. I_G = 10mA; Pulse Test, Duty Cycle < 1%.
2. Pulse test intended to guarantee reverse anode voltage capability for pulse commutation. Device should not be operated in the reverse blocking mode on a continuous basis.

X

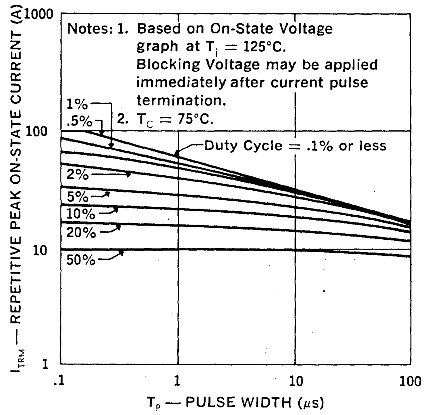
Switching Speed vs. Current
GA/GB300 Series



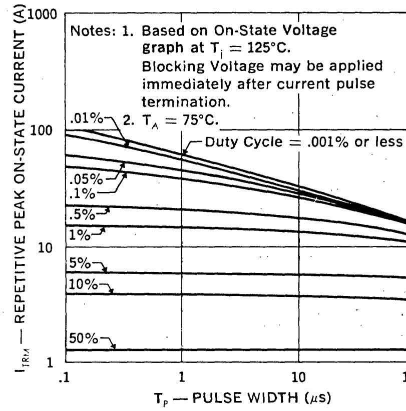
Peak Current vs. Pulse Width
GA300 Series



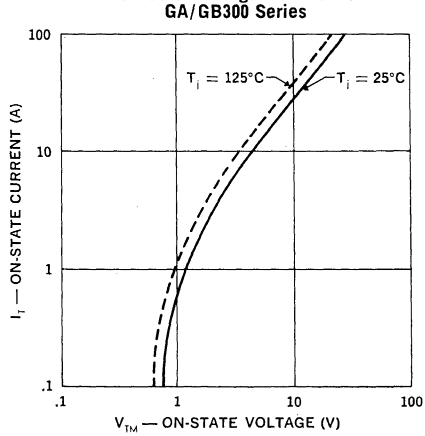
Peak Current vs. Pulse Width GB300 Series



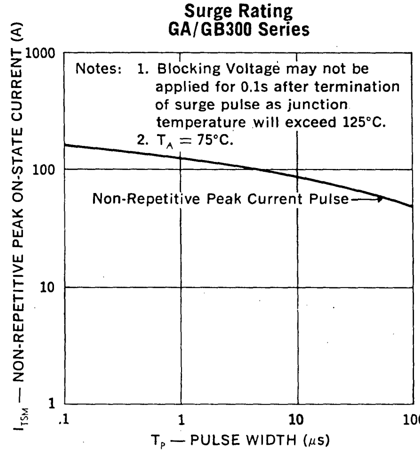
Peak Current vs. Pulse Width GB300 Series



On-State Voltage vs. Current GA/GB300 Series



Surge Rating GA/GB300 Series



TRIAC

.8 Amp. RMS, Plastic TO-92 600V

IB202
IB204
IB206

FEATURES:

- Forward Current: .8A RMS
- Voltage Ratings: to 600V
- High Surge Current: 8A
- Gate Sensitivity: 2mA Typical, 1st & 3rd Quad
- Hard Glass Passivated Junction
- Economical TO-92 Package

TYPICAL APPLICATIONS:

- Appliance Control Circuitry
- Speed Controls
- AC Switches
- Logic to A.C. Interface

DESCRIPTION:

This series of low current triacs is designed specifically for high volume, low cost AC switching applications. Supplied in the economical TO-92 package, these devices feature full hard glass passivated junctions and rugged mesa construction.

X

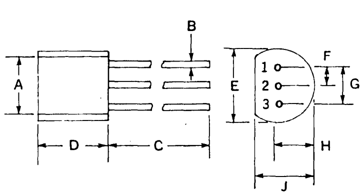
MAXIMUM RATINGS

	IB202	IB204	IB206
Repetitive Peak Off-State Voltage, V_{DRM}	200V	400V	600V
Repetitive Peak Reverse Voltage, V_{RRM}	200V	400V	600V

On-State Current, I_T RMS At 65°C Case, 180° Conduction Sinewave .8A
Surge (Non-Rep.) On-State Current, I_{TSM} 8A
Peak Gate Current, I_{GM} 1.0A
Peak Gate Power, P_{GM} 1W
Average Gate Power P_G (AV.) 1W
Reverse Gate Voltage, V_{GR} 6V
Storage Temperature Range, $T_{(STG)}$ .... −55°C to +150°C
Operating Temperature Range, $T_{(OP)}$ .... −55°C to +110°C
Circuit Fusing Consideration, I^2t @ −40 to 100°C, 1.0 to 8.3ms .... .25A²S

MECHANICAL SPECIFICATIONS

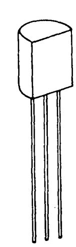
IB202, IB204, IB206 SERIES



	inches	millimeters
A	.135 MIN.	3.43 MIN.
B	.019-.016	.48- .41
C	.500 MIN.	12.7 MIN.
D	.210-.170	5.33-4.32
E	.205-.175	5.21-4.45
F	.055-.045	1.40-1.14
G	.105-.095	2.67-2.41
H	.105-.080	2.67-2.03
J	.165-.125	4.19-3.18

1 — MT2
2 — GATE
3 — MT1

TO-92

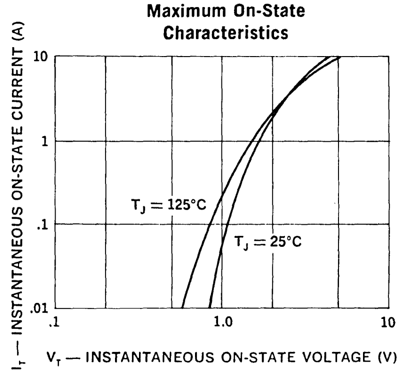


UNITRODE

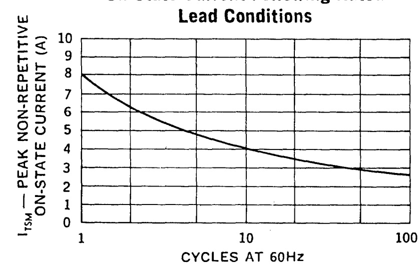
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM} I_{RRM}	— —	— —	.1 .1	mA mA	V_{DRM} = Rating, $T_C = 100°C$
Gate Trigger Current	I_{GT}	— —	— —	5 10	mA mA	V_D = 12V Quadrants 1, 3 (+ +, − −) V_D = 12V Quadrants 2, 4 (+ −, − +)
Gate Trigger Voltage	V_{GT}	— —	— —	2.0 3.0	V V	V_D = 12V Quadrants 1, 3 (+ +, − −) V_D = 12V Quadrants 2, 4 (+ −, − +)
Peak On-State Voltage	V_{TM}	—	—	1.8	V	I_{TM} = 1.0A Peak
Holding Current	I_H	—	—	15	mA	V_D = 12V
Steady State Thermal Resistance	$R\Theta_{J\text{-}C}$	—	—	50	°C/W	Steady State
Thermal Resistance	$R\Theta_{J\text{-}A}$	—	—	200	°C/W	

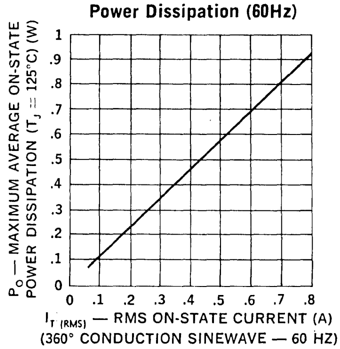
Maximum On-State Characteristics



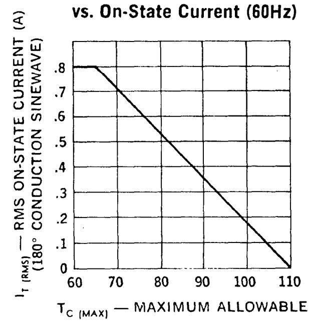
Maximum Allowable Non-Repetitive Peak On-State Current Following Rated Lead Conditions



Maximum On-State Power Dissipation (60Hz)



Maximum Allowable Case Temperature vs. On-State Current (60Hz)



SCRs
.5 Amp, Planar

FEATURES
- Voltage Ratings: to 400V
- Maximum Gate Trigger Current: 200μA
- Hermetically Sealed TO-18 Metal Can
- Planar Passivated Construction

DESCRIPTION

This Data Sheet describes Unitrode's line of hermetically sealed industrial SCRs designed for low-voltage, low-current sensing application. The ID100 Series is packaged in a TO-18 metal case with Unitrode's unique oxide passivated junctions, offering the highest degree of reliability and parameter stability for any device in its price range.
Typical applications include lamp driving, relay driving, sensor, pulse-generating and timing circuits.

ABSOLUTE MAXIMUM RATINGS

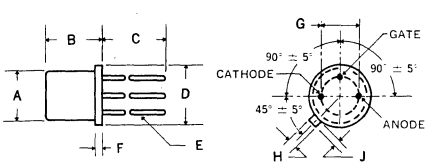
	ID100	ID101	ID102	ID103	ID104	ID105	ID106
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V	150V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V	150V	200V	300V	400V

On-State Current, I_T
- 75°C Ambient 250mA
- 100°C Case 0.5A

Repetitive Peak On-State Current, I_{TRM} 6A
Peak One Cycle Surge (Non-Rep.) On-State Current, I_{TSM} .... up to 30A
Peak Gate Current, I_{GM} 250mA
Average Gate Current, $I_{G(AV)}$ 25mA
Reverse Gate Voltage, V_{GR} 6V
Storage Temperature Range .... −65°C to +150°C
Operating Temperature Range .... −65°C to +125°C

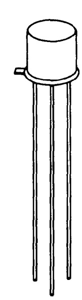
MECHANICAL SPECIFICATIONS

ID100-ID106



	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	$.017 \pm ^{.002}_{.001}$ DIA.	$.432 \pm ^{.051}_{.025}$
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-18



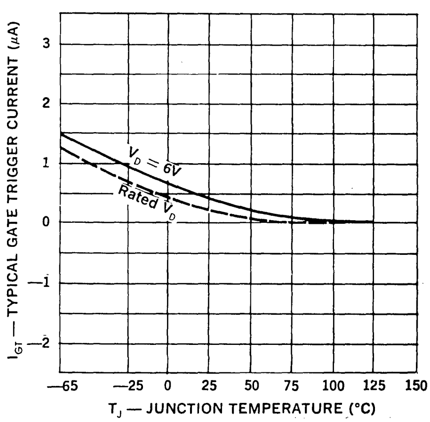
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

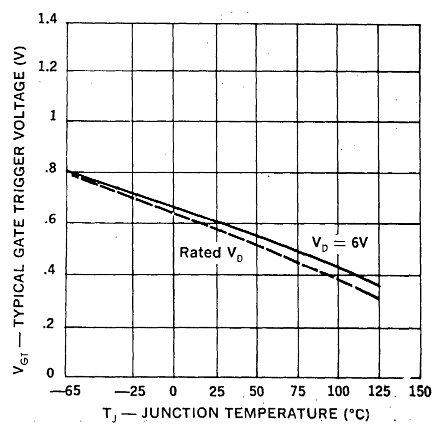
Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	5.0	50	μA	V_{DRM} = Rating, R_{GK} = 1K, T = 125°C, ID100-ID104
		—	10.0	100	μA	V_{DRM} = Rating, R_{GK} = 1K, T = 125°C, ID105-ID106
Reversing Current	I_{RRM}	—	10	50	μA	V_{RRM} = Rating, R_{GK} = 1K, T = 125°C, ID100-ID104
		—	15	100	μA	V_{RRM} = Rating, R_{GK} = 1K, T = 125°C, ID105-ID106
Gate Trigger Current	I_{GT}	—	5.0	200	μA	V_D = 5V, R_{GS} = 10K
		—	—	500	μA	V_D = 5V, R_{GS} = 10K, T = −40°C
Gate Trigger Voltage	V_{GT}	0.4	0.55	0.8	V	V_D = 5V, R_{GS} = 100Ω
		—	—	1.0	V	V_D = 5V, R_{GS} = 100Ω, T = −40°C
		0.10	—	—	V	V_D = 5V, R_{GS} = 100Ω, T = 125°C
Peak On-State Voltage	V_{TM}	—	—	1.7	V	I_{TM} = 1 Amp Pulse
Holding Current	I_H	—	1.0	5.0	mA	R_{GK} = 1K
		—	—	10.0	mA	R_{GK} = 1K, T = −40°C
Turn-on Time	t_{on}	—	0.5	—	μs	I_G = 10mA, I_T = 1A, V_D = 30V
Circuit Commutated Turn-off Time	t_q	—	8.0	—	μs	I_T = I_R = 1A, R_{GK} = 1K, ID100-ID104
		—	15.0	—	μs	I_T = I_R = 1A, R_{GK} = 1K, ID105-ID106

Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

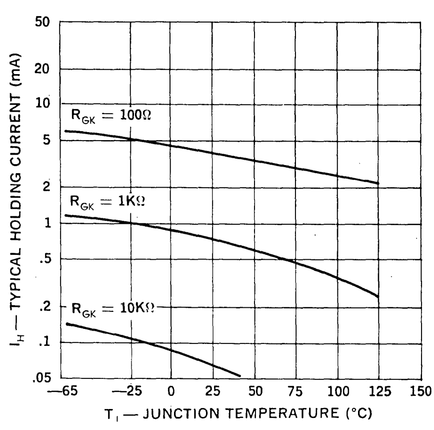
Gate Trigger Current vs. Junction Temp.



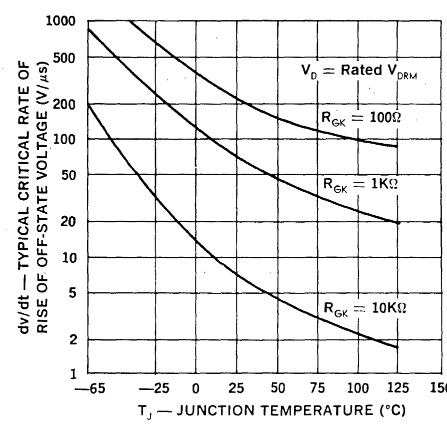
Gate Trigger Voltage vs. Junction Temp.



Holding Current vs. Junction Temp.



dv/dt vs. Junction Temp.



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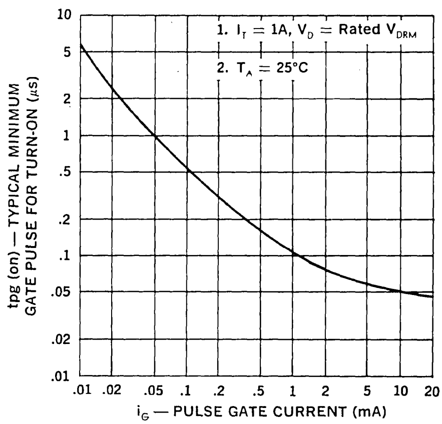
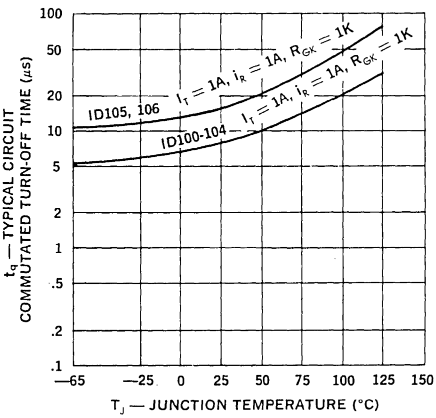
Gate Pulse for Turn-On vs. Pulse Gate Current

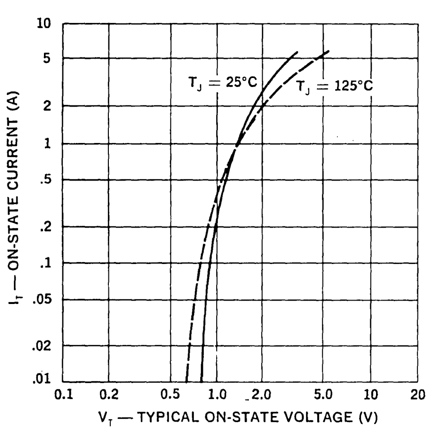


Circuit Commutated Turn-Off Time vs. Junction Temp.

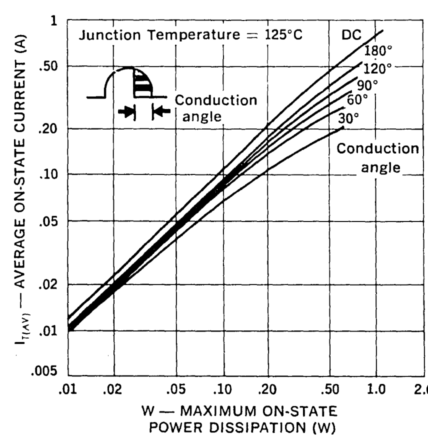


X

Current vs. On State Voltage



Current vs. Power Dissipation



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SCRs
1.6 Amp, Planar

ID200-ID203
ID300-ID301

FEATURES
- Voltage Rating: to 200V
- Max. Gate Trigger Current: 200μA
- Hermetically Sealed Metal Can
- Planar Passivated Construction

DESCRIPTION
This Data Sheet describes Unitrode's line of hermetically sealed industrial SCRs designed for high-voltage, medium-current control applications. The Series is packaged in a TO-39 metal case with Unitrode's unique oxide passivated junctions to ensure reliability and parameter stability.
Typical applications include relay equipment, motor controls, process controllers and pulse generators.

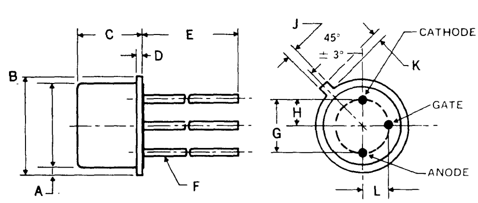
ABSOLUTE MAXIMUM RATINGS

	ID200	ID201	ID202	ID203	ID300	ID301
Repetitive Peak Off-State Voltage, V_{DRM}	50V	100V	150V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	50V	100V	150V	200V	300V	400V
Non-Repetitive Peak Reverse Voltage, V_{RSM} (<5ms)	75V	150V	225V	300V	400V	500V

On-State Current, $I_{T(RMS)}$	
70°C Case	1.6A
75°C Ambient	450mA
Peak One Cycle Surge (Non-Repetitive) On-State Current, I_{TSM}	15A
Repetitive Peak On-State Current, I_{TRM}	up to 30A
Rate of Rise of On-State Current, di/dt	100A/μs
I^2t (for times > 1.5 ms)	0.83A^2s
Peak Gate Current, I_{GM}	250mA
Average Gate Current, $I_{G(AV)}$	25mA
Reverse Gate Voltage, V_{GR}	6V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−40°C to +110°C

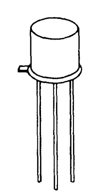
MECHANICAL SPECIFICATIONS

ID200-ID203 ID300-ID301



	ins.	mm.
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.35-6.60
D	.010-.030	.25-.76
E	.5 MIN.	12.70 MIN.
F	.017 ± .002/.001	.432 ± .051/025
G	.200	5.08
H	100	2.54
J	.031± 003	.79±.08
K	.029-.045	.74-1.14
L	.100	2.54

TO-39



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	—	10	μA	V_{DRM} = Rating, R_{GK} = 1K, T = 25°C
		—	5	100	μA	V_{DRM} = Rating, R_{GK} = 1K, T = 110°C
Reverse Current	I_{RRM}	—	—	10	μA	V_{RRM} = Rating, R_{GK} = 1K, T = 25°C
		—	10	100	μA	V_{RRM} = Rating, R_{GK} = 1K, T = 110°C
Gate Trigger Current	I_{GT}	—	—	200	μA	V_D = 5V, R_{GS} = 10K, T = 25°C
		—	—	500	μA	V_D = 5V, R_{GS} = 10K, T = −40°C
On-State Voltage	V_{GT}	0.4	0.52	0.8	V	V_D = 5V, R_{GS} = 100Ω, T = 25°C
		0.5	0.7	1.0	V	V_D = 5V, R_{GS} = 100Ω, T = −40°C
		0.2	—	—	V	V_D = 5V, R_{GS} = 100Ω, T = 110°C
Peak On — Voltage	V_{TM}	—	—	2.2	V	I_T = 4 Amp Pulse, T = 25°C
Holding Current	I_H	0.3	0.7	3.0	mA	R_{GK} = 1K, T = 25°C
		0.4	—	6.0	mA	R_{GK} = 1K, T = −40°C
		0.2	—	—	mA	R_{GK} = 1K, T = 110°C
Off-State Voltage — Critical Rate of Rise	dv/dt	—	20	—	V/μs	V_{DRM} = Rated, R_{GK} = 1K, T = 110°C
Turn-on Time	t_{on}	—	1.0	—	μs	I_G = 10mA, I_T = I_A, V_D = 30V, T = 25°C
Circuit Commutated Turn-off Time	t_q	—	—	40	μs	I_T = i_R = 1A, R_{GK} = 1K, T = 25°C

Note: Blocking voltage ratings apply over the full operating temperature range, provided the gate is connected to the cathode through a resistor, 1000 ohms or smaller, or other adequate bias is used.

SCRs

.8 Amp RMS, Plastic

FEATURES
- Voltage Ratings: to 100V
- Forward Current: 0.8A RMS
- Surge Current: 6A, 8 ms
- Gate Sensitivity: 200 μA max.
- TO-92 Plastic Package

DESCRIPTION

This plastic series features very fast switching performance, low forward voltage drop and a high degree of reliability and parameter stability. All units are fully planar passivated and are packaged in a rugged TO-92 case, constructed from a special epoxy compound that features excellent moisture resistance providing stable performance under high humidity conditions and good thermal transfer characteristics.

TYPICAL APPLICATIONS

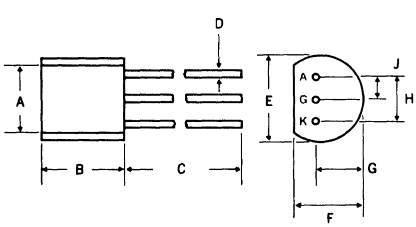
Lamp Driving	Process Controls	Remote Controls
Relay Driving	Pressure Controls	High Current SCR Driving
Relay Replacement	Display Systems	Timers
Alarm Systems	Touch Switches	Temperature Controls
Counters	and many other current sensing and control applications.	

ABSOLUTE MAXIMUM RATINGS

	IP100	IP101	IP102
Repetitive Peak Off-State Voltage, V_{DRM}	30V	60V	100V
Repetitive Peak Reverse Voltage, V_{RRM}	30V	60V	100V
On-State Current, I_T		0.8A	
Surge (Non-Rep.) On-State Current, I_{TSM}		6A	
Peak Gate Current, I_{GM}		1.0A	
Peak Gate Power, P_{GM}		1W	
Average Gate Power, P_G (Av.)		0.01W	
Reverse Gate Voltage, V_{GR}		6V	
Storage Temperature Range		−65°C to +150°C	
Operating Temperature Range		−65°C to +125°C	

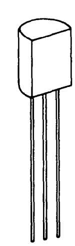
MECHANICAL SPECIFICATIONS

IP100-IP102



	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92

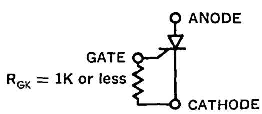


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

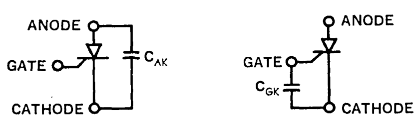
Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	— —	0.1 —	1.0 50	μA μA	V_{DRM} = Rating, R_{GK} = 1K V_{DRM} = Rating, R_{GK} = 1K, T = 125°C
Reverse Current	I_{RRM}	— —	0.1 —	1.0 50	μA μA	V_{RRM} = Rating, R_{GK} = 1K V_{RRM} = Rating, R_{GK} = 1K, T = 125°C
Gate Trigger Current	I_{GT}	— —	0.4 —	200 500	μA μA	V_D = 6V, R_{GS} = 10K, V_D = 6V, R_{GS} = 10K, T = −65°C
Gate Trigger Voltage	V_{GT}	— — 0.1	0.6 — —	0.8 1.0 —	V V V	V_D = 6V, R_{GS} = 100Ω V_D = 6V, R_{GS} = 100Ω, T = −65°C V_D = 6V, R_{GS} = 100Ω, T = 125°C
Peak On-State Voltage	V_{TM}	—	1.2	1.7	V	I_{TM} = 1 Amp Pulse
Holding Current	I_{HX}	— —	0.7 —	5.0 10.0	mA mA	R_{GK} = 1K, T = 25°C R_{GK} = 1K, T = −65°C
Critical Rate of Rise — Off-State Voltage	dv/dt	—	75	—	V/μs	V_D = Rating, R_{GK} = 1K,
Turn-on Time	t_{on}	—	.25	—	μs	I_G = 10mA, I_{T}, = 1A, V_D = 30V
Circuit Commutated Turn-off Time	t_q	—	20	—	μs	I_{TM} = I_R = IA, R_{GK} = 1K

DESIGN CONSIDERATIONS

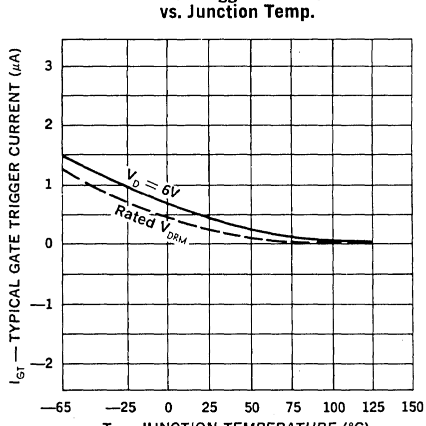
1. The IP100 Series SCRs are guaranteed to block their rated voltage over their rated operating temperature when a resistance of 1000 ohms or less is connected from gate to cathode as shown.



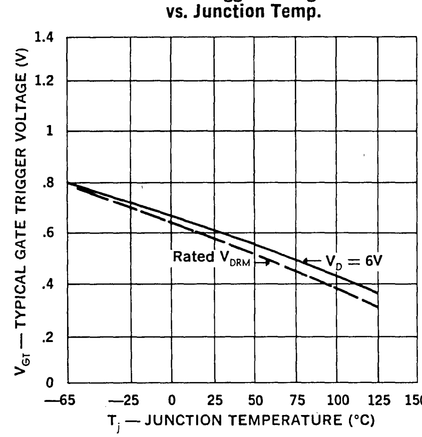
2. In cases where the SCR may be subjected to fast rising anode voltages a capacitor can be connected between anode or gate and cathode as shown, to serve as protection against dv/dt firing.



Gate Trigger Current vs. Junction Temp.

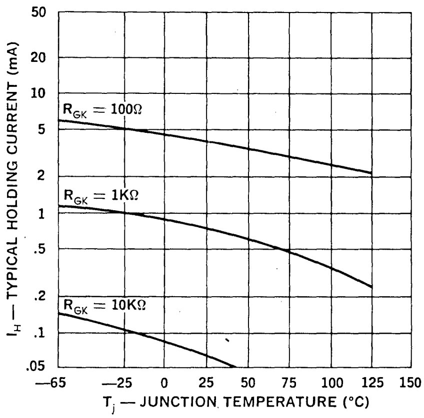


Gate Trigger Voltage vs. Junction Temp.

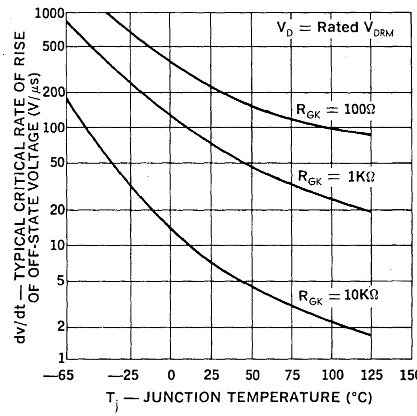


X

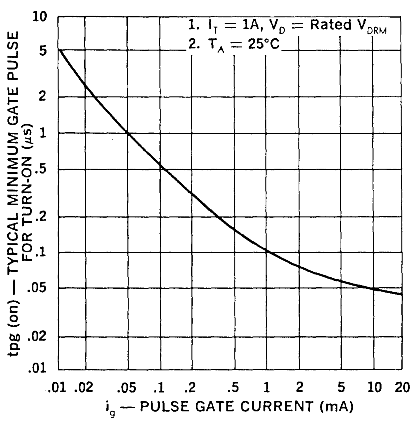
Holding Current vs. Junction Temp.



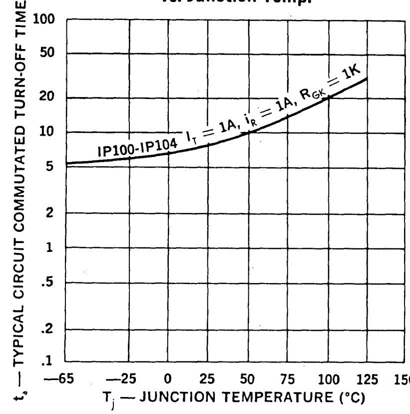
dv/dt vs. Junction Temp.



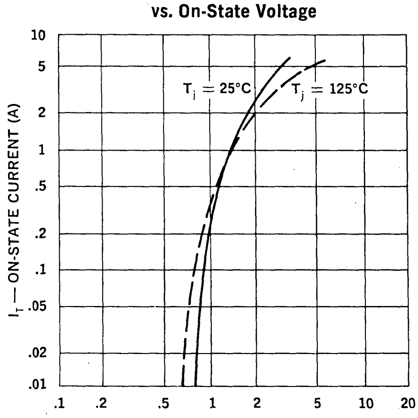
Gate Pulse For Turn-On vs. Pulse Gate Current



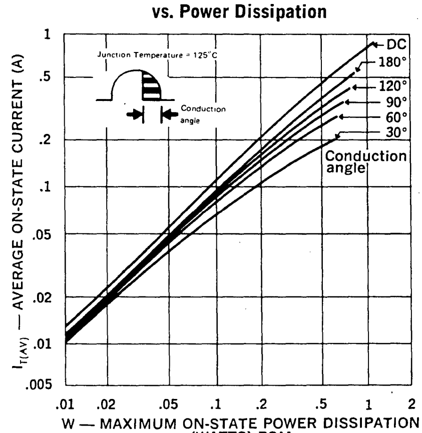
Circuit Commutated Turn-Off Time vs. Junction Temp.



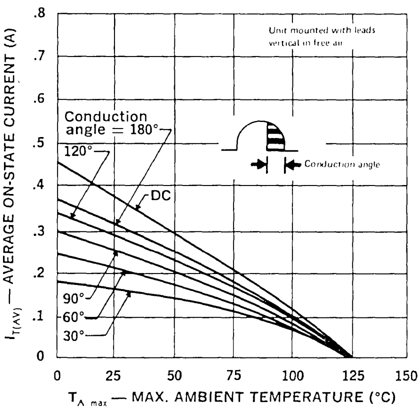
Current vs. On-State Voltage



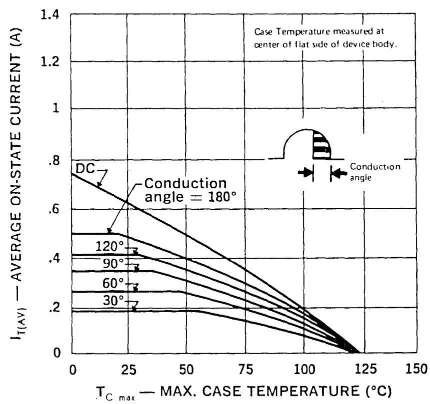
Current vs. Power Dissipation



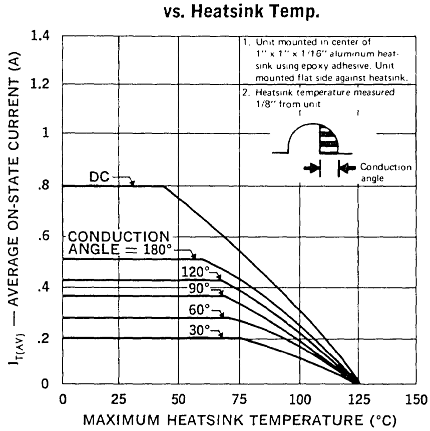
Current vs. Ambient Temp.



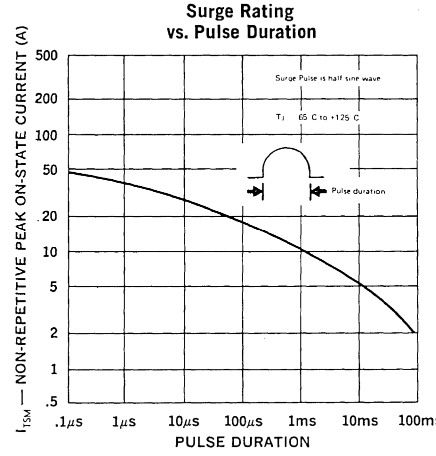
Current vs. Case Temp.



Current vs. Heatsink Temp.



Surge Rating vs. Pulse Duration



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SCRs

.8 Amp RMS, Plastic 400V

FEATURES:
- Forward Current: 1.0A RMS
- Voltage Ratings: to 400V
- High Surge Current: 15A, 8mS
- Gate Sensitivity: 30μA Typical
- Hard Glass Passivated Junction
- Economical TO-92 Package

DESCRIPTION:
This plastic PNPN device is rated at .8 Amp RMS maximum on-state current, with rated voltages up to 400 volts. All units in this series offer full hard glass passivation with sensitivity especially targeted for good transient immunity. Supplied in an economical TO-92 package, this device is well suited for many high volume applications.

TYPICAL APPLICATIONS

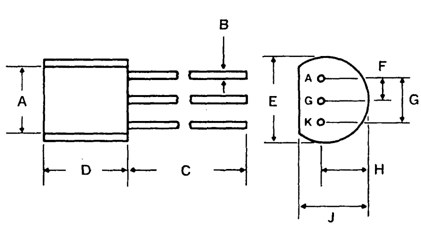
Lamp Driving	Process Controls	Remote Controls
Relay Driving	Pressure Controls	High Current SCR Driving
Relay Replacement	Display Systems	Timers
Alarm Systems	Touch Switches	Temperature Controls
Counters	and many other current sensing and control applications.	

MAXIMUM RATINGS

	IP103	IP104	IP105	IP106
Repetitive Peak Off-State Voltage, V_{DRM}	150V	200V	300V	400V
Repetitive Peak Reverse Voltage, V_{RRM}	150V	200V	300V	400V
On-State Current, I_T RMS At 60°C Case, 180° Conduction Sinewave	.8A			
Surge (Non-Rep.) On-State Current, I_{TSM}	15A			
Peak Gate Power, P_{GM}	1W			
Average Gate Power P_G (AV.)	0.01W			
Reverse Gate Voltage, V_{GR}	6V			
Storage Temperature Range	−55°C to +150°C			
Operating Temperature Range	−55°C to +110°C			

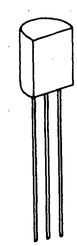
MECHANICAL SPECIFICATIONS

IP103-IP106



	inches	millimeters
A	.135 MIN.	3.43 MIN.
B	.019 - .016	.48 - .41
D	.210 - .170	5.33 - 4.32
C	.500 MIN.	12.7 MIN.
E	.205 - .175	5.21 - 4.45
J	.165 - .125	4.19 - 3.18
F	.055 - .045	1.40 - 1.14
G	.105 - .095	2.67 - 2.41
H	.105 - .080	2.67 - 2.03

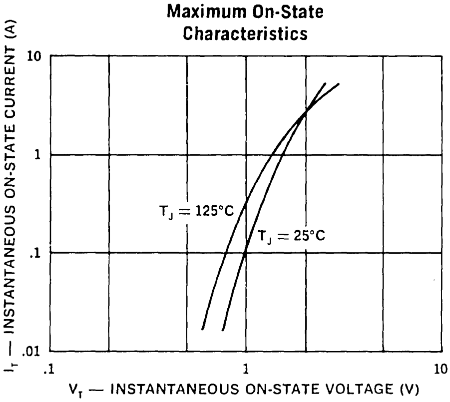
TO-92



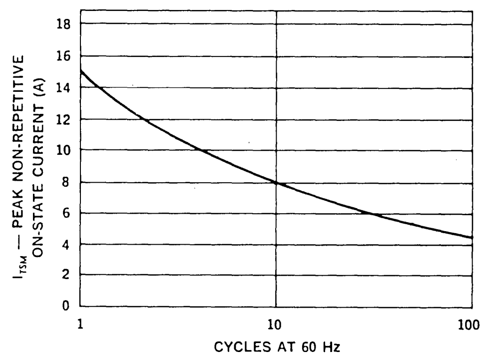
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	—	100	μA	V_{DRM} = Rating, R_{GK}= 1K, T= 110°C
Reverse Current	I_{RRM}	—	—	100	μA	V_{RRM} = Rating, R_{GK}= 1K, T= 110°C
Gate Trigger Current	I_{GT}	—	10	200	μA	$V_D = 6V$, $R_{GS} = 10K$
Gate Trigger Voltage	V_{GT}	— — 0.1	0.6 — —	0.8 1.2 —	V V V	$V_D = 6V$, $R_{GS} = 100\Omega$ $V_D = 6V$, $R_{GS} = 100\Omega$, T = − 55°C $V_D = 6V$, $R_{GS} = 100\Omega$, T = 110°C
Peak On-State Voltage	V_{TM}	—	—	1.5	V	$I_{TM} = 1$ Amp Pulse
Holding Current	I_{HX}	— —	2 —	5.0 10.0	mA mA	$R_{GK} = 1K$, T = 25°C $R_{GK} = 1K$, T = −55°C
Critical Rate of Rise — Off-State Voltage	dv/dt	—	75	—	V/μs	V_D = Rating, $R_{GK} = 1K$
Turn-on Time	t_{on}	—	0.5	—	μs	$I_G = 10mA$, $I_T = 1A$, $V_D = 100V$
Circuit Commutated Turn-off Time	t_q	—	15	—	μs	$I_T = I_R = 1A$, $R_{GK} = 1K$

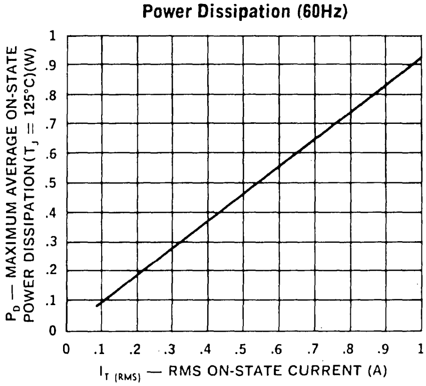
Maximum On-State Characteristics



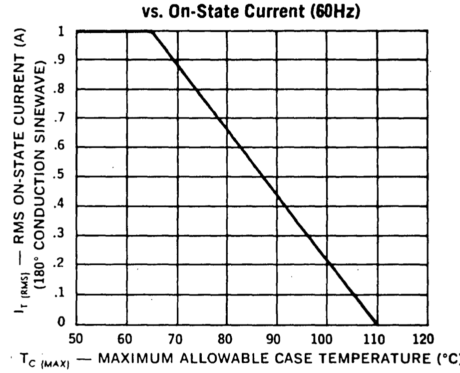
Maximum Allowable Non-Repetitive Peak On-State Current Following Rated Load Conditions



Maximum On-State Power Dissipation (60Hz)



Maximum Allowable Case Temperature vs. On-State Current (60Hz)



X

PUTs

Planar, TO-92, Plastic

FEATURES

- TO-92 Plastic Package
- Maximum Peak Current: 0.15 μA
- Minimum Valley Current: 70 μA
- Peak Forward Current: 5A
- Programmable Eta, R_{BB}, I_p and I_V
- Passivated Planar Construction for Maximum Reliability and Parameter Uniformity

DESCRIPTION

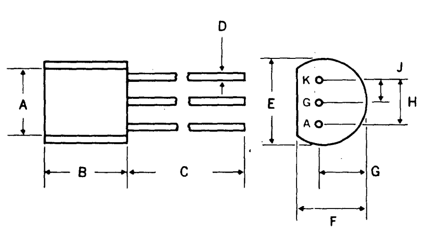
Functionally equivalent to standard unijunction transistors, Unitrode's Programmable Unijunction Transistors offer the distinct advantage of versatile programming. External resistors can be added to meet the designer's needs in programming Eta, R_{BB}, I_P and I_V functions. Applications include pulse and timing circuits, SCR trigger circuits, relaxation oscillators and sensing circuits. For additional information see Unitrode Application Note U-66.

ABSOLUTE MAXIMUM RATINGS

Anode-to-Cathode Voltage, V_{AK} .... ±40V
Gate-to-Cathode Forward Voltage, V_{GK} 40V
Gate-to-Anode Reverse Voltage, V_{GAR} 40V
Gate-to-Cathode Reverse Voltage, V_{GKR} .... −5V
Peak Recurrent Forward Current
  10μs, 1% Duty Cycle 5A
  100μs, 1% Duty Cycle 1A
Power Dissipation
  25°C Ambient 375mW
  Derating Factor .... 5mW/°C
Storage Temperature .... −55°C to +150°C
Operating Temperature Range .... −55°C to +100°C

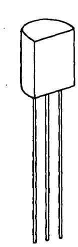
MECHANICAL SPECIFICATIONS

P13T1-P13T2



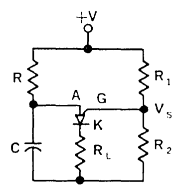
	INCHES	MILLIMETERS
A	.135 MIN.	3.42 MIN.
B	.170 - .210	4.31 - 5.33
C	.500 MIN.	12.70 MIN.
D	.016 - .019	.406 - .482
E	.175 - .205	4.44 - 5.21
F	.125 - .165	3.17 - 4.19
G	.080 - .105	2.03 - 2.66
H	.095 - .105	2.41 - 2.66
J	.045 - .055	1.14 - 1.40

TO-92

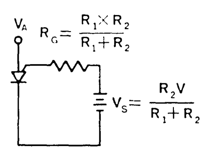


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

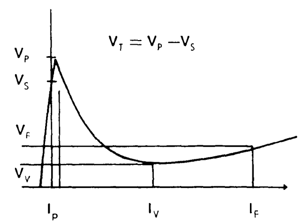
Test	Symbol	Fig.	P13T1 Min.	P13T1 Max.	P13T2 Min.	P13T2 Max.	Units	Test Conditions
Peak Current	I_p	1	—	5	—	1.0	μA	$R_G = 10k, V_s = 10V$
			—	2	—	0.15	μA	$R_G = 1\ M\Omega$
Valley Current	I_V	1	70	—	25	—	μA	$R_G = 10k, V_s = 10V$
			—	50	—	25	μA	$R_G = 1\ M\Omega$
Offset Voltage	V_T	1	0.2	0.6	0.2	0.6	V	$R_G = 10k, V_s = 10V$
			0.2	1.6	0.2	0.6	V	$R_G = 1\ M\Omega$
Gate-to-Anode Leakage	I_{GAO}	2	—	10	—	10	nA	$T = 25°C, V_s = 40V$
			—	100	—	100	nA	$T = 75°C$
Gate-to-Cathode Leakage	I_{GKS}	3	—	100	—	100	nA	$V_s = 40V$
Forward Voltage	V_F	4	—	1.0	—	1.0	V	$I_F = 50mA$
Pulse Output Voltage	V_o	5	9	—	9	—	V	
Pulse Output Rise Time	t_r	5	—	80	—	80	ns	



a) Typical Circuit



b) Equivalent Test Circuit



c) Characteristic Curve

Figure 1

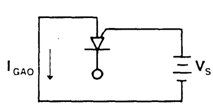


Figure 2

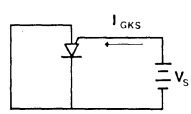


Figure 3

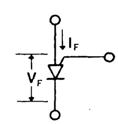


Figure 4

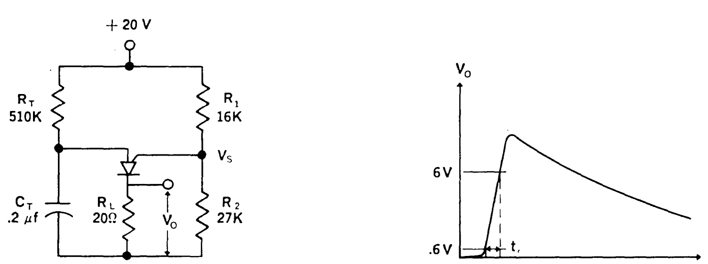


Figure 5

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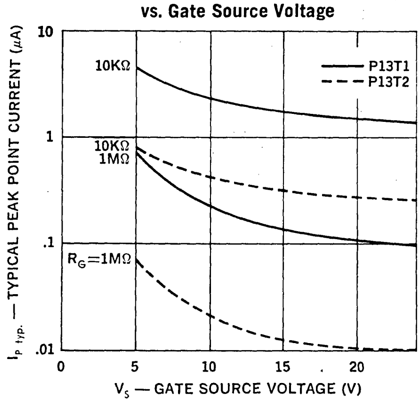
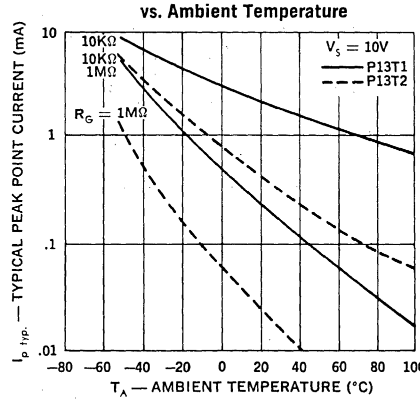
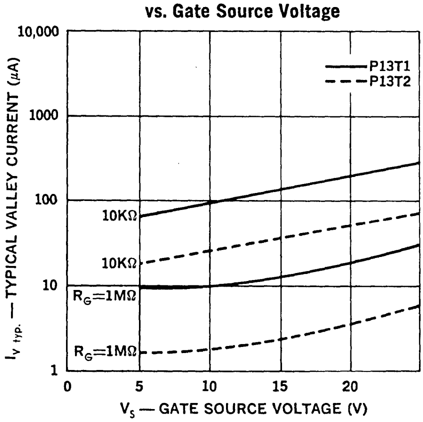
Typical Peak Point Current vs. Gate Source Voltage



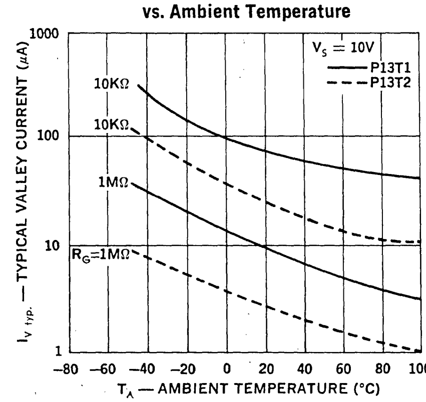
Typical Peak Point Current vs. Ambient Temperature



Typical Valley Current vs. Gate Source Voltage



Typical Valley Current vs. Ambient Temperature



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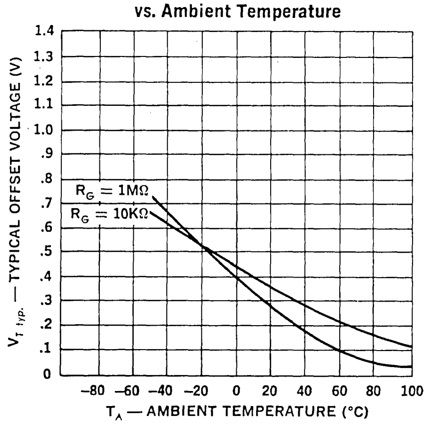
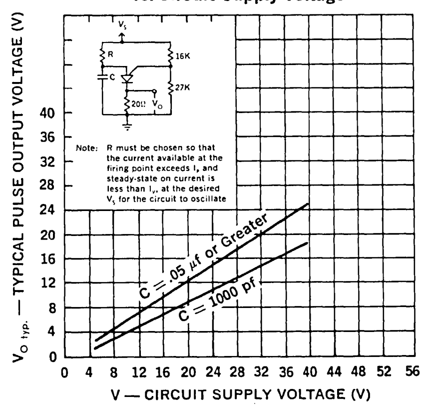
Typical Offset Voltage vs. Ambient Temperature



Typical Pulse Output vs. Circuit Supply Voltage



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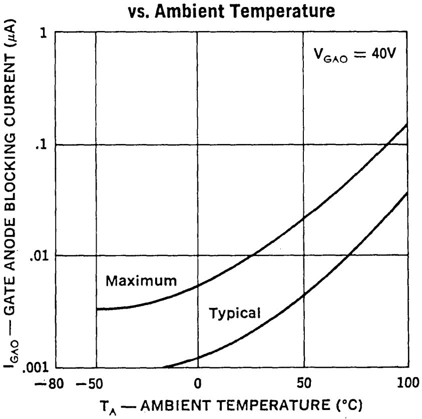
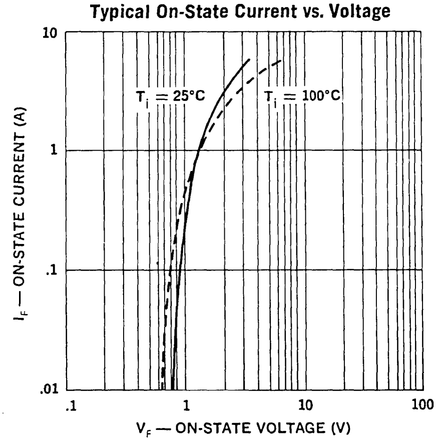
Gate-Anode Blocking Current vs. Ambient Temperature



Typical On-State Current vs. Voltage



PUTs

Planar, TO-18 Hermetic

FEATURES

- Voltage Ratings: to 100V
- Maximum Peak Current: 150nA
- Valley Current: as low as 25 μA
- Low Forward Voltage Drop
- Nano-Amp Leakage
- Hermetically Sealed TO-18 Metal Can

DESCRIPTION

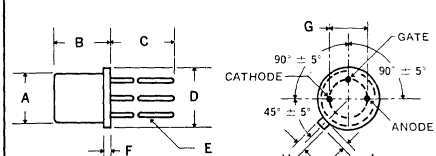
The Unitrode hermetically sealed TO-18 metal can series of programmable unijunction transistors feature blocking voltages to 100V, the highest available to designers. These PUTs are functionally equivalent to standard unijunction transistors, with the added advantages of programming versatility. External resistors can be added to program η, R_{BB}, I_p and I_v, depending upon your design requirements. All units are fully planar passivated. This series features a hermetically sealed TO-18 package for optimum reliability in all environmental conditions. Applications include pulse and timing circuits, SCR trigger circuits, relaxation oscillators, and sensing circuits. For further application information see Unitrode's Application Note 'J-66.

ABSOLUTE MAXIMUM RATINGS

Anode-to-Cathode Forward Voltage, V_{AK}	40V
Anode-to-Cathode Reverse Voltage, V_{AKR}	40V
Gate-to-Cathode Forward Voltage, V_{GK}	40V
Gate-to-Anode Reverse Voltage, V_{GAR}	40V
Gate-to-Cathode Reverse Voltage, V_{GKR}	5V
Peak Recurrent Forward Current	
10 μs 1% Duty Cycle	8A
100 μs 1% Duty Cycle	5A
Power Dissipation	
25°C Ambient	400mW
Derating Factor	3.2mW/°C
Storage Temperature Range	−55°C to +150°C
Operating Temperature Range	−55°C to +150°C

MECHANICAL SPECIFICATIONS

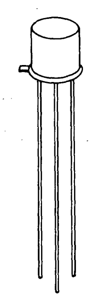
U13T1-U13T2



GATE CONNECTED TO CASE

	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA. / .001 DIA.	.432 ± .051 / .025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

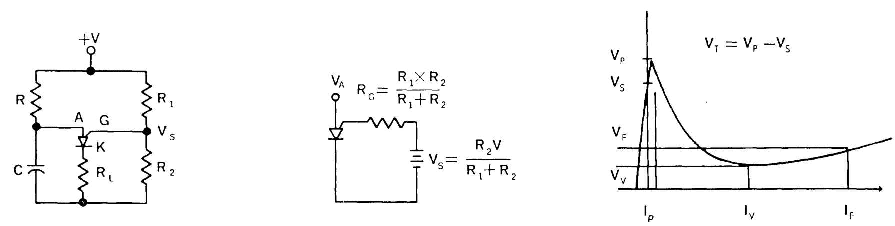
TO-18



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Fig.	U13T1 Min.	U13T1 Max.	U13T2 Min.	U13T2 Max.	Units	Test Conditions
Peak Current	I_P	1	—	5	—	1.0	μA	$R_G = 10k$, $V_s = 10V$
			—	2	—	0.15	μA	$R_G = 1$ Meg.
Valley Current	I_V	1	70	—	25	—	μA	$R_G = 10k$, $V_s = 10V$
			—	50	—	25	μA	$R_G = 1$ Meg.
Offset Voltage	V_T	1	0.2	0.6	0.2	0.6	V	$R_G = 10k$, $V_s = 10V$
			0.2	1.6	0.2	0.6	V	$R_G = 1$ Meg.
Gate-to-Anode Leakage	I_{GAO}	2	—	10	—	10	nA	$T = 25°C$, $V_s =$ rating
			—	100	—	100	nA	$T = 75°C$
Gate-to-Cathode Leakage	I_{GKS}	3	—	100	—	100	nA	$V_s =$ rating
Forward Voltage	V_F	4	—	1.5	—	1.5	V	$I_F = 50mA$
Pulse Output Voltage	V_o	5	6	—	6	—	V	
Pulse Output Rate of Rise	t_r	5	—	80	—	80	nS	



a) Typical Circuit

b) Equivalent Test Circuit

c) Characteristic Curve

Figure 1

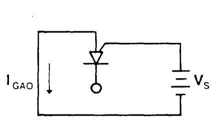


Figure 2

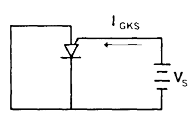


Figure 3

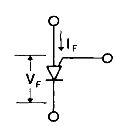


Figure 4

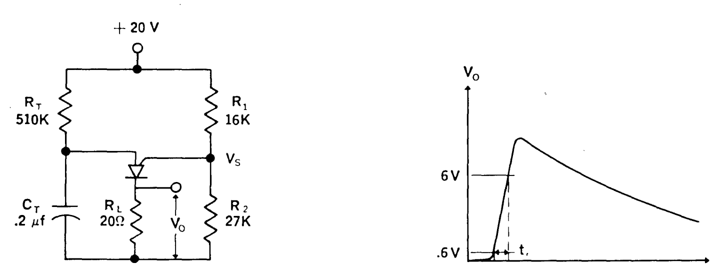


Figure 5

TRIACs
8 & 10A RMS, 800V, TO-220AB

USC1420
USC1440
USC1470
USC1490

FEATURES
- Voltage Ratings: to 800V
- Hard-Glass Passivated Junction
- Choice of Isolated and Non-Isolated Tab
- Economical Package
- High Surge Capability

DESCRIPTION
Unitrode power TRIACs combine the most advanced hard-glass passivated chips with the popular isolated and non-isolated TO-220AB package. They are particularly suited for AC loads in such applications as motor controls, light dimmers, power supplies and heating controls.

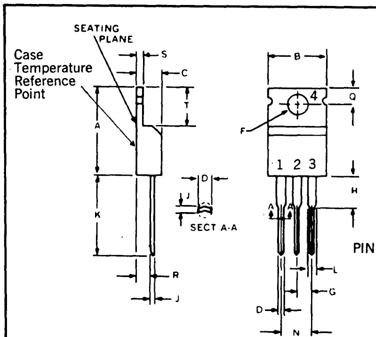
ABSOLUTE MAXIMUM RATINGS

	USC1420	USC1440	USC1470	USC1490
	Isolated Tab		Non-Isolated Tab	
Repetitive Peak Off-State Voltage, V_{DRM}				
USC1420-2 USC1440-2 USC1470-2 USC1490-2	200V			
USC1420-4 USC1440-4 USC1470-4 USC1490-4	400V			
USC1420-6 USC1440-6 USC1470-6 USC1490-6	600V			
USC1420-8 USC1440-8 USC1470-8 USC1490-8	800V			
On-State Current, $I_{T(RMS)}$ (@ T_C = 80°C)(1)	8A	10A	8A	10A
Peak Non-Repetitive Current, I_{TSM}	100A	100A	110A	110A
Fusing Time, I^2t(2) (RMS Amp²s, 8.3mS)	50	50	60	60
Steady State Thermal Resistance, $R_{\theta JC}$	3.1°C/W	2.5°C/W	3.0°C/W	2.2°C/W
Peak Gate Power, P_{GM}	16W			
Average Gate Power, $P_{G(AV)}$	0.5W			
Storage Temperature Range, T_{Stg}	−40° to +150°C			
Operating Temperature Range, T_j	−40° to +110°C			
Surge Isolation Voltage (Isolated Tab only)(3)	1600V			

Note 1. Reference mounting tab, 80°C.
Note 2. Ratings apply for either polarity of MT2 to MT1.
Note 3. Ratings apply from MT1 and MT2 and gate to device mounting tab. 60Hz sinusoidal wave form applied for one minute.

MECHANICAL SPECIFICATIONS

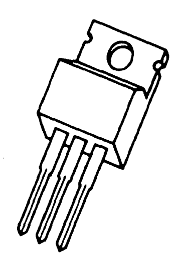
USC1420 USC1440 USC1470 USC1490



PIN 1. MT1
2. MT2
3. Gate
4. Electrically connected to MT2 on Non-Isolated Package

	ins.	mm.
A	.0.560-0.625	14.23-15.87
B	0.380-0.420	9.66-10.66
C	0.140-0.190	3.56-4.82
D	0.020-0.045	0.51-1.14
F	0.139-0.147	3.531-3.733
G	0.090-0.110	2.29-2.79
H	0.250	6.35
J	0.015-0.025	0.38-0.64
K	0.500-0.562	12.70-14.27
L	0.045-0.070	1.14-1.77
N	0.190-0.210	4.83-5.33
Q	0.100-0.120	2.54-3.04
R	0.080-0.115	2.04-2.92
S	0.045-0.055	1.14-1.39
T	0.230-0.270	5.85-6.85

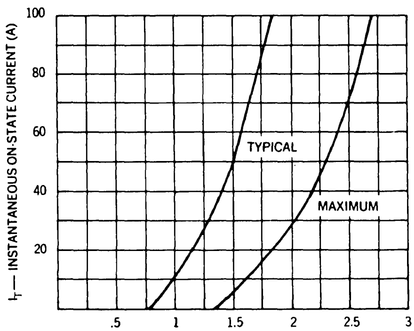
TO-220AB



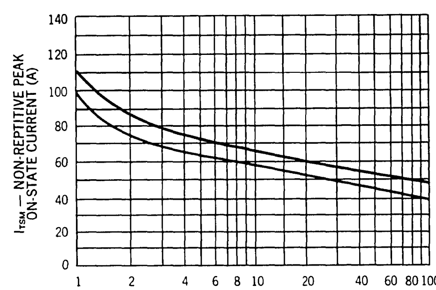
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	—	2.0	mA	V_{DRM} = Rating, T_C = 100°C
Gate Trigger Current	I_{GT}	— —	— —	50 50	mA mA	V_D = 12V Quadrants 1 & 2 (+ +, − −) V_D = 12V Quadrants 3 & 4 (− +, + −)
Gate Trigger Voltage	V_{GT}	—	—	2.0	V	V_D = 12V All Four Quardrants
Peak On-State Voltage	V_{TM}	—	—	1.6	V	I_{TM} = 12A Peak, USC1420, USC1470 I_{TM} = 14A Peak, USC1440, USC1490
Holding Current	I_H	—	—	30	mA	V_D = 12V
Critical Rate of Rise — Off-State Voltage	dv/dt	50	100	—	V/μS	V_{DRM} = Rating, T_C = 100°
Critical Rate of Rise — Commutated Off-State Voltage	dv/dt$_{(C)}$	3	10	—	V/μS	I_T = Rating,V_{DRM} = Rating, T_C = 65°

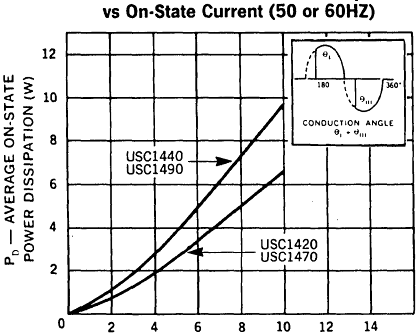
On-State Characteristics



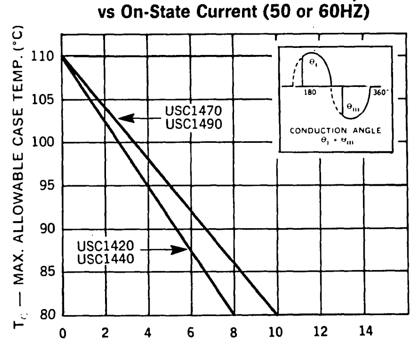
Maximum Allowable Non-Repetitive Peak On-State Current Following Rated Load Conditions



Maximum Conduction Power Dissipation vs On-State Current (50 or 60HZ)



Maximum Allowable Case Temp. vs On-State Current (50 or 60HZ)



X

TRIACs
15 & 20A RMS, 800V, TO-220AB

USC2120
USC2140
USC2250
USC2270

FEATURES
- Voltage Ratings: to 800V
- Hard-Glass Passivated Junction
- Choice of Isolated and Non-Isolated Tab
- Economical Package
- High Surge Capability

DESCRIPTION
Unitrode power TRIACs combine the most advanced hard-glass passivated chips with the popular isolated and non-isolated TO-220AB package. They are particularly suited for AC loads in such applications as motor controls, light dimmers, power supplies and heating controls.

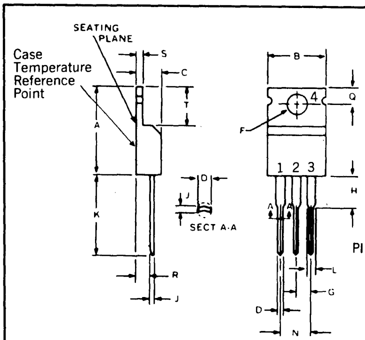
ABSOLUTE MAXIMUM RATINGS

<table>
<tr><th></th><th>USC2120</th><th>USC2140</th><th>USC2250</th><th>USC2270</th></tr>
<tr><td></td><td colspan="2">Isolated Tab</td><td colspan="2">Non-Isolated Tab</td></tr>
<tr><td>Repetitive Peak Off-State Voltage, V_{DRM}</td><td colspan="4"></td></tr>
<tr><td>USC2120-2 USC2140-2 USC2250-2 USC2270-2</td><td colspan="4">200V</td></tr>
<tr><td>USC2120-4 USC2140-4 USC2250-4 USC2270-4</td><td colspan="4">400V</td></tr>
<tr><td>USC2120-6 USC2140-6 USC2250-6 USC2270-6</td><td colspan="4">600V</td></tr>
<tr><td>USC2120-8 USC2140-8 USC2250-8 USC2270-8</td><td colspan="4">800V</td></tr>
<tr><td>On-State Current, $I_{T(RMS)}$(@ T_C = 80°C)(1)</td><td>15A</td><td>20A</td><td>15A</td><td>20A</td></tr>
<tr><td>Peak Non-Repetitive Current, I_{TSM}</td><td>150A</td><td>200A</td><td>150A</td><td>200A</td></tr>
<tr><td>Fusing Time, I^2t(2) (RMS Amp^{2}s, 8.3mS)</td><td>60</td><td>80</td><td>60</td><td>80</td></tr>
<tr><td>Steady State Thermal Resistance, $R_{\theta JC}$</td><td>2.0°C/W</td><td>1.5°C/W</td><td>1.8°C/W</td><td>1.3°C/W</td></tr>
<tr><td>Peak Gate Power, P_{GM}</td><td colspan="4">16W</td></tr>
<tr><td>Average Gate Power, $P_{G(AV)}$</td><td colspan="4">0.5W</td></tr>
<tr><td>Storage Temperature Range, T_{stg}</td><td colspan="4">−40° to +150°C</td></tr>
<tr><td>Operating Temperature Range, T_j</td><td colspan="4">−40° to +110°C</td></tr>
<tr><td>Surge Isolation Voltage (Isolated Tab only)(3)</td><td colspan="4">1600V</td></tr>
</table>

Note 1. Reference mounting tab, 80°C.
Note 2. Ratings apply for either polarity of MT2 to MT1.
Note 3. Ratings apply from MT1 and MT2 and gate to device mounting tab. 60Hz sinusoidal wave form applied for one minute.

MECHANICAL SPECIFICATIONS

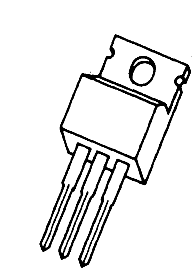
USC2120 USC2140 USC2250 USC2270



PIN 1. MT1
2. MT2
3. Gate
4. Electrically connected to MT2 on Non-Isolated Package

	ins.	mm.
A	0.560-0.625	14.23-15.87
B	0.380-0.420	9.66-10.66
C	0.140-0.190	3.56-4.82
D	0.020-0.045	0.51-1.14
F	0.139-0.147	3.531-3.733
G	0.090-0.110	2.29-2.79
H	0.250	6.35
J	0.015-0.025	0.38-0.64
K	0.500-0.562	12.70-14.27
L	0.045-0.070	1.14-1.77
N	0.190-0.210	4.83-5.33
Q	0.100-0.120	2.54-3.04
R	0.080-0.115	2.04-2.92
S	0.045-0.055	1.14-1.39
T	0.230-0.270	5.85-6.85

TO-220AB

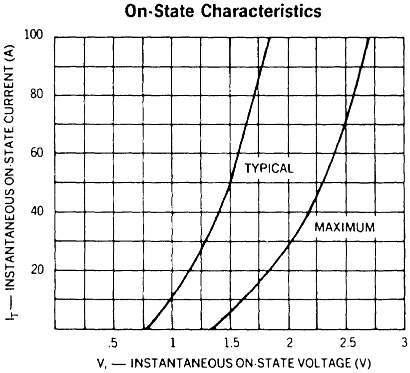


UNITRODE

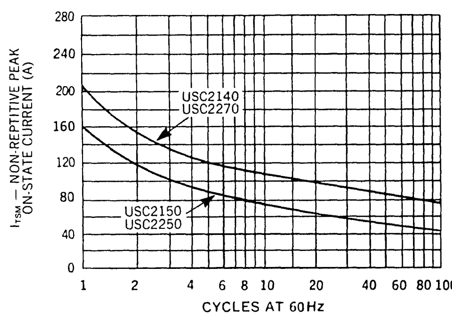
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Test	Symbol	Min.	Typical	Max.	Units	Test Conditions
Off-State Current	I_{DRM}	—	—	2.0	mA	V_{DRM} = Rating, T_C = 100°C
Gate Trigger Current	I_{GT}	— —	— —	50 75	mA mA	V_D = 12V Quadrants 1 & 3 (+ +, − −) V_D = 12V Quadrants 2 & 4 (− +, + −)
Gate Trigger Voltage	V_{GT}	—	—	2.5	V	V_D = 12V
Peak On-State Voltage	V_{TM}	—	—	1.9	V	I_{TM} = 21A Peak, USC2120, USC2250 I_{TM} = 28A Peak, USC2140, USC2270
Holding Current	I_H	—	—	50	mA	V_D = 12V
Critical Rate of Rise — Off-State Voltage	dv/dt	100	200	—	V/μS	V_{DRM} = Rating, T_C = 100°
Critical Rate of Rise — Commutated Off-State Voltage	$dv/dt_{(C)}$	3	10	—	V/μS	I_T = Rating,V_{DRM} = Rating, T_C = 65°

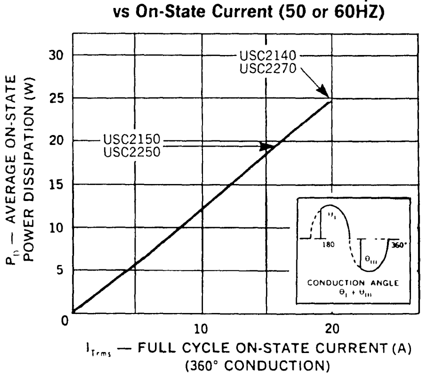
On-State Characteristics



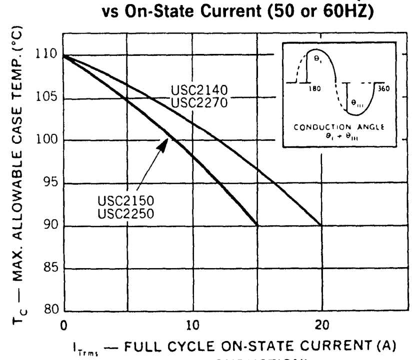
Maximum Allowable Non-Repetitive Peak On-State Current Following Rated Load Conditions



Maximum Conduction Power Dissipation vs On-State Current (50 or 60HZ)



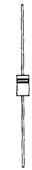
Maximum Allowable Case Temp. vs On-State Current (50 or 60HZ)



X

SWITCHING & GENERAL PURPOSE DIODES XI

SWITCHING AND GENERAL PURPOSE DIODES



SWITCHING

Type	Reverse Voltage (V)	Average Forward Current (mA)	Forward Voltage (V)	Reverse Recovery Time (ns)	Junction Capacitance (pF)
1N4453	30	200	.51-.63 @ 0.1mA		30
1N4154	35	150	1.0 @ 30mA	2	4
1N251*	40	75	1.0 @ 5mA	150	
1N4152	40	150	.49-.52 @ 0.1mA	2	2
1N4450	40	200	.42-.54 @ 0.1mA	4	4
1N4451	40	200	.4-.5 @ 0.1mA	10	6
1N4452	40	200	.42-.54 @ 0.1mA	50	30
1N4444	70	200	.44-.55 @ 0.1mA	7	2
1N3064**	75	75	1.0 @ 10mA	4	2
1N4532***	75	125	1.0 @ 10mA	4	2
1N4534***	75	150	.74-.88 @ 20mA	4	2
1N4151	75	150	1.0 @ 50mA	2	2
1N4153***	75	150	.49-.55 @ 0.1mA	2	2
1N4305	75	150	.5-.575 @ .25mA	2	2
1N4446	75	150	1.0 @ 20mA	4	4
1N4447	75	150	1.0 @ 20mA	4	2
1N4448	75	150	1.0 @ 100mA	4	4
1N4449	75	150	1.0 @ 30mA	4	2
1N3600***	75	200	.54-.62 @ 1mA	4	2.5
1N4149	75	200	1.0 @ 10mA	4	2
1N4150***	75	200	.54-.62 @ 1mA	4	2.5
1N4454***	75	200	1.0 @ 10mA	2	2
1N4500***	80	300	.64-.72 @ 10mA	6	4
1N4607	85	400	1.1 @ 400mA	10	4
1N662*	100	40	1.0 @ 10mA	500	3
1N663*	100	40	1.0 @ 100mA	500	3
1N914**	100	75	1.0 @ 10mA	5	4
1N4531***	100	125	1.0 @ 10mA	5	4
1N4148***	100	200	1.0 @ 10mA	4	4
1N3070**	200	100	1.0 @ 100mA	50	5
1N4938**	200	150	1.0 @ 10mA	50	5

GENERAL PURPOSE

Type	Reverse Voltage (V)	Average Forward Current (mA)	Forward Voltage (V)	Reverse Recovery Time (ns)	Junction Capacitance (pF)
1N456	30	90	1.0 @ 40mA		
1N457*	70	75	1.0 @ 20mA		
1N483B**	80	200	1.0 @ 100mA		
1N458*	150	55	1.0 @ 7mA		
1N3595***	150	150	.83-1.0 @ 200mA	3μs	2.5
1N459*	200	40	1.0 @ 3mA		
1N643*	200	40	1.0 @ 10mA	300	3
1N485B**	200	200	1.0 @ 100mA		
1N645**	270	400	1.0 @ 400mA		20
1N647**	480	400	1.0 @ 400mA		20

* Available as JAN.
** Available as JAN, JANTX.
*** Available as JAN, JANTX, JANTXV.

COMPUTER DIODE

General Purpose

JAN 1N251

FEATURES

- Metallurgical Bond
- Qualified to MIL-S-19500/188
- Planar Passivated Chip
- DO-7 Package
- Non-JAN Available

DESCRIPTION

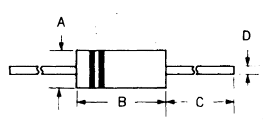
This device is particularly suited to applications where medium speed switching is required. Moisture free stability is ensured through hermetic sealing.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Peak Reverse Voltage	40V
Reverse Working Voltage	30V
Average Rectified Current	75mAdc
Surge Current, 1ms @ 125°C Free Air Temperature	125mA
Continuous Power Dissipation	150mW
Operating Temperature Range	−55°C to +150°C
Storage Temperature Range	−55°C to +150°C

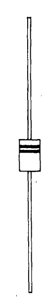
MECHANICAL SPECIFICATIONS

JAN 1N251



	INCHES	MILLIMETERS
A	.077 - .130	1.96 - 3.30
B	.195 - .300	4.95 - 7.62
C	1.0 - 1.5	25.4 - 38.1
D	.019 - .021	.48 - .53

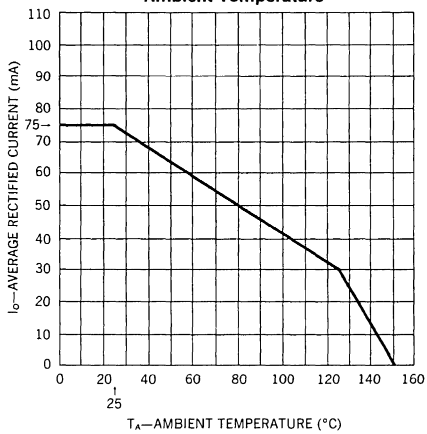
DO-7



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Reverse Current	Reverse Current	Reverse Current @ 125°C	Forward Voltage	Reverse Recovery Time
20μA @ V_R = 20V	0.1μA @ V_R = 10V	10μA @ 10V	1V @ I_F = 5mA	150ns @ I_F = 5mA, V_R = 10V R_L = 1KΩ, C_L = 10pf, I_{REC} = 0.5mA

Average Rectified Current vs. Ambient Temperature



XI

DIODE
Low Current

1N456
JAN 1N457
JAN 1N458
JAN 1N459

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/193
- Planar Passivated Chip
- DO-7 Package
- Non-JAN Available

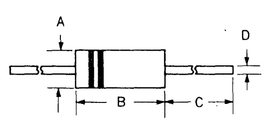
DESCRIPTION
General purpose low current diode with high reliability characteristics

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N456	JAN 1N457	JAN 1N458	JAN 1N459
Reverse Working Voltage	25V	60V	125V	175V
Peak Reverse Voltage	30V	70V	150V	200V
Average Output Current	90mA	75mA	55mA	40mA
Surge Current, 8.3mS	700mA	225mA	165mA	120mA
Operating Temperature Range	−65°C to +150°C			
Storage Temperature Range	−65°C to +200°C			

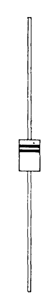
MECHANICAL SPECIFICATIONS

1N456
JAN 1N457, 1N458, 1N459



	INCHES	MILLIMETERS
A	.085 - .130	2.16 - 3.30
B	.230 - .300	5.84 - 7.62
C	1.0 - 1.5	25.40 - 38.10
D	.018 - .022	.46 - .56

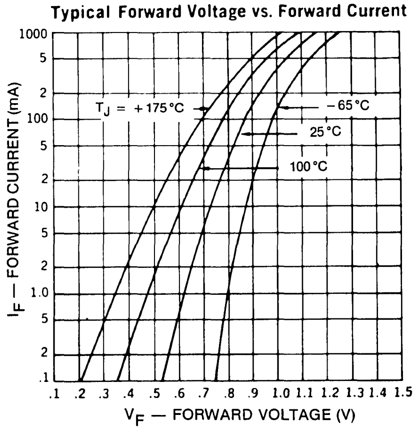
DO-7



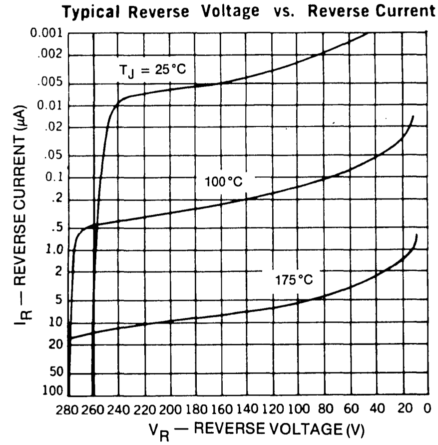
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Forward Voltage	Reverse Current	Reverse Current @T_A = 150°C	Peak Reverse Voltage @100μA
1N456	1.0V @ 40mA	25nA @ 25V	5μA @ 25V	30V
1N457, J	1.0V @ 20mA	25nA @ 60V	5μA @ 60V	70V
1N458, J	1.0V @ 7mA	25nA @ 125V	5μA @ 125V	150V
1N459, J	1.0V @ 3mA	25nA @ 175V	5μA @ 175V	200V

Typical Forward Voltage vs. Forward Current



Typical Reverse Voltage vs. Reverse Current



XI

DIODE

General Purpose
Low Current

JAN & JANTX 1N483B
JAN & JANTX 1N485B

FEATURES

- Metallurgical Bond
- Qualified to MIL-S-19500/118
- Planar Passivated Chip
- DO-7 Package
- Non-JAN Available

DESCRIPTION

This Series is useful in low current rectifying applications for military, industrial and commercial equipment.

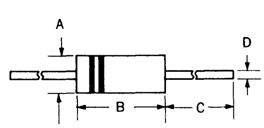
ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N483B	1N485B
Reverse Breakdown Voltage	80V	200V
Peak Working Voltage	70V	180V

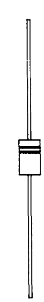
Average Output Current @ $T_A = 25°C$ 200mA
$T_A = 150°C$ 50mA
Current Derating 1.2 mAdc/°C from 25°C to 150°C and 1.0 mAdc/°C from 150°C to 200°C
Surge Current, 8.3mSec .... 2 Amps
Operating Temperature Range .... —65°C to +200°C
Storage Temperature Range .... —65°C to +200°C

MECHANICAL SPECIFICATIONS

J & JTX 1N483B, 1N485B



	INCHES	MILLIMETERS
A	.085 - .125	2.16 - 3.17
B	.230 - .300	5.84 - 7.62
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

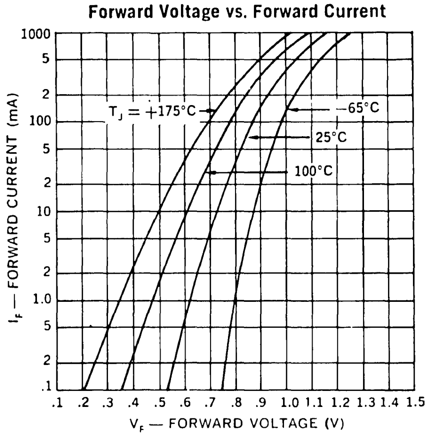


UNITRODE

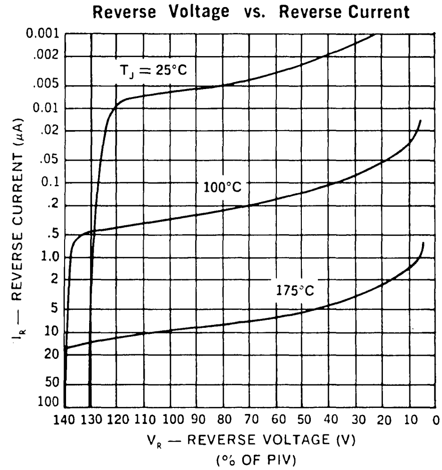
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Reverse Current @ 25°C	Reverse Current @ 25°C	Reverse Current @ 150°C	Forward Voltage @ 100mAdc, 8.5msec dc = 2% MAX.
1N483B 1N485B	25nA @ 70Vdc 25nA @ 180Vdc	100 μA(pk) @ 80V(pk) 100 μA(pk) @ 200V(pk)	5.0 μA @ 70Vdc 5.0 μA @ 180Vdc	1.0V(pk)

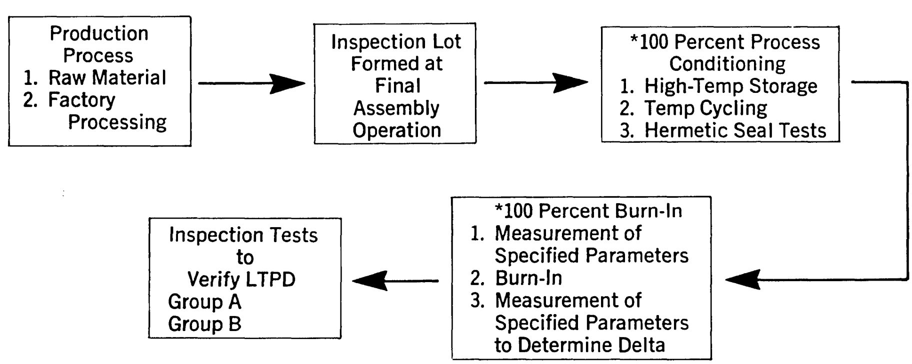
Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current



XI



*Order of the tests in the blocks shall be performed as shown.

Order of procedure diagrams for TX types only.

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COMPUTER DIODE
Switching

JAN 1N643
JAN 1N662
JAN 1N663

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/256
- Planar Passivated Chip
- DO-7 Package

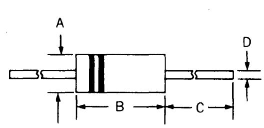
DESCRIPTION
This device is particularly suited to applications where medium speed switching is required. Moisture free stability is ensured through hermetic sealing.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N643	1N662	1N663
Peak Reverse Voltage	200V	100V	100V
Reverse Working Voltage	175V	80V	80V
Average Rectified Current	40mAdc	40mAdc	60mAdc
Surge Current, 8.3ms		500mA	
Operating Temperature Range		−65°C to +150°C	
Storage Temperature Range		−65°C to +175°C	

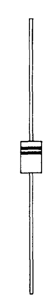
MECHANICAL SPECIFICATIONS

J 1N643, 1N662, 1N663



	INCHES	MILLIMETERS
A	.077 - .130	1.96 - 3.30
B	.195 - .300	4.95 - 7.62
C	1.0 - 1.5	25.4 - 38.1
D	.019 - .021	.48 - .53

DO-7



UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

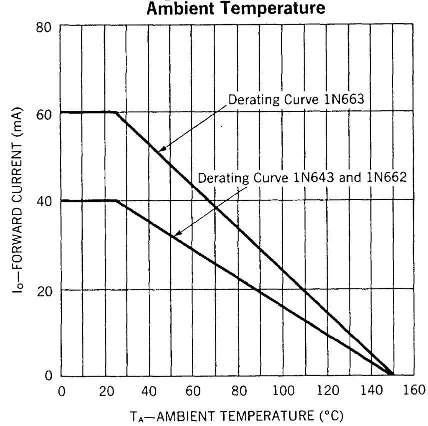
Type	Maximum Reverse Current @ 25°C	Maximum Reverse Current @ 25°C	Maximum Peak Reverse Current @ 25°C	Maximum Reverse Current @ 100°C	Maximum Reverse Current @ −65°C
1N643	25nAdc @ V_R = 10Vdc	1μAdc @ V_R = 100Vdc	100μA_{PK} @ V_R = 200V_{PK}	15μAdc @ V_R = 100Vdc	1μAdc @ V_R = 100Vdc
1N662	25nAdc @ V_R = 10Vdc	5μAdc @ V_R = 50Vdc	100μA_{PK} @ V_R = 100V_{PK}	100μAdc @ V_R = 50Vdc	5μAdc @ V_R = 50Vdc
1N663	25nAdc @ V_R = 10Vdc	5μAdc @ V_R = 75Vdc	100μA_{PK} @ V_R = 100V_{PK}	50μAdc @ V_R = 75Vdc	5μAdc @ V_R = 75Vdc

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Maximum Forward Voltage @ 25°C	Maximum Forward Voltage @ −65°C	Capacitance	Maximum Reverse Recovery Time
1N643	1.0Vdc @ I_F = 10mAdc	1.2Vdc @ I_F = 10mAdc	3pF @ V_R = 175V	300ns @ I_F = 5mA I_R = 17.5mA I_{REC} = 0.2nA
1N662	1.0Vdc @ I_F = 10mAdc	1.2Vdc @ I_F = 10mAdc	3pF @ V_R = 80V	500ns @ I_F = 5mA I_R = 17.5mA I_{REC} = 0.4nA
1N662	1.0Vdc @ I_F = 100mAdc	1.2Vdc @ I_F = 100mAdc	3pF @ V_R = 80V	500ns @ I_F = 5mA I_R = 17.5mA I_{REC} = 0.4nA

XI

Average Rectified Current vs. Ambient Temperature



RECTIFIERS
High Voltage, Low Current

JAN, JANTX 1N645, 1N647
JAN, JANTX & JANTXV 1N645-1, 1N647-1

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/240
- Planar Passivated Chip
- DO-35 or DO-7 Package
- Non-JAN Available

DESCRIPTION

These devices are useful in general purpose low current applications in high reliability and military equipment.

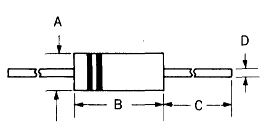
ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N645 1N645-1	1N647 1N647-1
Reverse Breakdown Voltage	270V	480V
Peak Working Voltage	225V	400V
Average Output Current, 25°C*	400mA	
150°C	150mA	
Surge Current, 8.3ms	5A	
Operating Temperature Range	−65°C to +150°C	
Storage Temperature Range	−65°C to +200°C	

*Derate 2.0mAdc/°C between 25°C and 150°C.

MECHANICAL SPECIFICATIONS

J, JTX 1N645, 1N647
J, JTX, & JTXV 1N645-1, 1N647-1

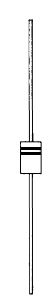


J, JTX 1N645, 1N647

	INCHES	MILLIMETERS
A	.085 - .130	2.16 - 3.30
B	.230 - .300	5.84 - 7.62
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

J, JTX, & JTXV 1N645-1, 1N647-1

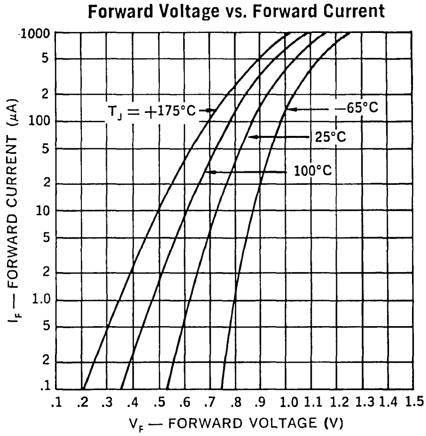
	INCHES	MILLIMETERS
A	.055 - .130	1.40 - 3.30
B	.140 - .300	3.55 - 7.62
C	1.0 MIN.	25.40 MIN.
D	.018 - .023	.46 - .58



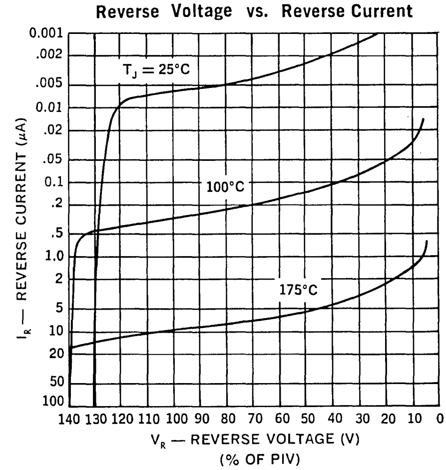
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

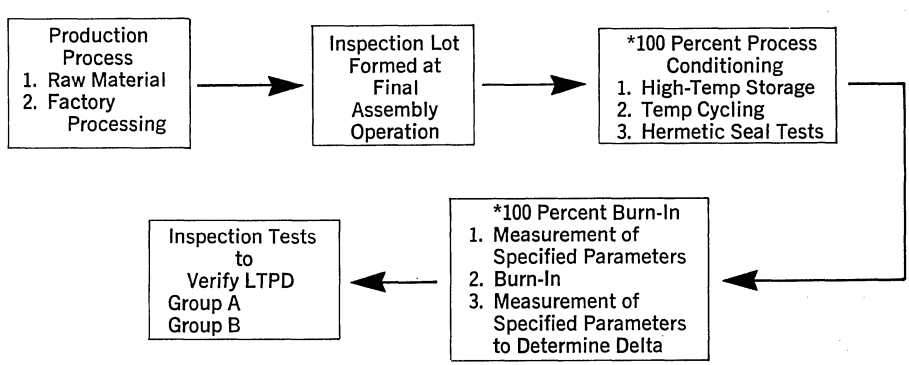
Type	Reverse Current @ 25°C	Reverse Current @ 50°C	Peak Reverse Current @ 25°C	Average Reverse Current @ 150°C	Forward Voltage @ 25°C	Capacitance
1N645	0.025μA @ 225Vdc	15μAdc @ 225Vdc	100μA (pk) @ 270V (pk)	100μAdc @ 225V (pk)	1.0Vdc @ I_F = 400mAdc 8.3ms	20pF V_R = 4 Vdc f = 1MHz V_{sig} = 50mV
1N645-1	0.050μA @ 225Vdc	25μAdc @ 225Vdc	100μA (pk) @ 270V (pk)	100μAdc @ 225V (pk)		
1N647	0.025μA @ 400Vdc	—	100μA (pk) @ 480V (pk)	100μAdc @ 400V (pk)		
1N647-1	0.050μA @ 400Vdc	—	100μA (pk) @ 480V (pk)	100μAdc @ 400V (pk)		

Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current





*Order of the tests in the blocks shall be performed as shown.

Order of procedure diagrams for TX types only.

XI

COMPUTER DIODE

General Purpose Switching

JAN, JANTX, 1N914
JAN, JANTX, JANTXV 1N4148
JAN, JANTX, JANTXV 1N4148-1
JAN, JANTX, JANTXV 1N4531

FEATURES

- Metallurgical Bond
- Qualified to MIL-S-19500/116
- Planar Passivated Chip
- DO-34 or DO-35 Package
- Non-JAN Available

DESCRIPTION

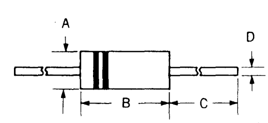
This series is very popular for general purpose switching applications in electronic equipment.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Reverse Breakdown Voltage		100V
Peak Working Voltage		75V
Average Output Current,	1N914	75mAdc
	1N4148	200mAdc
	1N4148-1	150mAdc
	1N4531	125mAdc
Surge Current, 8.3ms		500mA
Operating Temperature Range		−65°C to +175°C
Storage Temperature Range		−65°C to +200°C

MECHANICAL SPECIFICATIONS

J, JTX 1N914
J, JTX, JTXV 1N4148
J, JTX, JTXV 1N4148-1
J, JTX, JTXV 1N4531

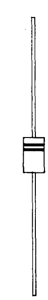


J, JTX & JTXV 1N4531

	INCHES	MILLIMETERS
A	.045 - .065	1.14 - 1.65
B	.080 - .110	2.032 - 2.79
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

J,JTX 1N914
J, JTX & JTXV 1N4148,-1

	INCHES	MILLIMETERS
A	.056 - .075	1.42 - 1.90
B	.140 - .180	3.55 - 4.57
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

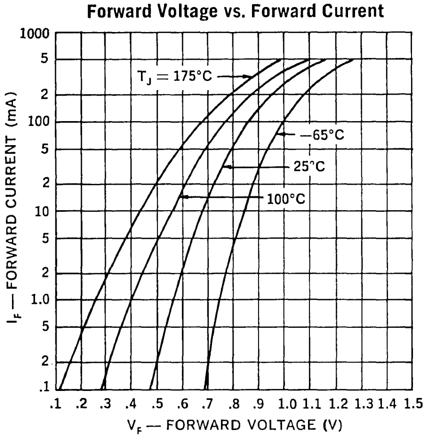


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

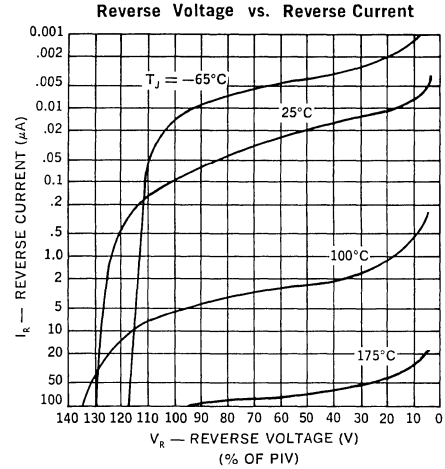
Reverse Current @ 25°C	Reverse Current @ 25°C	Peak Reverse Current @ 25°C	Reverse Current @ 150°C	Reverse Current @ 150°C
25nAdc @ $V_R = 20Vdc$	5.0μAdc @ $V_R = 75Vdc$	100μA (pk) @ $V_R = 100V$ (pk)	50μAdc @ $V_R = 20Vdc$	100μAdc @ $V_R = 75Vdc$

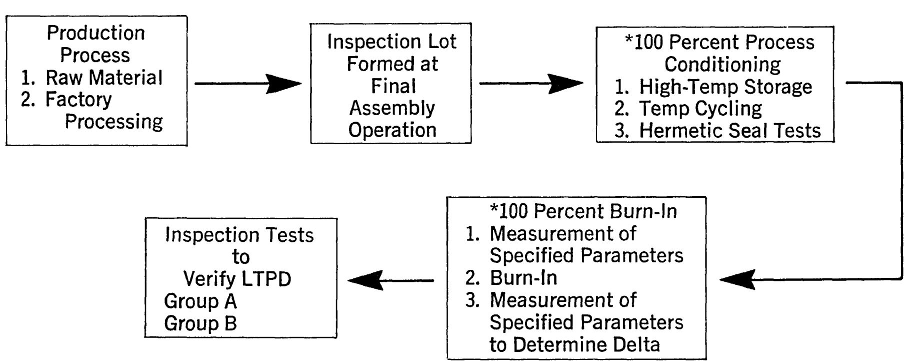
Forward Voltage	Foward Recovery Voltage	Forward Recovery Time	Reverse Recovery Time	Capacitance
1.0Vdc @ $I_F = 10mAdc$	5.0V (pk) @ $I_F = 50mAdc$	20ns @ $I_F = 50mAdc$	5ns @ $I_F = I_R = 10mA$ $R_L = 100$ ohms	4.0 pF @ $V_R = 0V, f = 1$ MHz $V_{sig} = 50mV$ (pk-pk) 28 pF @ $V_R = 1.5V, f = 1$ MHz $V_{sig} = 50mV$ (pk-pk)

Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current





*Order of the tests in the blocks shall be performed as shown.

Order of procedure diagrams for TX types only.

XI

COMPUTER DIODE
General Purpose Switching

JAN & JANTX 1N3064
JAN, JANTX & JANTXV 1N4454
JAN, JANTX & JANTXV 1N4454-1
JAN, JANTX & JANTXV 1N4532

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/144
- Planar Passivated Chip
- DO-7, DO-34 or DO-35 Package
- Non-JAN Available

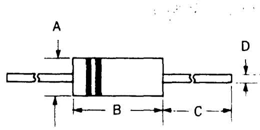
DESCRIPTION
Available in DO-7, DO-34 or DO-35 packages. Unitrode offers high temperature metallurgical bond, making these devices useful in high reliability applications.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Reverse Breakdown Voltage		75V
Peak Working Voltage		50V
Average Output Current,	1N3064	75mA
	1N4454,-1	200mA
	1N4532	125mA
Surge Current, 1sec,	1N3064	0.5A
	1N4454,-1	1A
	1N4532	0.5A
Operating Temperature Range		−65°C to +175°C
Storage Temperature Range		−65°C to +200°C

MECHANICAL SPECIFICATIONS

J & JTX 1N3064
J, JTX & JTXV 1N4454 & 1N4454-1
J, JTX & JTXV 1N4532



J, JTX & JTXV 1N4532

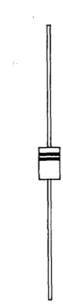
	INCHES	MILLIMETERS
A	.050 - .075	1.20 - 1.80
B	.085 - .120	2.04 - 2.88
C	1.0 MIN.	24.0 MIN.
D	.018 - .022	.0432 - .528

J & JTX 1N3064

	INCHES	MILLIMETERS
A	.078 - .107	1.98 - 2.72
B	.195 - .300	4.95 - 7.62
C	1.0 MIN.	24.0 MIN.
D	.018 - .022	.46 - .56

J, JTX & JTXV 1N4454,-1

	INCHES	MILLIMETERS
A	.056 - .075	1.42 - 1.90
B	.140 - .180	3.55 - 4.57
C	1.0 MIN.	24.0 MIN.
D	.018 - .022	.46 - .56

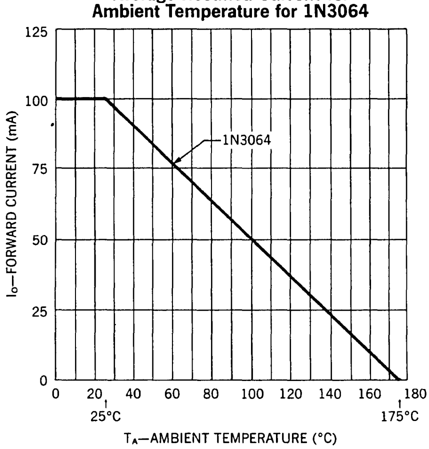


ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

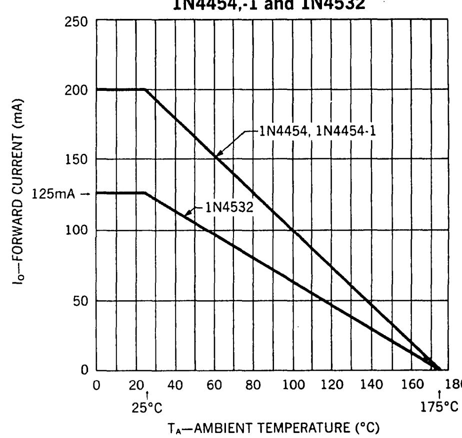
Type	Reverse Current @ 25°C	Reverse Current @ 150°C	Reverse Breakdown Voltage @ −65°C	Reverse Recovery Time	Capacitance
1N3064 1N4454 1N4454-1 1N4532	0.1μAdc @ V_R = 50V	100μAdc @ V_R = 50V	75Vdc @ I_R = 5μAdc	4ns @ $I_F = I_R$ = 10mAdc R_L = 100 ohms c ≤ 3pF	20pF @ V_R = 0 Vdc, f = 1 MHz V_{sig} = 50mV (pk to pk)

Forward Voltage	Forward Recovery Voltage	Forward Recovery Time
1.0Vdc @ I_F = 10mAdc	5.0V (pk) @ I_F = 100mAdc t_r ≤ 0.4ns	30ns I_F = 100mAdc t_r ≤ 0.4ns

Average Rectified Current vs. Ambient Temperature for 1N3064



Average Rectified Current vs. Ambient Temperature for 1N4454,-1 and 1N4532



XI

COMPUTER DIODE
Switching

JAN, JANTX 1N3070
JAN, JANTX 1N4938

FEATURES
- Double-plug Construction
- Qualified to MIL-S-19500/169
- Available in DO-7 or DO-35 package

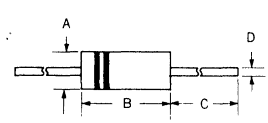
DESCRIPTION
Double-plug construction affords integral positive contact by means of a thermal compression bond. Moisture free stability is ensured through hermetic sealing. The coefficients of thermal expansion of the glass case and the dumet plugs are closely matched. Hot solder dipped leads are standard.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Reverse Breakdown Voltage 200V
Steady-State Forward Current at (or below) 25°C Free Air Temperature 150mA
Peak Surge Current, 1sec 500mA
Peak Surge Current, 1ms 2A
Continuous Power Dissipation at (or below) 25°C Free Air Temperature 250mW
Operating Temperature Range .... −65°C to +200°C
Storage Temperature Range .... −65°C to +200°C

MECHANICAL SPECIFICATIONS

J, JTX 1N3070
J, JTX 1N4938

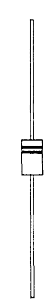


J, JTX 1N4938

	INCHES	MILLIMETERS
A	.065 MAX.	1.65 MAX.
B	.155 MAX.	3.94 MAX.
C	1.0 MIN.	25.4 MIN.
D	.020	0.51

J,JTX 1N3070

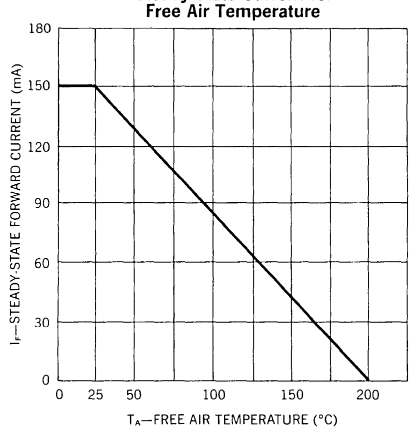
	INCHES	MILLIMETERS
A	0.085 MAX.	2.159 MAX.
B	.180 – 0.220	4.572 – 5.588
C	1.0 MIN.	25.4 MIN.
D	.018 – 0.022	0.457 – 0.559



ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Maximum Reverse Current @ 25°C	Maximum Reverse Current @ 150°C	Maximum Forward Voltage	Maximum Capacitance	Maximum Reverse Recovery Time
1N3070 1N4938	0.1μAdc @ 175Vdc	100μAdc @ 175Vdc	1Vdc @ I_F = 100mAdc	5pF @ V_R = 0, f = 1MHz	50ns @ I_F = 30mA, I_R = 30mA, I_{REC} = 1mA

Steady-State Current vs. Free Air Temperature



XI

COMPUTER DIODE
150 mA, Switching

JAN, JANTX, JANTXV 1N3595

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/241
- Planar Passivated Chip
- DO-7 Package
- Non-JAN Available

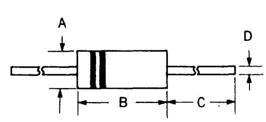
DESCRIPTION
A very useful device for medium current switching applications.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Peak Reverse Voltage	125V
Reverse Breakdown Voltage	150V
Average Output Current	150mAdc
Surge Current, 1S	500mA
1μS	4A
Operating Temperature Range	−65°C to +150°C
Storage Temperature Range	−65°C to +200°C

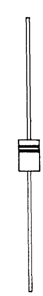
MECHANICAL SPECIFICATIONS

JAN, JANTX, JANTXV 1N3595



	INCHES	MILLIMETERS
A	.092 - .130	2.37 - 3.30
B	.130 - .300	3.30 - 7.62
C	1.0 - 1.5	25.40 - 38.10
D	.018 - .022	.46 - .56

DO-7



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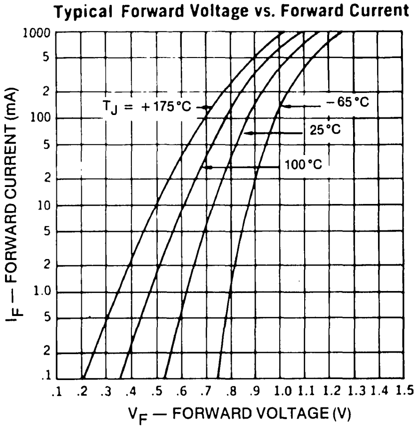
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

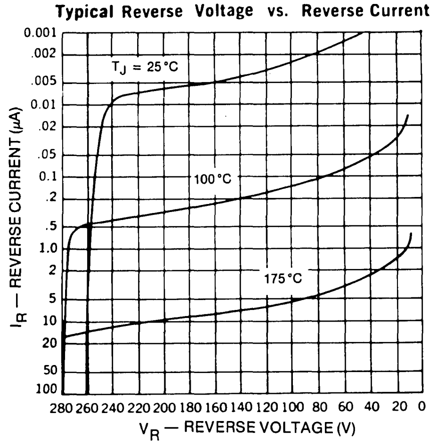
Limits	V_{F_1} I_F = 200mAdc	V_{F_2} I_F = 100mAdc	V_{F_3} I_F = 50mAdc	V_{F_4} I_F = 10mAdc	V_{F_5} I_F = 5mAdc	V_{F_6} I_F = 1mAdc
Min	0.83Vdc	0.79Vdc	0.74Vdc	0.65Vdc	0.60Vdc	0.52Vdc
Max	1.00Vdc	0.92Vdc	0.88Vdc	0.80Vdc	0.75Vdc	0.68Vdc

Limits	I_{R_1} V_R = 125Vdc	I_{R_2} V_R = 30Vdc T_A = 125°C	I_{R_3} V_R = 125Vdc T_A = 125°C	I_{R_4} V_R = 125Vdc T_A = 150°C	C V_R = 0Vdc f = 1MHz	t_{rr} I_F = 10mAdc V_R = 35Vdc
Min	—	—	—	—	—	—
Max	1.0nAdc	0.3μAdc	0.5μAdc	3.0μAdc	8.0pF	3.0μS

Typical Forward Voltage vs. Forward Current



Typical Reverse Voltage vs. Reverse Current



XI

COMPUTER DIODE

200mA
Low Power, Switching

JAN, JANTX & JANTXV 1N3600
JAN, JANTX & JANTXV 1N4150
JAN, JANTX & JANTXV 1N4150-1

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/231
- Planar Passivated Chip
- DO-7 or DO-35 Package
- Non-JAN Available

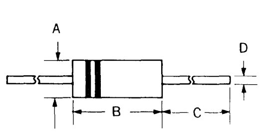
DESCRIPTION
This series of switching diodes is useful in many computer switching applications, for both military and commercial systems.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

Reverse Breakdown Voltage	75V
Peak Working Voltage	50V*
Average Output Current	200mA
Surge Current (1sec)	0.5A
(1μsec)	4.0A
Operating Temperature Range	−65°C to +175°C
Storage Temperature Range	−65°C to +200°C

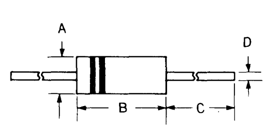
MECHANICAL SPECIFICATIONS

J, JTX & JTXV 1N3600

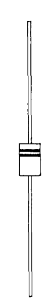


	INCHES	MILLIMETERS
A	.078 - .107	1.98 - 2.72
B	.195 - .300	4.95 - 7.62
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

J, JTX & JTXV 1N4150, 1N4150-1



	INCHES	MILLIMETERS
A	.056 - .075	1.42 - 1.90
B	.140 - .180	3.55 - 4.57
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56



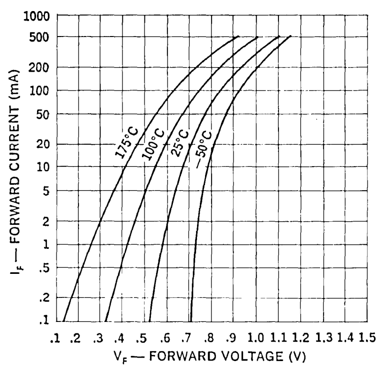
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

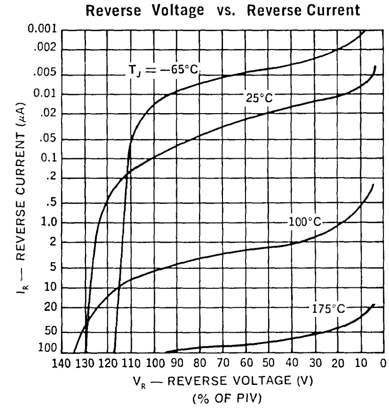
Characteristics	Forward Voltage	Forward Voltage	Forward Voltage	Forward Voltage	Forward Voltage	Reverse Breakdown Voltage
Conditions	V_{F1} $I_F = 1$ mAdc	V_{F2} $I_F = 10$ mAdc	V_{F3} $I_F = 50$ mAdc (pulse)	V_{F4} $I_F = 100$ mAdc (pulse)	V_{F5} $I_F = 200$ mAdc (pulse)	BV $I_R = 5.0\ \mu$Adc
Minimum Maximum	0.540 Vdc 0.620 Vdc	0.660 Vdc 0.740 Vdc	0.760 Vdc 0.860 Vdc	0.820 Vdc 0.920 Vdc	0.870 Vdc 1.00 Vdc	75 Vdc —

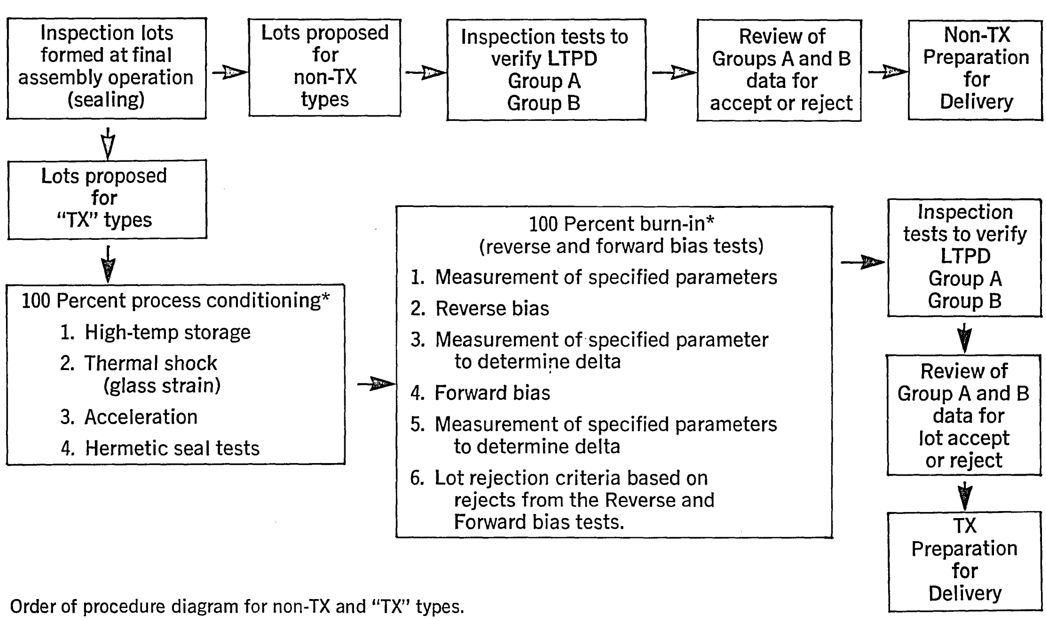
Characteristics	Reverse Current	Reverse Current	Junction Capacitance	Reverse Recovery Time	Reverse Recovery Time	Forward Recovery Time
Conditions	I_R $V_R = 50$ Vdc	I_R $V_R = 50$ Vdc $T_A = 150°C$	C $V_R = 0$ F = 1 MHz $V_{sig} = 50$ mv (p-p)	t_{rr1} $I_F = I_R =$ 10 to 200 mAdc; $R_L = 100$ ohms	t_{rr2} $I_F = I_R =$ 200 to 400 mAdc; $R_L = 100$ ohms	t_{fr} $I_F = 200$ mAdc; $t_p = 100$ nsec; $t_r = 0.4$ nsec
Maximum	0.1 μAdc	100 μAdc	2.5 pf	4 nsec	6 nsec	10 nsec

Typical Forward Current vs Voltage



Reverse Voltage vs. Reverse Current





Order of procedure diagram for non-TX and "TX" types.

COMPUTER DIODE
Switching

1N4149, 1N4151, 1N4154
1N4446, 1N4447, 1N4448
1N4449

FEATURES
- Metallurgical Bond
- Planar Passivated
- DO-35

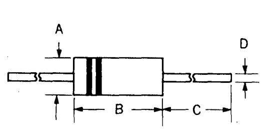
DESCRIPTION
This series offers Metallurgical Bonding and is very popular for general purpose switching applications.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N4149	1N4151	1N4154	1N4446	1N4447	1N4448	1N4449
Peak Reverse Voltage	75V	75V	35V	75V	75V	75V	75V
Average Rectified Current	200mAdc						
Surge Current, 8.3 mS	500mA						
Operating Temperature Range	− 65 °C to + 150 °C						
Storage Temperature Range	− 65 °C to + 200 °C						

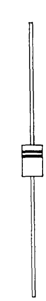
MECHANICAL SPECIFICATIONS

1N4149, 1N4151, 1N4154, 1N4446, 1N4447, 1N4448 1N4449



	INCHES	MILLIMETERS
A	.065	1.65
B	.155	3.94
C	1.0 MIN.	25.4 MIN.
D	.020	.51

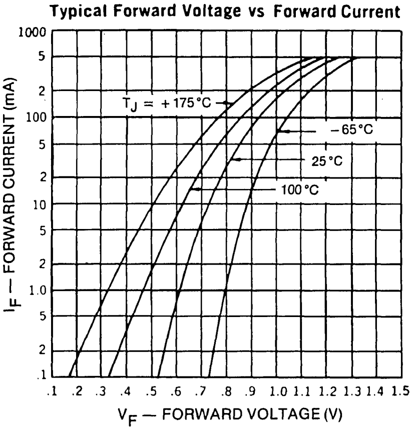
DO-35



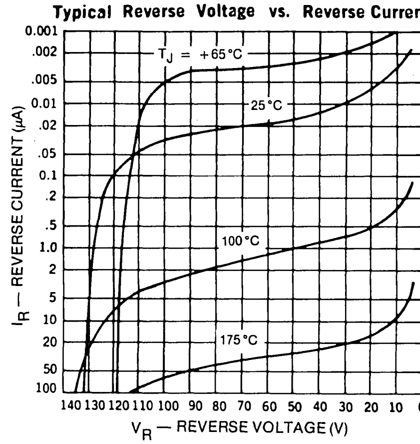
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Type	Peak Inverse Voltage	Forward Voltage @ 10mA	@ 20mA	@ 30mA	@ 50mA	@ 100mA	Reverse Current V_R nA	Reverse Current @ 150°C V_R μA	Junction Capacitance @ 0V	Reverse Recovery Time t_{RR}
1N4149	75	1.0	—	—	—	—	20 25	20 50	4pF	4nS
1N4151	75	—	—	—	1.0	—	50 50	50 50	4pF	2nS
1N4154	35	—	—	1.0	—	—	25 100	25 100	4pF	2nS
1N4446	75	—	1.0	—	—	—	20 25	20 50	4pF	4nS
1N4447	75	—	1.0	—	—	—	20 25	20 50	4pF	4nS
1N4448	75	—	—	—	—	1.0	20 25	20 50	4pF	4nS
1N4449	75	—	—	1.0	—	—	20 25	20 50	2pF	4nS

Typical Forward Voltage vs Forward Current



Typical Reverse Voltage vs. Reverse Current



XI

COMPUTER DIODE
Switching

1N4152, 1N4305, 1N4444

FEATURES
- Metallurgical Bond
- Planar Passivated
- DO-35 Package

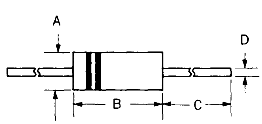
DESCRIPTION
This series offers Metallurgical Bonding and is very popular for general purpose switching applications.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N4152	1N4305	1N4444
Peak Reverse Voltage	40V	75V	70V
Reverse Working Voltage	30V	50V	50V
Average Rectified Current		200mAdc	
Surge Current, 8.3 mS		500mA	
Operating Temperature Range		−65°C to +150°C	
Storage Temperature Range		−65°C to +200°C	

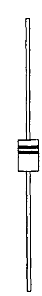
MECHANICAL SPECIFICATIONS

1N4152, 1N4305, 1N4444



	INCHES	MILLIMETERS
A	.065 MAX.	1.65 MAX.
B	.155 MAX.	3.94 MAX.
C	1.0 MIN.	25.40 MIN.
D	.020	.51

DO-35



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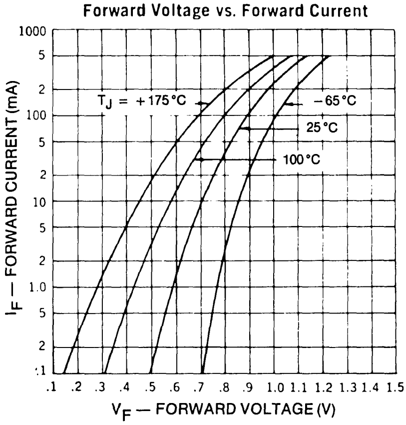
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

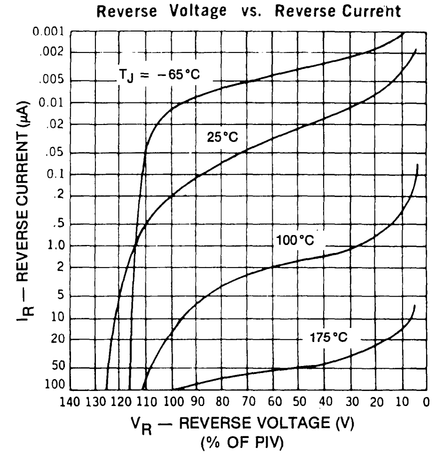
Type	Peak Inverse Voltage (V)	Forward Voltage @ 0.1mA		Forward Voltage @ 0.25mA		Forward Voltage @ 1.0mA		Forward Voltage @ 2.0mA		Forward Voltage @ 10mA		Forward Voltage @ 20mA		Forward Voltage @ 100mA	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max
1N4152	40	0.49	0.55	0.53	0.59	0.59	0.67	0.62	0.70	0.70	0.81	0.74	0.88	—	—
1N4305	75	—	—	0.505	0.575	0.55	0.65	0.61	0.71	0.70	0.85	—	—	—	—
1N4444	70	0.44	0.55	—	—	0.56	0.68	—	—	0.69	0.82	—	—	0.85	1.0

Type	Reverse Current		Reverse Current @ 150°C		Junction Capacitance @ 0V	Reverse Recovery Time t_{rr}
	V_R	(nA)	V_R	μA		
1N4152	30	50	30	500	2pF	2nS
1N4305	50	100	50	1000	2pF	2nS
1N4444	50	50	50	500	2pF	7nS

Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current



XI

COMPUTER DIODE
150mA
Switching Diode

JAN, JANTX & JANTXV 1N4153
JAN, JANTX & JANTXV 1N4534

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/337
- Planar Passivated Chip
- DO-34 or DO-35 Package
- Non-JAN Available

DESCRIPTION
This device is particularly suited to applications where tightly controlled forward characteristics and fast recovery time are important.

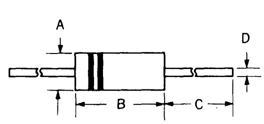
ABSOLUTE MAXIMUM RATINGS, AT 25°C

Reverse Breakdown Voltage 75V
Peak Working Voltage 50V
Average Output Current* 150mA
Surge Current, 1μs 2.0A
Operating Temperature Range .... −65°C to +200°C
Storage Temperature Range .... −65°C to +200°C

*Derate 0.86mAdc/°C for T_A above 25°C.

MECHANICAL SPECIFICATIONS

J, JTX & JTXV 1N4153
J, JTX & JTXV 1N4534

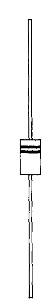


J, JTX & JTXV 1N4534

	INCHES	MILLIMETERS
A	.050 - .065	1.27 - 1.65
B	.080 - .120	2.03 - 3.05
C	1.0 - 1.5	25.4 - 38.1
D	.018 - .022	.46 - .56

J,JTX & JTXV 1N4153

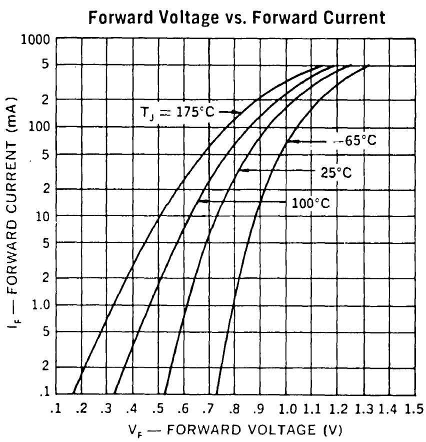
	INCHES	MILLIMETERS
A	.056 - .075	1.42 - 1.90
B	.140 - .180	3.55 - 4.57
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56

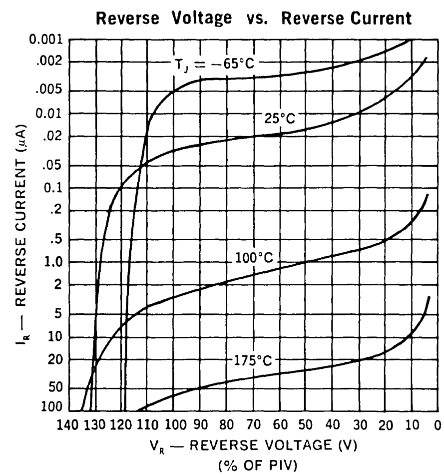


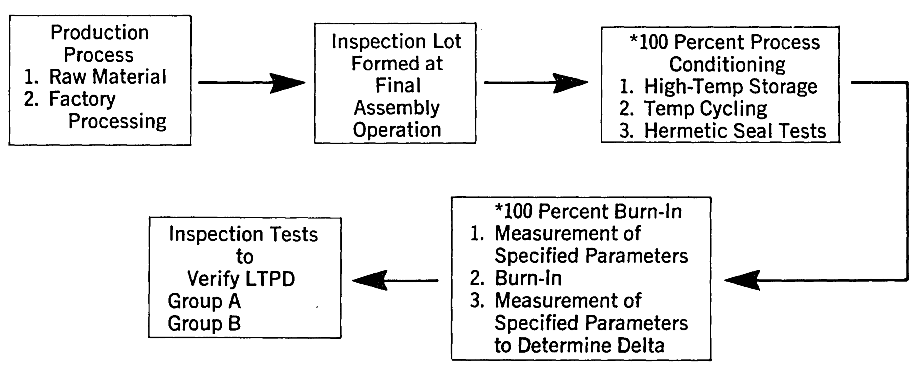
ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

Limit	V_{F1} $I_F = 100\ \mu Adc$	V_{F2} $I_F = 250\ \mu Adc$	V_{F3} $I_F = 1$ mAdc	V_{F4} $I_F = 2$ mAdc	V_{F5} $I_F = 10$ mAdc	V_{F6} $I_F = 20$ mAdc
Min Max	0.490Vdc 0.550Vdc	0.530Vdc 0.590Vdc	0.590Vdc 0.670Vdc	0.620Vdc 0.700Vdc	0.700Vdc 0.810Vdc	0.740Vdc 0.880Vdc

Limit	I_R $V_R = 50V$	I_{R2} $V_R = 50V$ $T_A = 150°C$	C $V_R = 0$ f = 1MHz	t_{rr} $I_F = I_R = 10mAdc$ $R_L = 100$ ohms	Reverse Breakdown Voltage $I_R = 5.0\mu Adc$
Min Max	— 0.05μAdc	— 50μAdc	— 2.0pF	— 4ns	75V —







*Order of the tests in the blocks shall be performed as shown.

Order of procedure diagrams for TX types only.

XI

COMPUTER DIODE
Switching

1N4450, 1N4451, 1N4453

FEATURES
- Metallurgical Bond
- Planar Passivated
- DO-35 Package

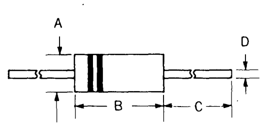
DESCRIPTION
This series offers Metallurgical Bonding and is very popular for general purpose switching applications.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N4450	1N4451	1N4453
Peak Reverse Voltage	40V	40V	30V
Reverse Working Voltage	30V	30V	20V
Average Rectified Current	200mAdc		
Surge Current, 8.3 mS	500mA		
Operating Temperature Range	−65°C to +150°C		
Storage Temperature Range	−65°C to +200°C		

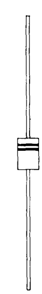
MECHANICAL SPECIFICATIONS

1N4450, 1N4451, 1N4453



	INCHES	MILLIMETERS
A	.065	1.65
B	.155	3.94
C	1.0 MIN.	25.4 MIN.
D	.020	.51

DO-35



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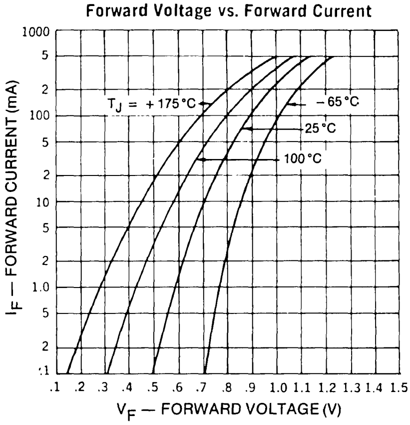
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

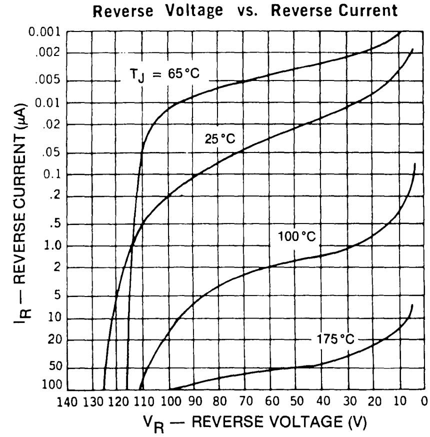
Type	Peak Inverse Voltage (V)	Forward Voltage @ 0.01mA		Forward Voltage @ 0.1mA		Forward Voltage @ 1.0mA		Forward Voltage @ 10mA		Forward Voltage @ 100mA		Forward Voltage @ 200mA		Forward Voltage @ 300mA	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max
1N4450	40	—	—	0.42	0.54	0.52	0.64	0.64	0.76	0.80	0.96	—	1.0	—	—
1N4451	40	—	—	0.40	0.50	0.51	0.61	0.62	0.72	0.75	0.875	—	—	—	1.0
1N4453	30	0.43	0.55	0.51	0.63	0.60	0.71	0.69	0.80	0.80	0.92	—	—	—	—

Type	Reverse Current V_R	(nA)	Reverse Current @ 150°C V_R	mA	Junction Capacitance @ 0V	Reverse Recovery Time t_{rr}
1N4450	30	50	30	500	4pF	4nS
1N4451	30	50	30	500	6pF	10nS
1N4453	20	50	20	500	30pF	—

Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current



XI

COMPUTER DIODE
High Conductance

1N4452, 1N4607

FEATURES
- Metallurgical Bond
- Planar Passivated
- High Conductance
- DO-35 Package

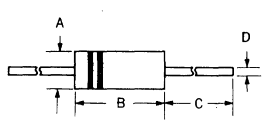
DESCRIPTION
This series offers Metallurgical Bonding and is specifically designed for high conductance switching applications such as core memories.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

	1N4452	1N4607
Peak Reverse Voltage	40V	85V
Reverse Working Voltage	30V	50V
Average Rectified Current	400mAdc	
Surge Current, 8.3 mS	1A	
Operating Temperature Range	−65°C to +150°C	
Storage Temperature Range	−65°C to +200°C	

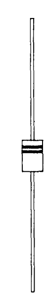
MECHANICAL SPECIFICATIONS

1N4452, 1N4607



	INCHES	MILLIMETERS
A	.065	1.65
B	.155	3.94
C	1.0 MIN.	25.4 MIN.
D	.020	.51

DO-35



UNITRODE

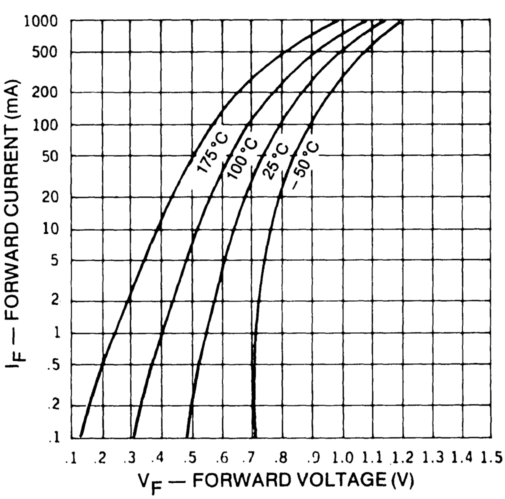
12/79

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

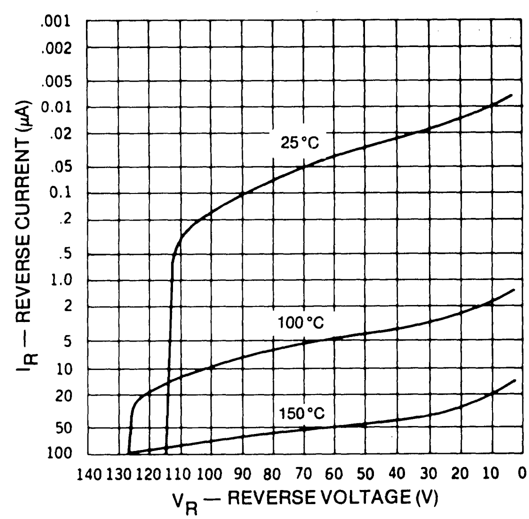
Type	Peak Inverse Voltage	Forward Voltage @ 0.1mA min	Forward Voltage @ 0.1mA max	Forward Voltage @ 1.0mA min	Forward Voltage @ 1.0mA max	Forward Voltage @ 10mA min	Forward Voltage @ 10mA max	Forward Voltage @ 100mA min	Forward Voltage @ 100mA max	Forward Voltage @ 250mA min	Forward Voltage @ 250mA max	Forward Voltage @ 350mA min	Forward Voltage @ 350mA max	Forward Voltage @ 400mA min	Forward Voltage @ 400mA max	Forward Voltage @ 600mA min	Forward Voltage @ 600mA max	Forward Voltage @ 1000mA min	Forward Voltage @ 1000mA max
1N4452	40V	0.42	0.54	0.51	0.62	0.60	0.71	0.71	0.83	—	—	—	—	—	—	—	1.0	0.90	1.2
1N4607	85V	0.39	0.50	0.50	0.60	0.61	0.72	0.74	0.87	0.81	0.95	—	1.0	—	1.1	—	—	—	—

Type	Reverse Current V_R	Reverse Current nA	Reverse Current @ 100°C V_R	Reverse Current @ 100°C mA	Reverse Current @ 150°C V_R	Reverse Current @ 150°C μA	Junction Capacitance @ 0V	Reverse Recovery Time t_{rr}
1N4452	30	50	—	—	30	500	—	50nS
1N4607	50	100	50	25	—	—	4pF	10nS

Typical Forward Voltage vs Forward Current



Typical Reverse Voltage vs Reverse Current



XI

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COMPUTER DIODE
500mA
Switching Diode

JAN & JANTX 1N4500

FEATURES
- Metallurgical Bond
- Qualified to MIL-S-19500/403
- Planar Passivated Chip
- DO-35 Package
- Non-JAN Available

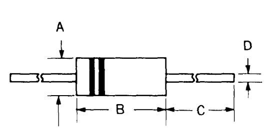
DESCRIPTION
This device is a fast switching, high conductance diode for military, space, high rel and other systems.

ABSOLUTE MAXIMUM RATINGS, AT 25°C

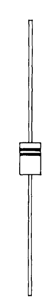
Reverse Breakdown Voltage	80Vdc
Peak Working Voltage	75Vpk
Average Output Current	300mAdc
Surge Current, 1sec	0.5A
1μsec	4.0A
Operating Temperature Range	−65°C to +175°C
Storage Temperature Range	−65°C to +200°C

MECHANICAL SPECIFICATIONS

J & JTX 1N4500



	INCHES	MILLIMETERS
A	.060 - .107	1.52 - 2.72
B	.140 - .300	3.55 - 7.62
C	1.0 MIN.	25.40 MIN.
D	.018 - .022	.46 - .56



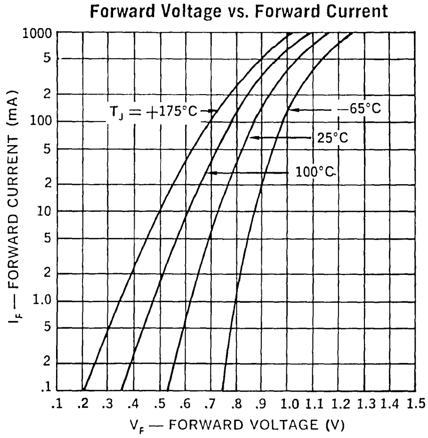
UNITRODE

ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

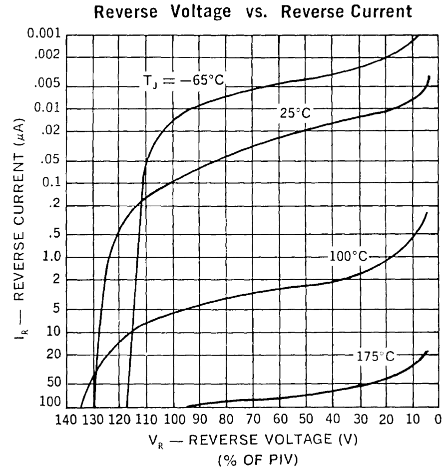
Limits	V_{F1} $I_F = 250\mu Adc$	V_{F2} $I_F = 1.0mAdc$	V_{F3} $_F = 10mAdc$	V_{F4} $I_F = 20mAdc$	V_{F5} 1/ $I_F = 300mAdc$	C $V_R = 0$ $100\ kHz \leqslant f \leqslant 1\ MHz$ $v_{sig} = 50$ mv (p-p)
	mVdc	mVdc	mVdc	mVdc	Vdc	pF
Minimum	470	520	640	670	—	—
Maximum	560	600	720	770	1.10	4.0

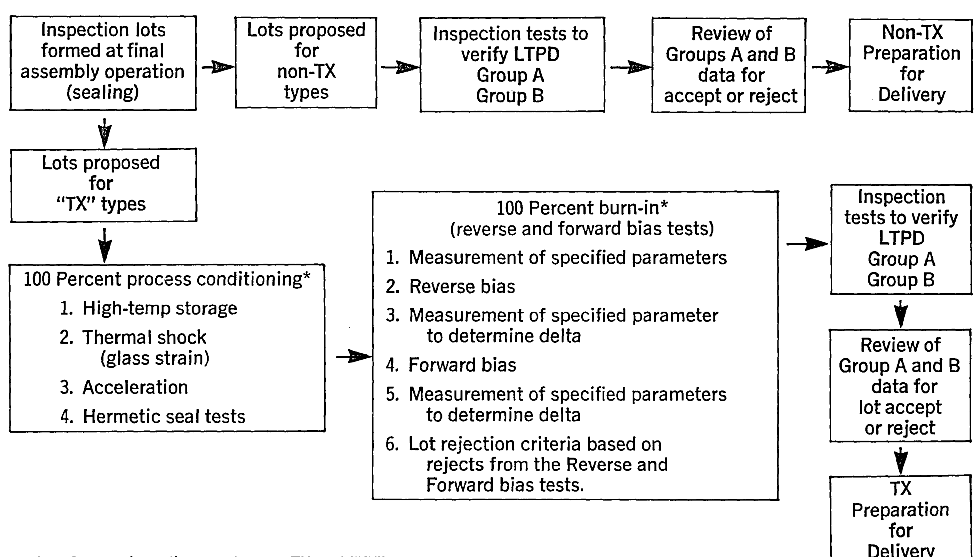
	I_R $V_R = 75Vdc$	B_V $I_R = 5\mu Adc$	I_R $V_R = 75Vdc$ $T_A = 150°C$	t_{rr} $I_F = I_R =$ 10 mAdc: $R_L = 100$ ohms
	nAdc	Vdc	μAdc	nsec
Minimum	—	80	—	—
Maximum	100		100	6.0

Forward Voltage vs. Forward Current



Reverse Voltage vs. Reverse Current





Order of procedure diagram for non-TX and "TX" types.

XI

PIN DIODES XII

PIN DIODES

PRODUCT SELECTION GUIDE

For applications information, see PIN Diode Designers' Handbook and Catalog (PD-500B)

SWITCHING PIN DIODES

Type	Voltage Rating Range	Capacitance (OV, 1 GHz) C_T max.	Forward Resistance (100mA, 1 GHz) R_S max.	Parallel Resistance (100V, 1 GHz) R_p min.	Average Thermal Resistance θ_A max.	Average Power Dissipation P_A max.	Peak Power Dissipation P_p max.	Carrier Lifetime I_F = 10mA τ min.
	(V)	(pF)	(Ω)	(KΩ)	(°C/W)	(W)	(KW)	(μS)
UM4000	100-1000	3.0	0.5	2	6	25	100	5.0
UM4900	100-600	3.0	0.5	2	4	37	100	5.0
UM6000	100-1000	0.5	1.7	15	25	6	25	1.0
UM6200	100-400	1.1	0.4	10	25	6	10	0.6
UM6600	100-1000	0.4	2.5	10	35	4	13	1.0
UM7000	100-1000	0.9	1.0	10	15	10	60	2.5
UM7100	100-800	1.2	0.6	8	15	10	35	2.0
UM7200	100-400	2.2	0.25	7	15	10	20	1.5

HIGH POWER ATTENUATOR & MODULATOR PIN DIODES

Type	Voltage Ratings Range	Total Capacitance (OV, 1 GHz) C_T max.	RF Resistance (100mA, 1 GHz) R_S max.	RF Resistance (10μA, 1 GHz) R_S min.	Average Thermal Resistance θ_A max.	Average Power Dissipation P_A max.	Carrier Lifetime I_F = 10mA τ min.
	(V)	(pF)	(Ω)	(Ω)	(°C/W)	(W)	(μs)
UM4300	100-1000	2.2	1.5	1000	8	18	5.0
UM7300	100-1000	0.7	3.0	3000	20	7.5	2.5

GENERAL PURPOSE PIN DIODE

Type	Voltage Rating (I_R=10μA)	Total Capacitance (50V, 1MHz) C_T max.	RF Resistance (10μA, 100 MHz) R_S min.	RF Resistance (20mA, 100 MHz) R_S max.	RF Resistance (100mA, 100MHz) R_S max.	Carrier Lifetime (I_R = 10mA) τ min.
	(V)	(pF)	(Ω)	(Ω)	(Ω)	(μs)
1N5767	100	0.4	1000 3000 typ.	8 4 typ.	2.5 1.5 typ.	1

XII

LOW DISTORTION ATTENUATOR PIN DIODES

Type	Voltage Rating I_R=10μA	Total Capacitance (OV, 100MHz) C_T max.	RF Resistance (100mA, 100MHz) R_S max.	RF Resistance (10μA, 100 MHz) R_S max.	Forward Current (R_S = 75Ω F = 100MHz) Typ.	Carrier Lifetime (I_F=10mA) Typ.
	(V)	(pF)	(Ω)	(Ω)	I_F (mA)	τ (μs)
1N5957	100	0.4	3.5	1500	1.0	2
UM9301	75	0.8	3.0	3000	1.1	4

TWO WAY RADIO ANTENNA SWITCHES

Type	Voltage Rating (I_R=10μA)	Total Capacitance (OV, 100MHz) C_T max.	RF Resistance (50mA, 100MHz) R_F max.	Transmit Harmonic Distortion F = 50MHz I = 20mA	Receive Third Order Distortion (Pin-10mW, 0 Bias) FA=50MHz FB=51MHz Max.	Average Power Dissipation P_A Max.
	(V)	(pF)	(Ω)	(dB)	(dB)	(W)
UM9401 and UM9402	50	1.5	1.0	–80	–60	5.5
UM9415	50	4.0	1.0	–80	60	10

PIN DIODES

For applications information, see PIN Diode Designers' Handbook and Catalog (PD-500B)

MICROSTRIP PACKAGED DIODES

Type	Series Resistance R_S max. (Ω)	Parallel Resistance R_P min. (KΩ)	Total Capacitance C_T max. (pF)	Carrier Lifetime τ min. (μs)	Voltage Rating (V)	Forward Voltage V_F typ. (V)
UM9601-UM9604	0.6	5	1.2	2.0	100, 400	.85
UM9605-UM9608	1.7	7	0.5	1.0	100, 400	.95

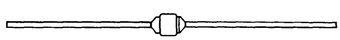
RADIATION DETECTOR

Type	Photocurrent $\frac{10^6 \text{ Rad (Si), 50V}}{\text{Sec}}$ mA min.	Photocurrent Rise Time nS Typ.	Reverse Current 50V μA max.	Capacitance F = 1 MHz, V = 50V pF max.
UM9441	4.0	10	1.0	15

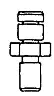
PACKAGE STYLES

For UM4000, 6000 & 7000 Series

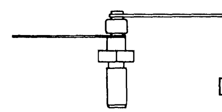
A Style
Basic Diode



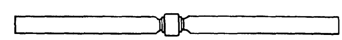
B Style
Round Axial Leads



***C Style**
Stud



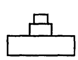
***D Style**
Insulated Stud



E Style
Ribbon Axial Leads

*Not available for UM6000, UM6600, UM6200.

For UM9600 Series



Cup
UM9601/2

Cup
UM9605/6

Flange
UM9603/4

Flange
UM9607/8

Drawings are not actual size.

VOLTAGE RATINGS

Series	100V	200V	400V	600V	800V	1000V
UM4000	√	√		√		√
UM4300	√	√		√		√
UM4900	√	√		√		
UM6000	√	√		√		√
UM6200	√	√	√			
UM6600	√	√		√		√
UM7000	√	√		√		√
UM7100	√	√	√		√	
UM7200	√	√	√			
UM7300	√	√		√		√

ORDERING INFORMATION

Part numbers of Switching and High Power Attenuator PIN diodes consist of the letters UM followed by four digits and one or two letters. The first two digits indicate the diode series, the next two digits specify the voltage rating in hundreds of volts. The remaining letters denote the package style. Reverse polarity is available for C, and D, style and denoted by adding second letter R.

For Example: UM|60|06|B|

Series 6000 | 600 Volts | Style B

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PIN DIODE

1N5767 (5082 - 3080)SERIES
1N5957 SERIES

Features

- Useful attenuation from 1 μA to 100 mA bias.
- Capacitance below 0.4 pF.
- Low distortion in switches and attenuators.
- Rugged Unitrode construction.

Description

The 1N5767 and 1N5957 PIN diodes are based upon low capacitance PIN chips designed with long minority carrier lifetime, and thick intrinsic width. Thus operation as low as 1 MHz is possible with low distortion. Additionally, the low diode capacitance allows useful operation well into the microwave frequency range.

The 1N5767 (5082-3080) is a general purpose low power PIN diode designed for both switch and attenuator applications.

The 1N5957 is primarily used as an attenuator PIN diode and is particularly suitable wherever current controlled, wide dynamic range resistance elements are required. The 1N5957 has also been characterized for the 75Ω attenuator, commonly employed in CATV systems.

MAXIMUM RATINGS

XII

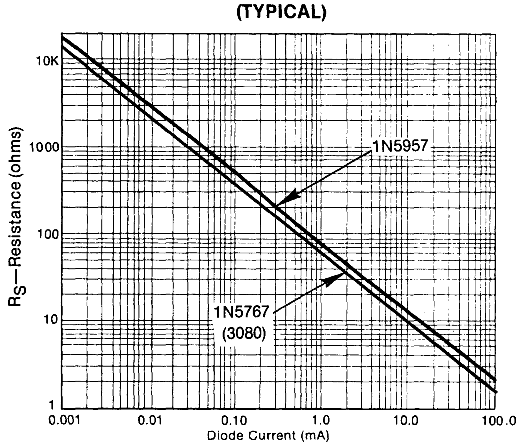
Reverse Voltage (V_R) — Volts (I_R = 10 μA)	100V
Average Power Dissipation: (25 ℃) Free Air (P_A)	400 mW (Derate linearly to 175 ℃)
Operating and Storage Temperature Range	−65 °C to +175 °C

UNITRODE

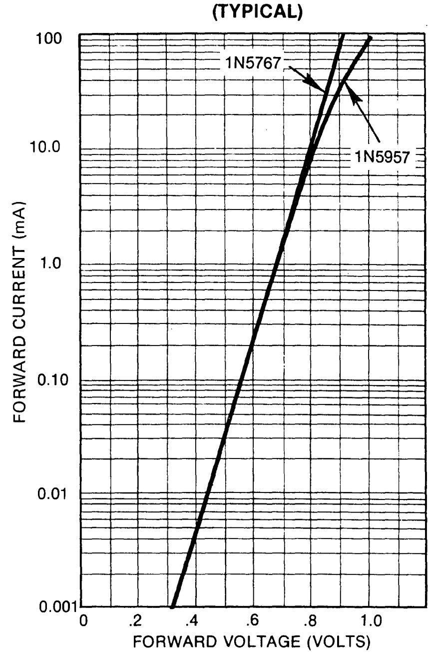
Electrical Specifications (25 °C)

Test	Symbol	1N5767 (5082-3080)	1N5957	Conditions
Total Capacitance (Max)	C_T	0.4 pF	0.4 pF	50V, 1 MHz
Series Resistance	R_S	1000Ω(min) 2000Ω(typ)	1500Ω(min) 3000Ω(typ)	10 μA, 100 MHz
Series Resistance	R_S	8Ω(max) 4Ω(typ)	8Ω(max) 6Ω(typ)	20 mA, 100 MHz
Series Resistance	R_S	2.5Ω(max) 1.5Ω(typ)	3.5Ω(max) 2.0Ω(typ)	100 mA, 100 MHz
Carrier Lifetime (Min)	τ	1.0 μS	1.5(min) 2(typ)	I_F = 10 mA
Reverse Current (Max)	I_R	10 μA	10 μA	V_R = Rating
Current for R_S = 75Ω (typ)	I_{75}	0.7 mA	0.8 mA– 1.2 mA	R_S = 75Ω
Return Loss (typ)	—	30 dB	30 dB	Diode terminates 75Ω line
Second Order Distortion (typ)	—	−40 dB	−50 dB	Bridged tee attenuator atten. = 10 dB
Third Order Distortion (typ)	—	−60 dB	−65 dB	P_{in} = 50 dBmV F_1 = 10 MHz, F_2 = 13 MHz

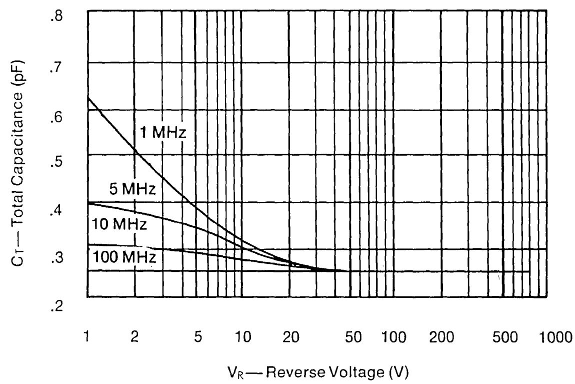
RESISTANCE VS FORWARD CURRENT (TYPICAL)



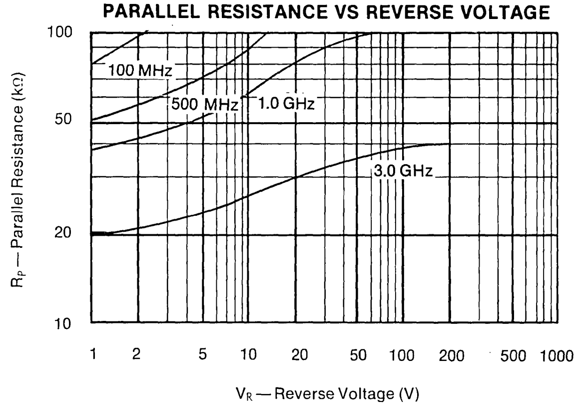
FORWARD VOLTAGE VS FORWARD CURRENT (TYPICAL)



TOTAL CAPACITANCE VS REVERSE VOLTAGE

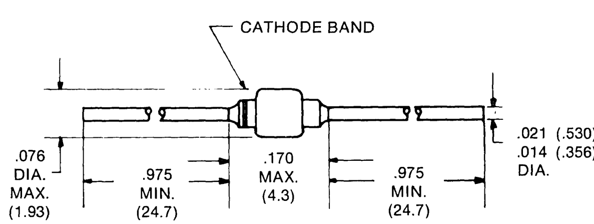


PARALLEL RESISTANCE VS REVERSE VOLTAGE



XII

MECHANICAL SPECIFICATIONS



Dimensions: Inches (Millimeters)

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PIN DIODE

UM4000 SERIES
UM4900 SERIES

Features

- Power dissipation to 37.5W
- Voltage ratings to 1000V
- Series resistance rated at 0.5Ω
- Carrier lifetime greater than 5μs

Description

The UM4000 and UM4900 series feature high power PIN diodes with long carrier lifetimes and thick I-regions. They are especially suitable for use in low distortion switches and attenuators, in the HF through S band frequencies. While both series are electrically equivalent, the UM4900 series have higher power ratings due to a shorter thermal path between chip and package. High charge storage and long carrier lifetime enable high RF levels to be controlled with relatively low bias current. Similarly, peak RF voltages can be handled well in excess of applied reverse bias voltage.

Both series have been fully qualified in high power UHF phase shifters and megawatt peak-power duplexers, accumulating thousands of hours of proven performance. Both types have been used in the design of antenna selectors and couplers, where inductive and capacitive elements are switched in and out of filter or cavity networks.

MAXIMUM RATINGS

Average Power Dissipation and Thermal Resistance Ratings

Package	Condition	UM4000		UM4900	
		P_D	θ	P_D	θ
A	25 °C Pin Temperature	25W	6 °C/W	37.5W	4 °C/W
B&E (Axial Leads)	½ in. (12.7mm) Overall Length to 25 °C Contact	12W	12.5 °C/W	12W	12.5 °C/W
B&E (Axial Leads)	Free Air	2.5W	—	2.5W	—
C (Studded)	25 °C Stud Temperature	25W	6 °C/W	37.5W	4 °C/W
D (Insulated Stud)	25 °C Stud Temperature	18.75W	8 °C/W	25W	6 °C/W

Peak Power Dissipation Rating

All Packages	1 μs Pulse (Single) at 25 °C Ambient	100 KW

Operating and Storage Temperature Range: −65 °C to +175 °C

UNITRODE

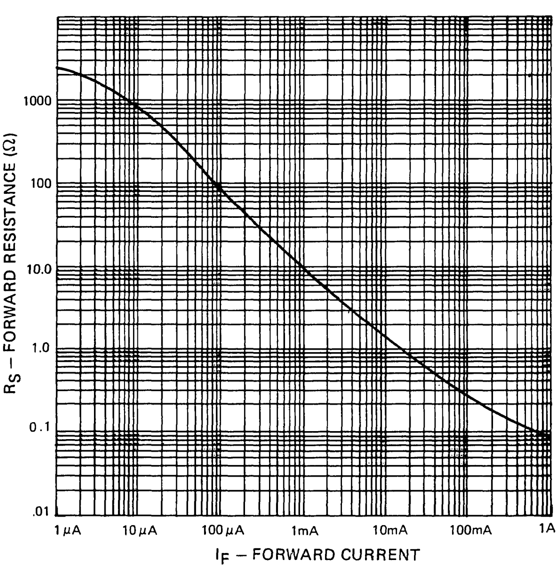
Voltage Ratings (25 °C)

Reverse Voltage (V_R) — Volts (I_R = 10 μ Amps)	Types	
100	UM4001	UM4901
200	UM4002	UM4902
400	—	—
600	UM4006	UM4906
1000	UM4010	—

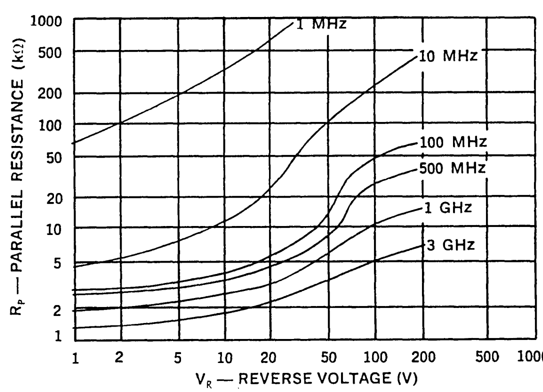
Electrical Specifications (25 °C)

Test	Symbol	UM4000 UM4900	Conditions
Total Capacitance (Max)	C_T	3 pF	0V, 1 GHz
Series Resistance (Max)	R_S	0.5Ω	100 mA, 1 GHz
Parallel Resistance (Min)	R_P	2 KΩ	100V, 1 GHz
Carrier Lifetime (Min)	τ	5μs	I_F = 10 mA
Reverse Current (Max)	I_R	10μA	V_R = Rating
I-Region Width (Min)	W	150μm	—

TYPICAL FORWARD RESISTANCE VS FORWARD CURRENT (F = 100 MHz)

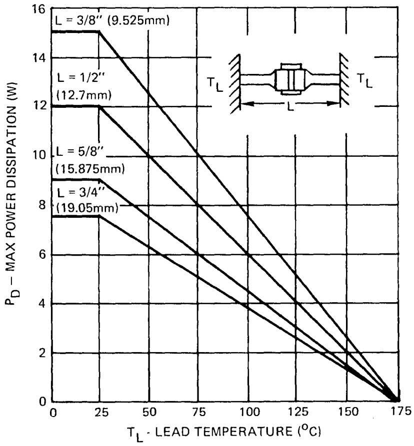


TYPICAL PARALLEL RESISTANCE CHARACTERISTIC

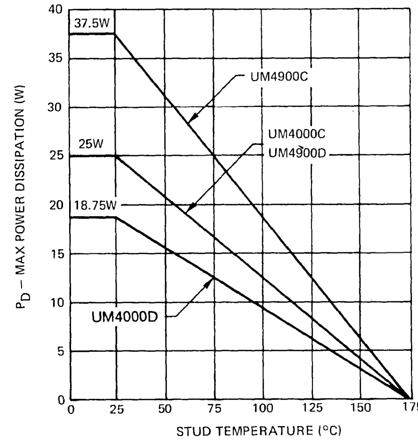


XII

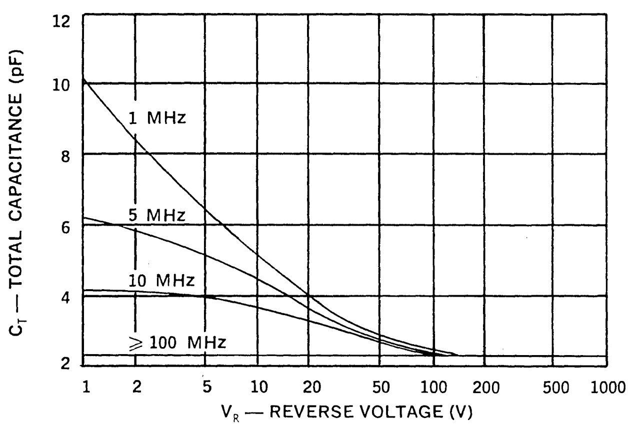
POWER RATING AXIAL LEADED DIODE



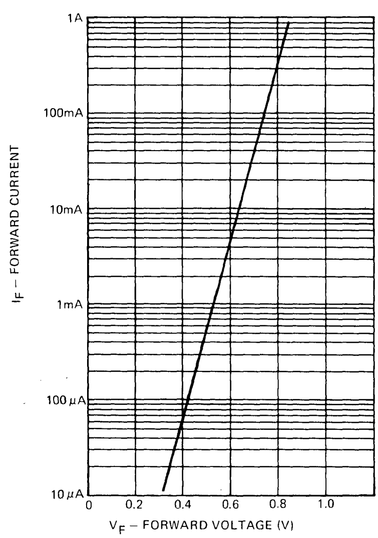
POWER RATING STUD MOUNTED DIODES



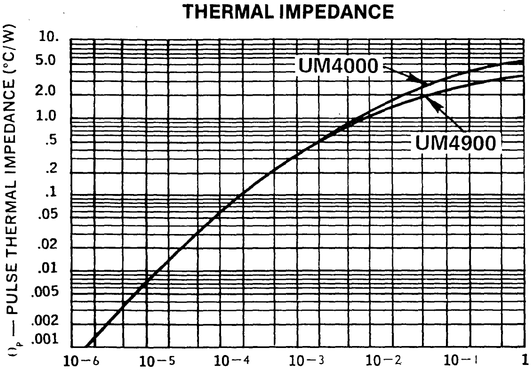
TYPICAL CAPACITANCE CHARACTERISTIC



DC CHARACTERISTICS FORWARD VOLTAGE VS FORWARD CURRENT (TYPICAL)



THERMAL IMPEDANCE



ORDERING INSTRUCTIONS

Part numbers of Unitrode PIN Diodes consist of the letters UM followed by four digits and one or two letters. The first two digits indicate the diode series, the next two digits specify the minimum breakdown voltage in hundreds of volts. The remaining letters denote the package style. Reverse polarity (anode large end cap) is available for the C style and denoted by adding second letter R.

For Example: UM|40|08|CR|

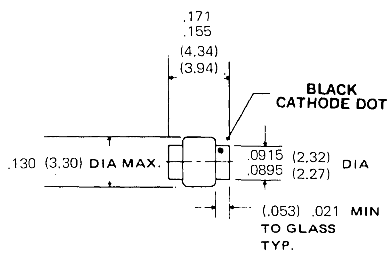
Series 4000 | 100 Volts | Style C | Reverse Polarity

MECHANICAL SPECIFICATIONS

UM4000 Series

Dimensions — English/Metric

STYLE A



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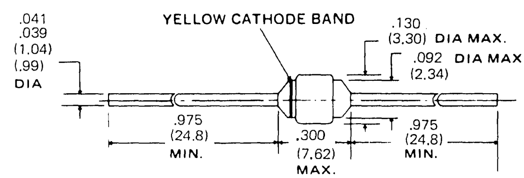
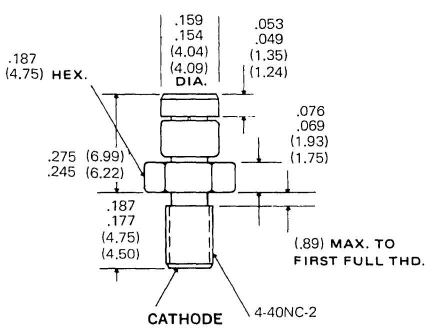
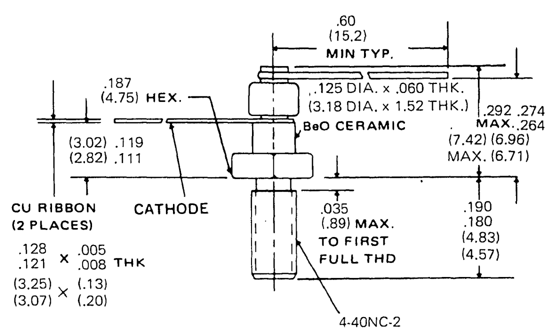


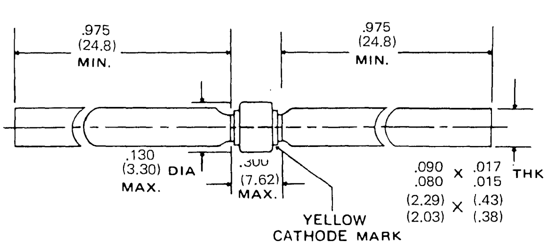
STYLE C
STUD



STYLE D
INSULATED STUD



STYLE E
RIBBON LEADS



XII

MECHANICAL SPECIFICATIONS (continued)

UM 4900 Series

Dimensions — English/Metric

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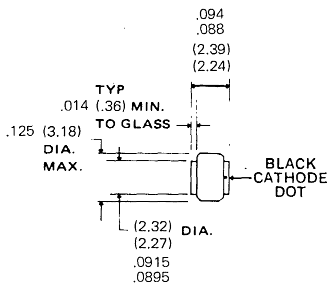
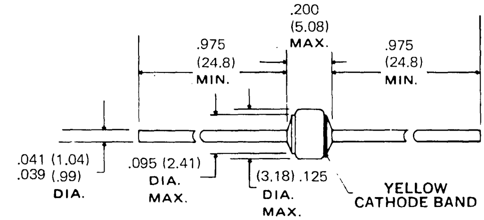
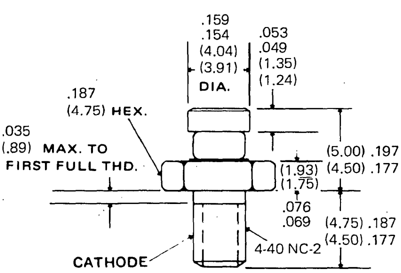


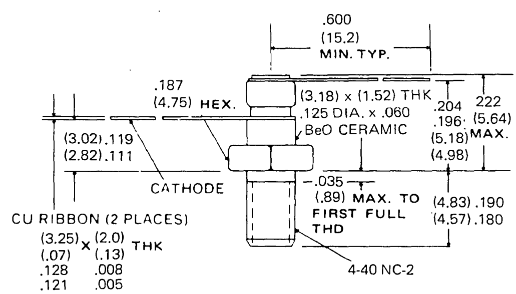
STYLE B



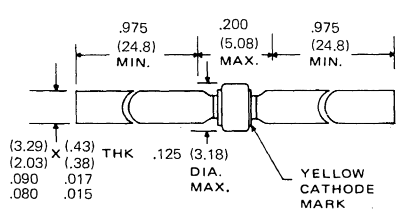
STYLE C
STUD



STYLE D
INSULATED STUD



STYLE E
RIBBON LEADS



PIN DIODE

UM4300 SERIES
UM7300 SERIES

For Attenuator Applications

Features

- Extremely low distortion performance
- Useful frequency range extends below 500 KHz
- Power dissipation to 20W (UM4300)
- Capacitance as low as 0.7 pF (UM7300)
- Voltage ratings to 1000V

Description

The UM4300 and UM7300 series combine a diode chip of extremely thick intrinsic region with a low thermal resistance construction. This results in diodes uniquely applicable to very low distortion linear attenuators and specialized switching functions. The UM4300 series, with large cross-sectional chip area offers the highest power capability, of the two series. The UM7300 series offers lower capacitance.

Both diode series are intended for use in linear attenuators operating from HF to beyond 1 GHz. Low distortion at low frequencies is a result of transit time frequencies below 5 MHz.

Operated as RF switches, either diode series can be operated at low dc reverse bias voltages, to hold off much higher RF voltage levels.

MAXIMUM RATINGS

XII

Average Power Dissipation and Thermal Resistance Ratings

Package	Condition	UM4300		UM7300	
		P_D	θ	P_D	θ
A	25 °C Pin Temperature	20W	7.5 °C/W	7.5W	20 °C/W
B&E (Axial Leads)	½ in. Total Length to 25 °C Contact	10W	15 °C/W	4W	37.5 °C/W
B&E (Axial Leads)	Free Air	2.5W	—	1.5W	—
C (Studded)	25 °C Stud	20W	7.5 °C/W	7.5W	20 °C/W
D (Insulated Stud)	25 °C Stud	15W	10 °C/W	6W	25 °C/W

Peak Power Dissipation Rating

		UM4300	UM7300
All packages	1 μs Pulse (Single) at 25 °C Ambient	500 KW	100 KW

Operating and Storage Temperature Range: − 65 °C to + 175 °C

UNITRODE

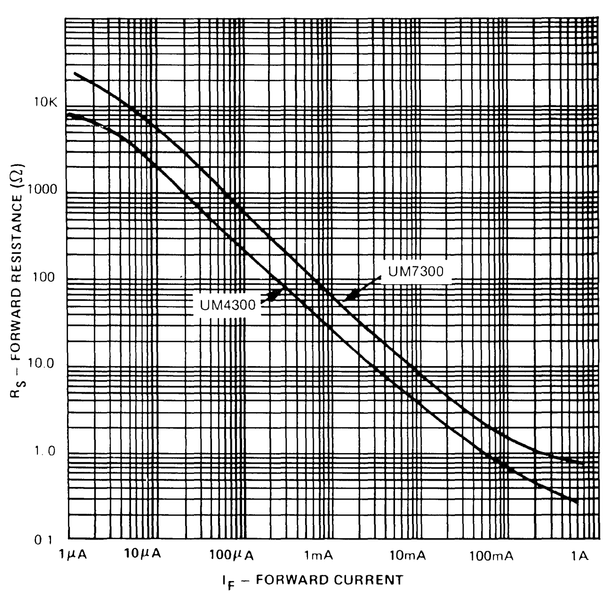
Voltage Ratings (25 °C)

Reverse Voltage (V_R) — Volts (I_R = 10 μA)	Types	
100V	UM4301	UM7301
200V	UM4302	UM7302
600V	UM4306	UM7306
1000V	UM4310	UM7310

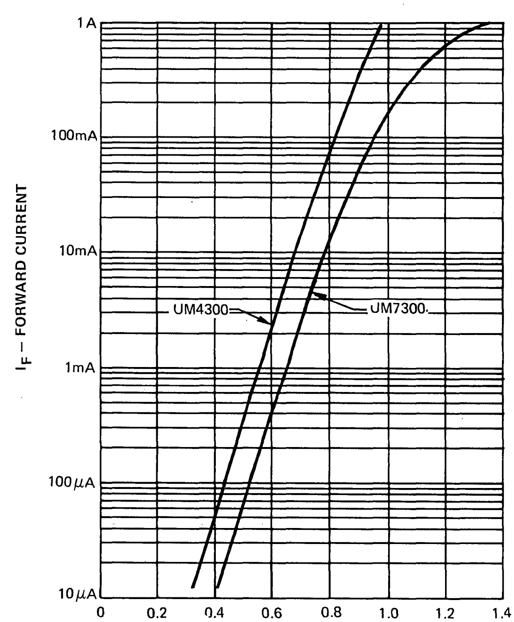
Electrical Specifications (25 °C)

Test	Symbol	UM4300	UM7300	Conditions
Total Capacitance (Max)	C_T	2.2 pF	0.7 pF	0V, 1 GHz
Series Resistance (Max)	R_S	1.5Ω	3.0Ω	100 mA, 1 GHz
Series Resistance (Min)	R_S	1000Ω	3000Ω	10 μA, 100 MHz
Carrier Lifetime (Min)	τ	6μs	4.0μS	I_F = 10 mA
Leakage Current (Max)	I_R	10μA	10μA	V_R = Rating
I-Region Width (Min)	W	250μm	250μm	—

TYPICAL FORWARD RESISTANCE VS FORWARD CURRENT (F = 100 MHz)

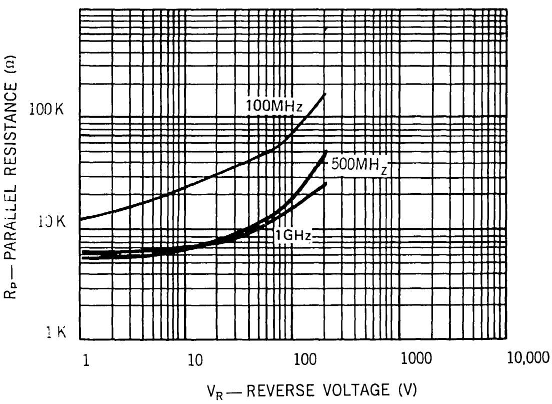


TYPICAL DC CHARACTERISTIC FORWARD VOLTAGE VS FORWARD CURRENT

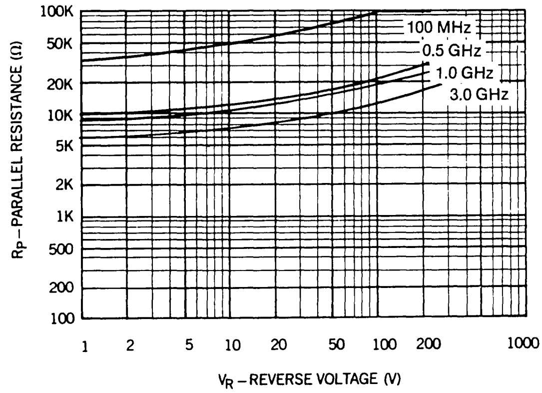


PARALLEL RESISTANCE VS REVERSE VOLTAGE

UM4300

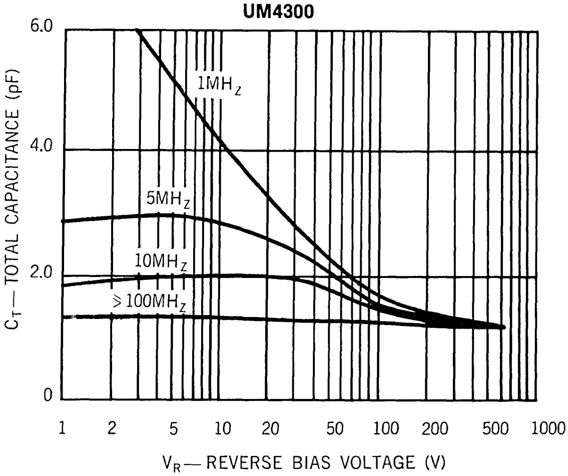


UM7300

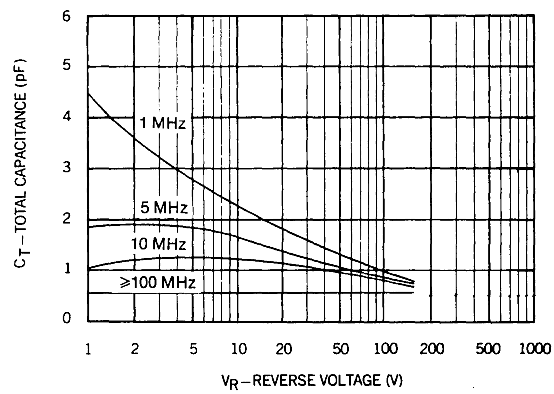


TOTAL CAPACITANCE VS REVERSE VOLTAGE

UM4300



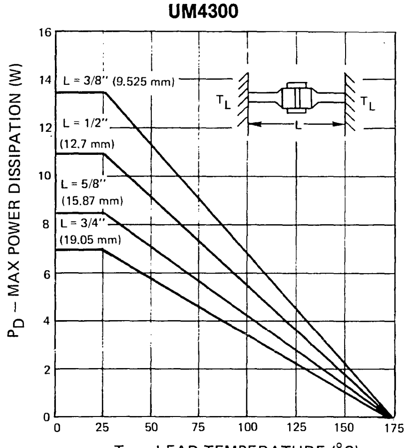
UM7300



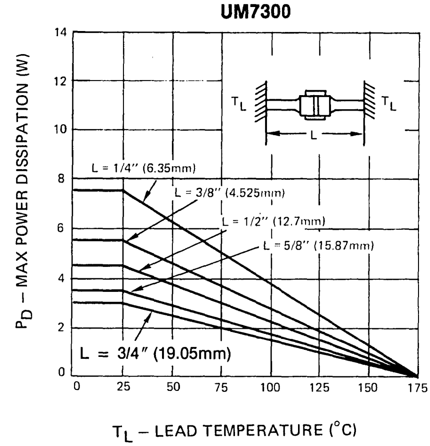
XII

POWER RATING AXIAL LEADED DIODE

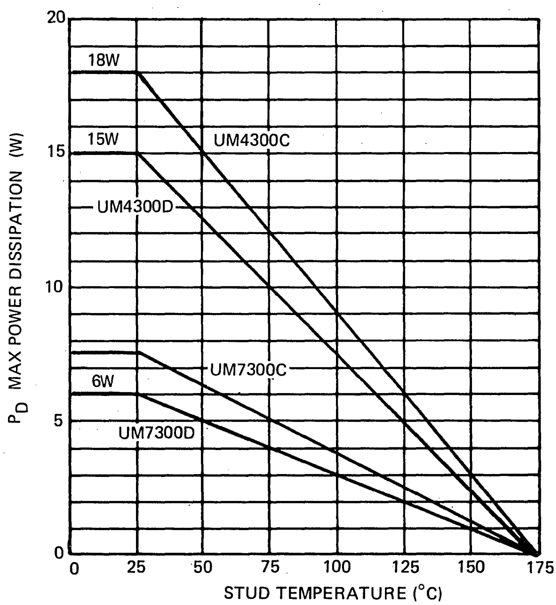
UM4300



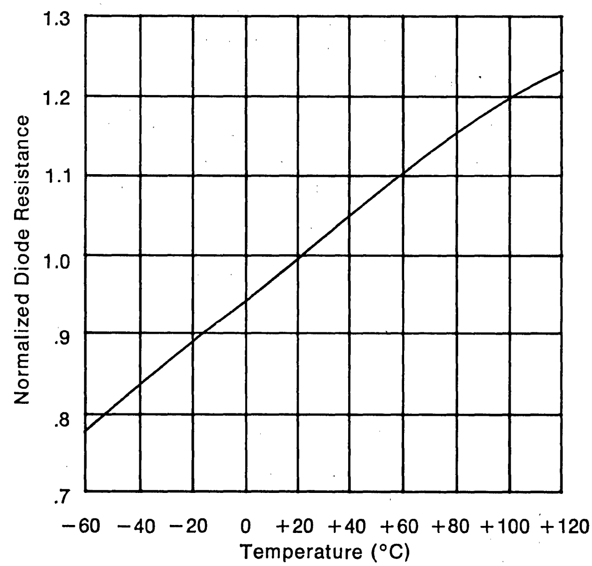
UM7300



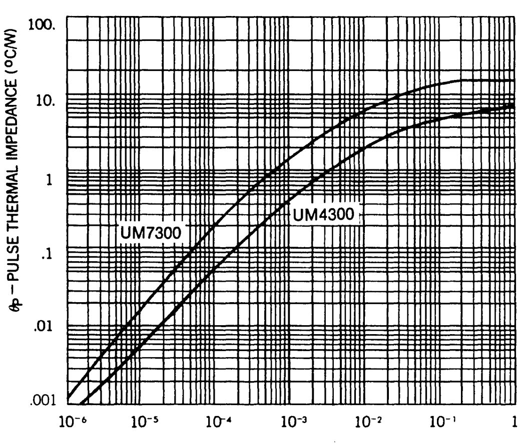
UM4300/UM7300 POWER RATING STUD MOUNTED DIODES



NORMALIZED R_S VS TEMPERATURE



PULSE THERMAL IMPEDANCE VS PULSE WIDTH



ORDERING INSTRUCTIONS

Part numbers of Unitrode PIN Diodes consist of the letters UM followed by four digits and one or two letters. The first two digits indicate the diode series, the next two digits specify the minimum breakdown voltage in hundreds of volts. The remaining letters denote the package style. Reverse polarity (anode on stud end) is available in C or D Styles and denoted by adding second letter R.

For Example: UM|73|01|C|

Series 7300 | 100 volts | Style C

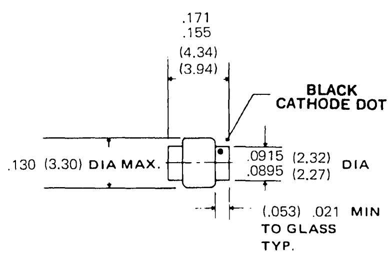
Reverse polarity available in C style. Part number designated by adding R.

MECHANICAL SPECIFICATIONS

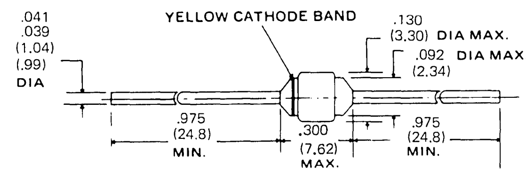
UM4300 SERIES

Dimensions — English/Metric

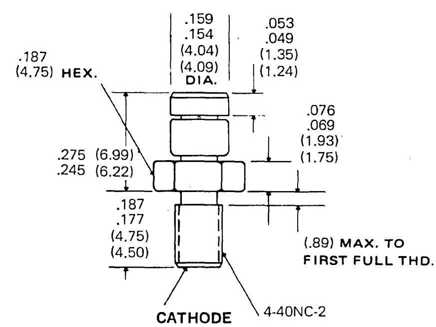
STYLE A



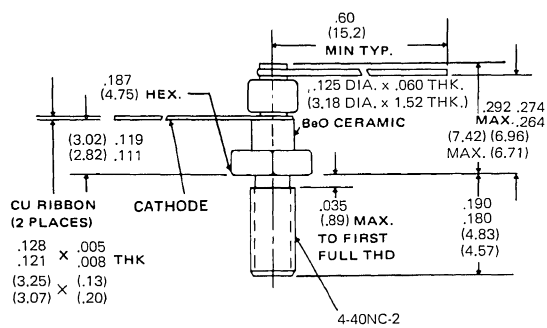
STYLE B



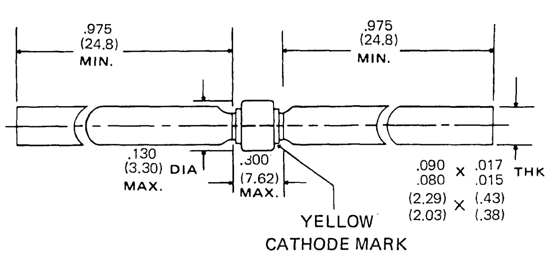
STYLE C
STUD



STYLE D
INSULATED STUD



STYLE E
RIBBON LEADS



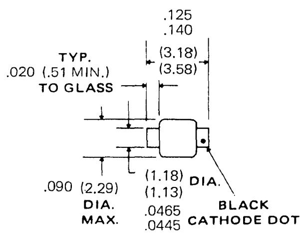
XII

MECHANICAL SPECIFICATIONS (continued)

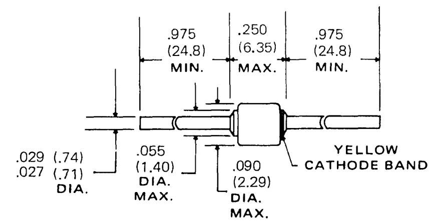
UM7300 Series

Dimensions — English/Metric

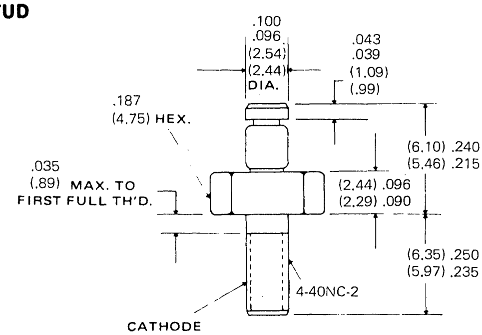
STYLE A



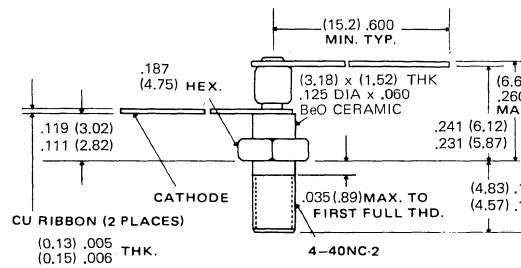
STYLE B



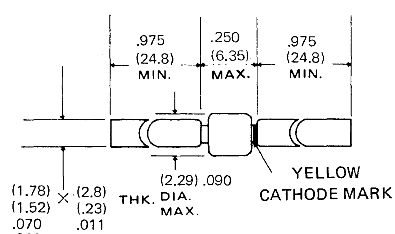
STYLE C
STUD



STYLE D
INSULATED STUD



STYLE E
RIBBON LEADS



PIN DIODE

UM6000 SERIES
UM6200 SERIES
UM6600 SERIES

eatures

- Capacitance specified as low as 0.4 pF (UM6600)
- Resistance specified as low as 0.4Ω (UM6200)
- Voltage ratings to 1000V
- Power dissipation to 6W

escription

These series of PIN diodes are designed or applications requiring small package size and moderate average power handling capa-ility. The low capacitance of the UM6000 and UM6600 allows them to be used as series switching elements to 1 GHz. The low resis-ance of the UM6200 is useful in applications where forward bias current must be mini-nized.

Because of its thick I-region width and ong lifetime the UM6000 and UM6600 have been used in distortion sensitive and high peak power applications, including receiver protectors, TACAN, and IFF equipment. Their ow capacitance allows them to be useful as ttenuator diodes at frequencies greater han 1 GHz. The UM6200 has been used successfully in switches in which low insertion loss at low bias current is required.

The "A" style package for this series is the smallest Unitrode PIN diode package. It has been used successfully in many microwave applications using coaxial, microstrip, and stripline techniques at frequencies beyond X-Band. The "B" and "E" style, leaded packages offer the highest available power dissipation for a package this small. They have been used extensively as series switch elements in microstrip circuits. The "C" style package duplicates the physical outline available in conventional ceramic-metal packages but incorporates the many reliability advantages of the Unitrode construction.

XII

AXIMUM RATINGS

verage Power Dissipation and Thermal Resistance Ratings

Package	Condition	UM6000 UM6200		UM6600	
		P_D	θ	P_D	θ
A&C	25°C Pin Temperature	6W	25°C/W	4W	37.5°C/W
B&E (Axial Leads)	½ in. Total Lead Length to (12.7mm) to 25°C Contact	2.5W	60°C/W	2.0W	75°C/W
B&E (Axial Leads)	Free Air	0.5W	—	0.5W	—

eak Power Dissipation Rating

All Packages	1 μs Pulse (Single) at 25°C Ambient	UM6000 - 25 KW UM6200 - 10 KW	UM6600 - 13 KW

Operating and Storage Temperature Range: −65°C to +175°C

UNITRODE

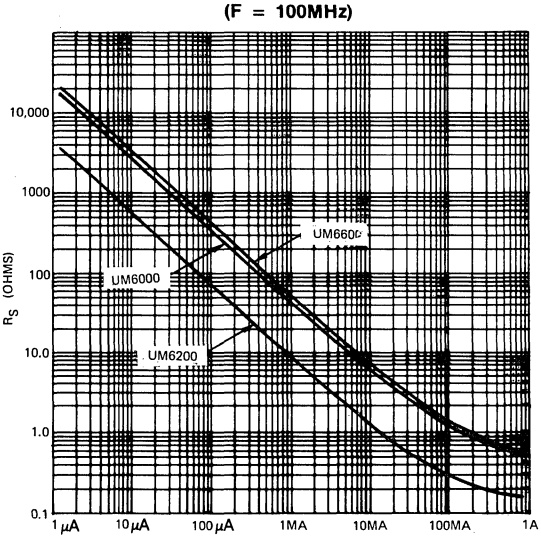
Voltage Ratings (25 °C)

Reverse Voltage (V_R) — Volts (I_R = 10 μA)	Types		
100V	UM6001	UM6201	UM6601
200V	UM6002	UM6202	UM6602
400V	—	UM6204	—
600V	UM6006	—	UM6606
1000V	UM6010	—	UM6610

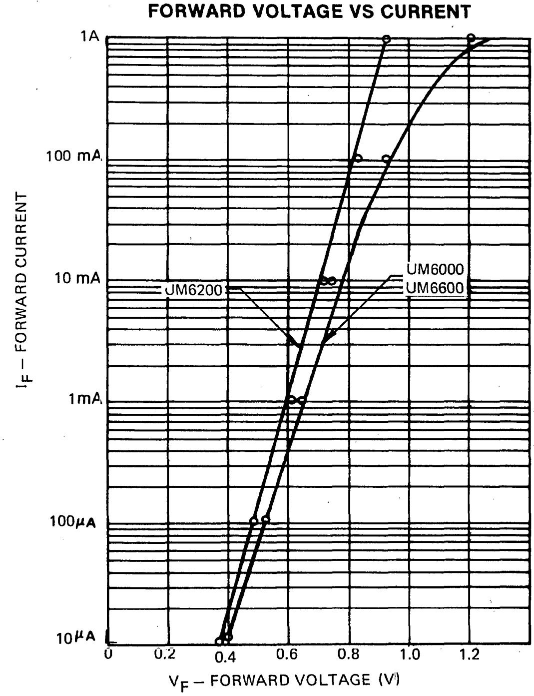
Electrical Specifications (25 °C)

Test	Symbol	UM6600	UM6000	UM6200	Conditions
Total Capacitance (Max)	C_T	0.4 pF	0.5 pF	1.1 pF	0V, 1 GHz
Series Resistance (Max)	R_S	2.5Ω	1.7Ω	0.4Ω	100 mA, 1 GHz
Parallel Resistance (Min)	R_P	10 KΩ	15 KΩ	10 KΩ	100V, 1 GHz
Carrier Lifetime (Min)	τ	1.0 μs	1.0 μs	0.6 μs	I_F = 10 mA
Reverse Current (Max)	I_R	10 μA	10 μA	10 μA	V_R = Rating
I-Region Width (Min)	W	150 μm	150 μm	40 μm	—

TYPICAL SERIES RESISTANCE VS FORWARD CURRENT (F = 100MHz)

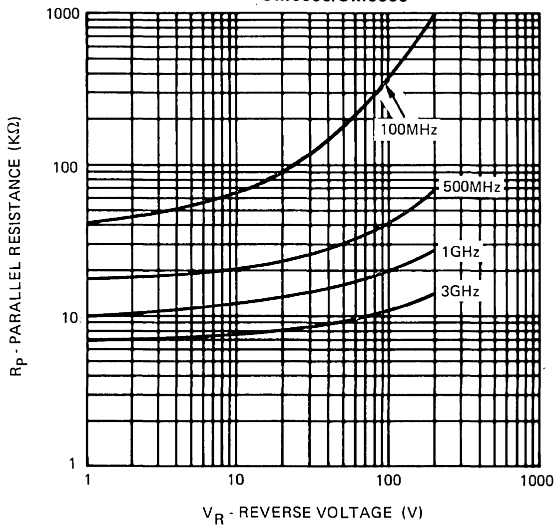


DC CHARACTERISTICS FORWARD VOLTAGE VS CURRENT

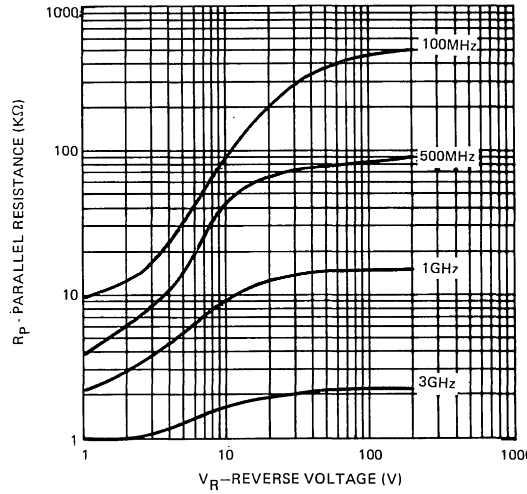


TYPICAL R_p VS VOLTAGE & FREQUENCY

UM6000/UM6600

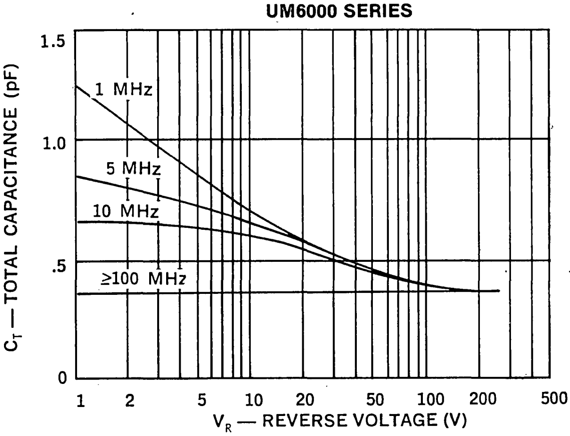


UM6200

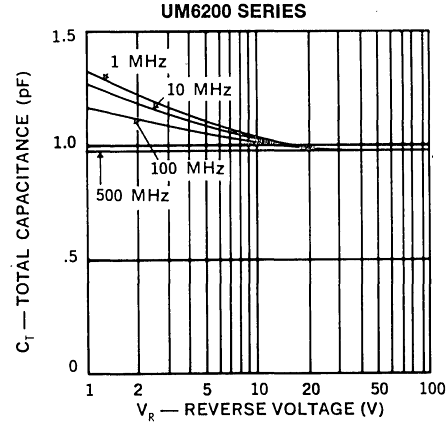


TYPICAL CAPACITANCE VS VOLTAGE AND FREQUENCY

UM6000 SERIES



UM6200 SERIES



XII

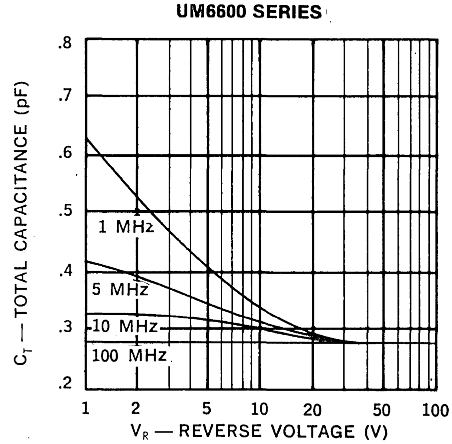
ORDERING INSTRUCTIONS

Part numbers of Unitrode PIN diodes consist of the letters UM followed by four digits and one or two letters. The first two digits indicate the diode series, the next two digits specify the minimum breakdown voltage in hundreds of volts. The remaining letters denote the package style. Reverse polarity (anode large end cap) is available for the C style and denoted by adding second letter R.

For Example: UM |60|06 |CR|

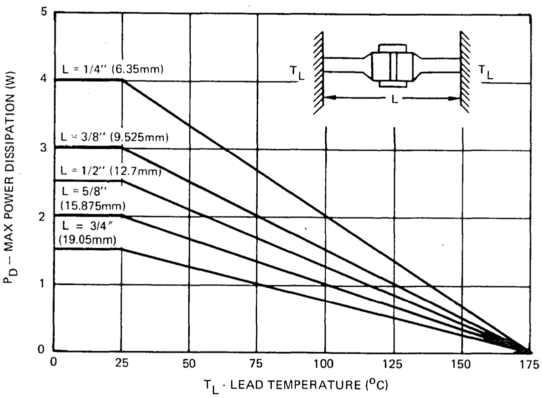
|Series 6000| |600 Volts| |Style C|Reverse Polarity|

UM6600 SERIES

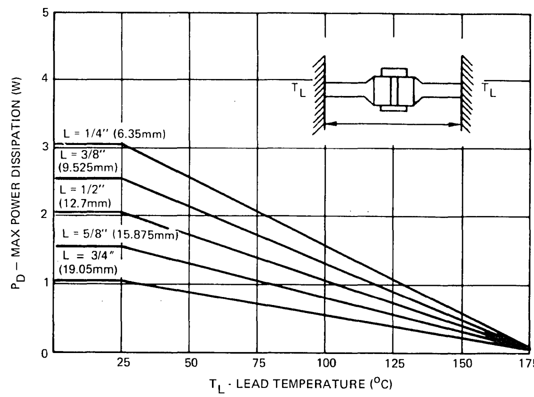


POWER RATING — AXIAL LEADED DIODE

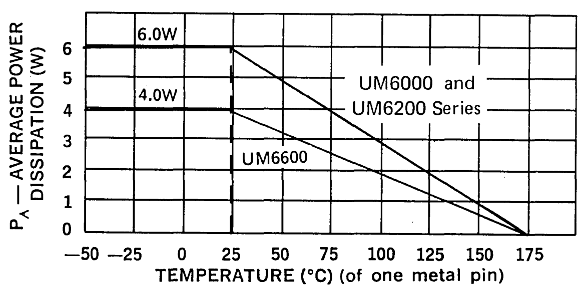
UM6000/UM6200



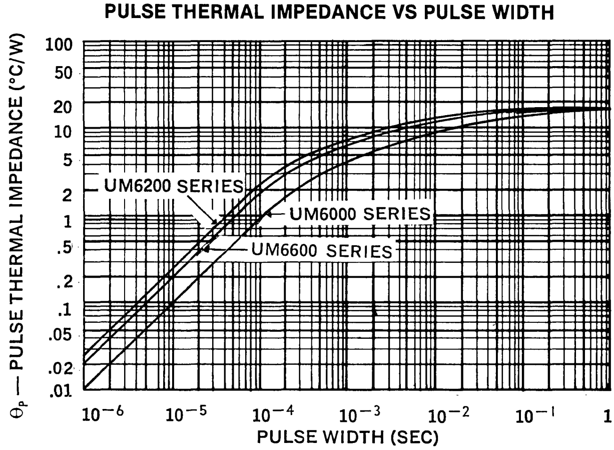
UM6600



POWER RATING

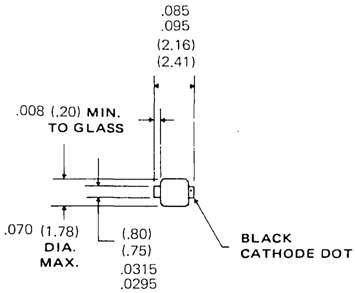


PULSE THERMAL IMPEDANCE VS PULSE WIDTH

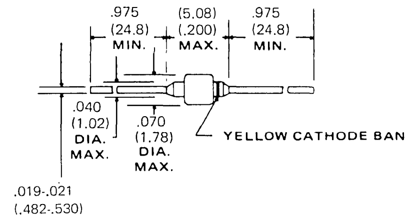


MECHANICAL SPECIFICATIONS

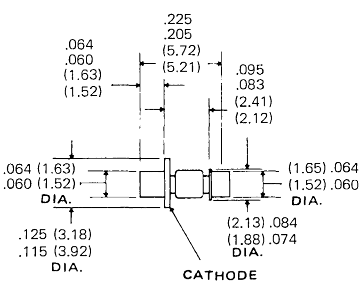
STYLE A



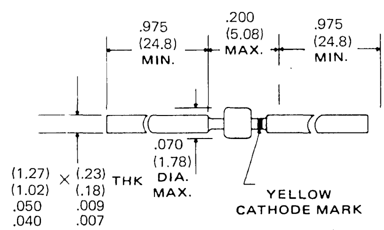
STYLE B



STYLE C
CARTRIDGE



STYLE E
RIBBON LEADS



XII

PIN DIODE

UM7000 SERIES
UM7100 SERIES
UM7200 SERIES

Features

- Voltage ratings to 1000V (UM7000)
- Wide variety of package styles
- Rated average power dissipation to 10W
- Cost effective in volume applications

Description

The UM7000 and UM7100 series offer moderately high power handling in combination with reasonably low levels of both series resistance and capacitance. The UM7200 series offers the lowest series resistance, but the highest capacitance of the group. The differences in specified performance, for each of the series, results from different I-region thicknesses. The three series have broad applicability in many RF and microwave switch and attenuator circuits. Additionally, the UM7100 in leaded versions, is usually the most cost-effective diode choice in high volume usage.

MAXIMUM RATINGS

Average Power Dissipation and Thermal Resistance Ratings

Package	Condition	P_D	θ
A	25°C Pin Temperature	10W	15°C/W
B&E (Axial Leads)	½ in.(12.7mm) Lead Length to 25°C Contact	5.5W	27.5°C/W
B&E (Axial Leads)	Free Air	1.5W	—
C (Studded)	25°C Stud Temperature	10W	15°C/W
D (Insulated Stud)	25°C Stud Temperature	7.5W	20°C/W

Peak Power Dissipation Rating

All Packages	1 μs Pulse (Single) at 25°C Ambient	UM7000 - 60 KW UM7100 - 35 KW UM7200 - 20 KW

Operating and Storage Temperature Range: −65°C to +175°C

UNITRODE

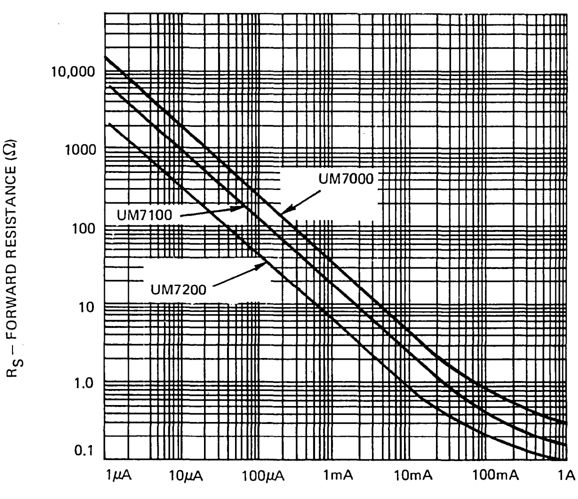
Voltage Ratings (25 °C)

Reverse Voltage (V_R) — Volts (I_R = 10 μA)	Types		
100V	UM7001	UM7101	UM7201
200V	UM7002	UM7102	UM7202
400V	—	UM7104	UM7204
600V	UM7006	—	—
800V	—	UM7108	—
1000V	UM7010	—	—

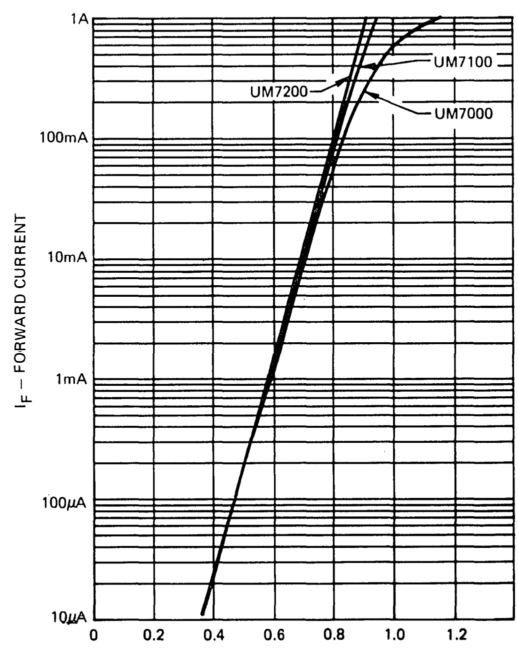
Electrical Specifications (25 °C)

Test	Symbol	UM7000	UM7100	UM7200	Conditions
Total Capacitance (Max)	C_T	0.9 pF	1.2 pF	2.2 pF	0V, 1 GHz
Series Resistance (Max)	R_S	1.0Ω	0.6Ω	0.25Ω	100 mA, 1 GHz
Parallel Resistance (Min)	R_P	10 KΩ	8 KΩ	7 KΩ	100V, 1 GHz
Carrier Lifetime (Min)	τ	2.5 μs	2.0 μs	1.5 μs	I_F = 10 mA
Reverse Current (Max)	I_R	10 μA	10 μA	10 μA	V_R = Rating
I-Region Width (Min)	W	150 μm	80 μm	40 μm	—

TYPICAL FORWARD RESISTANCE VS FORWARD CURRENT (F = 100 MHz)



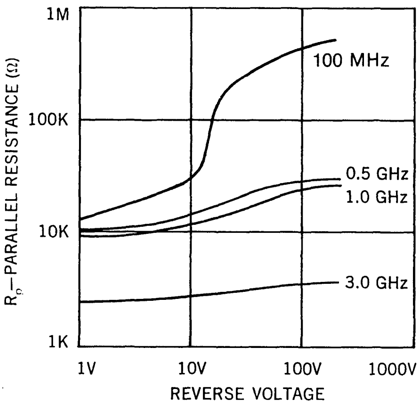
TYPICAL DC CHARACTERISTIC FORWARD VOLTAGE VS FORWARD CURRENT UM7000/UM7100/UM7200



XII

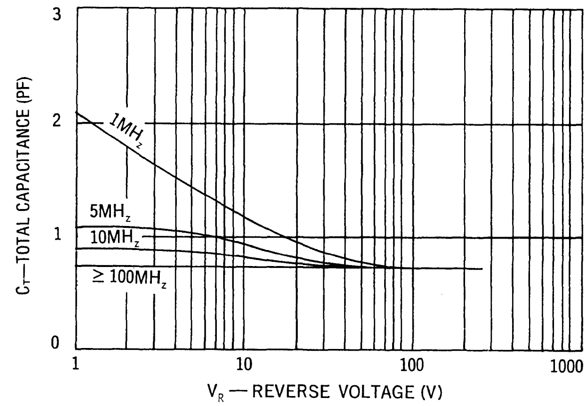
TYPICAL R_P CHARACTERISTIC

UM 7000 SERIES

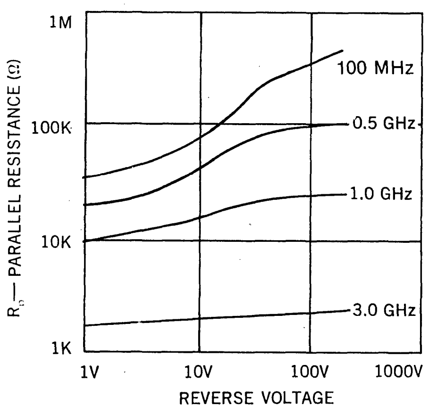


TYPICAL C_T CHARACTERISTIC

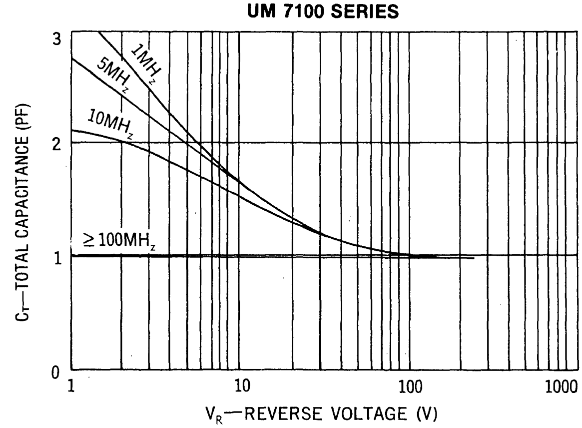
UM 7000 SERIES



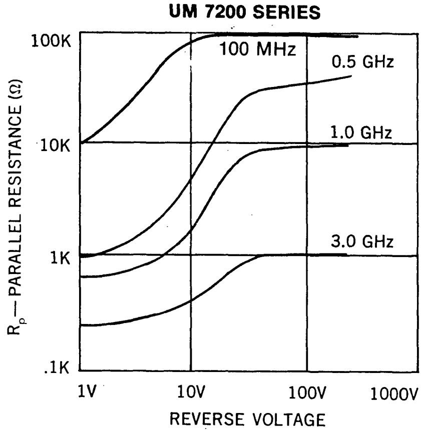
UM7100 SERIES



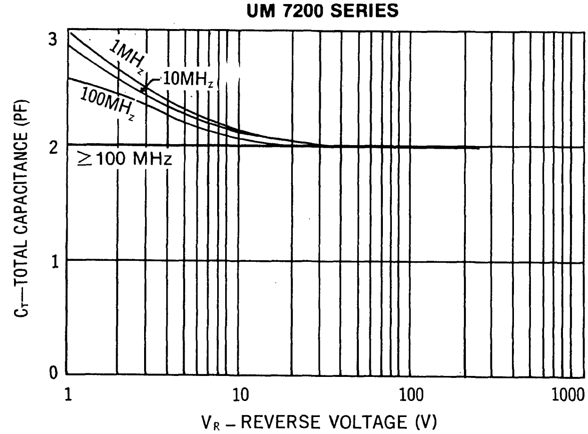
UM 7100 SERIES



UM 7200 SERIES



UM 7200 SERIES



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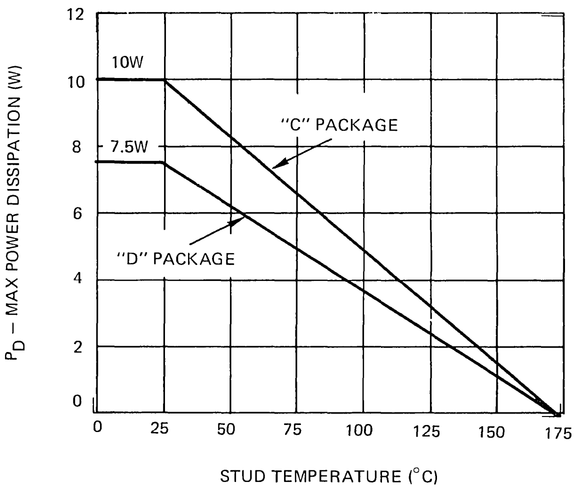
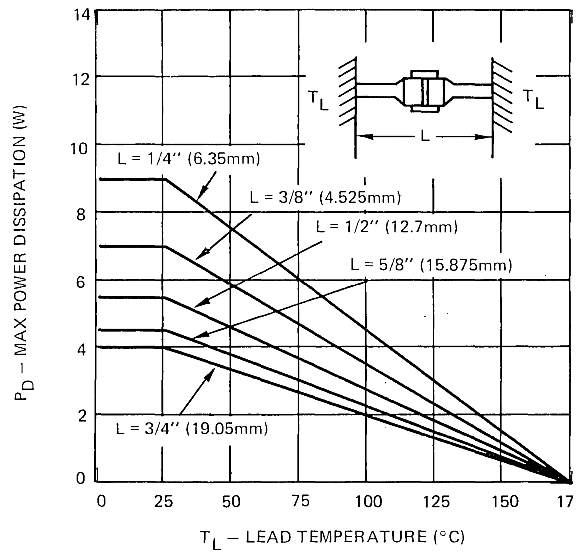
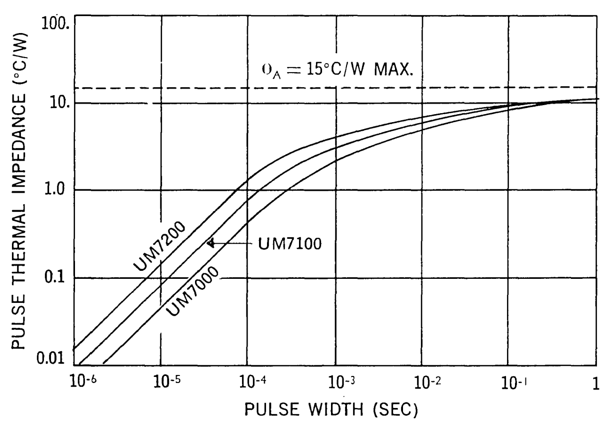
POWER RATING STUD MOUNTED DIODES



POWER RATING — AXIAL LEADED DIODES



PULSE THERMAL IMPEDANCE VS PULSE WIDTH



XII

ORDERING INSTRUCTIONS

Part numbers of Unitrode PIN Diodes consist of the letters UM followed by four digits and one or two letters. The first two digits indicate the diode series, the next two digits specify the minimum breakdown voltage in hundreds of volts. The remaining letters denote the package style. Reverse polarity (anode on stud end) is available in C or D Styles and denoted by adding second letter R.

For Example: UM |70|01|C|

|Series 7000| |100 volts| |Style C|

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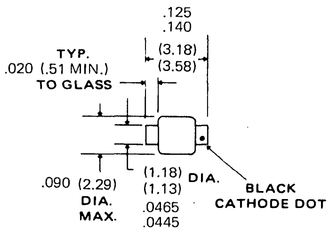
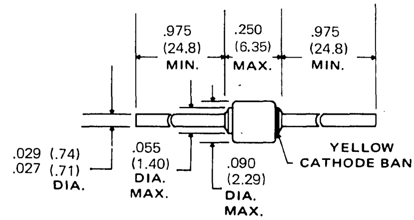
MECHANICAL SPECIFICATIONS

Dimensions — English/Metric

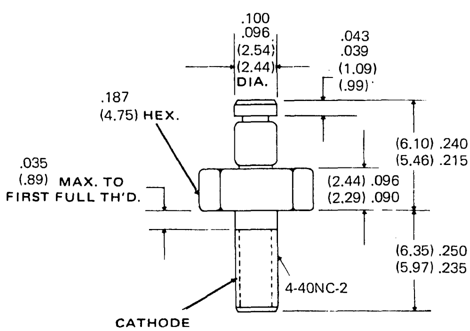
STYLE A



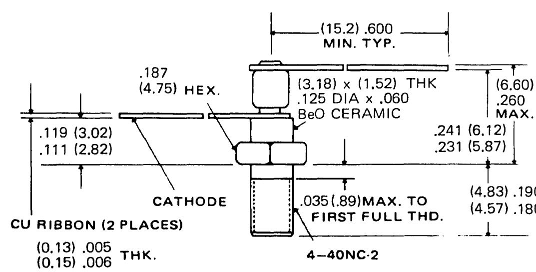
STYLE B



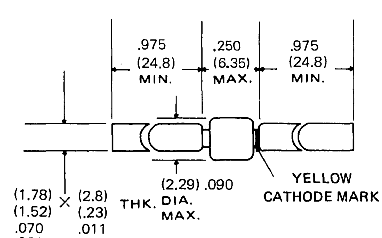
STYLE C
STUD



STYLE D
INSULATED STUD



STYLE E
RIBBON LEADS



ᵖIN DIODE

UM9301 SERIES

OMMERCIAL ATTENUATOR DIODE

'eatures

- Specified low distortion
- Low rectification properties at low reverse bias
- Resistance specified at 3 current points.
- High reliability fused-in-glass construction.

)escription

The UM9301 PIN Diode utilizes a special verall chip geometry with an extremely ick intrinsic "I" region, to offer unique apabilities in both RF switch and attenuator pplications. Volume production also makes e diode an economical choice suitable for any commercial low power equipments.

The UM9301 has been designed for use in ridged TEE attenuator circuits commonly utilized for gain and slope control in CATV amplifiers. Low distortion and high dynamic range are characteristic of the diodes' outstanding performance.

The UM9301 is also appropriate for switch applications, when little or no bias voltage is available. Frequent applications occur in portable 12 volt-powered communications equipments, operating at frequencies as low as 2 MHz.

IAXIMUM RATINGS

Reverse Voltage (V_R) — Volts (I_R = 10 μA)	75V
Average Power Dissipation @ (P_A) Leads ½ in. overall to 25°C Contact	1.0W (Derate linearly to 175°C)
Operating and Storage Temperature Range	−65°C to +175°C

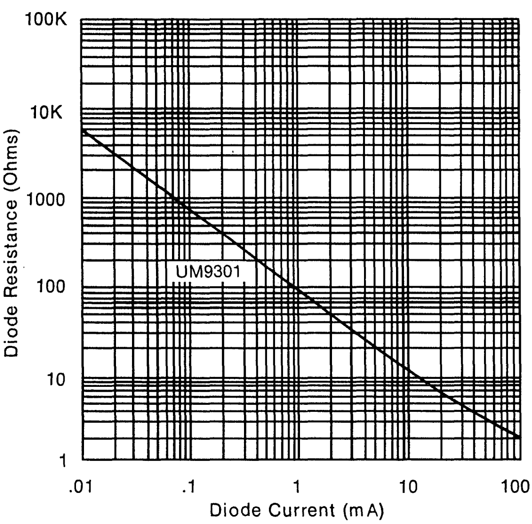
XII

UNITRODE

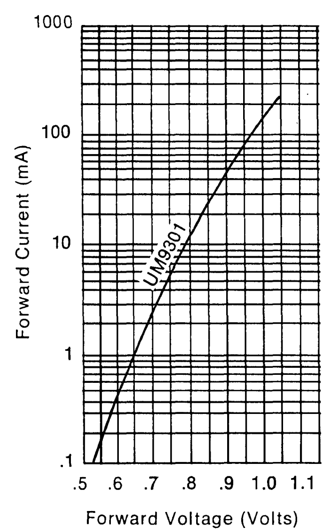
Electrical Specifications (25 °C)

Test	Min	Typ	Max	Units	Conditions
Diode Resistance R_S		1.7 80 5000	3.0 150	Ω Ω Ω	I = 100 mA, f = 100 MHz I = 1 mA, f = 100 MHz I = 0.01 mA, f = 100 MHz
	3000				
Current for R_S = 75Ω	0.5	1.1	2.0	mA	f = 100 MHz
Capacitance			0.8	pF	V = 0V, f = 100 MHz
Return Loss	25			dB	Frequency Range: 10 - 300MHz R_S = 75Ω @ 100 MHz Diode Terminates 75Ω line
Second Order Distortion		55	50	– dB	f_1 = 10 MHz, f_2 = 13 MHz P = 50 dBmV, See Test Circuit
		70		– dB	F_1 = 67 MHz, F_2 = 77 MHz P = 50 dBmV, See Test Circuit
Third Order Distortion		75	65	– dB	F_1 = 10 MHz, F_2 = 13 MHz P = 50 dBmV, See Test Circuit
		95		– dB	Triple Beat; 205 + 67 – 77 MHz P = 50 dBmV, See Test Circuit
Cross Modulation Distortion		75		– dB	12 Channel Test P = 50 dBmV, See Test Circuit Dix Hills Test Set
Reverse Current			10	μA	V = 75V
Carrier Lifetime	4.0			μs	I = 10 mA

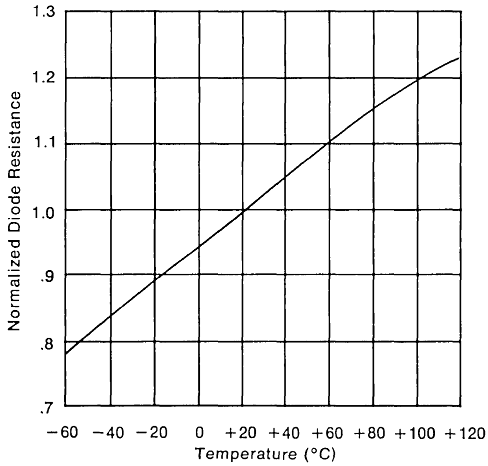
DIODE RESISTANCE VS DIODE CURRENT (TYPICAL)



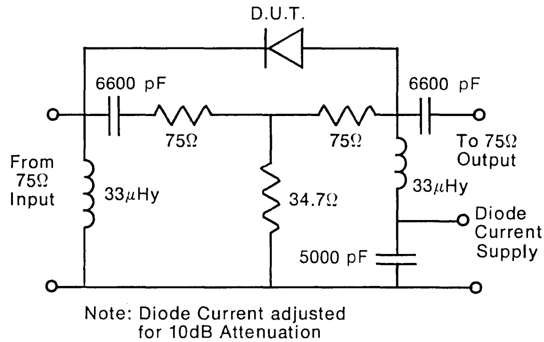
FORWARD CURRENT VS FORWARD VOLTAGE (TYPICAL)



NORMALIZED R_S VS TEMPERATURE

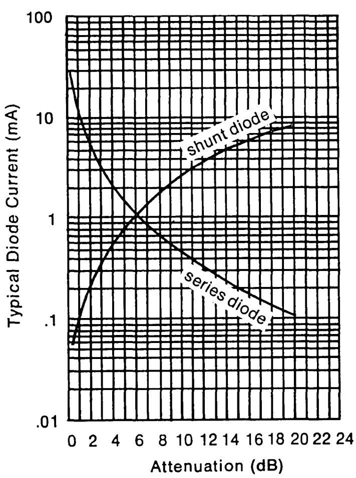


TEST CIRCUIT FOR DISTORTION MEASUREMENTS

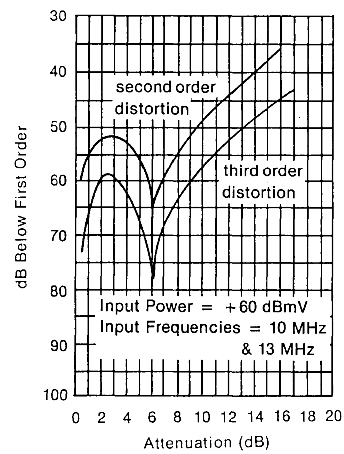


TYPICAL BRIDGED TEE ATTENUATOR PERFORMANCE

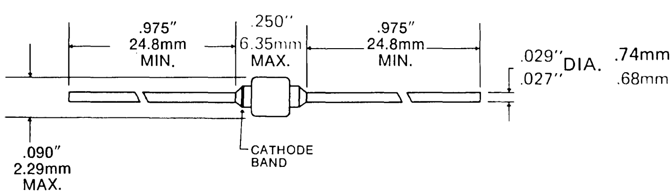
DIODE CURRENT VS ATTENUATION UM9301



DISTORTION ATTENUATION



MECHANICAL SPECIFICATIONS



XII

PIN DIODE

UM9401 SERIES
UM9402 SERIES
UM9415 SERIES

COMMERCIAL TWO-WAY RADIO ANTENNA SWITCH DIODES

Features

- Specified low distortion
- Unitrode ruggedness and reliability
- Low bias current requirements
- Priced for high quantity applications

Description:

Unitrode offers a series of PIN diodes specifically designed and characterized for solid state antenna switches in commercial two-way radios. Antenna switches using the UM9401 and UM9415 series PIN diodes provide high isolation, low loss and low distortion characteristics formerly possible only with electromechanical relay type switches.

The UM9401 and UM9402 diodes can handle above 100W of transmitter power, while the UM9415 will handle over 1000W. The extensive characterization of these PIN diodes in antenna switch applications has resulted in guaranteed low distortion specifications under transmit and receive conditions. These diodes also feature low forward bias resistance and high zero bias impedance which are required for low loss, high isolation and wide bandwidth antenna switch performance.

MAXIMUM RATINGS

	UM9401	UM9402	UM9415
Reverse Voltage (V_R) — Volts (I_R = 10 μA)	50V	50V	50V

Average Power Dissipation (P_A)			
Leads - ½ in. Overall to 25 °C Heat Sink	5.5W	—	10W
25 °C (Package Flange) Temperature	—	10W	—
Free Air	1.5W		2.5W

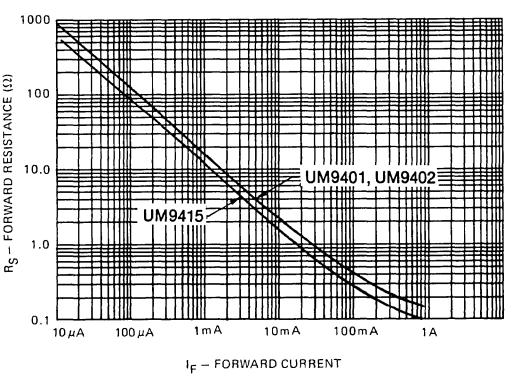
Operating and Storage Temperature Range	−65 °C to +175 °C

UNITRODE

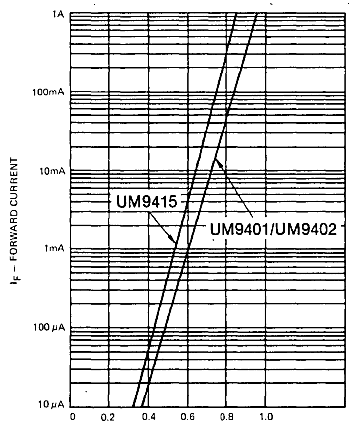
Electrical Specifications (at 25°C)

Test	Symbol	UM9401/UM9402			UM9415			Units	Conditions
		Min	Typ	Max	Min	Typ	Max		
Series Resistance	R_S		0.75	1.0		0.75	1.0	Ω	f = 100MHz typical I = 50 mA
Diode Capacitance	C_T		1.1	1.5			4	pF	f = 100 MHz V = 0V
Parallel Resistance	R_P	5K	10K		1K	2K		Ω	f = 100 MHz V = 0V
Carrier Lifetime	τ	1.0	2.0		5			μS	I = 10 mA
Transmit Harmonic Distortion	$\frac{R_{2A}}{A}, \frac{R_{3A}}{A}$			80			80	– dB	P_{IN} = 50W f = 50 MHz, I = 50 mA
Receive Third Order Distortion	$\frac{R_{2AB}}{A}$			60			60	– dB	P_{IN} = 10 mW, 0V Bias f_A = 50 MHz, f_B = 51 MHz
Reverse Leakage Current	I_R			10			10	μA	V = 50V
Forward Voltage	V_F			1.0			1.0	V	I_F = 50 mA

TYPICAL FORWARD RESISTANCE VS FORWARD CURRENT (F = 100 MHz)

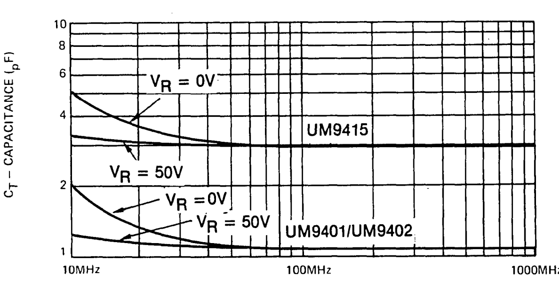


TYPICAL DC CHARACTERISTIC

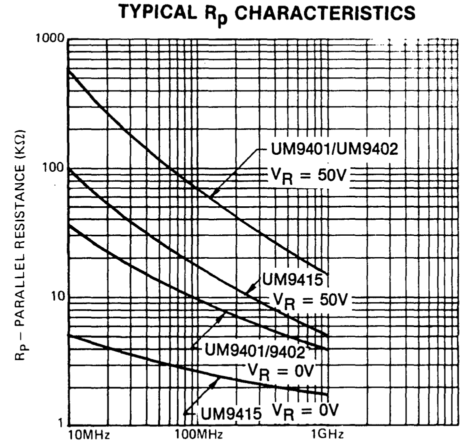


XII

TYPICAL CAPACITANCE CHARACTERISTIC



TYPICAL R_p CHARACTERISTICS



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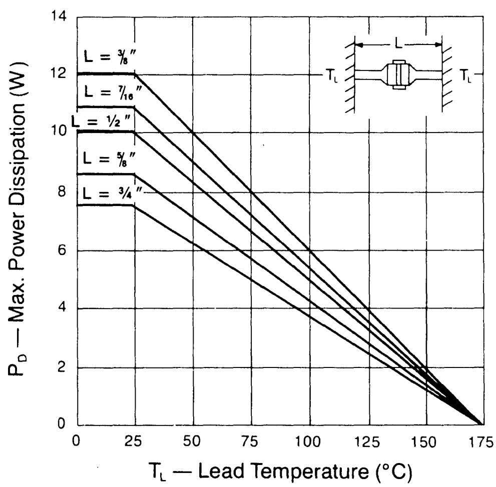
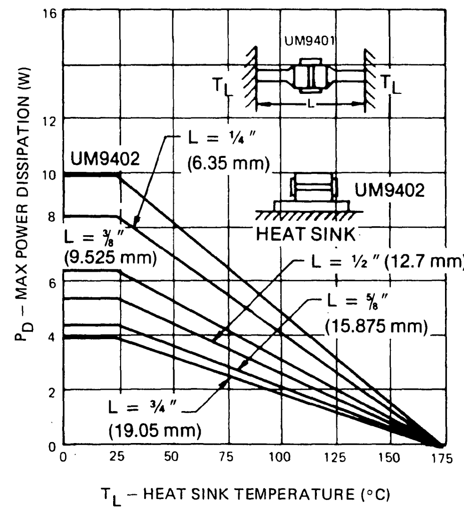
POWER RATING
UM9415

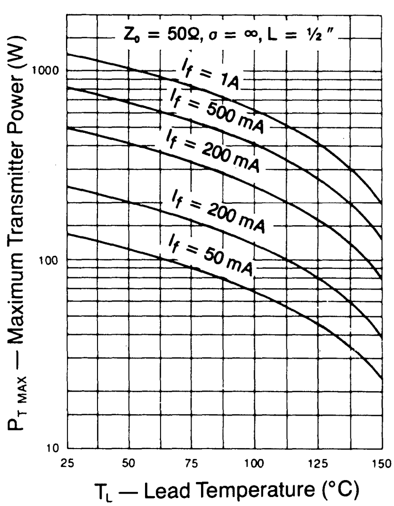


POWER RATING
UM9401/9402

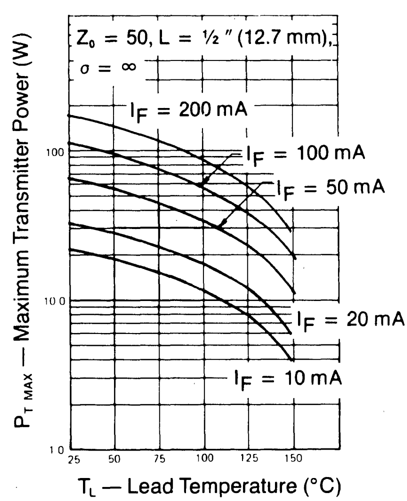


MAXIMUM TRANSMITTER POWER

UM9415



UM9401/UM9402



Maximum Transmitter Power

The maximum CW transmitter power, $P_{T(max)}$, a PIN diode antenna switch can handle depends on the diode resistance, R_S, power dissipation, P_D, antenna SWR, σ, and nominal impedance, Z_0. The expression relating these parameters is as follows:

$$P_{T(max)} = \frac{P_D \times Z_0}{R_D} \left(\frac{\sigma + 1}{2\sigma}\right)^2 \text{ [Watts]}$$

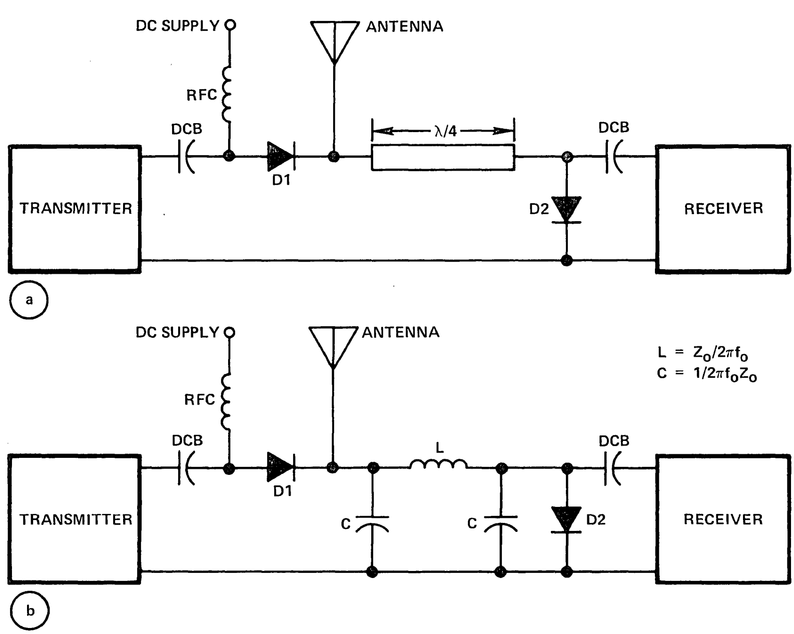
Characteristic curves are shown in the data section which give both the maximum and typical diode resistance, R_S as a function of forward current. The maximum power dissipation rating of the PIN diode depends both on the length of the diode leads and the temperature of the contacts to which the leads are connected. A graph defining the maximum power dissipation at various combinations of overall lead length (L) and lead temperature (T_L) is given in the data section. From these curves and the above equation, the power handling capability of the PIN diode may be computed for a specific application.

Curves are also presented which show the maximum transmitter power that an antenna switch using UM9401s and UM9415s can safely handle for various forward currents and lead temperatures. These curves are based on a typical design condition of a ½ in. total overall lead length, 50Ω line impedance and a totally mismatched antenna ($\sigma = \infty$). For the case of a perfectly matched antenna, the maximum transmitter power can be increased by a factor of 4.

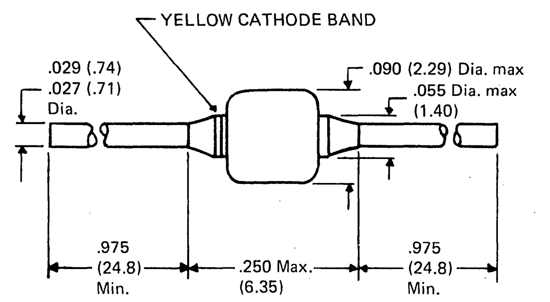
Design Information

A circuit configuration for a two-way radio antenna switch using PIN diodes consists of a diode placed in series with the transmitter and a shunt diode placed a quarter wavelength from the antenna in the direction of the receiver as shown. For low frequency operation, the quarter wave line may be simulated by lumped elements. Typical performance of antenna switches using PIN diodes forward biased at 100 mA is less than 0.2 dB insertion loss and 30 dB isolation during transmit; at zero bias the receive insertion loss is less than 0.3 dB. This performance is achievable across a ±20% bandwidth at center frequencies ranging from 10 to 500 MHz.

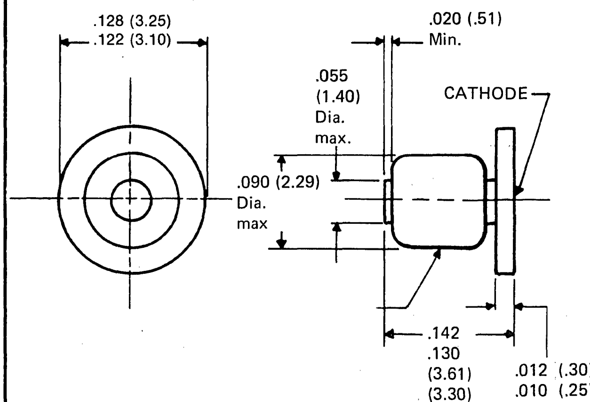
XII



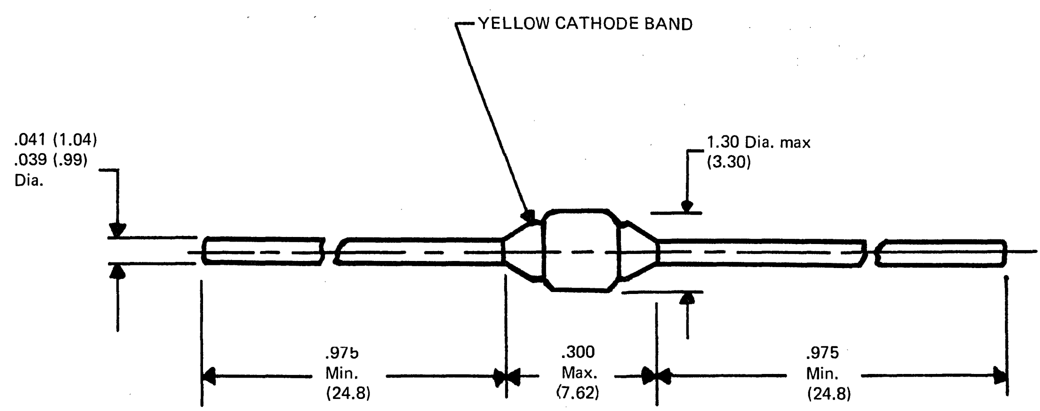
UM9401



UM9402



UM9415



Dimensions: inches (millimeters)

IN RADIATION DETECTORS

UM9441

atures

- High Photocurrent Sensitivity
- High Reliability Construction
- Fast Rise Time
- Wide Dynamic Range
- Hardness to Neutron Bombardment
- Low Operating Voltage

scription

Silicon PIN devices are effective detectors nuclear and electromagnetic radiation. is includes gamma radiation, electrons, d X-rays. The detectors can be used ross the temperature range of −55 °C to 175 °C instead of being restricted to use at v temperatures.

The absorbed radiation produces electron-le pairs in the space charge region. These arges are swept out by the applied field d result in a current flow proportional to e rate of absorbed radiation.

The Unitrode UM9441 series utilizes high sistivity material and is designed to have a iform area mesa structure to define the tive volume. The current sensitivity of these devices is proportional only to the I-region volume and is independent of temperature so long as applied voltage exceeds the saturation voltage. This structure also minimizes the effects of permanent damage caused by neutrons and other high energy radiation. Experiments on devices of the UM9441 design show no degradation in gamma sensitivity resulting from a total dose of 10^{14} neutrons/cm^2 of 1 MeV equivalent.

Package

The UM9441 is an axially leaded device constructed by metallurgically bonding the PIN chip in between two molybdenum refractory pins that are typically 0.125 inches in diameter and 0.050 inches long. Hyper-pure glass is then fused over this bond to form a voidless seal. Leads are then brazed to ends of molybdenum pins. This results in a high-reliability package using materials so well thermally matched that the UM9441 can withstand temperature shock or cycling from −196 °C to +300 °C.

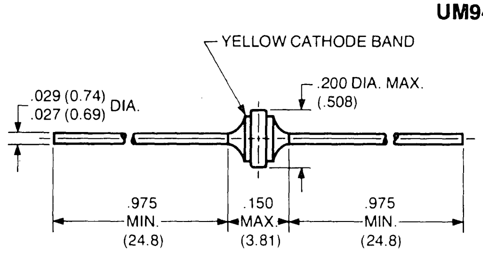
XII

SSOLUTE MAXIMUM RATINGS

everse Voltage 100V
otocurrent 1A
orage Temperature ... −55 °C to +200 °C
erating Temperature . −55 °C to +175 °C

ECHANICAL SPECIFICATIONS

UM9441



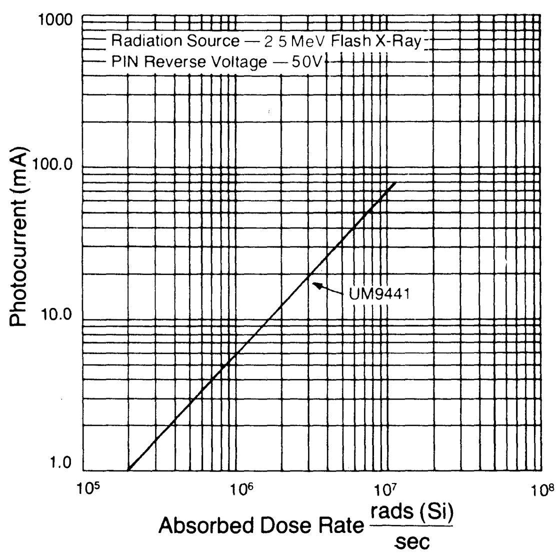
nensions in inches (millimeters)

UNITRODE

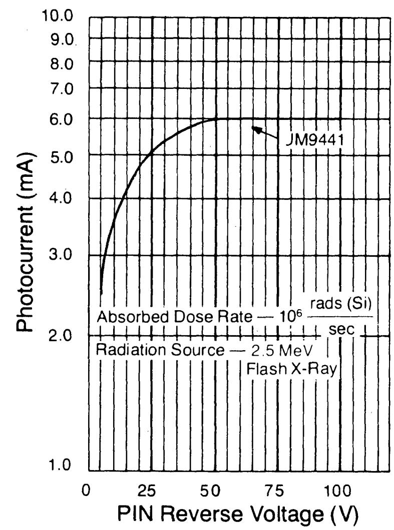
Electrical Specifications (at 25°C)

Test	Min	Typ	Max.	Units	Test Conditions
Photocurrent	4.0	6.0		mA	$V_R = 50V$ $10^6 \frac{\text{rads (Si)}}{\text{sec.}}$ 2.5 MeV Flash X-Ray Ion Physics Corp. FX-25
Photocurrent Rise Time (10%-90%)		10		ns	
Capacitance		10	15	pF	F = 1 MHz, V = 50V
Reverse Current			1.0	μA	V_R = 50V
Minority Carrier Lifetime	2.0			μS	I_f = 10mA

TYPICAL PHOTOCURRENT SENSITIVITY



TYPICAL VOLTAGE SENSITIVITY



RELIABILITY

The UM9441 is consistent with Unitrode's reputation as a manufacturer of high reliability semiconductors. Unitrode is equipped to perform JAN type testing, base-lining and documental conformance to a wide range of reliability testing. This commitment to reliability has enabled Unitrode to be a qualified supplier of semiconductor devices to many high-reliability programs such as:

APOLLO	MINUTEMAN
DRAGON	SPRINT
HAWK	TRIDENT
MARINER	VIKING

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PIN DIODE

or Microstrip 900MHz Antenna Switches
nd Microwave Applications

eatures

- Low Inductance Shunt Mount Package
- Characterized for Microstrip
- Unitrode Ruggedness and Reliability
- High Power Handling Capability
- Low Bias Current Requirement
- Excellent Distortion Properties
- Cost Effective in High Quantity Applications

escription

The UM9601-UM9608 series of PIN diodes was eveloped for shunt mount applications in nicrostrip circuits. Good switch performance is emonstrated at frequencies from UHF to 4GHz nd higher. This performance is achieved using iscrete low inductance Unitrode PIN diodes ssembled with special hardware to permit good lectrical and mechanical compatibility with nicrostrip transmission lines.

Design information is presented for prepara- on of microstrip circuit boards to accommodate nese PIN diodes. A detailed design for a 900MHz uarter-wave antenna switch is given. This witch which employs a low cost UM9401 axial eaded PIN diode in conjunction with a UM9601, erforms with 30dB receiver isolation over a 00MHz bandwidth and with transmitter nsertion loss of less than 0.4dB. This switch can afely handle transmitter power levels up to 100 vatts at infinite antenna SWR.

The Unitrode UM9601 series PIN diodes are constructed using a fused-in-glass process which results in a highly reliable, hermetic package. The process utilizes symmetrical, full faced metallurgical bonds to both surfaces of the silicon chip. This construction greatly minimizes the normal parasitic inductance and capacitance found in conventional glass or ceramic packaged diodes which employ straps, springs or whiskers.

The use of discrete UM9601-UM9608 diodes greatly minimizes handling problems commonly associated with passivated PIN diode chips while maintaining good microwave performance. In addition the power handling capibility of the UM9601-UM9608 series is considerably higher than PIN diode chips can provide.

Environmentally, the UM9601-UM9608 series PIN diodes can withstand thermal cycling from −195°C to +300°C and exceed all military environmental specification for shock, vibration, acceleration, and moisture resistance.

ypical Microwave Performance

	UM9601-UM9604			UM9605-UM9608		
Frequency	SPST Insertion Loss 0 Bias	SPST Isolation 100mA	SPNT* Isolation 100mA	SPST Insertion Loss 0 Bias	SPST Isolation 100mA	SPNT* Isolation 100mA
GHz	dB	dB	dB	dB	dB	dB
0.5	0.20	30	36	0.20	25	31
1.0	0.25	26	32	0.20	22	28
1.5	0.35	22	28	0.20	20	26
2.0	0.50	18	24	0.25	17	22
3.0	1.00	15	21	0.25	15	21
4.0	1.50	13	19	0.40	14	20

Performance based on SPST Measurements
In 0.025" (.635mm) Microstrip Test Circuit.

Note: All dimensions in inches and (millimeters).

UNITRODE

Maximum Ratings

	UM9601 - UM9604		UM9605 - UM9608	
	P_D	θ	P_D	θ
Flange at 25°C	7.5W	20°C/W	4W	37.5°C/W
Free Air	1.5W	—	0.5W	—

Peak Power 1μS Single Pulse at 25°C Ambient	25KW	10KW

Operating and Storage Temperature	−65°C to +175°C

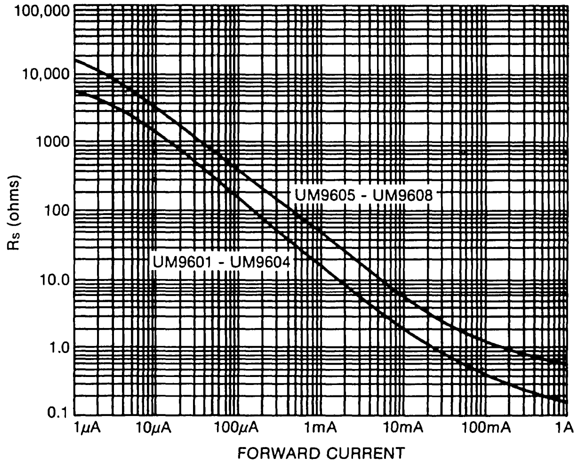
Reverse Voltage Ratings @ 10μA

100V	400V
UM9601 UM9603 UM9605 UM9607	UM9602 UM9604 UM9606 UM9608

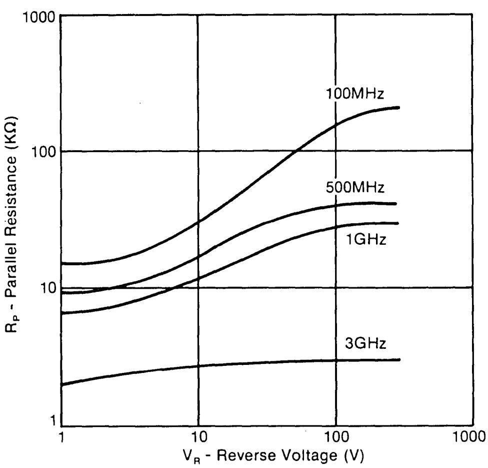
Electrical Specifications (at 25°C)

Test	Symbol	UM9601-UM9604			UM9605-UM9608			Units	Condition
		Min	Typ	Max	Min	Typ	Max		
Series Resistance	R_S	—	0.4	0.6	—	1.5	1.7	Ω	I = 100mA F = 1GHz
Parallel Resistance	R_P	5K	—	—	7K	—	—	Ω	Zero Bias F =1GHz
Total Capacitance	C_T	—	—	1.2	—	—	0.5	pF	Zero Bias F =1GHz
Carrier Lifetime	τ	2.0	—	—	1.0	—	—	μS	I_F = 10mA
Forward Voltage	V_F	—	0.85	—	—	0.95	—	V	I_F = 100mA
I-Region Width	W	80	—	—	150	—	—	μm	

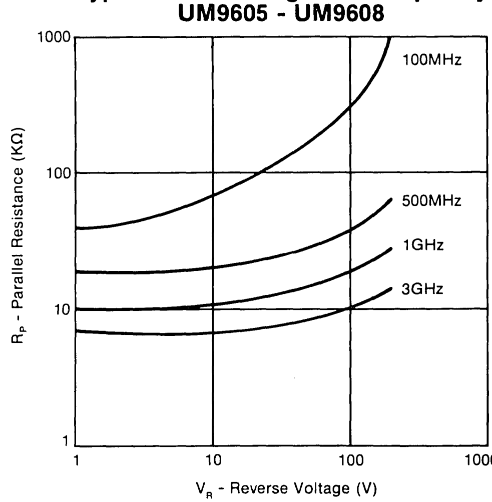
Typical Series Resistance vs Forward Current (F = 100MHz)



Typical R_P vs Voltage and Frequency UM9601 - UM9604

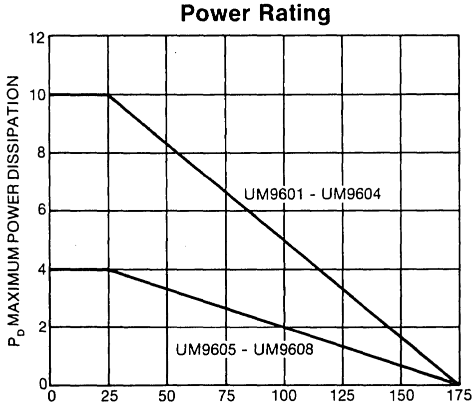


Typical R_P vs Voltage and Frequency UM9605 - UM9608

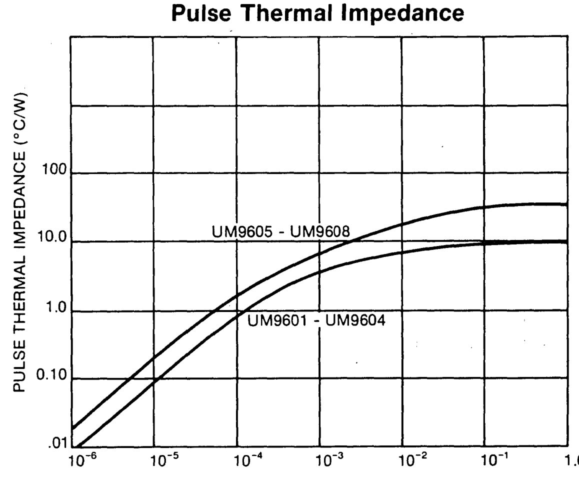


XII

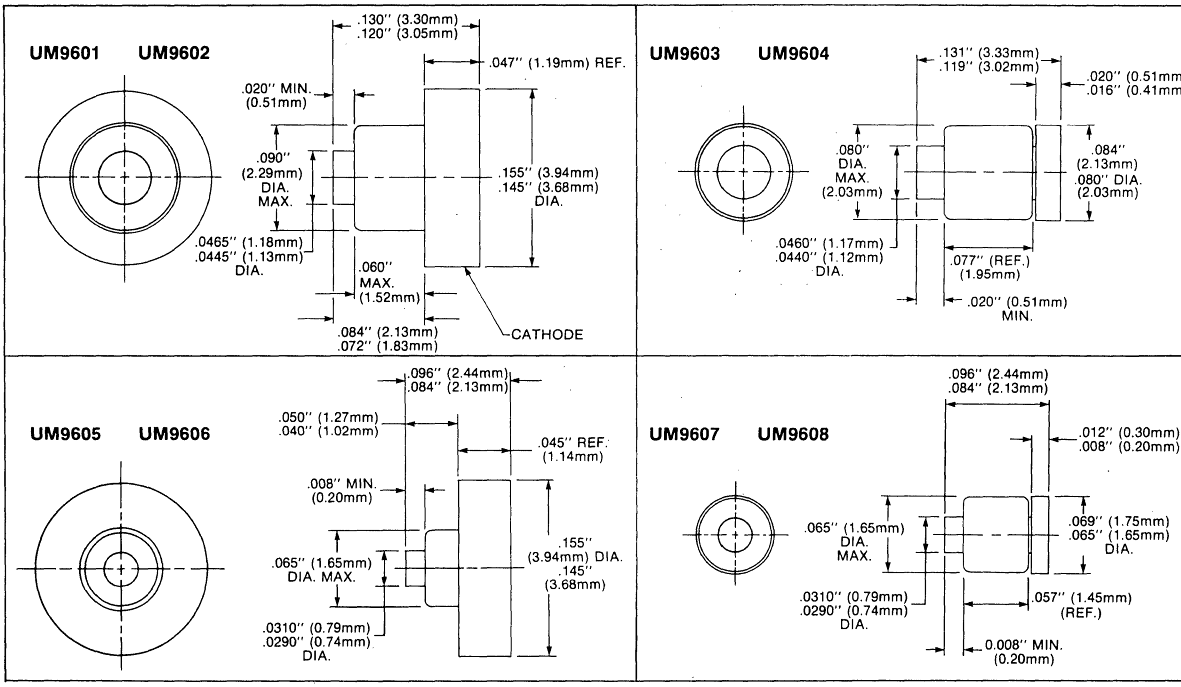
Power Rating



Pulse Thermal Impedance



Mechanical Specifications



Selection Guide

The following chart serves as a general guide for indicating the most likely diode from the series for a given application.

Applications	Recommended Types
1. High isolation switches to 2GHz at low dc drive 2. Quarter-wave antenna switches to 100 watts. 3. Priced for high volume commercial applications.	UM9601 (Affixes to microstrip ground plane.) UM9603 (Affixes to microstrip backing plate.)
High voltage rating version of UM9601 and UM9603 respectively for peak power handling to 3KW.	UM9602, UM9604
1. Low insertion loss switches to 4GHz. 2. Low distortion antenuator applications.	UM9605 (Affixes to microstrip ground plane.) UM9607 (Affixes to microstrip backing plate.)
High voltage version of UM9605 and UM9607 for peak power handling to 10KW.	UM9606, UM9608

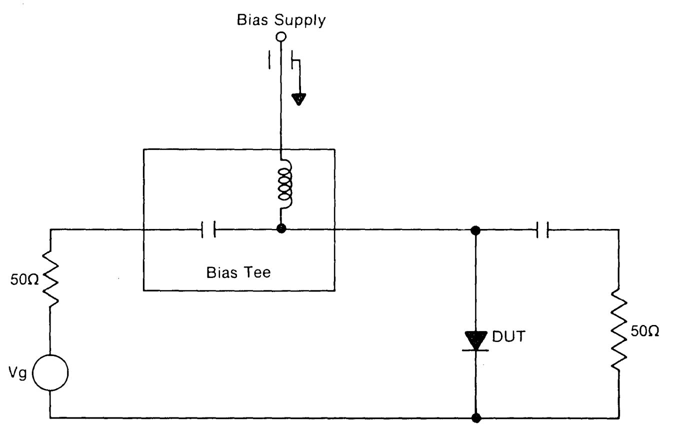
Microwave Characterization

The UM9601-UM9608 series has been designed and characterized as shunt switch elements at frequencies to 4GHz in microstrip circuits. Performance curves are given which demonstrate switch performance in 0.025" (.635mm) alumina microstrip.

The performance data were derived by evaluating externally biased microstrip circuits in which a UM9601 diode was installed. Each circuit consisted of a 1 inch length of 50 ohm nominal impedance 0.025" (.635mm) thick alumina microstrip and two SMA connectors. The data shown include the board and connector loss. Measurements performed using 0.050" (1.27mm) alumina substrates show similar performance at frequencies to 1.5GHz.

These circuits simulate simple SPST switches. Many designs require multithrow switches. It is important to recognize that a multithrow switch will have 6dB higher isolation than indicated for SPST switches. Also, a multithrow switch using shunt mounted PIN diodes require the diodes be placed a quarter-wavelength from the common port.

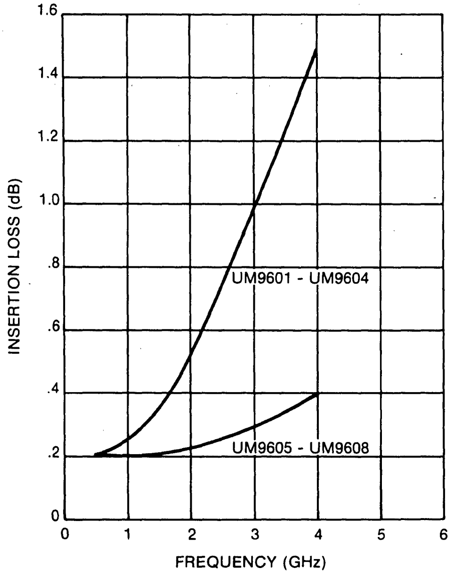
A further improvement in switch performance may be achieved by using 2 shunt PIN diodes in each arm spaced a quarter-wavelength from each other. In this case the isolation of each section will be twice the dB value of a SPST switch. The insertion loss due to the diodes should be less than twice the insertion loss of an SPST section due to the transforming effect of the quarter-wave line on the capacitance of a single diode.



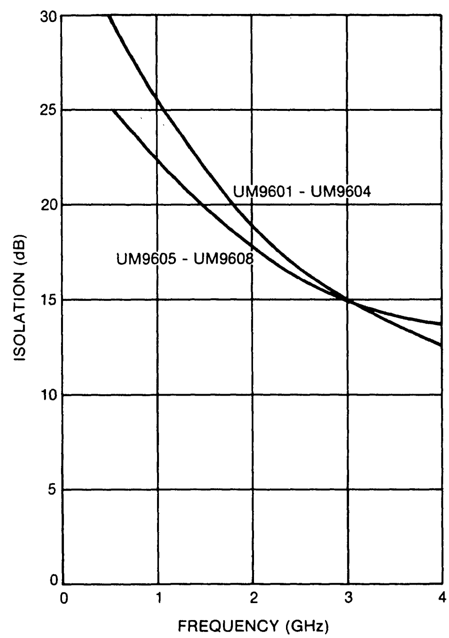
Microwave Test Circuit

XII

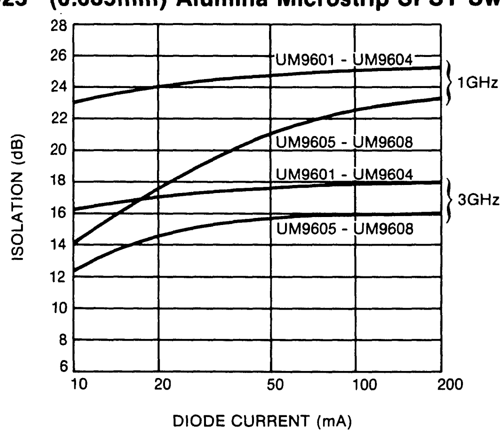
Typical Insertion Loss vs Frequency
0.025" (0.635mm) Alumina Microstrip SPST Switch
Diode at Zero Bias



Typical Isolation vs Frequency
0.025" (0.635mm) Alumina Microstrip SPST Switch
Diode Current = 100mA



Isolation vs Frequency and Diode Current
0.025" (0.635mm) Alumina Microstrip SPST Switch

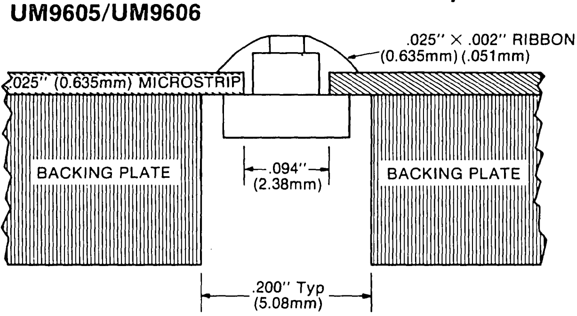


Installation in Microstrip

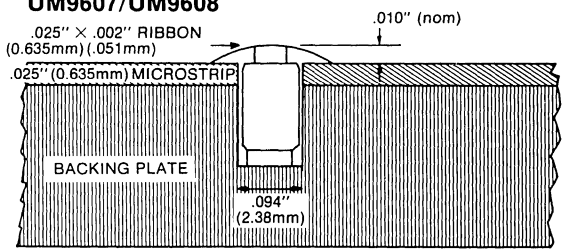
The cup type flange on the UM9601, UM9602, UM9605 and UM9606 is designed to be affixed to the ground plane surface of a microstrip board as shown. The UM9603, UM9604, UM9607 and UM9608 were designed to be affixed to a backing plate as shown. It was experimentally determined that at frequencies greater than 2GHz the anode of the diode should be approximately 0.010" (.254mm) above the top surface of the microstrip for lowest insertion loss.

For solder adhesion the microstrip may be heated to solder melting temperature (up to 300° C) with no damage to the diode. Conductive epoxy may also be employed. The thermal resistance of solder mounted UM9601-UM9604 in their test boards was less than 20° C/W; for the UM9605-UM9608 thermal resistance was less than 30° C/W.

UM9601/UM9602 UM9605/UM9606 Microstrip Mount



UM9603/UM9604 UM9607/UM9608 Microstrip Mount



Design Example - 900MHz Antenna Switch

An example of a practical circuit design using a UM9601 diode is a quarter-wave antenna switch covering the frequency of 800-900MHz. The circuit design for this switch is shown and was constructed using 0.025" (0.645mm) alumina microstrip.

This antenna switch uses a series mounted diode and a shunt mounted diode. The UM9601 was selected for the shunt mounted device (SPST performance at 1GHz: 0.2dB insertion loss and 25dB isolation) and because it is the lowest cost diode in the UM9601-UM9608 series. A UM9401 axial lead diode was chosen for the series mounted device.

The performance of this switch is displayed in the graphs and in the following table. It should be noted that the loss values are actual measured numbers including losses due to the capacitors, bias networks, connectors as well as the board. In a typical radio application where the antenna switch circuit board is integrated in the same microstrip board that contains transmitter and receiver elements the connector loss is eliminated. This will result in lower overall insertion loss values than indicated here.

The CW power handling capacity is determined by the allowable power dissipation of the series mounted UM9401. Using a gap in the line of 0.190" (4.82mm) and lead soldered attached spacing of 0.250" (0.635mm) the power rating of the UM9401 is 6 watts at a 25° C ambient. This was determined by performing a thermal resistance measurement on the circuit mounted UM9401. The relationship that derives the maximum transmitter power, P_T, is:

$$P_T = \frac{P_{DISS}}{R^S} \cdot Z_o \left(\frac{\sigma + 1}{2\sigma} \right)^2$$

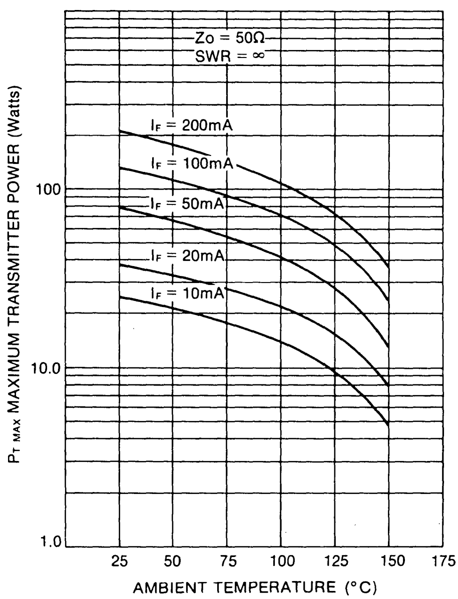
where σ = maximum antenna SWR

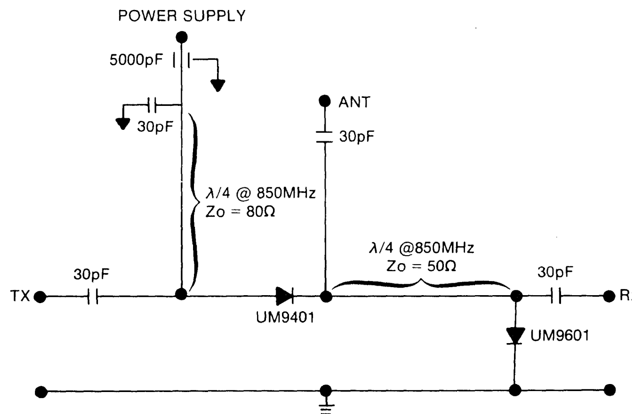
Using resistance values for the UM9401 and UM9601 the maximum transmitter power curve is given and shows that this circuit is able to handle 100 watts of transmitter power at 100mA forward biased and totally mismatched antenna at an ambient temperature of 60° C. For a perfectly matched antenna the power handling increases to 400 watts under the same bias and ambient temperature conditions.

XII

Distortion is an important consideration in the selection of a PIN diode antenna switch design. The UM9401 and UM9601 PIN diodes are designed for low distortion applications. The level of distortion produced by this 900MHz antenna switch when operated in the transmit state (forward bias of 100mA) is expected to be at least 90dB below the carrier for a 50 watt transmitter level. In the receiver state (zero bias) the intermodulation distortion caused by two in-band signals at 0dBm are estimated to be at least 100dB below this level.

Maximum Transmitter Power vs Forward Current for UM9601/UM9401 900MHz Microstrip Antenna Switch





Circuit Diagram

Antenna Switch Performance

Frequency Range 800-900MHz

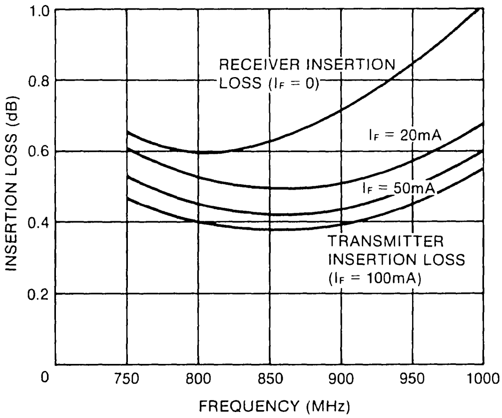
I. Transmit State
(I = 100mA, T_A = 60° C)

A. Maximum Transmitter Power - 100 watts (antenna SWR = ∞)
B. Maximum Transmitter Power - 400 watts (antenna SWR = 1)
C. Transmitter Insertion Loss - 0.4dB
D. Receiver Isolation - 31dB
E. Harmonic Distortion - −90dB (P_T = 100 watts)

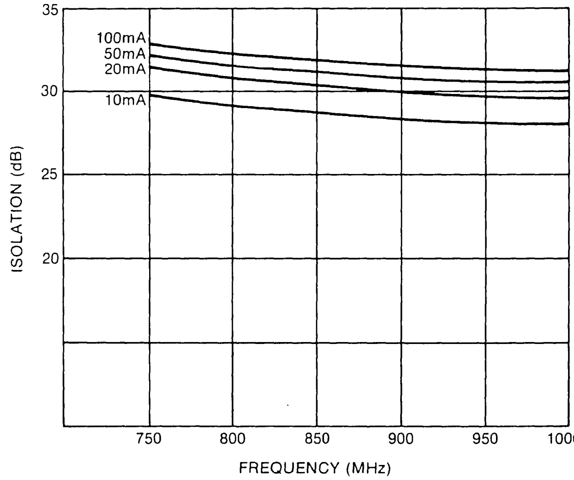
II. Receive State
(Zero Bias)

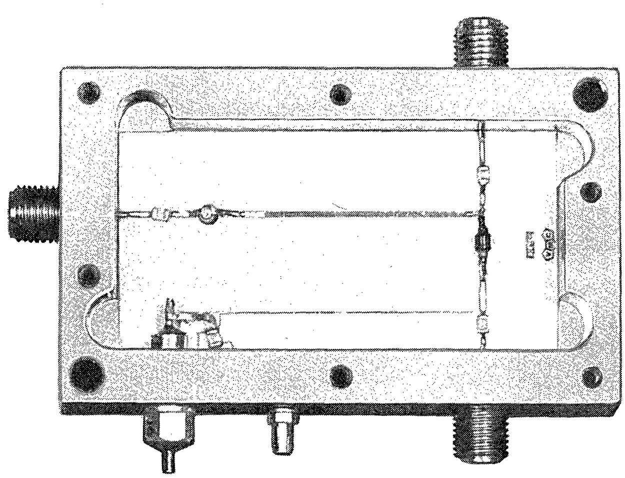
A. Receiver Insertion Loss - 0.6-0.7dB
B. Intermodulation Distortion - −100dB P_{in} = 0dBm

Antenna Switch Insertion Loss



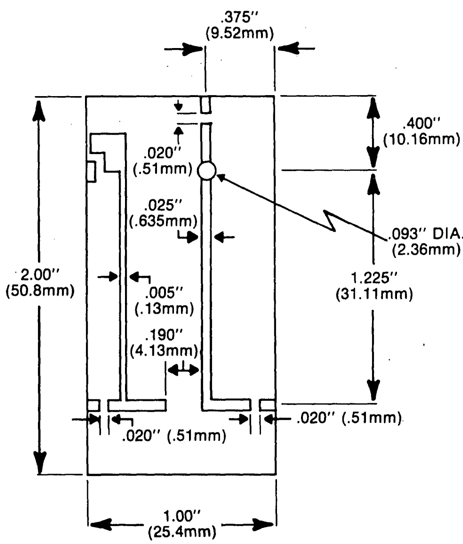
Receiver Isolation vs Frequency and Diode Current



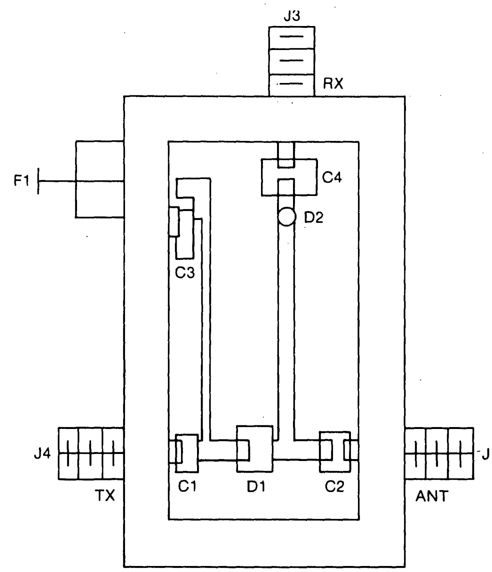


Photograph of 800-900MHz antenna switch test module using UM9401 and UM9601 PIN Diodes. In typical transceiver applications, the antenna switch circuit board is integrated.

XII



Substrate Drawing



Assembly Drawing

Parts List

F1	5000pF Feed through Filter	Erie 1270-016
C1-C4	30pF Chip Capacitor	Vitramon VJ0805A300KF
D1	PIN Diode	Unitrode UM9401
D2	PIN Diode	Unitrode UM9601
J1-J3	SMA Connector	Cablewave 971-028
	Substrate	Vectronics Microwave 79-9081-0401

SENSISTORS® XIII

SENSISTORS®

Positive – Temperature – Coefficient Silicon Thermistors

TG1/8
TM1/8

FEATURES

- Qualified to MIL-T-23648A
- TG1/8 – Similar to RTH42 (MIL-T-23648A/19)
- TM1/8 – Similar to RTH22 (MIL-T-23648A/9)
- Large Positive Temperature Coefficient ≏ 0.7%/°C
- Wide Resistance Value Ranges Available in 5% or 10% Tolerances

DESCRIPTION

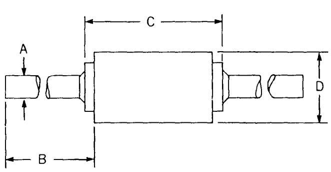
The TG1/8 thermistor is encapsulated in a glass, hermetically sealed package. The TM1/8 thermistor is encapsulated in a molded package. Both have hot solder-dipped leads and are used in temperature sensing and compensation circuits. They meet or exceed all of the requirements of MIL-T-23648A.

ABSOLUTE MAXIMUM RATINGS

	TG1/8	TM1/8
Power Dissipation at (or below) 25°C Free-Air Temperature (See Figure 1)	300mW	500mW
Power Dissipation at (or below) 100°C Free Air Temperature (See Figure 1)	125mW	
Operating Free-Air Temperature Range	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	

MECHANICAL SPECIFICATIONS

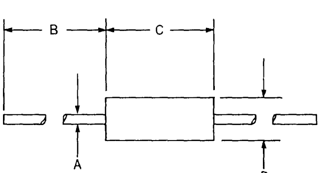
TG1/8



	INCHES	MILLIMETERS
A	.020 ± .002	.508 ± .051
B	1.0 MIN.	25.4 MIN.
C	.285 ± .015	7.239 ± .381
D	.095 ± .01	2.413 ± .254

TG

TM1/8



	INCHES	MILLIMETERS
A	.025 ± .003	.635 ± .076
B	1.0 MIN.	25.4 MIN.
C	.405 ± .015	10.287 ± .381
D	.14 ± .015	3.556 ± .381

TM

XIII

Sensitor® is a registered trademark of Unitrode Corporation

ELECTRICAL AND THERMAL CHARACTERISTICS

	TG1/8	TM1/8
Zero Power Resistance Ratio ($R_{25°C}/R_{125°C}$)	0.55 ± 15%	
Thermal Time Constant – Typical	35s	
Thermal Time Constant – Maximum	60s	

NOMINAL RESISTANCE AT VARIOUS TEMPERATURES

Standard Zero Power Resistance Value (Ω) at 25°C Free-Air Temperature	Type No.		Resistance (Ω) of Sensistor® at Temperature other than 25°C						
			-55°C	-15°C	0°C	50°C	75°C	100°C	125°C
10	TG1/8	TM1/8	6.15	7.9	8.63	11.6	13.5	15.45	17.5
12	TG1/8	TM1/8	7.38	9.48	10.356	13.92	16.2	18.54	21
15	TG1/8	TM1/8	9.225	11.85	12.945	17.4	20.25	23.175	26.25
18	TG1/8	TM1/8	11.07	14.22	15.534	20.88	24.3	27.81	31.5
22	TG1/8	TM1/8	13.53	17.38	18.986	25.52	29.7	33.99	38.5
27	TG1/8	TM1/8	16.605	21.33	23.301	31.32	36.45	41.715	47.25
33	TG1/8	TM1/8	20.295	26.07	28.479	38.28	44.55	50.985	57.75
39	TG1/8	TM1/8	23.985	30.81	33.657	45.24	52.65	60.255	68.25
47	TG1/8	TM1/8	28.905	37.13	40.561	54.52	63.45	72.615	82.25
50	TG1/8	TM1/8	30.75	39.5	43.15	58	67.5	77.25	87.5
56	TG1/8	TM1/8	34.44	44.24	48.328	64.96	75.6	86.52	98
68	TG1/8	TM1/8	41.82	53.72	58.684	78.88	91.8	105.06	119
82	TG1/8	TM1/8	47.724	63.14	69.454	95.94	112.34	129.888	147.6
100	TG1/8	TM1/8	58.2	77	84.7	117	137	158.4	180
120	TG1/8	TM1/8	69.84	92.4	101.64	140.4	164.4	190.08	216
150	TG1/8	TM1/8	87.3	115.5	127.05	175.5	205.5	237.6	270
180	TG1/8	TM1/8	100.8	135.9	150.84	212.4	252	292.14	334.8
220	TG1/8	TM1/8	123.2	166.1	184.36	259.6	308	357.06	409.2
270	TG1/8	TM1/8	151.2	203.85	226.26	318.6	378	438.21	502.2
330	TG1/8	TM1/8	184.8	249.15	276.54	389.4	462	535.59	613.8
390	TG1/8	TM1/8	218.4	294.45	326.82	460.2	546	632.97	725.4
470	TG1/8	TM1/8	263.2	354.85	393.86	554.2	658	762.81	874.2
500	TG1/8	TM1/8	280	377.5	419	590	700	811.5	930
560	TG1/8	TM1/8	308	414.4	467.6	672	795.2	927.36	1,075.2
680	TG1/8	TM1/8	374	503.2	567.8	816	965.6	1,126.08	1,305.6

NOMINAL RESISTANCE AT VARIOUS TEMPERATURES

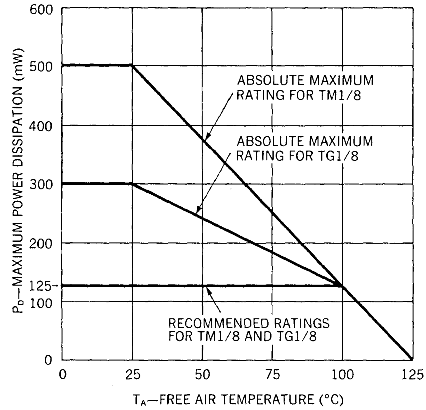
Standard Zero Power Resistance Value (Ω) at 25°C Free-Air Temperature	Type No.		Resistance (Ω) of Sensistor® at Temperature other than 25°C						
			-55°C	-15°C	0°C	50°C	75°C	100°C	125°C
820	TG1/8	TM1/8	451	606.8	684.7	984	1,164.4	1,357.92	1,574.4
1,000	TG1/8	TM1/8	550	740	835	1,200	1,420	1,656	1,920
1,200	TG1/8	TM1/8	660	888	1,002	1,440	1,704	1,987.2	2,304
1,500	TG1/8	—	772.5	1,095	1,237.5	1,845	2,175	2,505	2,940
	—	TM1/8	825	1,110	1,252.5	1,800	2,130	2,484	2,880
1,800	TG1/8	TM1/8	927	1,314	1,485	2,214	2,610	3,006	3,528
2,200	TG1/8	TM1/8	1,133	1,606	1,815	2,706	3,190	3,674	4,312
2,700	TG1/8	TM1/8	1,390.5	1,971	2,227.5	3,321	3,915	4,509	5,292
3,300	TG1/8	TM1/8	1,699.5	2,409	2,722.5	4,059	4,785	5,511	6,468
3,900	TG1/8	TM1/8	2,008.5	2,847	3,217.5	4,797	5,655	6,513	7,644
4,700	TG1/8	TM1/8	2,420.5	3,431	3,877.5	5,781	6,815	7,849	9,212
5,000	TG1/8	TM1/8	2,575	3,650	4,125	6,150	7,250	8,350	9,800
5,600	TG1/8	TM1/8	2,884	4,088	4,620	6,888	8,120	9,352	10,976
6,800	TG1/8	—	3,468	4,964	5,610	8,092	9,520	10,948	12,444
	—	TM1/8	3,502	4,964	5,610	8,364	9,860	11,356	13,328
8,200	TG1/8	—	4,182	5,986	6,765	9,758	11,480	13,202	15,006
	—	TM1/8	4,223	5,986	6,765	10,086	11,890	13,694	16,072
10,000	TG1/8	—	5,100	7,300	8,250	11,900	14,000	16,100	18,300
	—	TM1/8	5,150	7,300	8,250	12,300	14,500	16,700	19,600
12,000	—	TM1/8	6,180	8,760	9,900	14,760	17,400	20,040	23,520
15,000	—	TM1/8	7,215	10,680	12,210	18,150	21,450	25,050	28,500
18,000	—	TM1/8	8,658	12,816	14,652	21,780	25,740	30,060	34,200
22,000	—	TM1/8	10,582	15,664	17,908	26,620	31,460	36,740	41,800
27,000	—	TM1/8	12,987	19,224	21,978	32,670	38,610	45,090	51,300
33,000	—	TM1/8	15,873	23,496	26,862	39,930	47,190	55,110	62,700
39,000	—	TM1/8	18,759	27,768	31,746	47,190	55,770	65,130	74,100

DEVICE TOLERANCE

The actual resistance of the thermistor at T/°C may vary from the calculated value by an amount not exceeding the tolerances tabulated below.

Temperature	±5%	±10%
(°C)	(J)	(K)
-55	±15%	±20%
-15	±9%	±14%
0	±7%	±12%
25	±5%	±10%
50	±7%	±12%
75	±9%	±14%
100	±12%	±17%
125	±15%	±20%

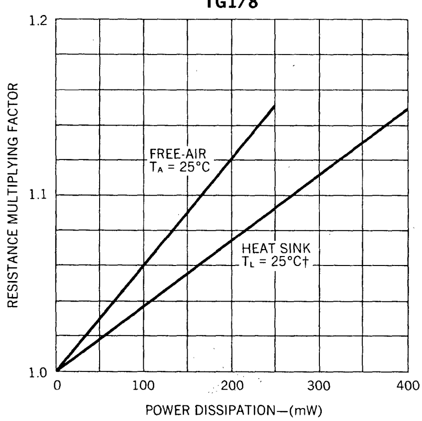
1. **Dissipation Derating Curves**



TYPICAL CHARACTERISTICS WITH POWER APPLIED

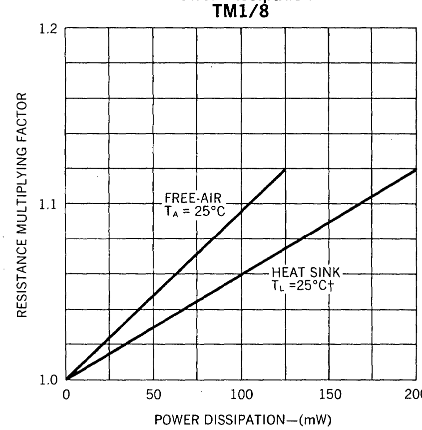
To determine resistance value with power applied, obtain a multiplying factor from the applicable curve below. The free-air curve is for the condition of heat removal by free-air convection only. The heat sink curve is for the maximum cooling rate condition of a heat sink strap, with leads attached to an infinite heat sink. Actual conditions encountered will be between these two extremes. After selecting an applicable multiplying factor from figure 2 or 3, multiply this by the 25°C zero power resistance. This product is then corrected for the actual ambient temperature by use of the appropriate temperature column in the Nominal Resistance at Various Temperatures table.

2. **Percent Resistance Change vs Power Dissipation TG1/8**



†T_L is lead temperature measured 1/16 inch from the body.

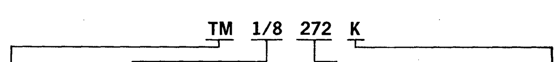
3. **Percent Resistance Change vs Power Dissipation TM1/8**



†T_L is lead temperature measured 1/16 inch from the body.

PART NUMBER DESIGNATION

TM1/8272K



STYLE	WATTAGE	RESISTANCE VALUE CODE	TOLERANCE
TM	1/8	270 = 27Ω	J = 5%
TG		271 = 270Ω	K = 10%
		272 = 2,700Ω	
		273 = 27,000Ω	

CAPACITORS XIV

CAPACITOR DESIGNERS' GUIDE

FACILITIES AND CAPABILITIES

Since 1973 Unitrode has supplied well over one half billion axial leaded monolithic ceramic capacitors to computer, general industrial, and commercial customers establishing the Company as a leading supplier of automatically insertable capacitors for high volume applications.

Our modern facility in San Diego, California, where our capacitor chips are manufactured, and Methuen, Massachusetts, where the chips are encapsulated and sealed are producing and shipping over 1,000,000 finished fully tested units a day.

Unitrode's ceramic multilayer capacitors are utilized in numerous varied applications such as digital computers, T.V. Games, communications/telecommunications, automotive regulators and ignition systems, machine tool controls, industrial and medical instrumentation, and electronic watches.

The Company's corporate marketing and sales headquarters are located in Lexington, Massachusetts. Strategically located Area and Regional Sales Offices backed by a worldwide network of the industry's most qualified team of manufacturers' representatives are prepared to provide any assistance you require to solve your capacitor problems and satisfy your requirements.

XIV

CAPACITOR DESIGNERS' GUIDE

DIELECTRIC CHARACTERISTICS INFORMATION

The following information on the characteristics of the dielectrics used in the manufacture of Unitrode's Monolithic Ceramic Capacitors is given in both absolute units and typical curves. Although the typical curves represent actual product, changes in dielectric formulations due to variations in raw material and other variations beyond our control require that the user take the curves as typical **only.** The factory should be consulted for performance data under non-standard conditions of temperature, voltage, etc.

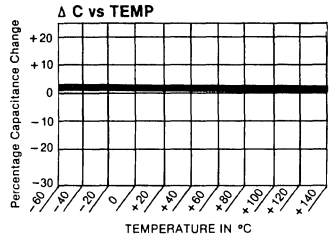
NPO (COG) — N CHARACTERISTIC

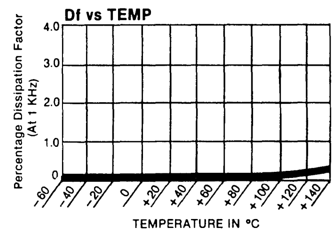
Unitrode's NPO dielectric is a Class 1 dielectric and is therefore extremely stable over wide variations of temperature, voltage, and frequency. Additionally this dielectric displays no aging characteristics.

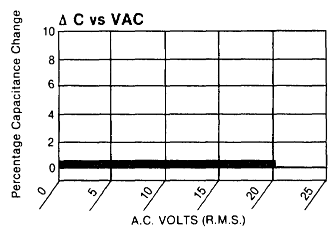
Performance Data

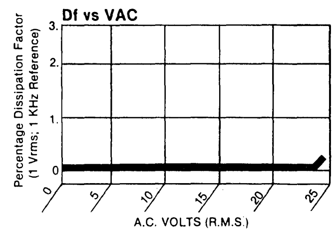
Temperature Characteristic	0 ±30 ppm/°C
Operating Temperature Range	−55°C to +125°C
Dissipation Factor @ 25°C	.1% @ 1MHz for ≤100pF and 1KHz above 100pF
Insulation Resistance @ 25°C With Rated Voltage Applied	100,000 megohms or 1000 megohm microfarads whichever is less
Insulation Resistance @ 125°C With Rated Voltage Applied	10,000 megohms or 100 megohm microfarads whichever is less
Dielectric Strength	250% of rated voltage with current limited to 50mA
Voltage Coefficient	None
Life Test	2 × rated voltage @ 125°C for 1000 hrs.
Available Tolerances	±.25pF, ±.5pF, ±1%, ±2%, ±5%, ±10%, ±20%

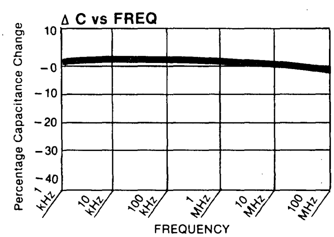
Typical Performance Curves

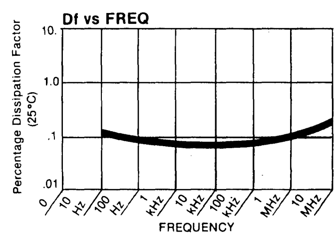


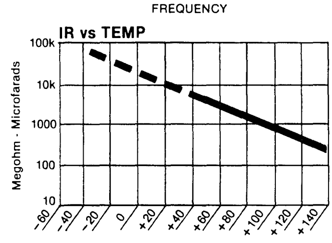


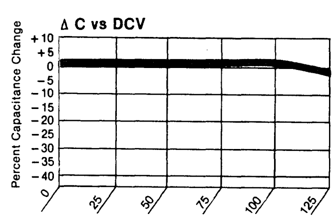












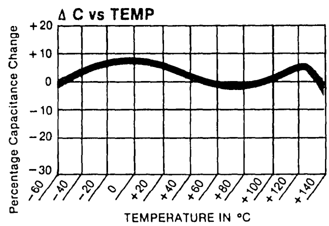
X7R (BX) — X CHARACTERISTIC

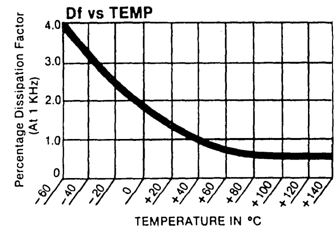
Unitrode's X characteristic is a Class 2 dielectric. It is a semi-stable material used for military and High-Rel products.

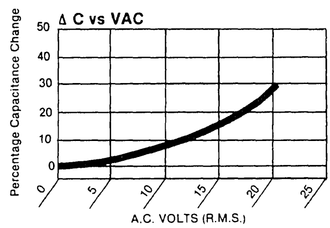
Performance Data

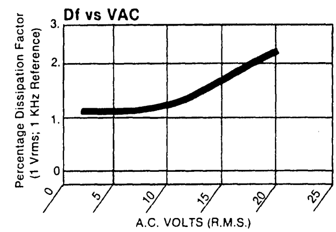
Temperature Characteristic	ΔC ±15% max from −55°C to +125°C
Operating Temperature Range	−55°C to +125°C
Dissipation Factor @ 25°C	2.5% max @ 1 VRMS @ 1KHz
Insulation Resistance @ 25°C With Rated Voltage Applied	100,000 megohms or 1000 megohm microfarads whichever is less
Insulation Resistance @ 125°C With Rated Voltage Applied	10,000 megohms or 100 megohm microfarads whichever is less
Dielectric Strength	250% of rated voltage with current limited to 50mA
Voltage Coefficient @ 25°C	−10% @ rated voltage
Voltage Temperature Limits	BX: ±15% @ 0 VAC; +15% −25% @ rated voltage −55°C to +125°C X7R: ±15% @ 0 VAC +15% −40% @ rated voltage −55°C to +125°C
Aging Rate	BX: Typically 1.5% per decade hr. 2% max. X7R: Typically 2% per decade hr. 2.5% max.
Life Test	2 × rated voltage @ 125°C, 1000 hrs.
Available Tolerances	±10%, ±20%, consult factory for ±5%

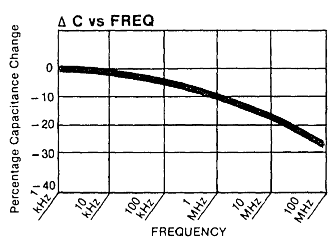
Typical Performance Curves

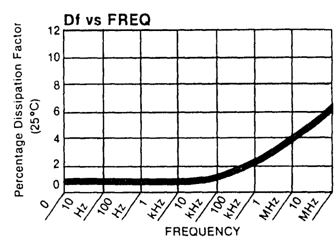


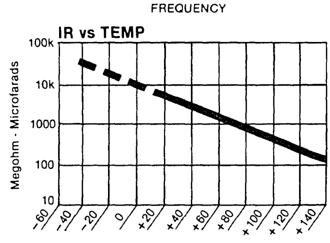


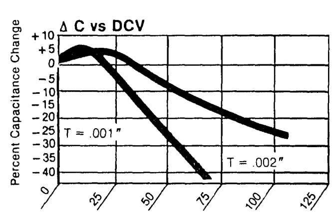












XIV

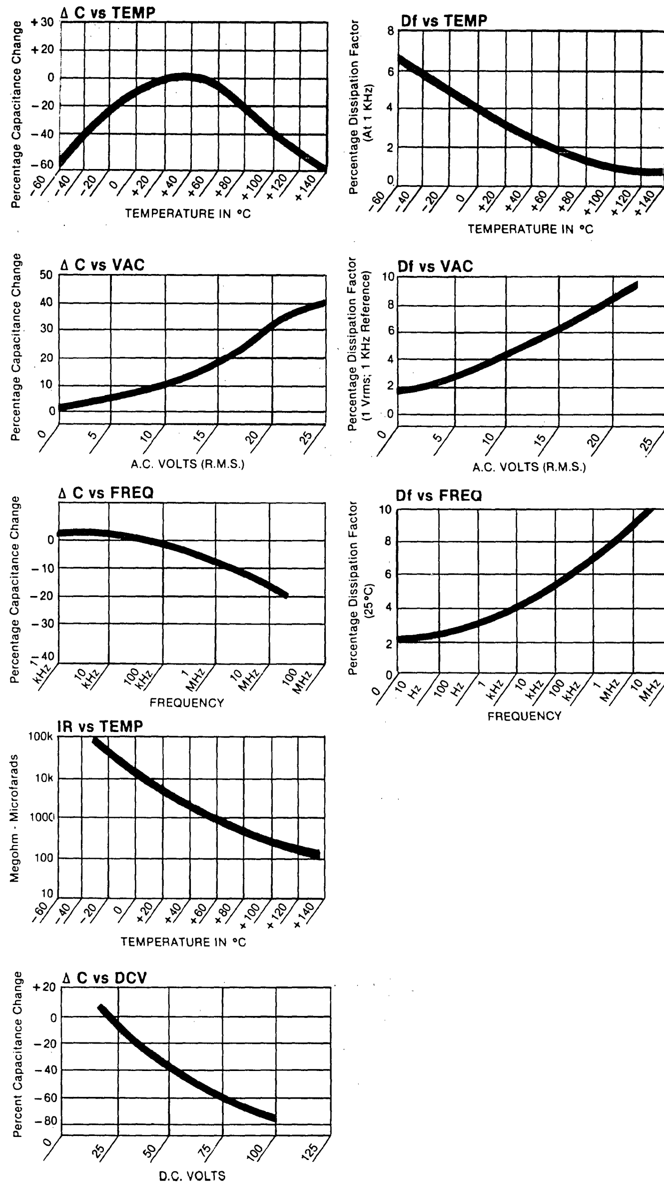
Z5U — CHARACTERISTIC

Unitrode's Z characteristic is a Class 2 dielectric material suited for room temperature applications. Typical applications are bypass and decoupling.

Performance Data

Temperature Characteristic	ΔC +22% −56% max from +10°C to +85°C
Operating Temperature Range	−55°C to +85°C
Dissipation Factor @ 25°C	4.0% max @ .3 VRMS @ 1KHz
Insulation Resistance @ 25°C With Rated Voltage Applied	100,000 megohms or 1000 megohm microfarads whichever is less
Insulation Resistance @ 85°C With Rated Voltage Applied	10,000 megohms or 10 megohm microfarads whichever is less
Dielectric Strength	250% of rated voltage below .5 mfd; 200% of rated voltage .5 mfd and above
Aging Rate	Typically 4% per decade hr. 6% max.
Life Test	1.5 × rated voltage @ 85°C, 1000 hrs.
Available Tolerances	±20%, +80%, −20%, GMV

Typical Performance Curves



CAPACITOR DESIGNERS' GUIDE

Unitrode capacitors provide optimum performance and dependability at the lowest possible cost. Capacitor chips are manufactured in our modern facility in San Diego, California, where advanced research programs are continually developing ways to improve ceramic formulations. Chips are encapsulated and sealed in our Methuen, Massachusetts facility, utilizing techniques that have made Unitrode a leading supplier of glass silicon switching diodes.

TEST SPECIFICATIONS

Unitrode conducts the following tests on all production lots. The tests are monitored or conducted and controlled by the Quality Assurance Department to assure the specification and test limit integrity is maintained.

CAPACITANCE: Capacitance is checked on 100% of each shipment lot with a final check on an AQL basis. Test conditions for NPO, X7E, and X7R dielectrics are 1 VRMS ±.25 VRMS and .3 VRMS for the Z5U.

DISSIPATION FACTOR: This parameter is also checked on a 100% basis. The limits are .1% for NPO, .5% for X7E, 2.5% for X7R and 4% for Z5U.

DIELECTRIC WITHSTANDING VOLTAGE: All dielectrics are tested at 250% of rated voltage with charging current limited to 50 mA maximum.

INSULATION RESISTANCE: Capacitors are tested to an AQL level at rated voltage for a maximum two minute charging time. All dielectrics are required to meet 100,000 megohms or 1000 megohm microfarads whichever is the lesser of the two.

All above specifications are at room temperature and humidity. Specific details are given for each dielectric under the Dielectric Characteristics Information Section.

HIGH RELIABILITY: All Unitrode product is manufactured to meet or exceed MIL-C-55681, MIL-C-11015 and MIL-C-39014 and Unitrode is prepared to offer for a nominal charge, units screened to the following specifications:

Test	MIL-STD-202 Method	Condition	Test Conditions
Burn-In	108	A	200% of rated voltage @ +125°C for NPO, X7E, and X7R dielectrics. 150% of rated voltage @ +85°C for Z5U dielectric; for 96 hours.
Dielectric Withstanding Voltage	301	—	250% of rated voltage for NPO, X7E, X7R and Z5U dielectric with charging current limited to 50mA.
Insulation Resistance	302	—	Rated voltage applied for 2 minutes maximum.
Thermal Shock	107	B	Exposure at temperature extremes for 30 minutes.
Capacitance	305	—	NPO, X7E, and X7R dielectrics; 1 VRMS ±.25 VRMS @ 1KHz. Z5U dielectric; .3 VRMS @ 1KHz.
Dissipation Factor	305	—	NPO, X7E, and X7R dielectrics; 1 VRMS ±.25 VRMS @ 1KHz. Z5U dielectric; .3 VRMS @ 1KHz.

XIV

Monolithic Ceramic Chip Capacitors

Unitrode Corporation has applied to monolithic ceramic capacitors the same dedication to product excellence achieved in semiconductors. In our goal in bringing you something better, design and production innovations derived from a mature technology are utilized in achieving uniformity of a high volume, high yield output and without quality compromise.

HOW TO ORDER

	D	103	K	P	N
SIZE CODE	VOLTAGE	VALUE	TOLERANCE	TERMINATION MATERIAL	TEMPERATURE CHARACTERISTIC

Size code

Ins.	mm.
1- .050 x .040	1.27 x 1.02
2- .080 x .050	2.03 x 1.27
3- .100 x .050	2.54 x 1.02
4- .150 x .050	3.81 x 1.02
5- .125 x .095	3.18 x 2.41
6- .180 x .050	4.57 x 1.27
7- .180 x .080	4.57 x 2.03
8- .175 x .125	4.45 x 3.18
9- .250 x .225	6.35 x 5.72

Voltage
C = 25VDC
D = 50VDC
E = 100VDC
F = 200VDC

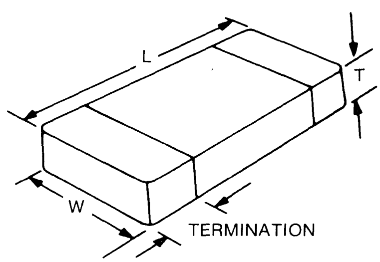
Value
Capacitance Value in pF (EIA Code)

Tolerance
C = ± .25pF (1pF-10pF)
D = ± .5pF (1pF-10pF)
F = ± 1%
G = ± 2%
J = ± 5%
K = ± 10%
M = ± 20%
Z = +80%, −20%

Termination material
A = Ag
B = PdAg
C = Solder Coat
(604 Ag STANDARD)

Temperature characteristic
N = NPO
X = X7R
Z = Z5U

MECHANICAL SPECIFICATIONS



SIZE	1		2		3		4		5		6		7		8		9	
	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.	ins.	mm.
L.	.050	1.27	.080	2.03	.100	2.54	.150	3.81	.125	3.18	.180	4.57	.180	4.57	.175	4.45	.250	6.35
W.	.040	1.02	.050	1.27	.050	1.27	.050	1.27	.095	2.41	.050	1.27	.080	2.03	.125	3.18	.225	5.72
T. MAX.	.040	1.02	.050	1.27	.050	1.27	.050	1.27	.060	1.52	.060	1.52	.050	1.27	.060	1.52	.060	1.52
Termination	.010	.25	.020	.51	.020	.51	.030	.76	.020	.51	.030	.76	.030	.76	.030	.76	.030	.76

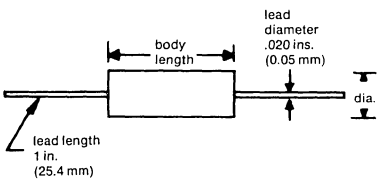
CAPACITANCE RANGES
CAPACITOR VALUE VS CHIP SIZE
MAXIMUM CAPACITANCE/VOLTAGE/CHIP

	NPO (COG)			X7R (BX)			Z5U (General Purpose)		
SIZE	**50V**	**100V**	**200V**	**25V**	**50V**	**100V**	**25V**	**50V**	**100V**
1	390pF	220pF	150pF	.01mF	6800pF	3300pF	.039mF	.027mF	.012mF
2	100pF	680pF	220pF	.033mF	.022mF	.01mF	.12mF	.082mF	.033mF
3	1500pF	820pF	560pF	.047mF	.027mF	.012mF	.15mF	.1mF	.039mF
4	2700pF	1800pF	1000pF	.082pF	.056mF	.027mF	.33mF	.22pF	.082mF
5	4700pF	3300pF	1800pF	.12mF	.082mF	.039mF	.56mF	.39mF	.15mF
6	3900pF	3700pF	1200pF	.12mF	.082mF	.039mF	.39mF	.27mF	.1mF
7	8200pF	5600pF	3900pF	.33mF	.22mF	.1mF	.82mF	.56mF	.22mF
8	.015mF	.01mF	5600pF	.47mF	.33mF	.18mF	1.0mF	.68mF	.27mF
9	.033mF	.018mF	.012mF	1.0mF	.68mF	.33mF	1.8mF	1.2mF	.47mF

CAPACITOR DESIGNERS' GUIDE

Glass-Sealed Axial Leaded Ceramic Capacitors

MECHANICAL SPECIFICATIONS



HOW TO ORDER

STYLE	PACKAGE			EIA CAPACITANCE CODE	TOLERANCE	VOLTAGE	TEMPERATURE CHARACTERISTIC
		ins.	mm.				
CG	A	.170 X .075	4.32 X 1.91	Capacitance	F =±1%	C=25	N=NPO
	B	.170 X .100	4.32 X 2.54	Value	G =±2%	D=50	X =X7R
	C	.200 X .100	5.08 X 2.54	in	J =±5%	E=100	Z =Z5U
	D	.260 X .100	6.60 X 2.54	pF	K =±10%	F=200	
	E	.300 X .100	7.62 X 2.54		M=±20%		
	F	.400 X .150	10.16 X 3.81		Z =+80%, -20%		
	*G	.300 X .150	7.62 X 3.81		V =GMV		

*Consult factory for values and voltages.

CAPACITOR VALUE VS PACKAGE

MAXIMUM CAPACITANCE/
VOLTAGE/PACKAGE

	NPO (COG)			X7R (BX)			Z5U (General Purpose)		
PKG	50V	100V	200V	25V	50V	100V	25V	50V	100V
A	330pF	150pF	68pF	.012mF	1200pF	1000pF	.039mF	.027mF	.01mF
B	560pF	680pF	220pF	.033mF	.022mF	.01mF	.082mF	.068mF	.022mF
C	1200pF	820pF	330pF	.047mF	.027mF	.012mF	.15mF	.12mF	.056mF
D	2700pF	1500pF	680pF	.082mF	.047mF	.022mF	.22mF	.18mF	1mF
E	4700pF	2200pF	1200pF	.15mF	.12mF	.039mF	.39mF	.27mF	.15mF
F	.01mF	5600pF	3300pF	.27mF	.22mF	.056mF	1.5mF	1.0mF	.27mF

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APPLICATION NOTES & DESIGN NOTES XV

APPLICATION AND DESIGN NOTES

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PROGRAMMABLE UNIJUNCTION TRANSISTORS

INTRODUCTION

The Programmable Unijunction Transistor is today's preferred device for low cost timing circuits, oscillators, sensing circuits, and a wide range of other applications where a variable voltage level threshold is desired. This note describes the principle of operation of the PUT, its electrical characteristics, and its various applications.

PRINCIPLE OF OPERATION

The PUT is a three-terminal device as shown in the schematic representation, Fig. 1a. The anode voltage V_A and the gate voltage V_G are measured with respect to the cathode (k). The corresponding anode, gate and cathode currents are given respectively by I_A, I_G, and I_K. The most general usage of a PUT involves an external gate resistor R_G as shown in Fig. 1a. Hence, the voltage generally referred to in characterizing PUT's is the applied voltage V_S rather than the gate voltage V_G which is less than V_S by the voltage drop across R_G.

The theory of operation of the PUT can perhaps be best understood by considering that it is a four-layer (PNPN) device, as is a silicon-controlled rectifier (SCR). The basic PUT structure is shown in Fig. 1b, in which it is noted that the gate is adjacent the anode, in contrast to an SCR in which the gate lead is adjacent the cathode. As shown in Fig. 1c, the PUT, has a two-transistor analogy, which is similar to that used to explain the operation of an SCR, except that the gate connection is common to the PNP base and the NPN collector. Regenerative switching occurs when the sum of the alpha's dynamically approach unity. The net result is that when the anode voltage exceeds the gate voltage by an amount equal to the emitter to base drop of the PNP transistor, the positive feedback drops the anode-cathode voltage and presents a negative resistance.

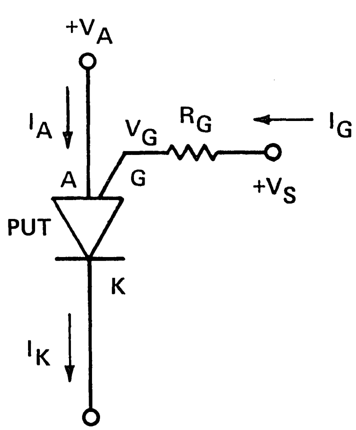

Figure 1a. PUT Parameters

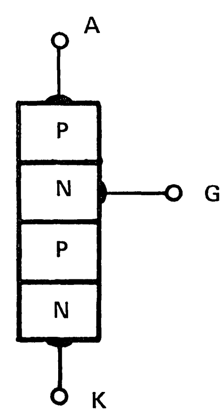

Figure 1b. PUT Structure

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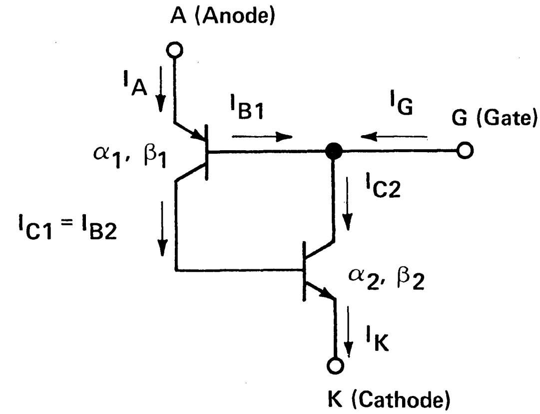

Figure 1c. Two Transistor Analogy

ANODE CHARACTERISTIC

The PUT, together with R_G as shown in Fig. 1a, exhibits a negative resistance characteristic illustrated in Fig. 2 for a fixed value of V_S and R_G. For anode voltages less than the peak voltage V_P at which a current I_{GA} flows. (Region I), a positive incremental resistance results. For anode currents above the valley current I_V, which occurs at the valley voltage V_V (Region III) a positive incremental resistance also occurs. However, for anode currents between the peak point current I_P and the valley current I_V (Region II) the incremental resistance is negative. This region is unstable and forms the basis for use in oscillator circuits. With V_A less than V_S forward anode current flows. At the peak current point, I_P where V_A exceeds V_P the PUT will regeneratively switch to its low impedance state: anode current increases rapidly to a level limited by external load resistance. The PUT will remain on this "ON STATE" until the anode current is reduced to a level below the valley current, I_V. At this point the PUT returns to its blocking or "OFF STATE", because operation in the negative region is unstable. Operation in the region between I_D and I_V will be covered in detail.

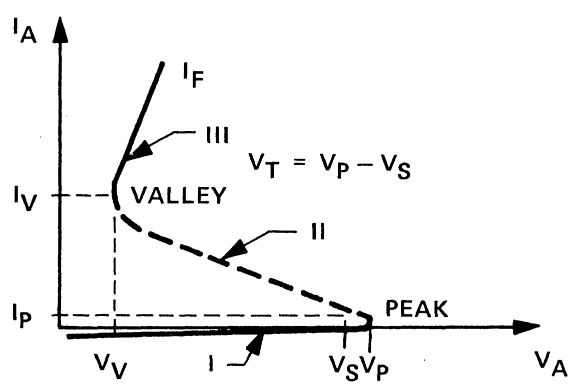

Figure 2. PUT Characteristics

ADVANTAGES

The primary advantage of the PUT over the UJT is the programmability of operating parameters such as peak point current (I_p), valley current (I_V), and offset voltage (V_T), which is defined as

$$V_T = V_P - V_S \tag{1}$$

These are easily programmed over a range by the choice of circuit components. Shown in Fig. 3 are the relationships between I_P and I_V vs stand off voltage (V_S) and gate source impedance (R_g). As observed from Fig. 3, operation at higher voltages allow a greater spread between I_P and I_V. The significance of this becomes apparent in applications where the negative resistance (Region II, Fig. 2) must be large and must remain relatively broad over a temperature range.

Other advantages of the PUT over the UJT are:

1. Lower current drain through R_1 and R_2; the UJT required several milliamperes of current, The PUT micro amperes of current.
2. Lower peak point current of the PUT allows use of larger R_t (timing resistor) therefore, the C_t may be smaller for the same time delay hence, lower in cost. Lower capacitance values also result in lower leakage current and lower temperature coefficient.
3. Higher efficiency is available due to greater energy transfer from the capacitor to the load. The on state voltage (V_F) is considerably lower for a PUT than for a UJT.
4. High or low operating voltages may be used; V_S as low as 2V or greater than 40V will operate the PUT.
5. The PUT has an overall extended operating range due to programmability of I_P and I_V.
6. Greater uniformity of triggering point. Stand off ratio η is not determined by manufacturing tolerance.

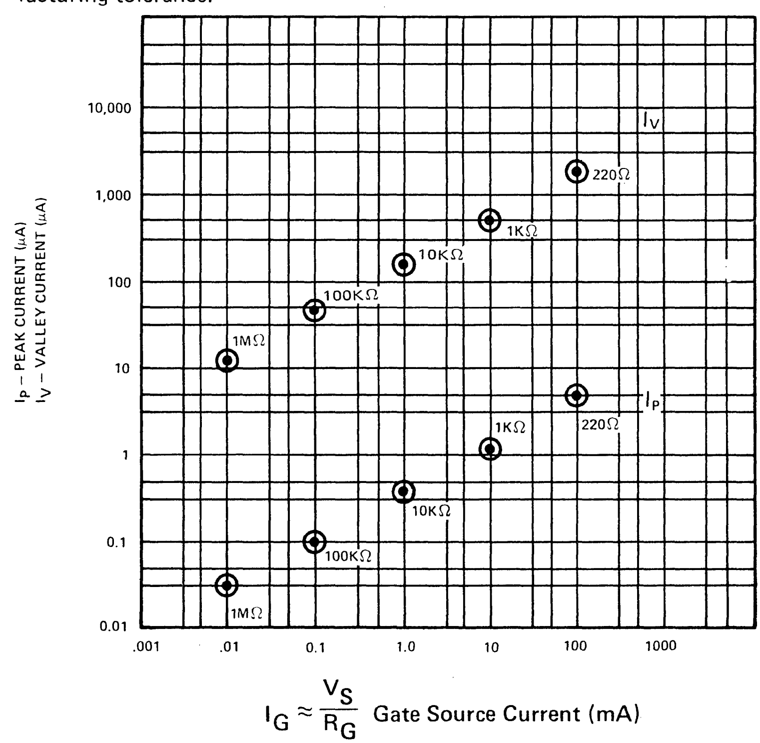

Figure 3.

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BASIC PUT OSCILLATOR

An analysis of the basic PUT oscillator demonstrates the inter-relationship of parameters. From Fig. 4b, the voltage Va changes at a rate determined by the R_tC_t charging path. When the PUT is operating in Region I, the anode voltage is given by

$$V_a = V_{BB}\,(1-e^{-t/R_tC_t}) \quad (2)$$

The standoff voltage is related to the supply voltage V_{BB}

$$V_S = \eta V_{BB} \quad (3)$$

where

$$\eta = \frac{R_1}{R_1 + R_2} \quad (4)$$

Triggering is accomplished when the voltage on the capacitor reaches the standoff voltage V_S; plus the offset voltage V_T, i.e.

$$V_{BB}\,(1-e^{-t/R_tC_t}) - V_T = \eta V_{BB} \quad (5)$$

The switching time occurs at

$$t = R_tC_t\,\ell n \left(\frac{1}{1-\eta-\frac{V_T}{V_{BB}}} \right) \quad (6)$$

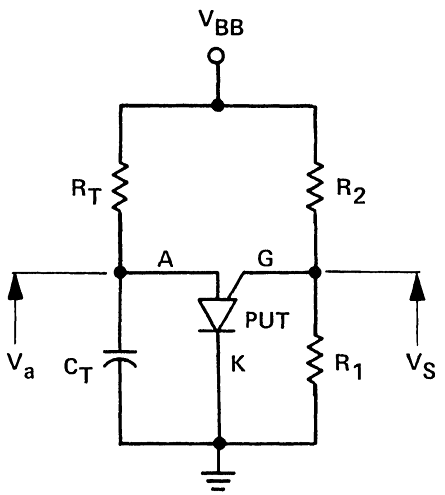
V_T varies only slightly with temperature having a temperature coefficient of about 2.5 mv/^{o}C.

Advantages of the PUT over the UJT are readily observed by comparing their operation in a simple relaxation oscillator circuit. Figure 4a shows a typical UJT oscillator with the simplified UJT model. In the off state the resistance ratio at the intersection of r_1 and r_2 is a fixed value represented by η (intrinsic stand off ratio). This ratio which determines the device triggering voltage is established in the manufacturing process by the resistance of the silicon material and the diode contact. Manufacturing tolerance result in values of η which typically range in value from about 0.4 to 0.9. Replacing the UJT with a PUT results in stable operation in any given circuit (Fig. 4b). The parameter stand-off ratio η is now established exclusively by setting the value of R_2 and R_1 and remains relatively temperature stable. I_P and I_V are controlled by gate source resistance R_g and stand off voltage V_S (Fig. 3). A detailed discussion of the PUT oscillator will be given.

Typical UJT Oscillator

UJT Model

Figure 4a.



$\eta = \frac{R_1}{R_1 + R_2}$	Standoff Ratio	
$V_S = \eta V_{BB}$	Standoff Voltage	
$V_T = V_P - V_S$	Offset Voltage	
$R_G = \frac{R_1 R_2}{R_1 + R_2}$	Gate Source Resistance	(7)

Fig. 4b

CONDITIONS FOR OSCILLATION

Switching on takes place at the peak point (I_P) switching off requires that current through the PUT be less than the valley current (I_V). Therefore, the load line must intersect the characteristic curve in the negative resistance region Fig. 5 and must be above the I_P point.

CONDITION FOR SUSTAINED OSCILLATION

$$\frac{V_{BB} - V_P}{R_T} (max) > I_P (max)$$

This condition insures current levels greater than the I_P (8)

$$\frac{V_{BB} - V_V}{R_T} < I_V$$

This condition insures current levels lower than the I_V (9)

$$1 - \eta >> \frac{V_T}{V_{BB}}$$

This condition insures more stable operation. (10)

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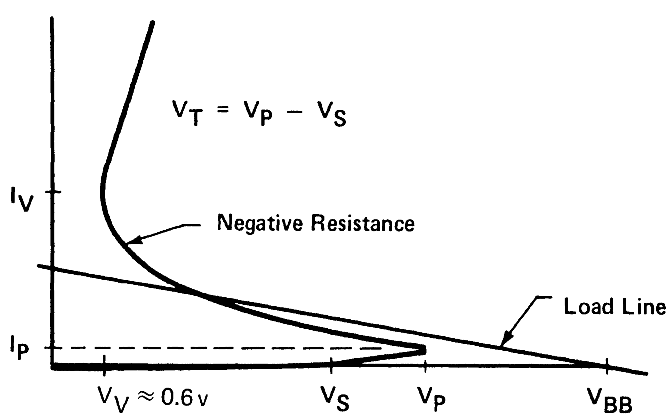

Figure 5. Offset Voltage

CONDITIONS FOR ONE SHOT OPERATION

$$\frac{V_{BB} - V_P}{R_T} > I_P \text{ (max)} \qquad \frac{V_{BB} - V_V}{R_T} > I_V$$

must be satisfied. Since the load current is in the positive resistance region, the PUT will LATCH on and remain on.

PUT OFFSET COMPENSATION

In order to compensate for offset voltage (V_T) temperature shift, a diode D_1 forward biased through R_D may be used Fig. 6. The value of R_D is selected by:

$$R_D = \frac{V_{BB}}{I_P \text{ (max)}}$$

A diode having a forward voltage temperature characteristic similar to the offset voltage temperature coefficient (TC) would provide optimum compensation.

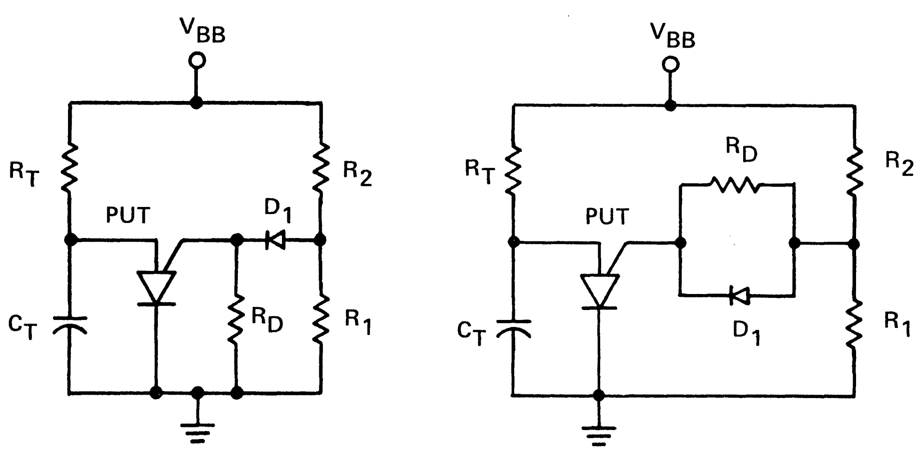

Figure 6. Offset Compensation Methods

TUNABLE FREQUENCY OSCILLATORS

Variable oscillator circuits which include active elements for discharging the timing capacitor C_T are shown in Fig. 7. A second method is given as in Fig. 8.

FREQUENCY RANGE
40 Hz to 65 kHz

OUTPUT PULSE

Rise time ~ 200 nsec.
Pulse width ~ 10 μsec.
Recovery time < 200 nsec.

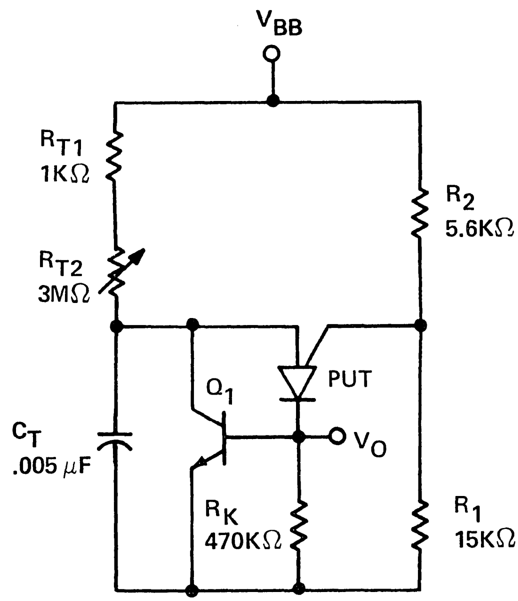

Fig. 7

FREQUENCY RANGE
40 Hz to 40 kHz

OUTPUT PULSE

Width ~ 5 μsec.

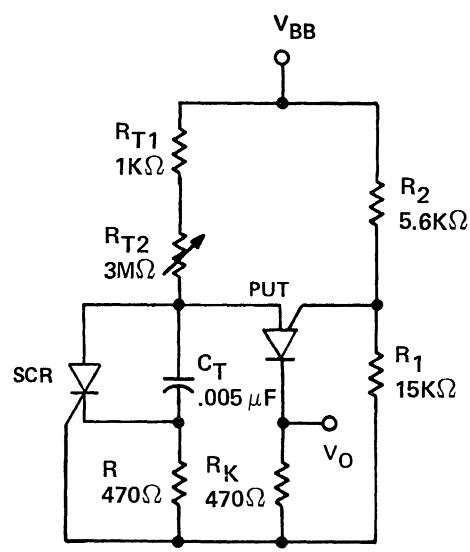

Fig. 8

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DESIGN EXAMPLE

A relaxation oscillator. A trigger generator is needed to provide a pulse of energy.

The required repetition rate is 1000 pulses per second. A power source of 20 Vdc is available.

Step 1 Select the value of R_1 and R_2 based on Ip, I_V requirements. For R_G = 10KΩ, (Fig. 3) R_1 ~ 27KΩ, R_2 ~ 16KΩ this will give an η of ~ 0.63. (Equations 7 and 4).

Step 2 From Fig. 9 with T given as 0.001 sec and η of 0.63. R_tC_t = 0.001, T/R_TC_T = 1 @ η = 0.63.

Step 3 The condition for sustained oscillation must be satisfied (equations 8 and 9) hence, 275K < R_t < 1.4 meg (using spec values for a 2N6027).

Step 4 The value of capacitance is chosen by considering the rise time and energy required. Since R_TC_T = 0.001 the C_T range is 0.0007 < C_T < 0.0036μfd. Choose a standard value of capacitance and resistance. For example, C_T = 0.002μfd and R_T = 470KΩ (Standard Value).

For this example R_t = 470KΩ, C_t = 0.002μfd. A cathode resistance of 20Ω will provide a pulse of current of 130 ma with a pulse width of 300 nsec.

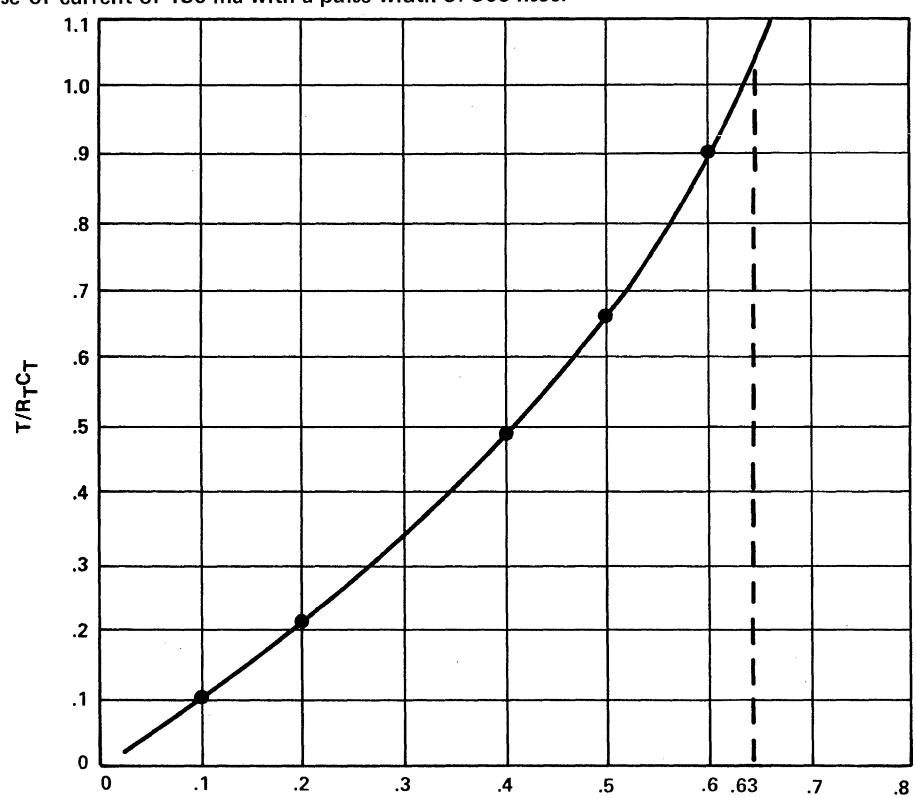

Fig. 9

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SWITCHING REGULATOR DESIGN GUIDE

I. The Advantages of the Switching Regulator

Unlike conventional "dissipative" series or shunt regulators, in which the power-regulating transistor operates in a continuous-conduction mode, dissipating large amounts of power at high load currents – especially when the input-output voltage difference is large – the switching regulator has high efficiency under all input and output conditions. Furthermore, since the power-transistor "switch" is always either cut off or saturated (except for a very brief transition between those two states), the switching regulator can achieve good regulation despite large changes in input voltage, and maintains high efficiency over wide ranges in load current.

Because the switching regulator regulates by varying the ON-OFF duty cycle of the power-transistor switch, and the switching frequency can be made very much higher than the line frequency, the filtering elements used in the power supply can be made small, lightweight, low in cost, and very efficient – i.e., with almost negligible power losses. It is possible to drive the switching regulator with very poorly filtered DC (in fact, in high-power applications, three-phase rectification *without* filtering of any kind is often used to develop the input DC from the power line), thereby eliminating large and expensive line-frequency filtering elements.

Finally, it is possible to design switching regulators with excellent load-transient properties, so that step increases of load current cause relatively small instantaneous changes in output voltage, recovery from which is essentially completed in a few hundred microseconds.

The switching regulator has become increasingly popular in new-equipment designs, not only in aerospace and defense applications, but in computers, industrial process control systems, instrumentation, and communication.

Compared to the dissipative regulator, the switching regulator does have some disadvantages which preclude its use in some applications. The primary power source delivers current to the switching regulator in pulses which, for efficiency reasons, have short rise and fall times. In those applications where a significant series impedance appears between the supply and the regulator, the rapid changes in current can generate considerable noise. This problem can be reduced by reducing the series impedance, increasing the switching time, or by filtering the input to the regulator.

A second problem of the switching regulator, compared to the dissipative regulator, is its response time to rapid changes in load current. The switching regulator will reach a new equilibrium only when the average inductor current reaches its new steady-state value. In order to make this time short, it is advantageous to use low inductor values, or else to use a large difference between the input and output voltage.

Improved circuits for controlling switching regulators have been developed at Unitrode, thereby eliminating some earlier design constraints and optimizing the performance attainable with available hardware. These new circuits permit taking full advantage of the economy and efficiency of the Unitrode PIC600 Series Hybrid Power Switch.

The design approach used herein is believed to be original, and to be clearly superior to earlier methods of calculating the key parameters and designing the power inductor . . . yielding explicit, accurate results in significantly less time than the approximate equations in common use.

II. The Switching Regulator Described and Characterized

The basic configuration of a switching regulator is shown in Figure 1. It accepts a DC voltage input, Ein, and regulates a DC ouput voltage, Eo, despite variations in Ein and load current. Although the static regulation, dynamic regulation, and ripple rejection of this type of regulator cannot be as easily optimized as they can in a continuous (so-called "dissipative") series regulator, its efficiency, power density (Watts output per cubic inch) and economy are all markedly superior to the series regulator . . . particularly for low-voltage, high-current supplies. Unlike a series regulator, it maintains high efficiency with high input voltages. Switching regulators can thus be employed with high efficiency to derive low voltage outputs from a high voltage unregulated supply.

All of these advantages derive from the method of regulating the output voltage: *by varying the duty cycle of a power-transistor switch,* rather than varying the voltage drop across a power transistor operating in the linear mode. Because the switch (Q1 in Figure 1) is always in the saturated state when it is conducting, and is otherwise completely non-conducting (except for a brief commutation time between the ON and OFF states), the power dissipated in the regulator is much lower than it would be in a series regulator for the same input and output conditions.

The basic switching regulator circuit functions as follows:

The control circuit causes transistor switch, Q1, to switch on and off at a predetermined frequency, f. During the time that Q1 is on, t_{on}, the input voltage, Ein, is applied to the input of the LC filter, causing current i_1 to increase. When Q1 is off, the energy stored in the inductor, L, maintains current flow to the load, circulating through "catch" diode D1. The input of the LC filter is now at zero Volts, i_1 decreases to its original value and the cycle repeats.

The output voltage, Eo, will equal the time average of the voltage at the input of the LC filter:

$$Eo = Ein\ t_{on}/\tau$$

where: $\tau = 1/f$

The control circuit senses and regulates Eo by controlling the duty cycle, $\alpha = t_{on}/\tau$. If Ein increases, the control circuit will cause a corresponding reduction in the duty cycle, α, so as to maintain a constant Eo.

$$Eo = \alpha\ Ein$$

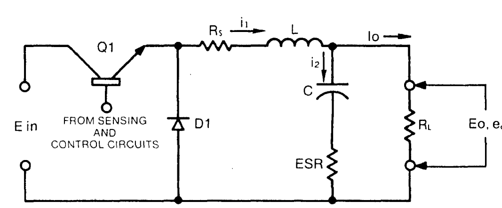

Figure 1. Switching Regulator Basic Configuration

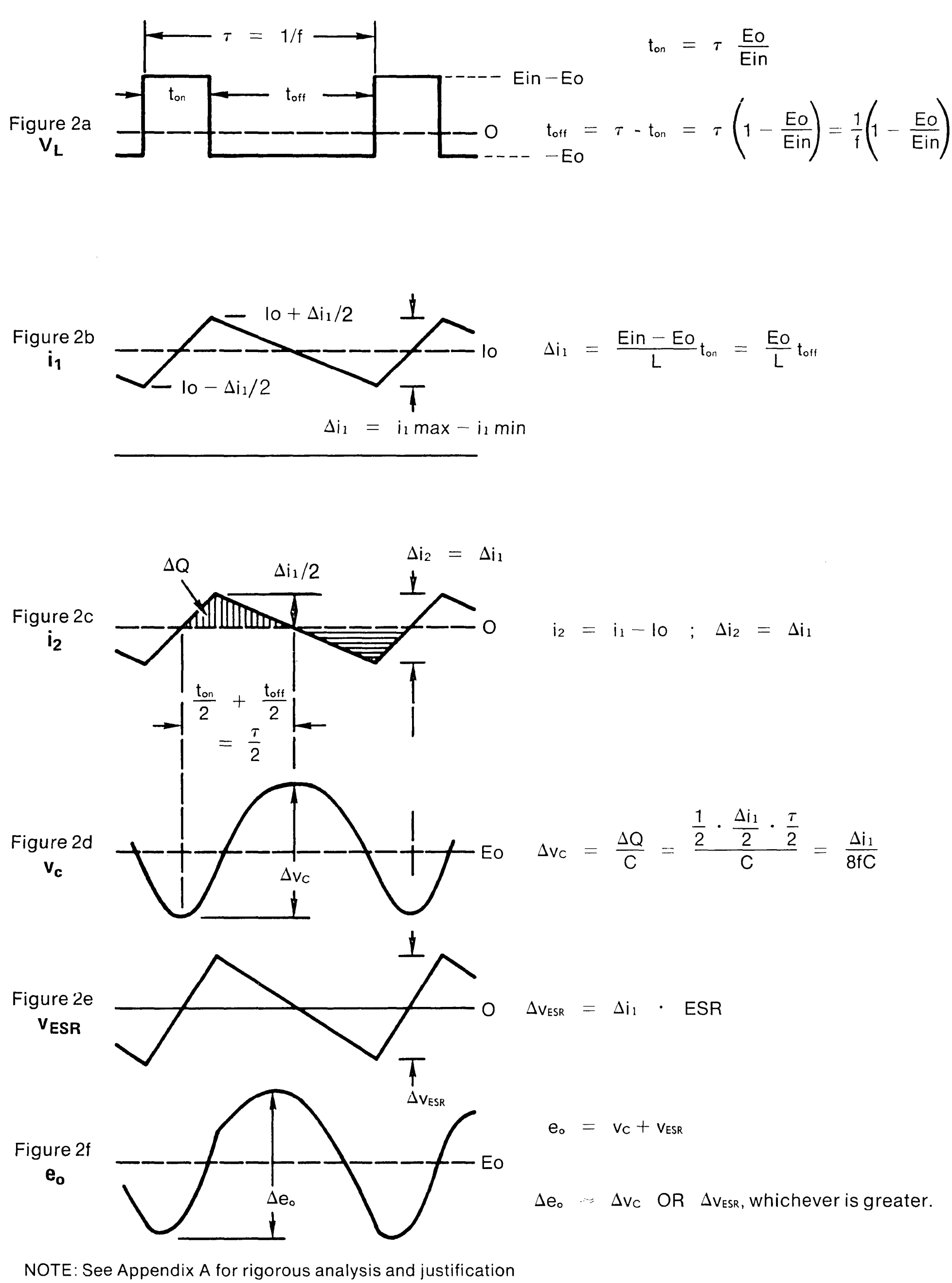

Figure 2. Switching Regulator Waveforms

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Figure 2 shows some of the important waveforms and equations which define the operation of the switching regulator power circuit. The following discussion is based on several simplifying assumptions which are explained and justified or corrected in Appendix A. The most significant assumptions are to neglect the saturation voltage of Q1, the forward drop of D1, and the series loss resistance, R_S, of the inductor, L.

Figure 2a shows the voltage across inductor, L, which equals (Ein − Eo) during t_{on} and (−Eo) during t_{off}. Under equilibrium conditions, when output load current, Io, is constant, the average voltage across L must, by definition, equal zero.

Figure 2b shows the current i_1 through the inductor. Under equilibrium output current conditions, the increase in current during t_{on}, Δi_1, must equal the decrease in current during t_{off}. The average value of i_1 equals the output current, Io.

Figure 2c shows current i_2 through the capacitor, which is equal to (i_1 − Io). The average value of $i_2 = 0$, and $\Delta i_2 = \Delta i_1$. Current i_2 causes a ripple voltage to appear at the output. The output ripple voltage, e_o, has two components, a capacitive component, v_C, and a resistive component, v_{ESR}, caused by the equivalent series resistance of the capacitor.

Figure 2d shows the capacitive component, v_C, of the ripple voltage, which is the time integral of the capacitor current, i_2. Note that v_C is the integral of a triangular wave, and is not sinusoidal. Also note that v_C is in "quadrature" with i_2, in the sense that v_C min and v_C max occur at times A and B, midway in the t_{on} and t_{off} intervals, when i_2 is zero. The total charge, ΔQ flowing into C is computed graphically by finding the area of the triangular current waveform between time A and time B (Area = ½ bh; $\Delta Q = ½ \times \tau/2 \times \Delta i_2/2$). The peak to peak capacitive ripple component $\Delta v_C = \Delta Q/C = \Delta i_1/8fC$. (The factor 8f for a triangular current waveform is comparable to $2\pi f$ for a sinusoidal input current.)

Figure 2e shows the resistive component, v_{ESR}, of the ripple voltage which simply equals $i_2 \times$ ESR, and is in phase with i_2.

Figure 2f, the total output ripple voltage, e_o, is the sum of the waveforms in Figures 2d and 2e. Note that since v_C and v_{ESR} are in quadrature, the greater of these two components dominates, and for all practical purposes the peak to peak output ripple voltage, Δe_o, is equal to either Δv_C or Δv_{ESR} whichever is greater.

The magnitude of v_{ESR} in comparison with v_C shown in these waveforms is not exaggerated. Indeed, when designing a switching regulator to operate at frequencies greater than 20 kHz in order to achieve small size and low cost in the L and C filter elements, the ESR of the capacitor usually dominates completely. Even when high quality capacitors (low ESR) are employed, it is usually necessary to use a larger capacitance value than would otherwise be required in order to realize the ESR required to achieve the ripple objective of the design.

With conventional free running switching regulator control circuits, capacitor ESR also causes very significant departure from the design frequency, which can result in large ripple magnitude, inductor saturation, and switching transistor failure. In the circuits developed at Unitrode and presented in the next section, the frequency-variation effect caused by ESR is effectively eliminated, leaving only the ripple consideration.

Detailed design considerations for switching regulator power circuits are contained in Section IV.

III. Applications Circuits for Switching Regulators

The design and performance of conventional switching regulators are usually dominated by the ESR of the output capacitor. However, in the group of circuits described in this section, the following parametric relationships and circuit characteristics are easily and economically attained:

- The switching frequency may be selected and established at the optimum value for the switching components, and *will be independent of the value of the ESR of the output capacitor.*
- The value of t_{off} is held relatively constant, over wide ranges of load current and input voltage, and independent of the ESR of the output capacitor. Constant t_{off} results in constant ripple current and output ripple voltage.
- Settable overcurrent limiting is provided, thereby protecting both the load and the switching transistors under all conditions, and preventing saturation of the power inductor during the startup transient period, thereby minimizing startup overshoot.
- The overcurrent limiting circuit is significantly lower in dissipation than conventional current-limit-feedback arrangements.
- The drive current to the power output (switch) stage is regulated to a pre-determined value, for best efficiency and optimum switching speed. Drive current is automatically increased at low temperatures and decreased at high temperatures, thereby maintaining optimum drive conditions for the power switch.

Note that, although the use of this circuit approach permits essentially constant "t_{off}" operation even with capacitors having relatively high ESR, the output ripple voltage is increased by high ESR. (If the ripple developed across ESR is significantly larger than that developed across C, then the ripple is essentially proportional to ESR.)

Not all of the circuits that follow have all of the virtues listed above, but the exceptions will be noted. Figure 3 typifies this family of regulators. It is shown implemented by the popular LM305 regulator IC, and a Unitrode Series PIC600 Hybrid Power Switch, comprising a quasi-Darlington switching transistor, a fast recovery catch diode, and transistor bias resistors, all matched for optimum efficiency and switching speed (up to 100 kHz without derating). The configuration of Figure 3 is a *positive* output regulator, with performance characteristics as follows:

Ein = 20 to 40V

Eo = 5V ± 1%

Δe_o = 100 mV p-p (2% p-p ripple)

Io = 2 to 10A

Isc = 12A

Regulation versus Ein (20 to 40V) <25 mV

Transient Recovery Time for step change in load current from 2A to 10A, or 10A to 2A <150 μsec.

f = 50 kHz nominal

Efficiency >70%

The circuit of Figure 3 operates in the fixed-off-time mode; hence, output ripple is independent of input voltage over wide ranges. In this circuit, two feedback signal paths are provided:

- *DC Feedback.* A fraction of the DC output voltage, Eo, is fed back to the inverting input of the LM305 through voltage divider R1, R2. The DC voltage at the inverting input is compared to a reference voltage (approximately 1.8V) within the LM305, and the LM305 regulates Eo so that the voltage fed back to the inverting input is essentially equal to the built in reference voltage. The R1, R2 divider ratio therefore establishes the level of the DC output voltage, Eo. Resistor R5 improves output voltage regulation versus input voltage changes by feeding a small compensating voltage proportional to the input voltage into the inverting input of the LM305.

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- *AC Feedback.* Capacitor C1 feeds back an AC voltage waveform to the inverting input of the LM305. This voltage is proportional to the output ripple voltage plus the AC voltage developed across R_l, $\Delta e_o + \Delta v_{Rl}$.

  Capacitor C2 feeds back an AC voltage to the non-inverting input of the LM305. This voltage is proportional to the output ripple voltage plus the AC voltage across R3, $\Delta e_o + v_{R3}$.

When the circuit values are properly established, the same fraction of Δe_o is fed back to both inverting and non-inverting inputs, thereby effectively cancelling. The operation of the switching regulator is thus rendered independent of the output ripple voltage developed across the C or ESR of the output capacitor.

Since the Δe_o components cancel each other, the LM305 essentially compares Δv_{Rl} at the inverting input to Δv_{R3} at the non-inverting input. Voltage Δv_{R3} is a rectangular waveform with a peak-to-peak amplitude equal to I drive × R3, where I drive is the base drive to the hybrid switching transistor provided by the LM305, and Δv_{Rl} is a triangular waveform with a peak-to-peak amplitude equal to $\Delta i_1 \times R_l$, where Δi_1 is the ripple current through inductor L. When the drive current is on, Δv_{R3} is at its peak positive amplitude. As i_1 increases, v_{Rl} increases proportionately. When the positive amplitude of Δv_{Rl} reaches Δv_{R3}, this causes the LM305 to switch off the drive current, Δv_{R3} immediately drops to its peak negative amplitude, and i_1 starts to fall. When Δv_{Rl} reaches a negative amplitude equal to Δv_{R3}, the LM305 switches the drive current back on, and the process repeats. In this manner, the LM305 controls the power switch so that Δi_1 is fixed. Since $t_{off} = \Delta i_1 \times L/Eo$, with fixed values of L and Eo, t_{off} is fixed and independent of changes in Ein or capacitor C or ESR values.

R4, connected between pins 1 and 8 of the LM305, establishes the desired level of base drive for the PIC600 Series Hybrid Power Switch, and determines the hysteresis voltage across R3.

Current-limiting action is provided by transistor Q1, the collector of which is connected to the "gate" or "inhibit" terminal of the LM305 (pin 7). When the load current is normal, Q1 is cut off and pin 7 floats; but when the voltage drop across R_l increases to a value greater than the sum of V_{BE} (Q1) and v_{R3}, Q1 turns on, cutting off the drive current from the LM305 and, ultimately, the power switch. This cutoff action is made to "latch" by the fact that, with the drive cut off, v_{R3} disappears. This keeps Q1 on, until the current through R_l drops significantly – enough to make the voltage drop across R_l fall below the V_{BE} of Q1.

The current through R_l, following such an overload cutoff action, falls linearly at the rate of Eo/L. When Q1 is cut off, drive current is restored. The circuit will then continue to switch on and off at a frequency comparable to normal operation, with the average current limited at the design limit, and power dissipation held to safe values.

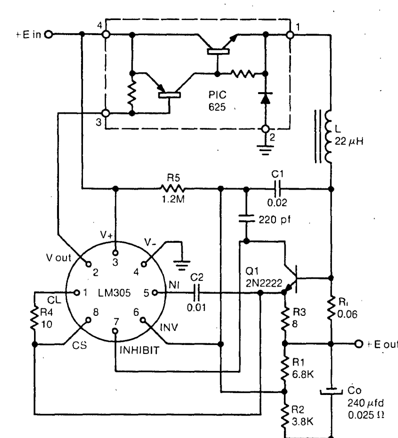

Figure 3. Positive Voltage Switching Regulator

Transient response of the switching regulator of Figure 3 is shown in Figures 4, 5, and 6.

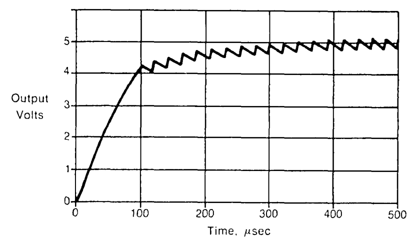

Figure 4. Ein from 0 to 25V

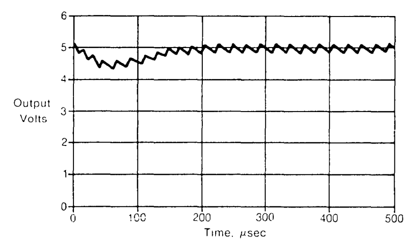

Figure 5. Io from 4A to 10A

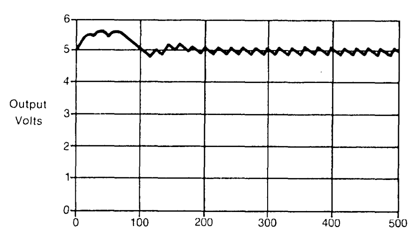

Figure 6. Io from 10A to 4A

It is usually necessary to employ a noise filtering capacitor across the input of any switching regulator. This functions to prevent the steep waveform of the rectangular current pulse associated with the power switch turning on and off from propagating into the Ein supply line. The capacitance value required is a function of the impedance characteristics of the Ein supply and intervening wiring. Watch out for underdamped resonance with the inductance of the input wiring, or transient induced ringing may occur. The input capacitor must have short leads, and the ground side should preferably be connected directly to the ground side of the output filter capacitor.

A 10A negative voltage switching regulator, utilizing an LM304 and PIC600 series, is shown in Figure 7.

A reference voltage is determined by resistor R1 and R2. The error amplifier controls the output voltage at twice the voltage across R2. Diode D1 is used to ensure a potential difference of less than 2V at the unregulated input (pin 5) with respect to the reference supply (pin 3). (If the unregulated supply terminal gets more than 2V positive with respect to reference supply, the collector isolation junction of transistor Q6 of LM304 becomes forward biased and disrupts the reference.)

Current limiting is achieved, in Figure 7, by means of reducing the reference voltage to ground with the help of transistor Q1 and resistor R8, instead of turning off the base drive to the power output switch as in Figure 3.

The functions of the rest of the components and the operation of the switching regulator are the same as described for Figure 3.

A positive switching regulator using a μA723 is shown in Figure 8.

The basic performance and circuit operation is the same as Figure 3.

The circuit shown in Figure 9 is a high voltage positive switching regulator. Because the LM305 (like almost all IC regulators) cannot be operated at supply voltage in excess of 40V, this circuit uses a fraction of Ein as a power supply for the IC circuit by means of zener diode and current limiting resistor R9. The voltage isolation between LM305 and power switch, and the regulated base drive to the power switch are provided by transistor Q2.

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The basic operation of the circuit and design approach is the same as that of a low voltage positive switching regulator.

The circuit shown in Figure 10 is a negative high voltage switching regulator.

This circuit is similar to the low voltage negative switching regulator with a minor modification. Transistor Q2, resistor R10 and R11 are all used to provide regulated base drive to the power output stage and also to provide the voltage isolation between power output stage and LM305. The resistor R9 is used to limit current through zener diode under steady state and startup conditions.

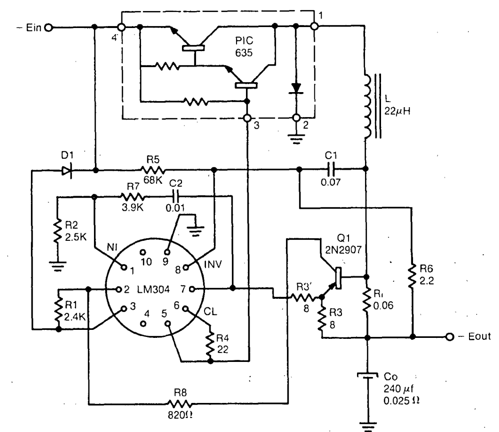

Figure 7. Negative Voltage Switching Regulator

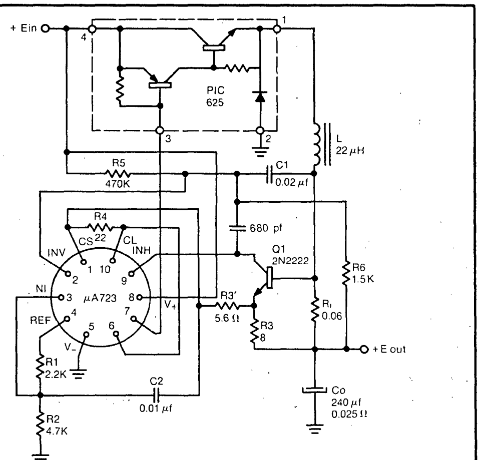

Figure 8. Positive Voltage Switching Regulator

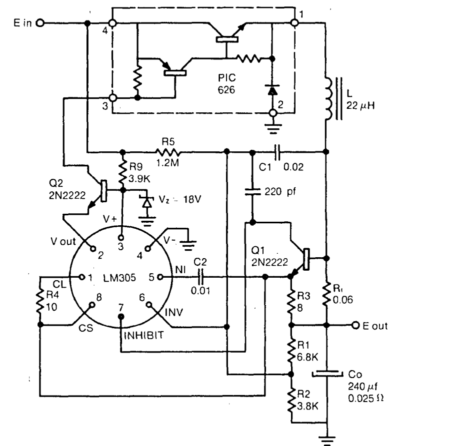

Figure 9. High Voltage Positive Switching Regulator

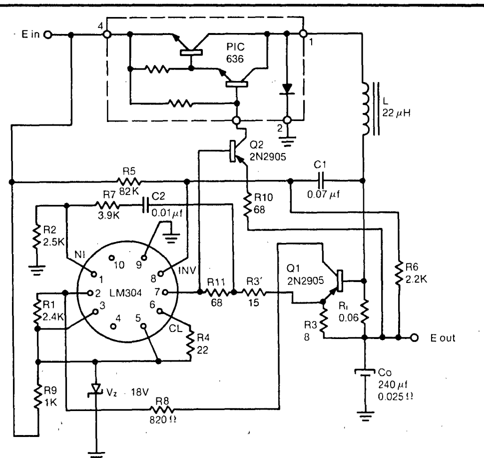

Figure 10. High Voltage Negative Switching Regulator

IV. Designing the Power Circuit

In designing a switching regulator power supply, the following parameters will normally be predefined. Specific values shown for each parameter will be used as the basis for a design example:

Eo	=	5V Output Voltage
Δe_o	=	100 mV Output Ripple Voltage, Peak to Peak
Io max	=	10A Output Current, Full Load
Io min	=	2A Output Current, Minimum Load
Ein max	=	40V Input Voltage, Maximum
Ein min	=	20V Input Voltage, Minimum

The first step in the design is to decide on the operating frequency of the switching regulator. No concrete rules can be given for this decision.

High frequency operation is distinctly advantageous in that the cost, weight and volume of both L and C filter elements are reduced. However, above the frequency where the capacitor ESR exceeds its capacitive reactance, no further reduction in capacitor size or cost will occur. This frequency, in the range of 1-50 kHz, depends upon the "quality" of the capacitor in terms of ESR. Above this frequency, the inductor will continue to diminish in size and cost, although when the inductor reaches a very small size, cost will level off.

Operation above 20 kHz is desirable to eliminate the possibility of audio noise.

The main factor limiting high frequency operation is the drop in efficiency caused by switching losses in the power switching transistor and "catch" diode. The higher cost of these fast switching semiconductors required to operate efficiently at high frequencies must be weighed against the reduced cost, size and weight of the L and C components to arrive at the optimum frequency for any specific application. It may be desirable to work the design through at several frequencies in order to make a decision.

In the specific application defined at the beginning of this section, the power output (Eo × Io max) is 50W. Referring to the specification for the Unitrode PIC 625/635 Hybrid Power Switch, the DC losses (Transistor V_{CEsat}, Diode V_F) under the conditions of this application amount to 10W. The following tabulation shows the switching losses and overall efficiency at several frequencies.

Frequency	**1 kHz**	**20 kHz**	**50 kHz**	**100 kHz**
Power output	50	50	50	50
DC losses	10	10	10	10
Switching losses	0.05	1	2.5	5
Total power input	60.05	61	62.5	65
Realizable efficiency	83.3%	82%	80%	77%

For our example, we will choose a frequency of 50 kHz, even though the efficiency is not significantly reduced at 100 kHz. At 100 kHz most currently available tantalum and aluminum electrolytic capacitors begin to exhibit series inductance.

Transistors and diodes which do not have the fast switching capabilities of the PIC 625/635 will become efficiency limited at much lower frequencies. Note that in this specific application, a dissipative regulator design will incur power losses in the series transistor of 350W, resulting in an efficiency of 12.5 percent!

The control circuits shown in the previous section control the on-off switching periods by sensing and controlling the ripple current, Δi_1, through the inductor L. This mode of operation results in a constant ripple current and (assuming Eo and L are fixed) constant off time, t_{off}, independent of input voltage. The relationship between t_{off}, f, Eo, and Ein is as follows (from Figure 2a):

$$t_{off} = (1 - Eo/Ein) / f$$

With t_{off} and Eo fixed by the control circuit, f will change when Ein changes, and f will be maximum when Ein is maximum. In our specific example,

$$f\,max = 50\text{ kHz}$$
$$Ein\,max = 40\text{ V}$$
$$Eo = 5\text{V}$$

XV

so that:

$$t_{off} = (1 - 5/40) \ / \ 50{,}000 = 17.5\,\mu sec$$

Now, with t_{off} fixed at 17.5 μsec, if Ein changes to Ein min = 20V,

$$f_{min} = \frac{(1 - Eo/Ein)}{t_{off}} = \frac{(1 - 5/20)}{17.5 \times 10^{-6}} = 43 \text{ kHz}$$

The fact that the frequency changes slightly with Ein is really not important, as stated earlier, because constant t_{off} operation results in more constant output ripple than constant frequency operation.

Having determined (or assumed) the maximum operating frequency and calculated t_{off}, we next proceed to find specific values for L and C. L and C together form a low pass filter which reduces the rectangular waveform at the filter input to a DC output voltage, Eo, with a small amount of ripple, Δe_o, superimposed. To achieve a specified Δe_o requires a specific LC product, independent of load current. Theoretically, this LC product can be achieved with any L/C ratio – small L and large C, or large L and small C (or very large L and no C at all, using instead the load resistance R_L as one element of an L/R filter). There are, however, several practical economic and performance considerations that apply to selecting specific L and C values.

It is favorable to push in the direction of small L and large C for the following reasons:

1. Under the power and frequency ranges commonly encountered in switching regulator circuits, it costs more to store energy in an inductor than in a capacitor. Also, an inductor will have considerably greater weight and volume than a capacitor with equal energy storage capacity. Small L and large C, within the limits defined below, will usually result in the lowest cost, weight and size design.
2. Small L and large C results in low "surge impedance" of the filter, hence better transient behavior with step changes in load current.
3. Losses in a practical inductor are higher than in a capacitor with equal energy storage capacity (assuming low ESR). This again argues for small L, large C.

One major objection to a low L/C ratio is that it causes large and sometimes intolerable overshoot in input current and output voltage on startup, when the circuit is first energized. Input current overshoot can saturate the inductor and destroy the switching transistor. The current limiting feature of the applications circuits shown in Section III effectively controls the startup transient, thereby protecting all components and minimizing voltage overshoot. With current limiting, this problem is eliminated and no longer pertains to the selection of L and C values.

Referring to Figure 2b and its associated equations, the peak-to-peak ripple current through the inductor, Δi_1, is inversely proportional to the inductance, L. As L is made smaller, Δi_1 increases. Maximum limits on Δi_1 determine how small L is permitted to be, as follows:

1. The instantaneous current through L ranges between a maximum of $Io + \Delta i_1/2$ and a minimum of $Io - \Delta i_1/2$. If $\Delta i_1/2$ is permitted to become larger than Io, the minimum inductor current becomes a negative value. This is impossible, since neither the switching transistor nor the "catch" diode will conduct. Therefore, the switching regulator goes into a discontinuous mode of operation which is perfectly safe, but the frequency changes considerably and regulation with output current changes becomes relatively poor. The worst case consideration to insure that discontinuous operation does not occur is to make $\Delta i_1/2$ equal to the *minimum* load output current, Io min, or $\Delta i_1 = 2$ Io min.

   It is not practical to apply this criterion if Io min is very small (<0.05 Io max) because Δi_1 would then be very small, forcing an impractically large L value. In applications where Io min is very small, there are two alternatives: (a) raise Io min by preloading the supply, or (b) make $\Delta i_1 = 2(0.05$ Io max$) = 0.1$ Io max realizing that when Io becomes less than 0.05 Io max, the discontinuous mode will occur.

2. The maximum peak current is equal to the full load current, Io max $+ \Delta i_1/2$. As L is decreased, the corresponding increase in Δi_1 will begin to cause a significant increase in the maximum peak current. Since the inductor must be designed not to saturate at the maximum peak current, this begins to negate the cost, size and weight advantages of making the L value smaller. Higher peak currents will have an adverse effect on efficiency and transistor drive requirements, and may require transistor and "catch" diodes with higher current ratings (and higher cost). It is, therefore, recommended that $\Delta i_1/2$ be no greater than 0.25 Io max, which will limit the maximum peak current to 1.25 Io max, or Δi_1 max $= 0.5$ Io max.

In summary:

$\Delta i_1 = 2$ Io min, within the following somewhat arbitrary limits:

Δi_1 min $= 0.1$ Io max

Δi_1 max $= 0.5$ Io max

In our example, Io min $= 2$A, Io max $= 10$A. Calculating $\Delta i_1 = 2$ Io min $= 4$A, which is acceptable since Δi_1 max $= 0.5 \times 10\text{A} = 5$A, and Δi_1 min $= 0.1 \times 10\text{A} = 1$A.

Now that t_{off} and Δi_1 have been determined, L can be calculated as follows:

$$L = \frac{Eo \times t_{off}}{\Delta i_1} = \frac{5 \times 17.5 \times 10^{-6}}{4} = 21.9\,\mu H$$

The final step is to determine the requirements for the capacitor C and ESR values which will result in the desired output ripple voltage, Δe_o. Since the two components of Δe_o : Δv_C and Δv_{ESR}, are in "quadrature", we can consider each component separately, with a worst case error of less than 20 percent when both components are equal. This much error is highly unlikely, since the ESR component usually dominates completely when operating at high frequencies.

From Figure 2d:

$$C = \frac{\Delta i_1}{8f\,\Delta v_C}$$

note that C varies inversely with f. In order to achieve Δv_C less than the desired maximum Δe_o, the minimum value for C must be determined at the lowest frequency, f_{min}, calculated previously.

$$C\,min = \frac{\Delta i_1}{8f_{min}\,\Delta e_o\,max} = \frac{4}{8 \times 43 \times 10^3 \times 100 \times 10^{-3}} = 114\,\mu F$$

From Figure 2e:

$$ESR\,max = \frac{\Delta v_{ESR}}{\Delta i_1} = \frac{\Delta e_o\,max}{\Delta i_1} = \frac{100 \times 10^{-3}}{4} = 0.025\Omega$$

With high frequency operation, capacitor ESR usually dominates, forcing the use of a C value much greater than C min in order not to exceed ESR max.

Subsequent sections deal with designing the inductor and selecting the capacitor and other components of the switching regulator.

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V. Design of the Power Inductor

This simplified nomographic method facilitates selecting the smallest core that will achieve the desired characteristics of the power inductor. This procedure is useful in selecting the proper core and determining wire size, number of turns, copper losses, and temperature rise. It also permits investigating the effects of change in assumed initial conditions and in "trimming" the design.

A detailed analysis of this inductor design procedure is contained in Appendix B.

Tables 1 and 2 give core parameters for a variety of commonly used ferrite pot cores and Mo-Permalloy toroids. (Note: There is no significance to the selection of manufacturers, nor is any intended. Many manufacturers make roughly equivalent cores in these sizes, with similar magnetic properties.)

Ferrite and Mo-Permalloy powder are excellent core materials for the switching regulator inductor. Since the rms AC current through the inductor is small compared to the DC current, AC losses in the winding and core losses will be negligible compared with DC winding losses.

Selection of the proper core for a specific application is a process concerned with two factors: (1) The core must provide the desired inductance without saturating magnetically at the maximum peak overload current, i_1 max. In this respect each core has a specific $(LI^2)_{sat}$ energy storage capability. (2) The core must have a window area for the winding which admits the number of turns necessary to obtain the required inductance with a wire size which will result in acceptable DC losses in the winding at the full load output current, Io. Each core has a specific $(LI^2)_{diss}$ capability that will result in a specific power loss or temperature rise.

The significant core parameters are primarily core size and the magnetic gap in series with the flux path. Consider a very small (for the application) ferrite pot core with no air gap. The effective permeability, μ_e, will be very large because there is no gap. Relatively few turns will be required to achieve the desired inductance, and the power loss at Io will be small, but the core cannot store the required energy $L(i_1 \max)^2$ without saturating. If we introduce a gap into this core, the energy storage capability increases (the extra energy is actually stored in the gap, not in the ferrite material). However, the gap causes the effective permeability to drop, which requires more turns of finer wire to achieve the desired inductance. If the core is too small, as the gap is increased to the point required to achieve the necessary energy storage capability without saturating, the DC resistance of the increased number of turns of finer wire has increased to the point where the power dissipation and temperature rise is too great. This conflict is resolved by going to a larger core with appropriate gap.

To facilitate core selection, Tables 1 and 2 contain tabulated values of $(LI^2)_{sat}$ energy storage capability (saturation limited) and $(LI^2)_{25C}$ capability (based on power dissipation resulting in 25°C temperature rise). These values have been calculated for various size cores with different gaps, by methods described in Appendix B. Also given in the tables are the power dissipation corresponding to a 25°C rise for each core size, and the effective window area for the winding, A_W'. Tabulated A_L values relate to different gaps. (A_L is the inductance index at a particular gap setting – defined as the inductance in mH for 1000 turns.)

The optimum cores for switching regulator inductor applications generally have quite large gaps, and consequent relatively low A_L values. This is fortuitous, since the core properties are then dependent mostly on the gap itself, and variations in the magnetic materials of the core are swamped out, resulting in excellent stability and linearity. Note, however, that in the ferrite pot core table, many of the lower A_L values are not supplied as stock items by the manufacturer, and the desired gap must be ground to size on a special order basis.

Mo-Permalloy powder cores are effectively "gapped" by the manufacturer by means of varying the amount of non-magnetic binder that holds the Mo-Permalloy particles together within the core, and by the size and shape of the Mo-Permalloy particles. Thus, the "gap" is actually distributed throughout the core material. These cores are supplied with many different A_L values in each size.

One of the main advantages of ferrite pot cores and ferrite E-I cores (not tabulated, but worth considering) is that the winding is easily formed on a bobbin which is subsequently assembled within the two-piece core assembly. Ferrite toroids are not recommended because of the practical difficulty of introducing a gap. Mo-Permalloy toroids are not as convenient to wind, but this is not a serious problem as most switching regulator inductor designs require few turns of relatively heavy wire.

Example of Inductor Design

The example shown below will illustrate the method of solution, as drawn on the nomograph of Figure 11.

Given:

$$L = 21.9\,\mu H$$
$$Io = 10A$$
$$i_1\,max = 14A \text{ (current limited)}$$
$$Eo \times Io = 50W \text{ (output of regulator)}$$

Copper losses not to exceed 1% of output power, and temperature rise of inductor not to exceed 25°C.

Step 1: Draw line ① from Io = 10A on the "I" scale, to 0.0219 mH (21.9 μH) on the "L" scale through the "LI^2" scale. Note that $LI_o^2 = 2.19$ millijoules.

Step 2: Draw line ② from i_1 max = 14A on the "I" scale to the 0.0219 mH on the "L" scale through the "LI^2" scale. Note that $L(i_1\,max)^2 = 4.3$ millijoules.

Step 3: Find the smallest core in Tables 1 or 2 that has $(LI^2)_{25C}$ capability greater than LI_o^2 defined in step 1, and $(LI^2)_{sat}$ capability greater than $L(i_1 max)^2$ defined in step 2. This appears to be a 2616-3B7 pot core with $A_L = 160$ from Table 1, or an A-291061-2 toroid from Table 2.

Step 4: Actual temperature rise of the core and power loss can be calculated as follows:

Temperature rise of pot core;

$$\text{Actual } \Delta T = 25°C \frac{LI_o^2 \text{ (step 1)}}{(LI^2)_{25C} \text{ from core table}} = 25°C \times \frac{2.19}{2.288} = 24°C$$

Power loss in inductor;

$$\text{Actual } P_W = P_{25C} \times \frac{LI_o^2}{(LI^2)_{25C}} = 0.547 \times \frac{2.19}{2.288}\,W = 0.524W$$

Actual power loss in the inductor as a percentage of the power output of the switching regulator is:

$$\frac{P_W \times 100\%}{Eo \times Io} = \frac{0.524 \times 100\%}{50} = 1.05\%$$

If power losses are not acceptable, then select a core with higher $(LI^2)_{25C}$ capability.

Step 5: In the nomogram, draw line ③ from 0.0219 mH on the "L" scale through $A_L = 160$ on "A_L" scale to the "N" scale. Note that 12 turns are required to obtain the desired inductance.

Step 6: Enter the $A_W' = 0.193$ from the table for the core selected on the "A_W'" scale. Draw ④ from "N" scale where N = 12 through $A_W' = 0.193$ to the "wire size" scale. From this scale, note that wire size is AWG 15.2. Select the next highest integer, AWG 16, in order to fit within the available window area. This will result in a slight increase in power loss and temperature rise.

The same procedure applies if a toroid is selected instead of a pot core.

If both the LI_o^2 and $L(i_1max)^2$ values calculated in steps 1 and 2 are less than the appropriate limiting (LI^2) values for the core selected, it is suggested that the L value of the application be increased until one or the other of the core limits is reached. This will permit reduction of Δi_1, and reduce the requirements of the output capacitor.

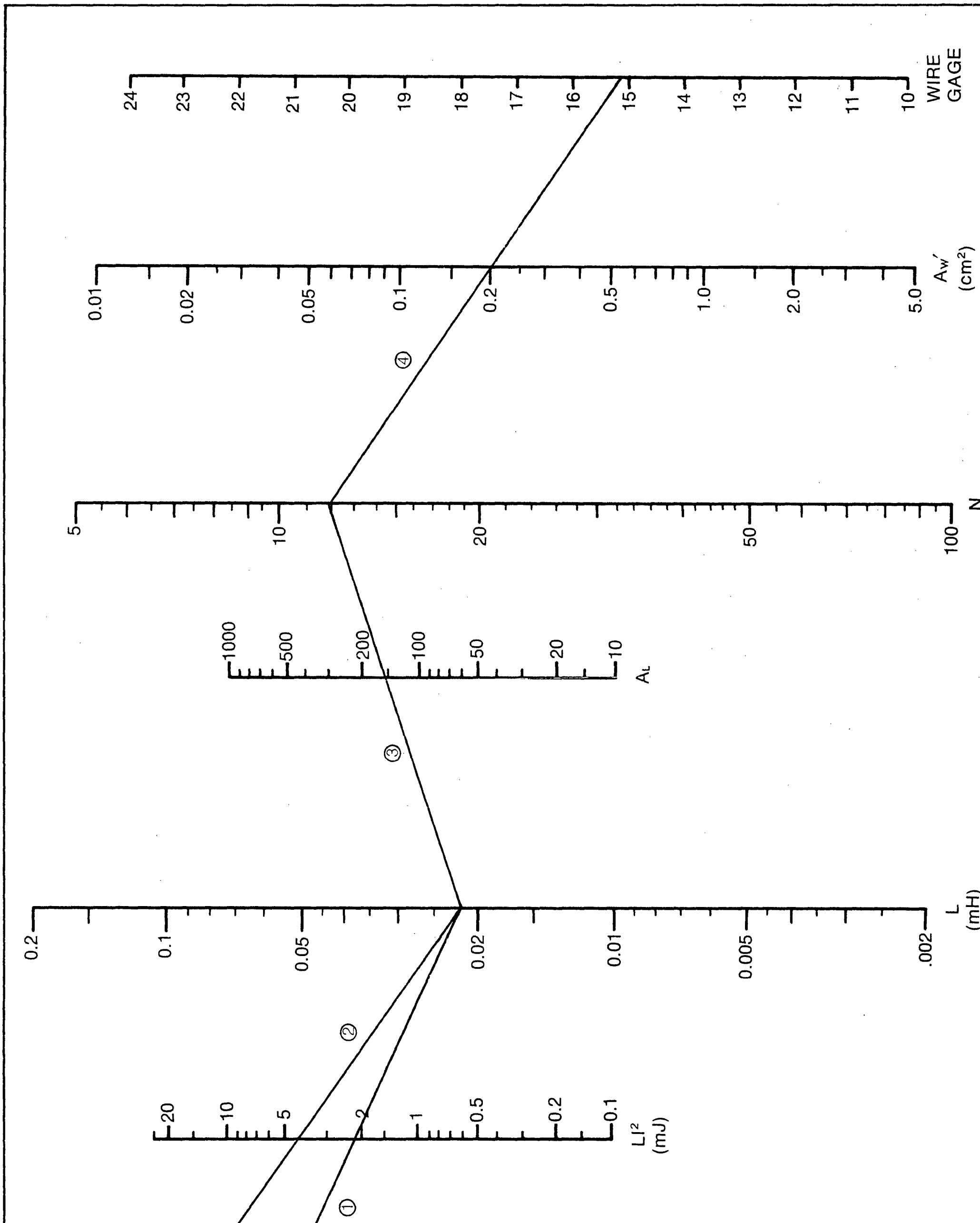

Figure 11. Inductor Design Nomograph

Table 1. Ferrite Pot Cores

Ferroxcube Part No.	Dimensions (inches)		Power Dissipation 25°C rise (watts)	Window Area 0.65 A_W (cm²)	Inductor Index	Saturation Limit (mJ)	Dissipation Limit 25°C rise (mJ)
	(OD)	(HT)	(P_{25C})	(A_W')	(A_L)	($(LI^2)_{sat}$)	($(LI^2)_{25C}$)
1107-A100-3B7	0.445	0.264	0.100	0.034	100	0.200	0.077
1107-A160-3B7	0.445	0.264	0.100	0.034	160	0.144	0.124
1408-A100-3B7	0.559	0.334	0.158	0.063	100	0.490	0.180
1408-A160-3B7	0.559	0.334	0.158	0.063	160	0.324	0.288
1811-A160-3B7	0.716	0.428	0.259	0.122	160	1.02	0.719
2213-A160-3B7	0.858	0.538	0.358	0.193	160	2.12	1.32
2616- * -3B7	1.024	0.640	0.547	0.263	160*	5.06	2.29
2616-A250-3B7	1.024	0.640	0.547	0.263	250	3.24	3.58
3019- * -3B7	1.201	0.754	0.754	0.382	200*	8.57	4.90
3622- * -3B7	1.418	0.880	1.04	0.486	200*	18.4	7.21
4229- * -3B7	1.697	1.16	1.60	0.910	200*	31.8	17.9

*Indicates not stock item. Gap must be ground to obtain desired A_l.

Table 2. Mo-Permalloy Toroids

Arnold Part No.	Dimensions (inches)		Power Dissipation 25°C rise (watts)	Window Area 0.5 A_W (cm²)	Inductor Index	Saturation Limit (mJ)	Dissipation Limit 25°C rise (mJ)
	(OD)	(HT)	(P_{25C})	(A_W')	(A_L)	($(LI^2)_{sat}$)	($(LI^2)_{25C}$)
A-307032-2	0.425	0.180	0.072	0.082	32	0.180	0.065
A-051027-2	0.530	0.217	0.125	0.192	27	0.296	0.199
A-189043-2	0.710	0.280	0.209	0.319	43	0.782	0.659
A-059043-2	0.930	0.330	0.346	0.703	43	1.55	2.06
A-894075-2	1.09	0.472	0.520	0.781	75	3.40	4.32
A-291061-2	1.33	0.457	0.708	1.47	61	4.54	8.97
A-298028-2	1.33	0.457	0.708	1.47	28	9.90	4.12
A-085035-2	1.60	0.605	1.04	2.14	35	20.1	8.65
A-087059-2	1.875	0.745	1.48	2.14	59	40.2	16.0

VI. Component Selection

1. *Power Switching Components*

Voltage ratings of the power switching transistor and catch diode must be greater than the maximum input voltage, Ein, including any transient voltages that may appear at the input of the switching regulator. Low transistor $V_{CE\,sat}$ and diode V_F at full load output current are important considerations to maintain high efficiency (Ref efficiency calculations – Appendix A).

Fast switching diodes and transistors are required to maintain good efficiency in high frequency switching regulators. Transistor switching losses become significant when combined rise time plus fall time exceeds approximately $0.025 \times \tau$. Thus, for 50 kHz operation, $t_r + t_f$ should be approximately 0.5 μsec or less. Transistor delay and storage times do not affect efficiency, but cause delays in turn on and turn off resulting in lowering the frequency of operation and increasing ripple. Combined $t_d + t_s$ should be less than $0.05 \times \tau$.

Unitrode manufactures a broad variety of fast switching power transistors and Darlingtons, which are listed in the Power Transistor & Darlington Product Selection Guide. Their combinational high voltage, high current, low saturation voltage and medium to fast switching characteristics make them ideal for this application.

The diode reverse recovery time must be no more than about half the current rise time through the transistor. If this requirement is not met, large amplitude reverse recovery current spikes will be drawn from the input power supply causing severe EMI problems. Large transient currents through the transistor may cause degradation or second breakdown. Referring to Figure 1, Section II, during the time that the transistor is off, the catch diode is conducting the output current, Io, and the transistor V_{CE} equals Ein. When base drive is applied to the transistor to turn it on, current through the transistor rises from 0 to Io. During this current rise time interval, t_{ri}, the diode remains in forward conduction, but the diode current declines from Io to 0, since the inductor maintains the total current at a constant value equal to Io. If the diode has recovered at the end of the t_{ri} interval, the voltage across the transistor will start to decrease and the diode will go into the reverse direction. This period of time is the transistor voltage rise time interval, t_{rv}, which is terminated when the transistor V_{CE} reaches $V_{CE\,sat}$ and the diode V_R reaches Ein. If the diode has *not* recovered at the end of the t_{ri} interval, it will remain a low impedance instead of proceeding smoothly into the reverse direction. Transistor current will increase well above Io until the diode recovers, pulling the additional current through the diode in the reverse direction.

This problem has probably caused more grief in switching regulator applications than any other, and almost completely dominates diode selection. Diode switching losses will be completely negligible if the diode is fast enough to minimize the recovery problem, i.e., two to three times faster than the transistor turn-on rate.

Unitrode UES rectifiers, listed in the Rectifier Product Selection Guide, are uniquely suited to this type of application. With low forward drop and typical recovery time of 20 nsec from forward currents as high as 50A, they cause no discernible recovery spike when used in conjunction with Unitrode's medium frequency switching transistors.

Unitrode PIC600 Hybrid Power Switches summarized in the Switching Regulator Power Circuits Product Selection Guide combine in a single package the UES rectifier and power switching transistor with its associated drive transistor and bias resistors. Power transistor, drive transistor and rectifier are matched to optimize switching speeds and $V_{CE\,sat}$. Available in NPN and PNP versions, the PIC600 series can operate at 50 kHz with only 2.5 percent loss of efficiency compared with operation at lower frequencies. Significant reduction of EMI can be achieved because of the reduction of circuit wiring.

2. *Output Filter Capacitor.*

The most difficult component selection problem for high frequency switching regulator applications is to find and specify an output capacitor with suitably low ESR. Most tantalum and aluminum electrolytic capacitor types do not have ESR specifications (probably because ESR is not very good). In some cases, the dissipation factor, DF, is given in the specification. However, DF is usually specified at 60 Hz, which is more indicative of effective *parallel* resistance, and is virtually useless in determining ESR. When DF is specified at 1 kHz or higher, it may be used to determine ESR:

$$ESR = DF(\%) \times 0.01 \times X_C = \frac{DF(\%) \times 0.01}{2\pi fC}$$

The power circuit design example given in Section IV requires an output capacitor with C_{min} of 114 μfd and ESR_{max} of 0.025Ω. The capacitor which comes closest to meeting this requirement (after a limited search) is solid tantalum, Mallory THF, 120 μfd @ 10V. This capacitor has a max DF of 8% at 1 kHz, which defines $ESR_{max} = 0.106\Omega$. ESR is typically 0.05Ω. Two of these capacitors in parallel are required, based on typical ESR, to achieve an ESR of 0.025Ω; four in parallel are required, based on ESR_{max} of the capacitor. The aluminum electrolytic which comes closest (again based on a limited search) is the Sprague 672D series, 1000 μfd @ 12V, which has an ESR_{max} of 0.065Ω @ 50 kHz. Typical ESR is 0.025Ω. In either case, a much larger C value is required in order to achieve the desired ESR. This does have the advantage of reducing transient voltage changes with sudden changes in load current.

It is worth noting again that with the control circuits shown in Section III (unlike conventional switching regulator control circuits), the operating frequency will remain relatively constant, regardless of ESR, although the output ripple voltage will vary directly with ESR. In some cases, it may be economically advantageous to increase the value of L (and the size and cost of the inductor) in order to reduce ripple current, $\Delta i_1 = \Delta i_2$, and thereby increase the ESR_{max} requirement.

In addition to considering the C and ESR values and appropriate voltage derating for the application, most capacitors have maximum RMS ripple current or max RMS ripple voltage ratings which should not be exceeded. Actual RMS ripple current and voltage in the application can be calculated as follows:

$$\Delta e_{o\,RMS} = \Delta e_o \text{ p-p}/3.0$$

$$\Delta i_{RMS} = \Delta i_1 \text{ p-p}/3.5$$

In the design example of Section IV, $\Delta e_{o\,RMS} = 0.033V$, which is less than the 0.05V max ripple rating of the 10V Mallory THF capacitor, and $\Delta i_{RMS} = 1.14A$, which is less than the 2.47A max ripple current rating of the 1000 μfd, 12V Sprague 672D capacitor.

Series inductance of the capacitor is usually not significant compared to ESR at frequencies below 100 kHz. However, inductance can become dominant if good wiring practices are not followed. Specifically, the ground side of the catch diode should be returned directly and as close as possible to the ground side of the capacitor, and capacitor lead length including circuit wiring on both sides of the capacitor should be minimized.

3. *Control Amplifier and Reference.*

Control circuits for switching regulators can be designed around IC operational amplifiers and separate voltage references, or around low power voltage regulator IC's which have built-in references. Voltage regulator IC's such as the LM304, LM305, and μA723 have the added advantage that the output current they provide to drive the power switching transistor can be caused to diminish at higher temperatures, which conforms to the transistor drive requirements vs. temperature and helps to maintain optimum switching speeds over a range of temperatures. Amplifiers used in the control circuit should be uncompensated in order to obtain fast switching speeds, otherwise the delay times introduced will result in lower frequency operation and larger ripple amplitudes, and may cause circuit instability.

Appendix A
Analysis of Power Circuit

The design equations for the switching regulator power circuit used throughout this design guide were based on several simplifying assumptions, which will now be dealt with.

The simplified equations neglected the effect of "catch" diode forward drop, V_F, transistor saturation voltage, V_{sat}, and the IR drops in the inductor and current sensing resistor, Io R_X. If a design is implemented using the values of L, C, ESR, and Δi derived from the simplified equations, then t_{on}, t_{off}, f, and Δe_o will differ from the design values because of the effect of the simplifying assumptions as follows, from Figure 2b:

Simplified :

$$\Delta i_1 = \frac{(Ein - Eo)t_{on}}{L} \quad (1)$$

Exact :

$$\Delta i_1 = \frac{(Ein - Eo - V_{sat} - Io\,R_X)t_{on}'}{L} \quad (2)$$

Simplified :

$$\Delta i_1 = \frac{Eo\,t_{off}}{L} \quad (3)$$

Exact :

$$\Delta i_1 = \frac{(Eo + V_D + Io\,R_X)t_{off}'}{L} \quad (4)$$

Note that Δi_1 is fixed, because the control circuit controls this value directly. Instead of the original design values of t_{on} and t_{off}, actual values t_{on}' and t_{off}' will be observed. Since Δi_1 is fixed, we can equate Equations (1) to (2) and (3) to (4):

$$\frac{t_{on}'}{t_{on}} = \frac{(Ein - Eo)}{(Ein - Eo - V_{sat} - IoR_X)} \quad \text{and}$$

$$\frac{t_{off}'}{t_{off}} = \frac{Eo}{Eo + V_D + IoR_X}$$

Although the actual t_{off}' is less than the assumed t_{off}, t_{on}' is greater than the assumed t_{on}, so that their net effect on the operating frequency is reduced. In the worst-case, when Eo is small (5V) and Ein is high (50V), the actual frequency will be 25 percent higher than the original assumed frequency, resulting in a very slight drop in efficiency. Output ripple component Δv_C will be smaller because of the higher frequency, and Δv_{ESR} will not change because Δi_1 is fixed. Component tolerances will result in larger deviations than those caused by the use of the simplified equations.

The only other assumption that could have possible significance is that the transistor switching times are negligible at the highest frequency of operation. The validity of this assumption is normally assured by selecting appropriate devices (see Section VI). This also applies to the speed of the control circuit. If delay time through the control circuit in addition to transistor turn-on and turn-off times is significant with respect to the total period, τ, the consequent delay in turning the power circuit on and off will cause a proportional increase in Δi_1 and Δe_o, and a proportional decrease in frequency.

Efficiency Calculations: The efficiency of a switching regulator depends upon the factors given in the following equation:

$$\text{Efficiency} = \frac{Pout}{Pin} \times 100\%$$

$$= \frac{Eo \times Io}{Eo \times Io + P_T + P_D + p_T + p_D + P_L + P_l + p_C + P_C}$$

Note that the worst case for each factor does not necessarily occur under the same conditions.

1. *DC Losses – Transistor.* (Worst case when Ein is lowest because t_{on} is largest.)

$$P_T = V_{CE\,sat} \times Io \times \frac{t_{on}}{\tau}$$

where: $\frac{t_{on}}{\tau} = \frac{Eo}{Ein}$

2. *DC Losses – Diode.* (Worst case when Ein is highest.)

$$P_D = V_F \times Io \times \frac{t_{off}}{\tau}$$

where: $\frac{t_{off}}{\tau} = 1 - \frac{Eo}{Ein}$

3. *Switching Losses – Transistor.* (Worst case when Ein is high. $t_d + t_s$ do not contribute to power losses.)

$$p_T = Ein \times Io \frac{t_r + t_f}{2\tau}$$

where: $t_r = t_{rv} + t_{ri}$, $t_f = t_{fv} + t_{fi}$

4. *Switching Losses – Diode.*

This is a very complex calculation if diode recovery time is not much smaller than the transistor rise time, because the diode will short-circuit the power supply prior to turn-off, affecting the transistor dissipation, possibly causing second breakdown, and generating intolerable EMI. By using a diode whose recovery time is not more than half the transistor rise time, all these problems become negligible.

5. *DC Losses – Inductor.* (AC losses are negligible when Δi_1 is small compared to Io.)

$$P_L = Io^2 \times R_S$$

where: R_S is equal to effective series resistance of inductor.

6. *DC Losses – Current Sense Resistor.* (AC losses negligible when Δi_1 is small compared to Io.)

$$p_l = Io^2 \times R_l$$

7. *AC Losses – Capacitor.* (Usually negligible.)

$$p_C = \frac{\Delta i_1^2}{12} \times ESR$$

8. *Control Circuit Losses.* (Base drive to switching transistor is dominant, but usually negligible.)

$$P_C = Ein \times I_b \times \frac{t_{on}}{\tau} = Eo \times I_b$$

where: $\frac{t_{on}}{\tau} = \frac{Eo}{Ein}$

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Appendix B
Analysis of Power Inductor Design

This appendix describes the methods used to develop the core tables given in Section V and the nomographic method for design of the power inductor. Core parameters for any cores not listed in the tables can be derived from the equations given.

The following equations provide the basis for this design approach. Equation (1a) defines the value of inductance, L, in terms of basic core parameters and the total number of turns, N, wound on the core:

$$L = N^2 \times 0.4\pi \mu \frac{A_e}{\ell_e} \times 10^{-5} \quad \text{mH} \quad (1a)$$

where:
- μ = effective permeability of core
- ℓ_e = effective magnetic path length – cm
- A_e = effective magnetic cross section – cm^2

For most standard cores, the above calculation has been simplified by listing the compound parameter A_L, called the "inductor index", as follows:

$$L = N^2 A_L \times 10^{-6} \quad \text{mH} \quad (1b)$$

where: $A_L = 0.4\pi \mu \frac{A_e}{\ell_e} \times 10$ mH for 1000 turns

Multiplying both sides of Equation (1b) by I^2,

$$LI^2 = (NI)^2 A_L \times 10^{-6} \quad \text{millijoules} \quad (2)$$

Core Saturation Limits.

Any specific core has a maximum ampere-turn, NI, capability limited by magnetic saturation of the core material. $(NI)_{sat}$ is listed in some core catalogs, in which case the maximum $(LI^2)_{sat}$ capability of the core can be calculated from Equation (2). $(NI)_{sat}$ is related to the saturation flux density, B_{sat}, as follows:

$$(NI)_{sat} = 10 \frac{B_{sat} A_e}{A_L} \quad \text{ampere-turns} \quad (3)$$

Substituting Equation (3) into (2),

$$(LI^2)_{sat} = \frac{B_{sat}^2 A_e^2 \times 10^{-4}}{A_L} \quad \text{millijoules} \quad (4)$$

Values of $(LI^2)_{sat}$ are given for each core represented in Tables 1 and 2 of Section III. Equation (2) *or* (4) was employed, using values for either B_{sat} or NI which would result in a reduction of A_L (and L) of 20 percent under maximum overload conditions, according to the core manufacturer's data. The core selected for an application must have an $(LI^2)_{sat}$ value greater than $L(i_1 \max)^2$ to insure that the core will not saturate under maximum peak overload current conditions.

Power Dissipation and Temperature Rise Limits.

In switching regulator applications, the AC current component is small compared to the DC current through the power inductor. Power dissipation in the inductor is almost entirely DC losses in the winding. DC resistance of the winding, R_s, is calculated from the following:

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$$R_s = \rho \frac{\ell_w}{A_x} N \quad \text{ohms} \qquad (5)$$

where: ℓ_w = mean length of turn – cm
A_x = effective area of wire – cm²
ρ = resistivity of wire – Ω-cm

Core geometry provides a certain window area, A_W, for the winding, but only a fraction of this area can be occupied by the actual conductor. The *effective* window area, A_W' is taken as 0.5 A_W for toroids, and 0.65 A_W for pot cores. This allows for wasted area of uniformly wound round wire with HF insulation, allows for the fact that the central fourth of the window area of a toroid cannot practically be filled, and allows for a single section bobbin in the case of the pot core. The number of turns, area of wire, and effective window area of a fully wound core are related by:

$$A_x = \frac{A_W'}{N} \text{cm}^2 \qquad (6)$$

Substituting Equation (6) into (5):

$$R_s = \rho \frac{\ell_W}{A_W'} N^2 \quad \text{ohms} \qquad (7)$$

Multiplying both sides of Equation (7) by I^2, the power dissipation in the winding, P_L, is:

$$P_L = I^2 R_s = I^2 \rho \frac{\ell_W}{A_W'} N^2 \quad \text{Watts} \qquad (8)$$

Substituting for N from Equation (1b), and rearranging:

$$LI^2 = P_L \frac{A_L A_W'}{\rho \ell_W} \times 10^{-6} \quad \text{millijoules} \qquad (9)$$

Equation (9) shows that the LI^2 capability is directly related to, and is limited by the maximum permissible power dissipation. Using a value for P_L that will result in a 25°C rise in the temperature of the inductor, values of $(LI^2)_{25C}$ are calculated for each core in Tables 1 and 2 of Section III. For these calculations, resistivity, ρ, is assumed to be 1.9×10^{-6} Ω-cm, the resistivity of copper wire at 65°C. The power dissipation that will result in a 25°C rise is calculated and tabulated for each core as follows:

$$\Delta T = 850 \frac{P_L}{A_s} \quad {}^\circ\text{C} \qquad (10)$$

where: ΔT = temperature rise
A_s = surface area of inductor – cm²

The factor 850 in the above equation represents a temperature rise of 850°C for 1W power dissipation from 1 cm² surface area, empirically determined for natural convection cooling. The surface area, A_s, used in the calculation is taken as the top and sides of the inductor, ignoring the mounted bottom surface. Substituting a temperature rise of 25°C:

$$P_{25C} = \frac{25 \times A_s}{850} \quad \text{Watts} \qquad (11)$$

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Appendix C
Analysis of Application Circuits

The design equations for the critical components and operating parameters of Figure 3, Section III, are given below, for the following design objectives:

$$E_o = +5V$$
$$\Delta e_o = 100\text{ mV p-p}$$
$$E_{in} = 20V \text{ min, } 40V \text{ max}$$
$$I_o = 2A \text{ min, } 10A \text{ max}$$
$$\text{Current Limit} = 14A \text{ max peak}$$

Using the procedure described in Section IV, the following parameters were established:

$$f = 50\text{ kHz (nominal)}$$
$$t_{off} = 17.5\ \mu sec$$
$$L = 22\ \mu H$$
$$C = 120\ \mu F \text{ min}$$
$$\text{ESR of capacitor} = 0.025\ \Omega \text{max}$$
$$\Delta i_1 = 4A$$

From the manufacturer's design data for the LM305, we know that: the internal reference voltage, V_{ref}, is 1.8V, nominal; the impedance of the inverting input is very high; the threshold level of the drive-current-limiting circuit is 0.30V; and the impedance of the non-inverting input (Rin) is 2.4K, nominal.

From the Unitrode data for the PIC625 Hybrid Power Switch, the drive current (I drive) required for Io = 10A is 30 mA. The V_{BE} of Q1 is taken as 0.6V.

First, we may calculate the values R1 and R2 of the output divider. We will make the effective parallel resistance of R1 and R2 equal to 2.4K, so that the impedance at the inverting input will be approximately the same as the noninverting input of the LM305:

$$\frac{R2}{R1 + R2} = \frac{Vref}{Eo} = \frac{1.8}{5}$$

$$\frac{R1\ R2}{R1 + R2} = Rin = 2.4K$$

The resulting values are R1 = 6.8K, R2 = 3.8K. R2 may be trimmed for precise setting of Eo.

C1 and C2 function to provide negative and positive AC feedback, and should be large enough to result in small losses to the AC signals. Assuming that Rin = (R1 × R2)/(R1 + R2), the value of C1 should be twice the value of C2, so that the negative feedback will be dominant over positive feedback at all frequencies, thereby ensuring circuit stability. The following relationships satisfy these conditions:

$$C2 \geqq \frac{1}{Rin \times f} \quad ; \quad C1 = 2 \times C2$$

where: f = the nominal switching frequency.

These equations are satisfied by C2 ≈ 0.01 μF and C1 = 0.02 μF. Making C1 and C2 too large will have an adverse effect on transient recovery time of the switching regulator.

R4 is calculated from the threshold voltage of the LM305 drive current limiting circuit and the required base drive current.

$$R4 = \frac{V\ threshold}{I\ drive} = \frac{0.3V}{0.03A} = 10\Omega$$

Current sampling resistor R_l is determined by the desired short circuit current limit and the V_{BE} of Q1. As described in Section III, under *current overload conditions,* current i_1 ranges between two values. The maximum instantaneous overload current is defined by: $i_1 \times R_l = V_{BE} + V_{R3}$. The minimum instantaneous overload current is defined by: $i_1 \times R_l = V_{BE}$.

Since Δi_1 has been previously defined as 4A p-p, if we assume a minimum value of 10A for i_1 under overload conditions, then the maximum peak overload value for i_1 will be 14A, and the average value of i_1 = Io under overload conditions is 12A.

$$R_l = \frac{V_{BE}}{i_1\ (\text{min overload})} = \frac{0.6V}{10A} = 0.06\Omega$$

Power dissipation in R_l will be 6W under full load conditions, and 8.64W under overload conditions.

R3 determines Δi_1 under overload conditions as well as for normal operation of the switching regulator:

$$R3 \times I_{drive} = R_l \times \Delta i_1$$

$$R3 = \frac{R_l \times \Delta i_1}{I_{drive}} = \frac{0.06 \times 4}{0.030} = 8\Omega$$

The value of R5 is determined empirically to optimize regulation versus changes in Ein. With R5 omitted, Eo changes approximately 70 mV when Ein is changed from 20V to 40V. With R5 = 1.2 MΩ, the change in Eo is reduced to less than 25 mV.

THE IMPORTANCE OF RECTIFIER CHARACTERISTICS IN SWITCHING POWER SUPPLY DESIGN

With the increasing interest in switching regulated power supplies designers have directed much of their effort to selecting transistors with low switching losses and adequate power handling capability. While recognizing that they must use fast recovery rectifiers, less attention has been given to "how fast" or "what type of recovery characteristic" is desired. More detailed knowledge of rectifier behavior allows determination of the magnitude of increased losses and stress on the transistor by the non-ideal diode. By choosing the best available rectifier, transistor stress can be minimal, thereby resulting in higher reliability. Other benefits are:

A. Improved power supply efficiency
B. Lower noise
C. Lower cost and/or
D. Smaller size and weight

The performance of fast recitifiers in the most popular switching circuits is discussed below.

"Switcher" inputs use available DC voltages, or rectifiers directly off the AC line. This DC "input" is converted by semiconductor switches operating at high frequency in circuits such as buck, flyback or boost regulators and in pulse-width-modulated or square wave inverters.

Inverter output rectifiers and regulator "catch" diodes are subject to unusual stresses due to the fast switching rates and very low impedance seen by the diode during the reverse transient (diode turn-off) and a momentary high impedance during diode turn-on.

These new square wave switching supplies are limited in efficiency and frequency by transistor stress and switching losses, some of which is due to diode switching characteristics. Faster transistors and diodes are helping to increase efficiency and/or frequency. At low output voltages, and lower frequency the DC characteristics ($V_{CE(sat)}$ and V_F) have the major influence on efficiency. However, as frequency and/or input voltage increase the switching characteristics become increasingly important.

BUCK REGULATOR ANALYSIS

Ideal Diode — For better understanding consider the buck regulator and resulting waveforms, using an *ideal* diode and assuming linear current rise and fall in the power transistor during switching. Similar considerations apply to other types of switching regulator circuits.

The transistor "on" time, t controls the conversion such that,

$$(1)\ V_o = \frac{t}{\tau} V_i$$

where τ is the period. t is determined by the control circuit which senses output voltage and controls transistor base drive.

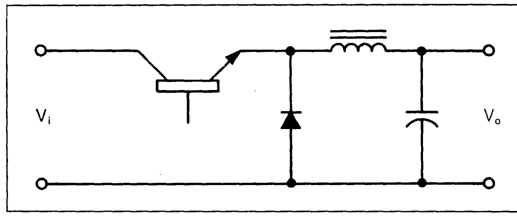

Figure 1a

In this regulator the inductor current is essentially constant as it flows alternately through the transistor or "catch" diode. The sum of the transistor current and diode current must always equal the current in the inductor, which cannot change instantaneously.

At t_0 the diode is conducting inductor current while the transistor is blocking the input voltage.

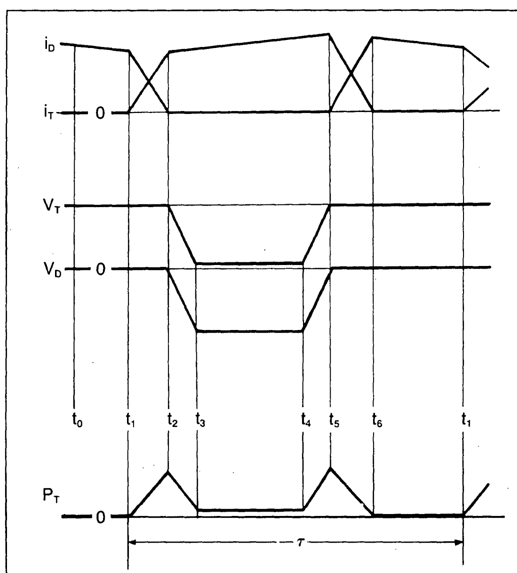

Figure 1b

t_1 to t_2 is the current rise time t_{ri} of the transistor. Since inductor current is not changing, the diode current must decrease. The forward biased diode maintains full input voltage across the transistor.

At t_2 the transistor is conducting all the inductor current so the diode turns off and voltage across the transistor

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starts to decrease toward $V_{CE\ (sat)}$.

t_2 to t_3 is the voltage rise time, t_{rv} of the transistor.

From t_3 to t_4 the transistor is saturated and conducting the inductor current i_L.

At t_4 the transistor starts to turn off and V_{CE} increases.

t_4 to t_5 is the voltage fall time t_{fv} of the transistor. During this time the transistor must conduct the entire inductor current because the diode is still reverse biased. At t_5 the diode is forward biased and the transistor is blocking the full input voltage. Diode current starts to increase and the transistor current decreases, the sum equalling i_L.

t_5 to t_6 is the current fall time t_{fi} of the transistor. Diode current increases in a complementary manner. From t_6 to t_1 the transistor is off and the diode is conducting all the inductor current.

To simplify the illustration assume the inductor current constant and equal to I_o. Transistor dissipation P_T is the sum of transient switching and DC losses. Neglecting losses due to DC leakages, which are generally negligible:

$$(2)\quad P_T = \frac{V_i\, I_o}{2} \frac{(t_{ri} + t_{rv} + t_{fv} + t_{fi})}{\tau} + \frac{V_{CE\ (sat)}\, I_o\, (t_4 - t_3)}{\tau}$$

$$(3)\quad P_T = \frac{I_o}{\tau}\left\{\frac{V_i}{2}(t_{ri} + t_{rv} + t_{fv} + t_{fi}) + V_{CE(sat)}\,(t_4 - t_3)\right\}$$

Practical diode — Now consider how the non-ideal diode with reverse recovery, junction capacitance, forward recovery and DC loss affects the circuit of Figure 1a.

In Figure 1c the solid lines are the waveforms using a practical diode in a buck regulator circuit. Comparing them with the dotted lines of the ideal diode previously considered we see three significant differences during transient switching and one during DC conduction:

1. The peak collector current increases (above I_o) during a period of high dissipation t_2 to t_2'.
2. Rise times t_{ri} and t_{rv} are increased. $(t_2' - t_1) > (t_2 - t_1)$ and $(t_3' - t_2') > (t_3 - t_2)$.
3. Maximum collector voltage peaks up above V_i briefly at t_5.
4. The diode has DC loss (from t_6 to t_1) and switching loss (principally from t_2' to t_3').

From the P_T curve of Figure 1c it is obvious that transistor power dissipation increases above that of (3) due to the "real" diode, — see the hatched regions.

The magnitude of these detrimental factors depends on the choice of rectifier. Before considering losses more fully let us examine the switching periods in greater detail.

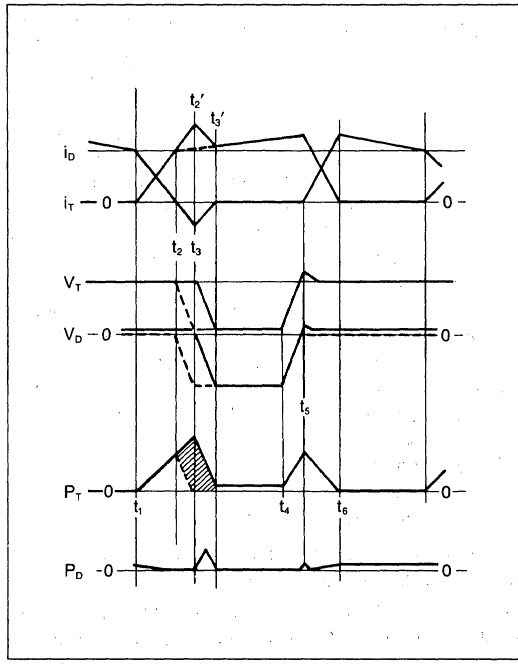

Figure 1c

TRANSISTOR TURN-ON BEHAVIOR

The transistor "turn-on transient", when the diode is switching from forward conduction to reverse blocking, results in the following transistor and diode waveforms:

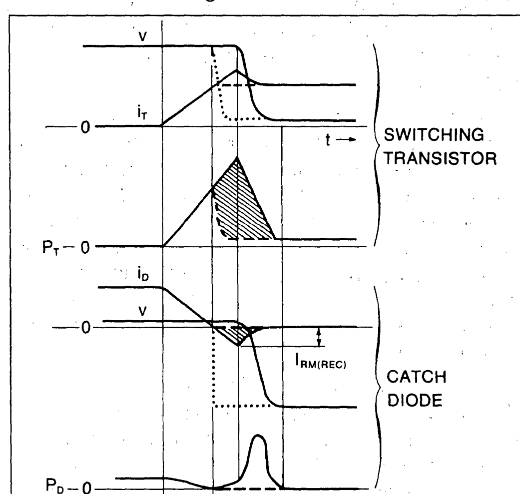

Figure 2

Dashed lines show what the current and power would be if the *diode* were ideal to the extent of having no reverse recovery time or junction capacitance. (Dotted lines show the voltage for the ideal diode case.) The reverse diode current caused by diode capacitance and recovered charge is shown by the cross hatched area of the i_D curve. The transistor must conduct this reverse diode current as well as the inductor current. The grey area represents additional transistor dissipation due solely to the diode recovered charge and capacitance.

Faster switching transistors will not necessarily result in reduced switching losses. Unless a diode with recovery time 2 or 3 times faster than the transistor current rise time is used, a faster transistor will increase the peak recovery current in the diode and thus increase overall switching losses. Furthermore, a diode with a "soft" recovery characteristic will cause more dissipation than an "abrupt" type with the same peak recovery current. The relationship of recovery characteristic to switching rate is discussed in Appendix B. With many switching transistors now available a 200 nS fast-recovery rectifier will have a peak recovery current $I_{RM(REC)}$ greater than shown in the i_D waveform of Figure 2, where it is about ⅓ of the forward current. This rather modest additional collector current (of 33% above that limited by an ideal diode) can cause increased transistor power dissipation of 100 to 150% during the turn-on period. Other serious problems can occur from high peak currents, such as noise transients in the line, the transistor coming-out of saturation and forward-biased second breakdown.

Rectifiers are now available with recovery characteristics to keep these problems minimal. Their use is required for a switching supply of maximum reliability and efficiency.

TRANSISTOR TURN-OFF BEHAVIOR:

When the transistor turns off, the diode turn-on characteristic usually has little effect on power dissipation but may cause voltage spiking, with resulting noise and the possibility of exceeding the transistor voltage ratings. Diode characteristics and conditions under which these transients occur are discussed in Appendix C. The voltage spike is due to the forward recovery characteristic and, when present, will occur as shown (dotted) in Figure 3. To correct it a snubber (series RC across the diode) may be needed. However, the choice of an optimum diode will minimize or eliminate this need.

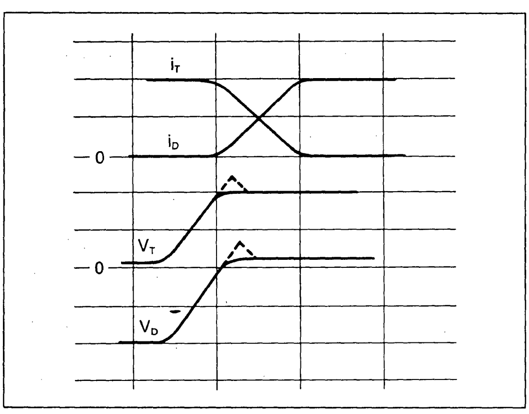

Figure 3

POWER LOSSES IN THE SEMICONDUCTOR DEVICES

DC Losses in the buck regulator occur alternately when the diode is forward conducting and when the transistor is turned on. Referring to Figure 1 these intervals are t_6 to t_1 and t_3 to t_4 respectively. During *either* interval the dissipation is independent of input voltage, V_i, or output voltage, V_o, depending only on load current and device voltage drop. *Total circuit DC losses* are a function of V_o/V_i because a) this ratio relates to "on" time and b) transistor $V_{CE(sat)}$ will probably not equal diode V_F. Neglecting switching intervals the dissipation due to DC losses is:

$$(4)\quad P_{DC} = V_F I_O \frac{V_i - V_o}{V_i} + V_{CE\,(sat)} I_o \frac{V_o}{V_i}\ .$$

Loss of efficiency due to DC losses is greatest when V_o is low, with diode loss being more significant when V_i is relatively high and transistor loss dominating when V_i is close to V_o.

Transient (switching) losses in the regulator vary considerably with voltage, being highest at "high line" V_i (see Eq. 3). Furthermore, high voltage transistors and rectifiers generally have longer switching times than low voltage types. Speed and "recovery characteristic" (see Appendix B), and consequently losses, can vary greatly between different device types and manufacturing processes. A relationship for calculating approximate transient dissipation of practical devices during the transistor turn-on interval is given in Appendix B. The other component (turn-off interval) can be similarly developed but it is not significantly affected by diode selection. However, when transistors and/or drive techniques are chosen for shorter fall times overall losses are reduced *and* the benefits of optimum diode selection become more significant. Proper diode (and transistor) selection is important in all switching supplies, but the higher the voltage (and frequency) the more significant will be the effect of selection on switching losses.

OTHER SWITCHING CIRCUITS

The pulse-width-modulated inverter (PWM) supply (Figure 4a) has much in common with the buck regulator. Output rectifiers also perform the catch diode function. Current waveforms are shown in Figure 4b,

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with overshoot due to diode reverse recovery and capacitance. Here again slow diodes cause additional transistor stress, usually not reduced significantly by transformer impedance. Leakage reactance will often require the use of a snubber, to protect the transistor.

Transistor "on" time t and the turns-ratio control the conversion such that

$$(5)\ V_o = \frac{2t\ N_s}{\tau N_p}\ V_i$$

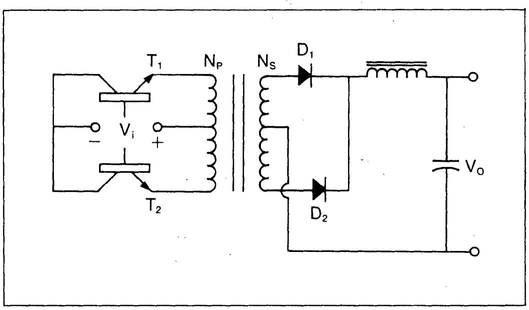


Figure 4a

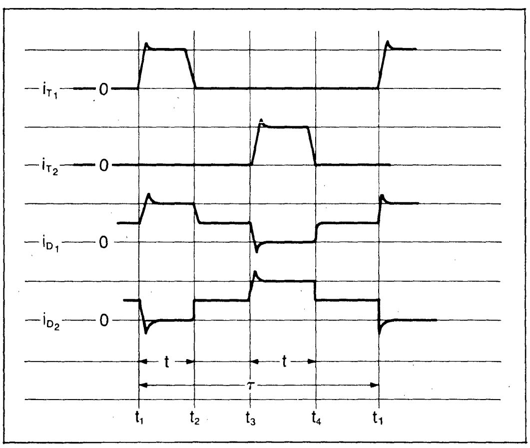


Figure 4b

From t_1 to t_2 transistor T_1 and diode D_1 conduct, with diode current equal to inductor current i_L.

At t_2 the transistor turns off and the inductor "pulls" i_L equally through D_1 and D_2.

At t_3 transistor T_2 turns on, driving full i_L through D_2 and causing D_1 to be reversed biased. D_2 current is increased by the recovery current of D_1, and T_2 current also increases proportionally.

From t_4 to t_1 both transistors are again off and at t_1 the events of t_3 occur on the opposite device pair.

One difference between the inverter and the regulator is that here the DC diode losses are more significant because they (D_1 and/or D_2) are conducting the full cycle regardless of V_i to V_o ratio. Another difference is that here the diode recovery is from half, rather than full, load current.

The square wave inverter can be considered, in terms of device operation, a special case of the PWM where 2t approaches τ. Regulation is achieved by varying V_i.

EMI, RFI, NOISE —

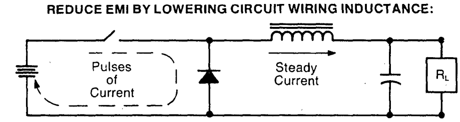
Given any inductance in a circuit "loop" of wiring, a rapid current change will generate a voltage transient, $V = L\ di/dt$, and the energy in such a transient will vary with the square of the current, $E = \frac{1}{2}LI^2$. The interference and voltage spiking will be easier to filter if the energy is low and has predominantly high frequency components.

We can establish a priority of factors for reducing EMI:

1. $I_{RM(REC)}$ should be as low as possible, — accomplish by diode selection (see Appendix B and Fig. 7).
2. L (circuit loop) should be minimum, — accomplish by layout and interconnect geometry. (See Fig. 5).
3. Use a "soft recovery" diode (See Appendix B). However, this is an item of possible trade-off since such a device may have longer t_{rr}, higher $I_{RM(REC)}$ and, thus, create much higher switching loss.

An ultra-fast device with moderate recovery (vs. abrupt or soft) will often be the best choice.

REDUCE EMI BY LOWERING CIRCUIT WIRING INDUCTANCE:



Low L needed in loop shown in grey. Avoid ground loop noise by returning input capacitor directly to diode.

Figure 5a

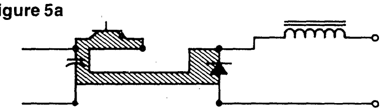


Figure 5b

SELECTING THE BEST SWITCHING RECTIFIER

Ratings and characteristics have different priorities and significance when they are to be applied to these power switching circuits. Selection should be based on the following:

1. Peak inverse voltage, PIV of "catch" diodes must at least equal the highest input voltage, while PIV of center-tap output rectifiers must be at least twice the maximum output voltage in a square wave inverter and much greater in the pulse width modulated inverter. More significant perhaps are the transient voltages in practical fast switching circuits partly due to wiring inductance and rectifier's own recovery. Unless these are intentionally clipped, damped, or "designed out" it is advisable to use a safety factor of 2 or 3. PIV selected should apply over a range from lowest ambient to the highest expected junction temperature.

2. Reverse recovery time t_{rr} must be much lower than the rise time of the transistor with which it will be used, — preferably by at least 3 times when measured at conditions similar to circuit operation. Selection is complicated because rectifiers are normally specified at conditions less severe than in power switching circuits. Furthermore, correlation between test conditions is not always the same (see Table I of Appendix B).

Following preliminary selection from available data the devices should be compared in a circuit developing the highest current, junction temperature and rate of current switching (− di/dt) expected.

The desired goal is to minimize peak recovery current $I_{RM(REC)}$ and switching loss. Note that these are the same order of magnitude with Schottky rectifiers (due to high capacitance, principally) as with the fastest PN rectifiers. The figures below illustrate these points. Figure 6 shows the variation of peak current with switching rate, using the Unitrode UES 801 in a special test circuit. Figure 7 shows the difference in $I_{RM(REC)}$ and t_{rr} when representative fast recovery DO-5 devices are measured in a JEDEC test circuit at different temperatures. In Figure 8 the incremental collector current (the peak value in excess of 30 A) for a 30 A buck regulator using 50, 100, and 200 nS catch diodes is plotted as a function of transistor rise time (and resulting di/dt). Figures 9a, b, and c show the loss of efficiency due to transistor turn-on dissipation as a function of operating frequency, with 3 transistor rise times and 3 diode recovery times, in a regulator operated with 40 V in and 10 V out. Similar figures can be developed for other conditons using the model and assumptions in Appendix B.

3. Forward voltage should be as low as possible to optimize efficiency, especially for inverter output rectifiers and regulators with high V_i/V_o ratios. Loss of efficiency due to V_F is most significant at low output voltages. Figure 10, which relates this loss to device choice over the range of available forward voltages, applies to output rectifiers of inverter supplies with popular output voltages.

Schottky rectifiers have the lowest V_F and are therefore widely used as output rectifiers for 5 V supplies. Their limitations in PIV, transient voltage capability and temperature must be considered when applying them in other applications.

Selection should be based on conditions where losses are most significant, — at rated supply output current and anticipated junction temperature. The approximate range of V_F, at rated current and 25°C, as well as at more typical operating conditions, is shown in Figure 11 for representative fast rectifier types. Note that the Unitrode UES series is closest to the Schottky, especially at expected operating conditions.

4. Maximum average rectified output current at maximum expected case or ambient temperature must always be considered. Note however, that standard current rating is based on a half sine waveform. These square wave applications at average current equal to this rating will usually dissipate somewhat lower power, and, thus, be used conservatively. However, regulators with $V_i \lesssim 1.5\ V_o$ should use a catch diode with a higher rating than the average current it conducts at full load.

5. Peak voltage $V_{F(DYN)}$ during forward recovery will be of significance when using transistors with fast fall times at close to the V_{CE} rating. This is further discussed in Appendix C. See Table II for typical performance of representative devices. At lower values of di/dt the peak voltages will be lower.

6. Surge current (8.3 mS) is not of great significance because transistor saturation limits fault current. If the power supply is designed to provide rapid charging of a large output capacitor the "overload" requirement for the charge time (perhaps 0.1 to 2 seconds or so) must be considered.

$I_{RM(REC)}$ & t_{rr} vs $\frac{di}{dt}$

CONDITIONS I_{FM} = 10A, LINEAR SLOPE. UNITRODE UES 801 RECTIFIER.

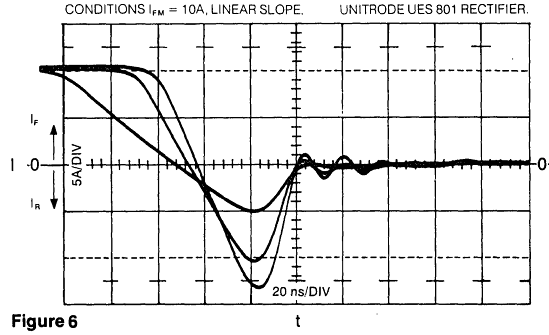


Figure 6

$I_{RM(REC)}$ & t_{rr} of DO5 FAST RECTIFIERS

CONDITIONS: I_{FM} = 30A $-\frac{dI}{dt}$ = 30A/µS (30V JEDEC)

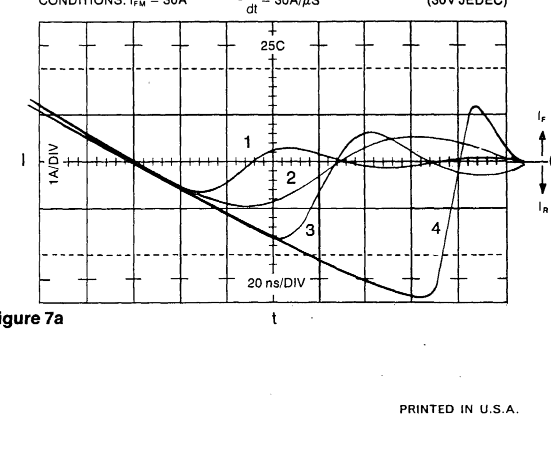


Figure 7a

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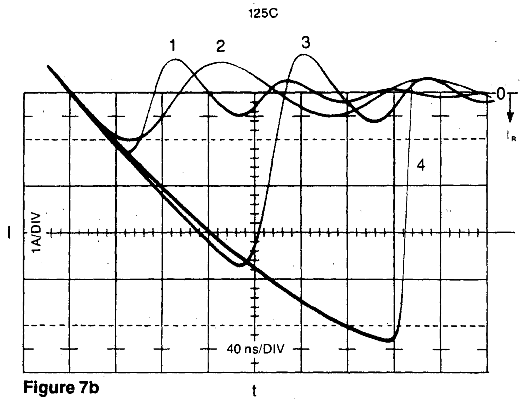


Figure 7b

DEVICE TYPE	$I_{RM(REC)}$		t_{rr}		t_{rr} MAX. At Low Current Cond'ns.
	25°C (A)	125°C (A)	25°C (nS)	125°C (nS)	
1	0.6	1.3	50	72	50
2	1.0	1.0	86	95	—
3	1.7	3.7	86	185	100
4	2.9	5.4	142	296	200

1 Unitrode UES 803
2 Schottky rectifier.
3 100nS rectifier.
4 200nS rectifier.

Figure 7c

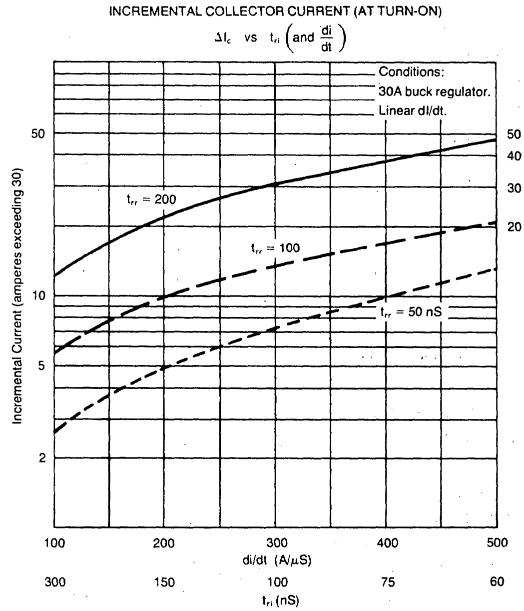
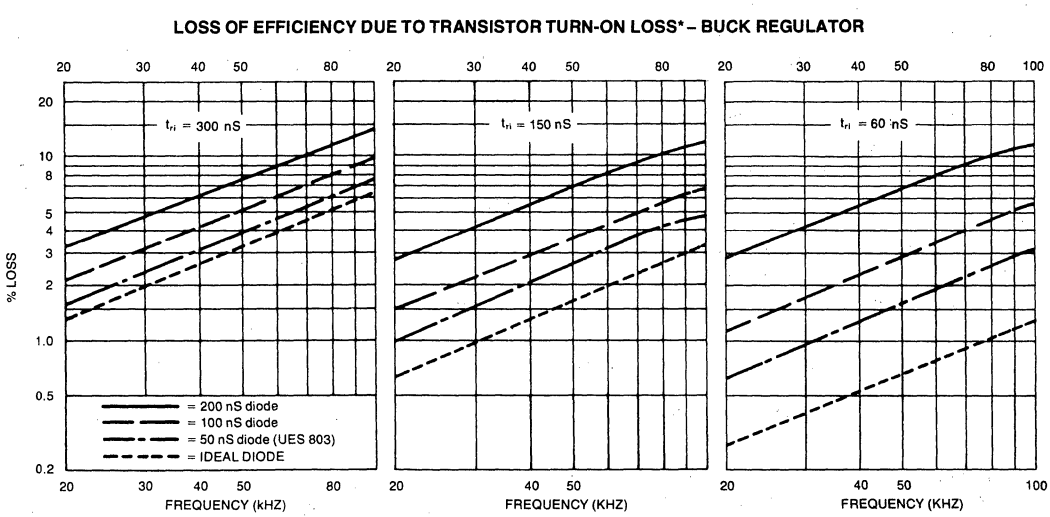


Figure 8



* Calculations of total switching losses (diode and transistor) per model in Appendix B for a 30A buck regulator with V_{in} = 40V and V_{OUT} = 10V.

Figure 9

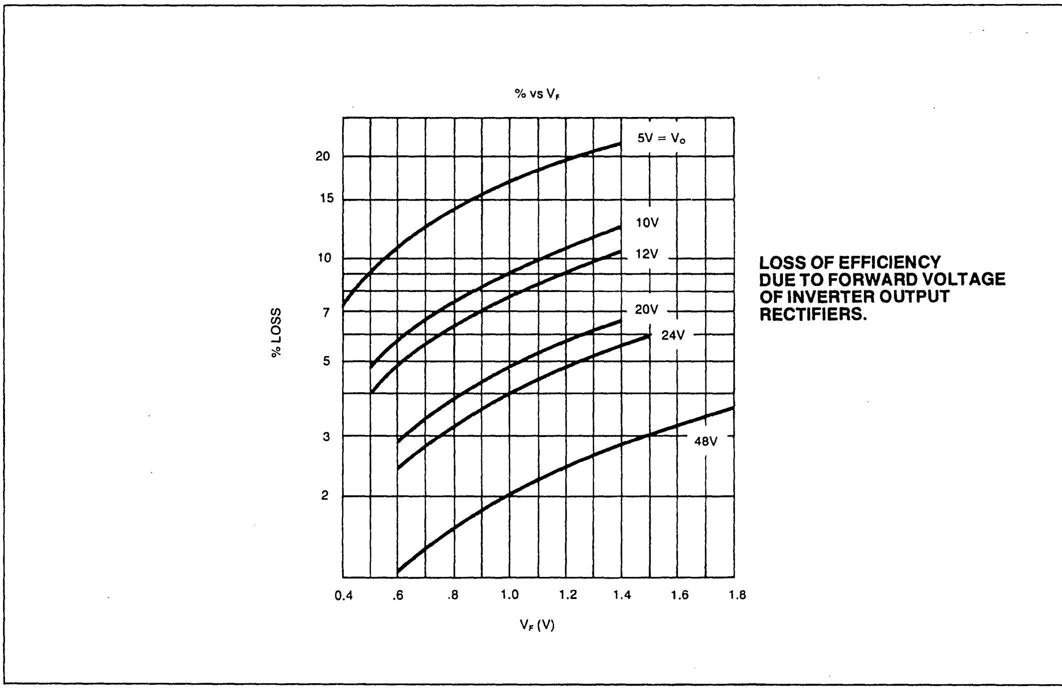
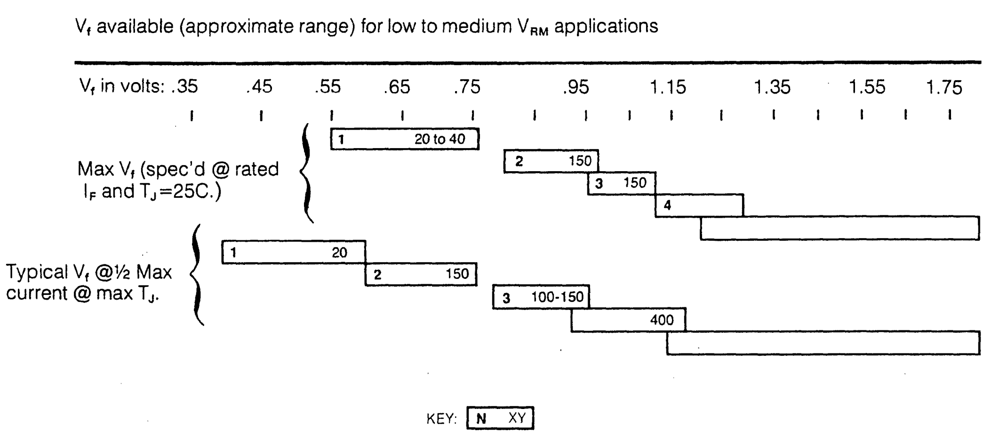


Figure 10



1 = Schottky.

2 = Unitrode UES 150 V series.

3 = Other devices for low forward voltage.

4 = Typical fast recovery (200 nS) devices.

5 = Fast devices to 800 V.

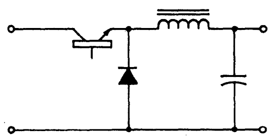
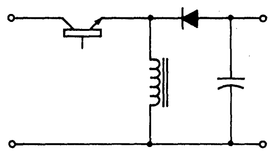
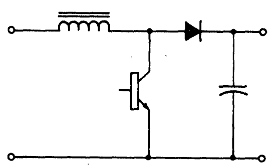
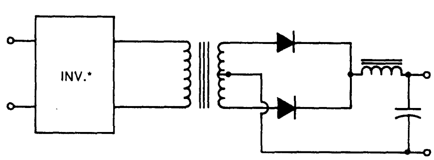
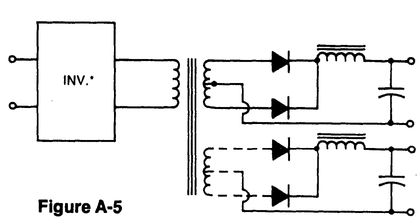
N = Device Class

XY=V_{RW}
(Max. at T_J noted above).

Figure 11

Appendix A
"Off-Line" Supplies

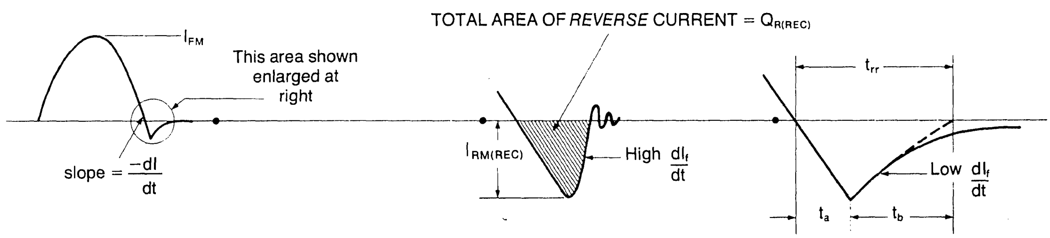
FROM RECTIFIED, OFF-LINE (OR OTHER DC) SOURCE

BASIC CIRCUIT	TYPE	FEATURES
Figure A-1 	a) Buck Regulator	$V_o < V_{in}$. Output non-isolated. Easy to filter output. Noisy input.
Figure A-2 	b) Flyback Regulator	V_o opposite polarity from V_{in}. (Unless isolated). Output can be isolated. Output can be stepped up to HV. Noisy input and output.
Figure A-3 	c) Boost Regulator	$V_o > V_{in}$. Output non-isolated. Hard to filter output. Quiet input.
 **Figure A-4**	d) PWM (Variable Duty Cycle) Inverter.	Used with single V_o, - also common for lab supplies. Provides isolation. Does not need separate catch diode, - rectifiers serve this function, possibly with small HV diodes in primary for magnetizing current.
INPUT FROM a, b, or c.  **Figure A-5**	e) Square Wave Inverter (50% Duty)	Regulation provided by previous input. Regulates one of (possible) multiple outputs. Uses high transistor count. Provides isolation. Does not need separate catch diode, - rectifiers serve this function, possibly with small HV diodes in primary for magnetizing current.

(*) INV. = Bridge, center-tap, or half-bridge inverter.

Appendix B
Reverse Recovery Behavior and Dissipation

1. Waveforms and definition of terms:



JEDEC test - standard slope = 25A/μS
Figure B-1

"ABRUPT"
Figure B-2

"SOFT"
Figure B-3

2. Discussion of Variables:
Any PN junction diode operating in the forward direction contains stored charge in the form of excess minority carriers. The amount of stored charge is proportional to the forward current level.

The diode or rectifier in a switching regulator is switched from forward conduction to reverse at a specific ramp rate (−dI/dt) determined by the external circuit, usually by the turn-on time of the associated switching transistor. During the first portion of the reverse recovery period, t_a, charge stored in the diode is able to provide more current than the circuit demands, so that the device appears to be a short circuit. Transition from t_a to t_b occurs when stored charge has been depleted to the point where it can no longer supply the increasing current demanded by the circuit. The device becomes a high impedance and during t_b the reverse voltage is permitted to increase. Reverse current, no longer circuit determined, dwindles as excess stored charge depletes to zero. Stored charge is depleted by the reverse current flow and also by recombination within the device.

At (−dI/dt) rates which are slow relative to the rate of recombination of the specific device relatively little stored charge is swept out. Recovery time, t_{rr} is determined mainly by the recombination rate, independent of (−dI/dt). Peak reverse recovery current $I_{RM(REC)}$, and total charge associated with reverse current, $Q_{R(REC)}$ are almost directly proportional to (−dI/dt) (Region I, Figure B-4). The recovery characteristic with slow (−dI/dt) rates tends to be soft.

When the (−dI/dt) rate is fast compared to recombination rate (transistor turn-on faster than diode recovery time), t_{rr} decreases as −dI/dt increases, because more of the available stored charge is swept out sooner, leaving little to be depleted by recombination. As (−dI/dt) increases, peak recovery current increases and can become much greater than the original forward current level. However, $Q_{R(REC)}$ levels off as (−dI/dt) increases because it can only approach but not exceed the total stored charge which is a function of the original forward current level (Region II, Figure B-4).

Higher voltage devices have poorer recovery characteristics because they require thicker regions of higher resistivity, resulting in greater volume of stored charge and longer recombination rates.

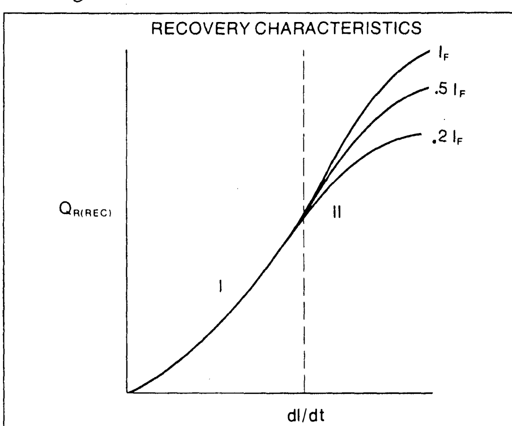


Figure B-4

With a given I_F and dI/dt the $Q_{R(REC)}$, $I_{RM(REC)}$, and t_{rr} all increase with temperature. Recovery characteristic changes as well (generally becoming more abrupt if reverse current is not circuit limited, and softer if limited). Furthermore, $Q_{R(REC)}$ increases and recovery generally softens if higher circuit voltage is applied to a given diode.

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3. Comparison of devices at popular test conditions:
Table I, below, shows measured t_{rr} values (in nanoseconds) using ultra-fast and fast recovery DO-5 rectifiers.

I_F (A)	I_R (A)	−di/dt (A/μS)	T (°C)	$I_{R(REC)}$ (t_{rr} Measured to (A))	UNITRODE UES803	MANUFACTURER B	C	D	E
0.5	1.0	step	25	0.25	38	50	42	—	—
1.0	1.0	step	25	0.10	45	75	50	63	120
1.0	1.0	step	125	0.10	60	90	122	135	300
	(85V JEDEC circuit)								
30	—	30	25	0	75	120	85	105	150
30	—	30	125	0	100	150	140	210	300
30	—	100	25	0	45	72	66	92	—
30	—	100	125	0	65	114	106	160	—
MAX t_{rr} per manufacturer's stated condition					50	50 to 100			200

Table I

4. Turn-on switching losses, assuming linear V and I transitions:

With an ideal diode, switching losses are entirely in the transistor as follows (from Eq. 2).

$$\text{(B1)}\; P_{(tri)} = V_{in} \cdot \frac{I_C}{2} \cdot \frac{t_{ri}}{\tau}$$

$$\text{(B2)}\; P_{(trv)} = \frac{V_{in}}{2} \cdot I_C \cdot \frac{t_{rv}}{\tau}$$

A practical diode with finite t_{rr} and $I_{RM(REC)}$ will cause *additional* switching losses as follows:

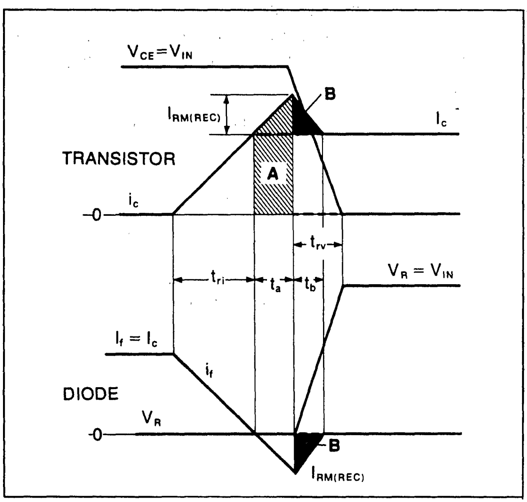

Figure B-5

Diode recovery time component t_a effectively increases transistor rise time, and delays the voltage transition, t_{rv}. During time t_a, the diode conducts reverse current but remains a low impedance. Transistor V_{CE} remains equal to V_{in} while collector current continues to rise above I_C to $I_C + I_{RM(REC)}$. The entire amount of charge shown in shaded area A results in increased switching loss in the *transistor only* (increase in diode loss is negligible):

$$\text{(B3)}\; P_{(t_a)} = V_{in}\left(I_C + \frac{I_{RM(REC)}}{2}\right)\frac{t_a}{\tau}$$

$$\text{(B4)}\; t_a = t_{ri}\left(\frac{I_{RM(REC)}}{I_C}\right)$$

$$\text{(B5)}\; P_{(t_a)} = V_{in}\left(I_C + \frac{I_{RM(REC)}}{2}\right)\left(\frac{t_{ri}}{\tau}\;\frac{I_{RM(REC)}}{I_C}\right)$$

$$\text{(B6)}\; P_{(t_a)} = V_{in} \cdot I_{RM(REC)}\left(1 + \frac{I_{RM(REC)}}{2 I_C}\right)\frac{t_{ri}}{\tau}$$

If diode $I_{RM(REC)}$ is half of I_C (1.5:1 current overshoot in transistor) total transistor switching losses during current turn-on ($t_{ri} + t_a$) will be 2.25 times greater than with an ideal diode (Eq. B1).

During diode recovery time component t_b, the diode continues to conduct reverse current, but becomes a high impedance, permitting the transistor voltage transition, t_{rv}, to take place. Diode reverse current during t_b causes increased switching losses in the transistor and/or the diode. It is difficult to quantify these losses in the diode and transistor separately, since transistor V_{CE} is decreasing and diode V_R is increasing during all or part of period t_b. However, the total increase in losses in both diode and transistor during t_b is:

$$\text{(B7)}\; P_{(t_b)} = V_{in} \cdot \frac{I_{RM(REC)}}{2} \cdot \frac{t_b}{\tau}$$

$$\left(\text{area B} = \frac{I_{RM(REC)}}{2} \cdot t_b\right)$$

Note: $P_{(t_b)}$ loss is in *addition* to the ideal diode case transistor losses, $P_{(t_{rv})}$ (Eq. B2). With a very fast diode, t_b will be much shorter than t_{rv}, and most of the $P_{(t_b)}$ loss will occur in the transistor, although it will be negligible. With a slow diode, where t_b is much longer than t_{rv}, $P_{(t_b)}$ loss will be significant and will occur mostly in the diode.

$P_{(t_a)}$ is usually much greater than $P_{(t_b)}$. Since all of $P_{(t_a)}$ is dissipated in the transistor, it can be seen that most of the increased switching losses caused by diode reverse recovery are borne by the switching transistor, not by the rectifier.

Appendix C
Forward Recovery Behavior and Characterization

When used in some circuits, any diode may exhibit the phenomenon known as forward recovery. Under these conditions, the device has an impedance which, for a short time after initial application of forward current, is higher than its normal "on" value. The magnitude and duration of this transient impedance will depend on circuit conditions and device design, varying from no effect in many circuits to a few microseconds in the worst case. When present, the effect is generally less with fast-recovery rectifiers, and much less with "computer-type" switching diodes.

Circuits with very fast current rise time, in the direction of forward conduction, will allow this phenomenon to appear. Generally, these will be low-inductance circuits which allow the current to rise from zero to rated forward current in less than the reverse recovery time for fast stud-mounted rectifiers, and in less than 0.1 x t_{rr} for lead mounted fast devices.

When such a source has a high voltage, of at least 10 times V_F, the forward recovery phenomenon exhibits an initial higher-than-steady-state forward voltage. The rise time of current is not limited by the diode and the peak voltage decays to the specified measurement level in the "forward recovery time" t_{fr}. The peak voltage $V_{F(DYN)}$ will be strongly influenced by the current rise time di/dt, and current I_F.

When a fast-rise source has an open circuit (compliance) voltage of less than several times the diode V_F, the forward recovery phenomenon may exhibit a delay in the rise of forward current. In this case the peak diode voltage is limited by the source, and the "turn-on" time is the rise time to 90% of I_F.

A comparison of the Unitrode UES 803 with a typical 200 nS rectifier is shown in Table II below.

	Unitrode UES 803		**DO5 200 nS**	
Test Condition	**$V_{F(DYN)}$ (v)**	**t_{fr} (nS)**	**$V_{F(DYN)}$ (v)**	**t_{fr} (nS)**
I_F to 1A in 8 nS	1.2	20	12	300
I_F to 1A in 125nS and continuing to 50A with t_r = 10μS	0.9	—	2.8	350

Table II

XV

FLYBACK AND BOOST SWITCHING REGULATOR DESIGN GUIDE

Section One — Flyback Regulator

I. Definition

The flyback switching regulator described in this application note accepts a DC voltage input and provides a regulated output voltage of opposite polarity. This method of conversion, compared to a conventional DC to DC converter, provides advantages of high efficiency, low cost, circuit simplicity, and a rather wide, easily selectable choice of the regulated output voltage. The switching transistor is not stressed to second breakdown in either the forward or reverse bias modes. Thus, it provides a reliable method of converting the input voltage. The disadvantage of the flyback switching regulator described here is that it provides no isolation and requires a large output filter capacitor. Primary usage of this type of regulator is in low current and/or high voltage applications.

II. Design Approaches to Flyback Regulator

The principal difference between a flyback regulator and a buck regulator (Ref. Unitrode Design Guide U-68) is the manner in which energy is transferred to the output capacitor. In a buck regulator, energy is provided continuously, while in a flyback regulator, energy is pumped in a discontinuous fashion. The flyback regulator can be operated in two modes.

A. Continuous Mode (see Figure 1a)

In this mode of operation, a large inductor is required to insure that the inductor current never goes to zero. Although the current through the inductor flows continuously, the charging current to the filter capacitor is in the form of discontinuous current pulses. This large peak-to-peak current waveform requires a much larger filter capacitor than the buck regulator. Component cost is higher than with the discontinuous mode of operation because of the large inductance required, and transient response is worse.

B. Discontinuous Mode (see Figure 1b, 1c)

In this mode, the regulator is designed such that at maximum output load current and minimum input voltage, the transistor starts conducting as soon as the catch diode stops conducting. At a lower output current or higher input voltage there is a dead time when neither device conducts.

The output voltage can be regulated by varying the duty cycle of the transistor switch.

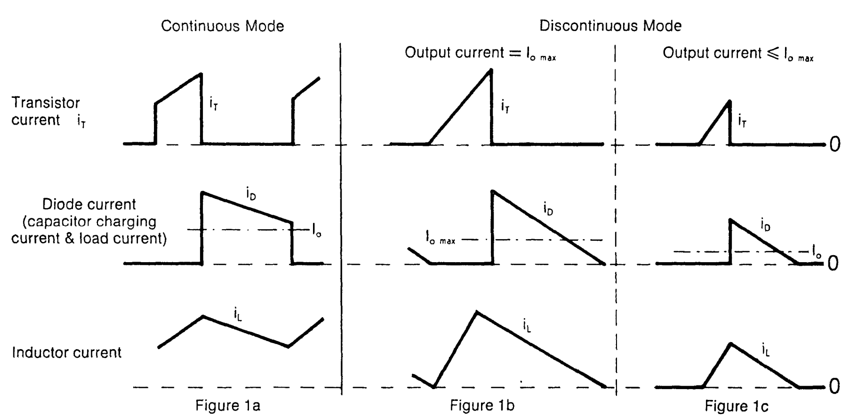

Figure 1. Current Waveforms

III. The Flyback Switching Regulator Described and Characterized

The basic circuit configuration and generalized current waveforms are shown in Figure 2. When transistor Q_1 is turned on, the supply voltage, E_{IN}, is applied across power inductor L. The current through the inductor rises linearly to a peak current level I_p:

$$I_p = \frac{E_{IN} \times t_T}{L} \quad \text{A.}$$

This results in an energy transfer from the input supply to the power inductor:

$$W = \frac{1}{2} L I_p^2 \quad \text{B.}$$

When the transistor turns off, a voltage is induced across inductor L which forces the current to flow through diode D_1. All of the energy stored in the inductor is transferred to the output capacitor and load R_L, and the inductor current diminishes linearly from I_p to zero according to the relationship:

$$I_p = \frac{E_o \times t_D}{L} \quad \text{C.}$$

The power delivered to the load is equal to the peak energy stored in the inductor times the number of pump cycles per second:

$$P_{out} = E_o \times I_o = \frac{1}{2} L I_p^2 \times f \quad \text{D.}$$

The voltage induced in the inductor is such that E_o is opposite in polarity from E_{IN}. The relationship between E_o and E_{IN} is established by combining equations A and C, eliminating I_p and L:

$$\frac{E_o}{E_{IN}} = \frac{t_T}{t_D} \quad \text{E.}$$

DC output current I_o is equal to the average current through the diode:

$$I_o = \frac{I_p}{2} \times \frac{t_D}{\tau} = \frac{I_p}{2} \times t_D \times f$$

The output voltage can be regulated by operating at a fixed frequency and varying the transistor on time, t_T. However, because of the inherent "pumping" action of the flyback regulator, the output voltage diminishes while the switching transistor is on, and increases when the transistor is off. This characteristic makes it difficult to control on a fixed frequency basis.

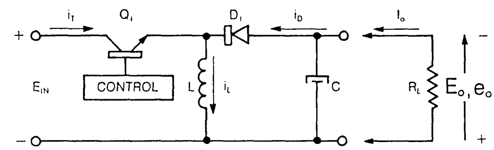

Figure 2a. Flyback Switching Regulator

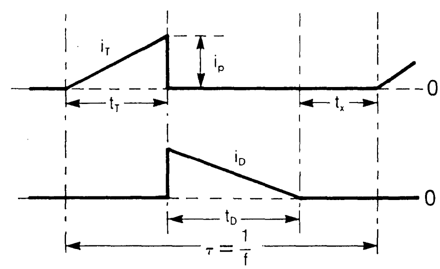

Figure 2b. Generalized Current Waveforms of a Flyback Switching Regulator

The simplest approach to controlling the flyback regulator in the discontinuous mode is to establish a fixed peak current through the inductor, which determines a fixed diode conduction time, t_D. Frequency then varies directly with output current, and transistor on-time varies inversely with input voltage. This is the approach used in this application note, resulting in a simple and economical control circuit.

IV. Worst Case Design Conditions

Design equations based on the fixed peak current mode of operation are shown in Figure 3. The worst case condition exists when input voltage is low while output current is at maximum. Under these worst case conditions, frequency is maximum and t_x is zero because the pass transistor turns on as soon as diode stops conducting.

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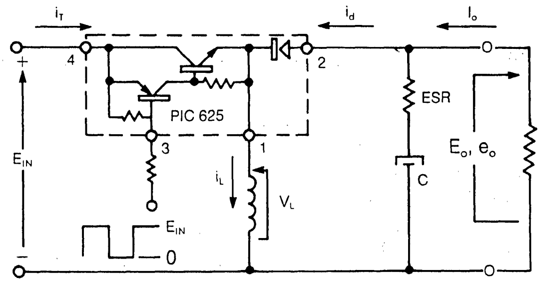
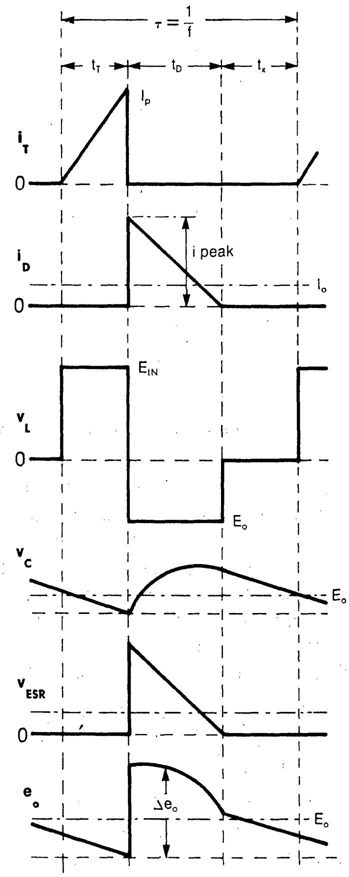


GIVEN:
$E_{IN\ (min)}$
E_o
$I_{o\ (max)}$
f_{max}
Δe_o

WORST CASE:
$E_{IN} = E_{IN\ (min)}$
$I_o = I_{o\ (max)}$
$t_x = 0$



$$I_p = 2\,I_{o\ max}\,(E_o/E_{IN\ (min)} + 1) = \text{constant}$$

$$t_D = \frac{1}{f_{max}\,(E_o/E_{IN\ (min)} + 1)} = \text{constant}$$

$$L = \frac{t_D \times E_o}{I_p} = \frac{t_T \times E_{IN}}{I_p}$$

$$f = \frac{1}{\tau} = f_{max}\,\frac{I_o}{I_{o\ (max)}}$$

$$C_{min} = \frac{I_p \times t_D}{2\,\Delta e_o}$$

(worst case $I_o \rightarrow 0$)

$$ESR_{max} = \frac{\Delta e_o}{I_p}$$

Figure 3. Flyback Regulator

V. Circuit Design and Description

In designing a flyback switching regulator power supply, the following parameters will normally be predefined. Numerical values are given and computed for the example shown in Figure 4.

E_o = 5V output
Δe_o = 100 mV output ripple voltage peak to peak
$I_o max$ = 2.5A
$E_{IN} min$ = 9V (minimum)
$E_{IN} max$ = 15V (maximum)

Since the output voltage is derived from pulses of current, it is desirable to keep the operating frequency as high as possible in order to obtain small size and lower cost of the filter inductor and capacitor. However, above 5-10 kHz, capacitor impedance is usually dominated by its equivalent series resistance, ESR, rather than C value. Since the ESR remains essentially constant regardless of operating frequency, operation at higher frequencies does not enable the size and cost of the capacitor to be further reduced.

Also, at higher frequencies, transistor switching losses become significant. Thus, a maximum operating frequency of 25 kHz is chosen for this design.

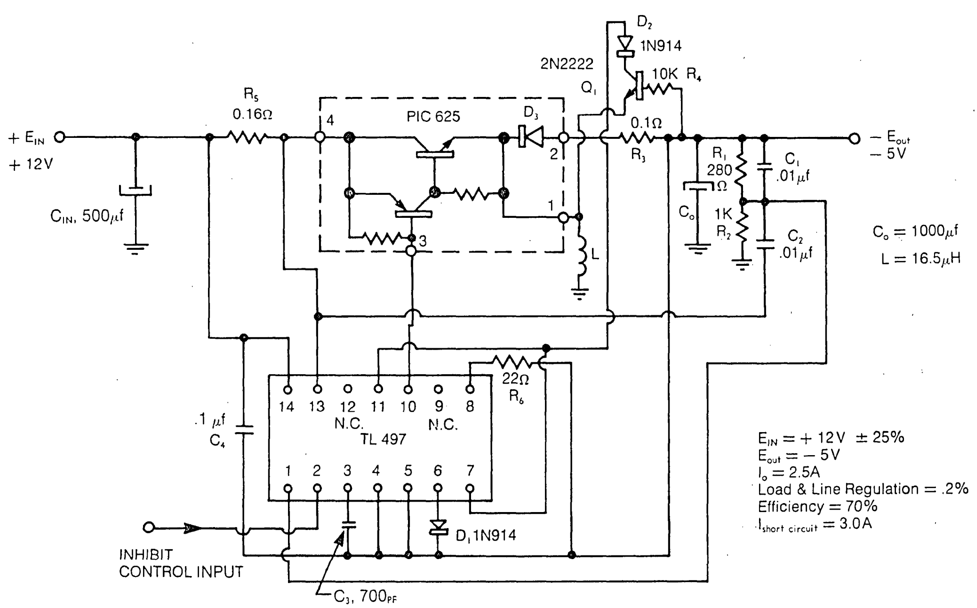


Figure 4. Flyback Regulator, +12V Input, −5V Output

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Referring to Figure 3, the design calculations are:

$$I_p = 2\,I_o max\,(E_o/E_{IN} min + 1) = 2 \times 2.5\,(5/9 + 1)$$
$$= 7.8A \text{ (constant)}$$

$$t_D = \frac{1}{f_{max}\,(E_o/E_{IN} min + 1)} = \frac{1}{25 \times 10^3\,(5/9 + 1)}$$
$$= 25.7\,\mu s \text{ (constant)}$$

$$L = \frac{t_D \times E_o}{I_p} = \frac{25.7 \times 10^{-6} \times 5}{7.8}$$
$$= 16.47\,\mu H$$

$$C_{min} = \frac{I_p \times t_D}{2\,\Delta e_o} = \frac{7.8 \times 25.7 \times 10^{-6}}{2 \times 0.1}$$
$$= 1002\,\mu F$$

$$ESR_{max} = \frac{\Delta e_o}{I_p} = \frac{0.1}{7.8} = 0.0128\,\Omega$$

The operating frequency will change in proportion to load current, I_o:

$$f = f_{max} \times \frac{I_o}{I_{o\,max}}$$

The PIC625 hybrid power output stage incorporates a fast PNP quasi-darlington switching transistor and UES catch diode. The quasi-darlington switch requires 30 mA of drive current. This drive current is provided with diode D_1 and Resistor R_6 in conjunction with the Integrated circuit TL497. (Refer to Figure 4)

$$I_{DRIVE} = \frac{V_{be}}{R_6} = \frac{0.65}{R_6}$$
$$\therefore\ R_6 = 22\,\Omega$$

The output voltage is preset by divider network R_1 and R_2, according to the relationship:

$$E_o = \left[1 + \frac{R_2}{R_1}\right] V_{REF}$$

where $V_{REF} = 1.22V$. Assuming a nominal value for $R_2 = 1K$, then:

$$R_1 = 320\,\Omega$$

R_1 may be trimmed to obtain the precise output voltage.

The TL497 control circuit operates in the current limiting mode under normal operating condition. Thus, the peak current value, I_p, is determined by the current limiting resistor R_5. Capacitor C_3 is required to prevent the TL497 from terminating the transistor on-time prematurely. This causes an 8 μs delay, once over-current is detected at the short circuit sense input (pin 13 of TL497) before the transistor switch turns off. The delay time is the time required to charge capacitor C_3 to the predetermined voltage level before drive current to the pass transistor is removed. The current limit threshold voltage is about 1.2 volts.

$$R_5 = \frac{1.2V}{I_p}$$
$$= \frac{1.2}{7.8A}$$
$$= 0.153\,\Omega$$

The function of transistor Q_1, diode D_3 and resistor R_3 and R_4 is to provide short circuit protection. The transistor Q_1 prevents turn-on of the pass transistor as long as the catch diode continues to conduct. Thus, it limits the maximum current and operating frequency under short circuit conditions. D_2 and R_4 providing voltage isolation to transistor Q_1.

C_2 is required for circuit stabilization; capacitor C_1 provides AC coupling of ripple voltage to the control circuit. C_{IN} and C_o are filter capacitors.

Unitrode Switching Regulator Design Guide U-68 covers the design of a buck regulator, and contains a section on power inductor design which is applicable to the flyback and boost regulators.

Section Two — Boost Switching Regulator

The boost switching regulator is described briefly in this application note. It accepts a DC voltage input and provides a regulated output voltage which must be greater than input voltage.

The basic circuit configuration of a boost regulator is shown in Figure 5. When the transistor switch is turned on, the supply voltage E_{IN} is applied across power inductor L. The diode is reverse biased by voltage E_o. Energy is transferred from the input supply to the power inductor. When the transistor is turned off, the energy stored in the inductor L induces a voltage such that the diode conducts and transfers the energy to the load and the output capacitor. In addition to the energy stored in the inductor, additional energy is transferred from the input directly to the output during the diode conduction time.

This pumping action, similar to the flyback regulator, also makes it desirable to operate the boost regulator in the discontinuous mode with a fixed peak current through the inductor. However, unlike the flyback regulator, in the boost regulator the diode conduction time is not fixed, but varies according to the input voltage:

$$t_D = \frac{L\, I_p}{E_o - E_{IN}}$$

Output voltage is regulated by controlling the duty cycle:

$$\frac{E_o}{E_{IN}} = \frac{t_T}{t_D} + 1$$

Since the ripple voltage across the output capacitor is directly proportional to diode conduction time, t_D, capacitor requirements are determined by the maximum t_D:

$$t_D \max = \frac{L\, I_p}{E_o - E_{IN}\,(\max)}$$

The Figure 6 is a complete schematic diagram of a boost switching regulator. It accepts +12V of DC input voltage and provides regulated +24V of output voltage.

The design procedure and circuit description is similar to the flyback switching regulator.

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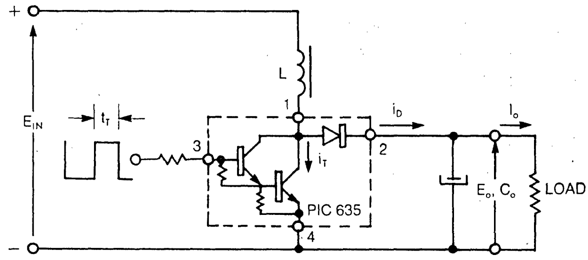
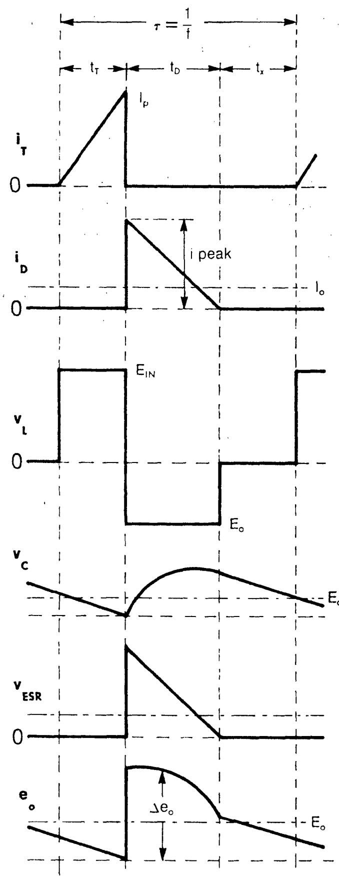


GIVEN:
$E_{IN\ (max)}$
$E_{IN\ (min)}$
E_o
$I_{o\ (max)}$
$f_{(max)}$
Δe_o

WORST CASE:
$E_{IN} = E_{IN\ (min)}$
$I_o = I_{o\ (max)}$
$t_x = 0$



$$I_p = 2\, I_{o\ max}\,(E_o/E_{IN\ (min)}) = \text{constant}$$

$$t_{D\ (min)} = \frac{1}{f_{max}\,(E_o/E_{IN\ (min)})}$$

$$L = \frac{t_{D\ (min)}\,(E_o - E_{IN\ min})}{I_p}$$

$$f = \frac{1}{\tau} = f_{max}\,\frac{I_o}{I_{o\ (max)}} \times \frac{E_o - E_{IN}}{E_o - E_{IN\ (min)}}$$

$$C_{min} = \frac{I_p \times t_{D\ max}}{2\,\Delta e_o}$$

(worst case $I_o \rightarrow 0$)

$$ESR_{max} = \frac{\Delta e_o}{I_p}$$

Figure 5. Boost Regulator

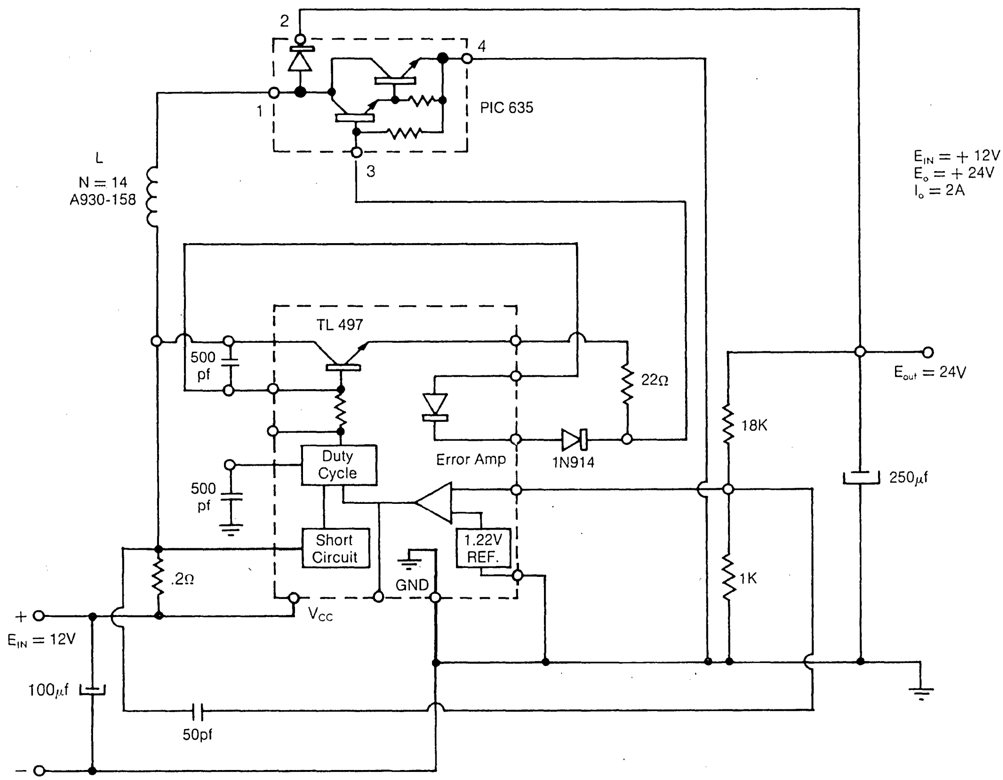


Figure 6. Boost Switching Regulator

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Appendix A — Derivation of Design Equations

The basic circuit configuration of the flyback switching regulator is shown in Figure 3. Assuming a fixed value of peak current, I_p, and output volts, E_o, the following equations are evident:

$$E_{IN}\,t_T = E_o\,t_D = I_p \times L \quad \text{.......... 1.}$$

$$t_T = t_D \times E_o/E_{IN} \quad \text{.......... 1a.}$$

$$\tau = t_T + t_D + t_X = 1/f \quad \text{.......... 2.}$$

Worst case $\tau = \tau_{min}$, $f = f_{max}$, $t_X = 0$, $E_{IN} = E_{IN}$ min. Substituting Equation 1a:

$$\tau_{min} = \frac{1}{f_{max}} = t_D\,(E_o/E_{IN}\,\text{min} + 1) \quad \text{.......... 2a.}$$

$$\therefore\ t_D = \frac{1}{f_{max}\,(E_o/E_{IN}\,\text{min} + 1)} \quad \text{.......... 2b.}$$

Since in Equation 1, E_o, I_p and L are all constant values for a given application, t_D is also a constant value.

By inspection of Figure 3 output current waveforms:

$$I_o = \frac{I_p}{2} \times \frac{t_D}{\tau} = \frac{I_p}{2} \times t_D \times f \quad \text{.......... 3.}$$

Taking worst case conditions and substituting Equation 2b:

$$I_o\,\text{max} = \frac{I_p}{2} \times f_{max} \times \frac{1}{f_{max}\,(E_o/E_{IN}\,\text{max} + 1)} \quad \text{.......... 3a.}$$

$$\therefore\ I_p = 2\,I_o\,\text{max}\,(E_o/E_{IN}\,\text{max} + 1) \quad \text{.......... 3b.}$$

Rearranging Equation 1:

$$L = \frac{t_D \times E_o}{I_p} \quad \text{.......... 1b.}$$

The ripple voltage, Δv_c, across the output filter capacitor:

$$\Delta v_c = \frac{\Delta Q}{C} \quad \text{.......... 4.}$$

The worst case net charge into the capacitor is equal to the area under the diode current waveform

$$\Delta Q_{max} = \frac{I_p \times t_D}{2} \quad \text{.......... 4a.}$$

Substituting into Equation 4 and rearranging:

$$\therefore\ C_{min} = \frac{I_p \times t_D}{2\,\Delta e_o} \quad \text{.......... 4b.}$$

The ripple voltage, v_{ESR} across the capacitor series resistance, ESR.

$$v_{ESR} = I_p \times ESR \quad \text{.......... 5.}$$

$$\therefore\ ESR_{max} = \frac{\Delta e_o}{I_p} \quad \text{.......... 5a.}$$

The frequency, f, will vary as a function of load current. Rearranging Equation 3:

$$\frac{I_o}{f} = \frac{I_p}{2} \times t_D = I_o\,\text{max}/f_{max} \quad \text{.......... 6.}$$

$$\therefore\ f = f_{max} \times \frac{I_o}{I_{o\,max}} \quad \text{.......... 6a.}$$

and

$$f_{min} = f_{max} \times \frac{I_{o\,min}}{I_{o\,max}}$$

THERMAL DESIGN CONSIDERATIONS FOR OPERATING UNITRODE'S TO-92 TRANSISTORS AND DARLINGTONS IN PULSED-POWER APPLICATIONS

Introduction

Unitrode's power Darlingtons (U2TA506, U2TA508, U2TA510) and power transistors (UPTA510, UPTA520, UPTA530 and UPTB520, UPTB530, UPTB540, UPTB550) in economical TO-92 plastic packages are ideally suited for use in pulsed power applications, such as lamp driving or printer driving where the inrush or pulse drive current can be as high as several amperes. When compared with transistors or Darlingtons in conventional power packages, the Unitrode TO-92 devices offer cost savings of 50% or more, take up significantly less board space, and lend themselves to tape and reeling and automatic insertation. They also offer the advantage of a maximum operating junction temperature ($T_{J(max)}$) of 175°C versus 150°C or 125°C for other plastic packaged devices.

Thermal considerations are of prime concern when the TO-92 power transistors and Darlingtons are used in pulsed power applications. This Design Guide provides a method for determining the junction temperature and maximum allowable peak power dissipation for the U2TA506, U2TA510 and UPTB520 series when they are operated at frequencies of 10 kHz or less, where the switching losses are negligible and can be ignored. This method is valid for the vast majority of pulse applications.

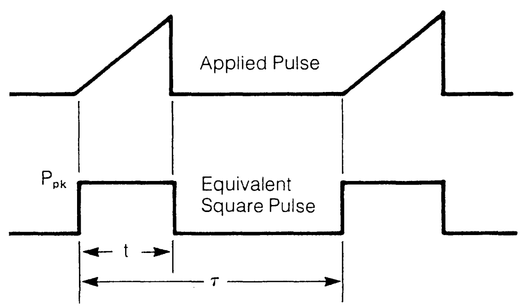
Thermal Analysis

A detailed transient thermal analysis is required to determine the peak junction temperature and maximum allowable power dissipation since the junctions of the transistor or Darlington are subjected to temperature excursions due to the applied, periodic power pulses.

A) Effective Pulsed Thermal Impedance

The effective pulsed thermal impedance (Θ_p) of a device subjected to a periodic train of power pulses can be calculated as follows:

$$\Theta_p=(\Theta_{j\text{-}A})(D) + (1-D)(r(t+\tau))-r(\tau) + r(t) \quad \ldots\ldots. (1)$$



Where:
- t = pulse width
- τ = period
- D = t/τ (Duty Cycle)
- $r(t+\tau)$ = transient thermal impedance at time $t + \tau$
- r(t) = transient thermal impedance at time t
- $\Theta_{j\text{-}A}$ = DC junction to ambient thermal impedance
- P_{pk} = The peak power of a square power pulse with equivalent energy to that of the actual power pulse.

Figure 1. Power Pulses

The DC junction to ambient thermal impedance ($\Theta_{j\text{-}A}$) is 200°C/W maximum for the UPTA510 and UPTB520 series and is 155°C/W maximum for the U2TA506 Series.

The transient thermal impedance for the U2A506, UPTA510, and UPTB520 series can be obtained from the curves presented in Figure 2:

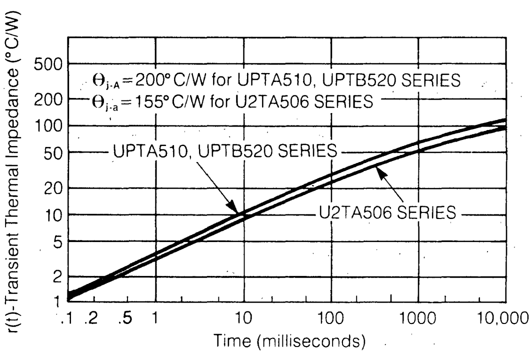


Figure 2. Junction to Ambient Transient Thermal Impedance

B) Peak Junction Temperature

The peak junction temperature of a device subjected to a periodic train of power pulses can be calculated using the previously derived effective pulsed thermal impedance as follows:

$$T_{j\,(peak)} = T_{Ambient} + (P_{pk})\,(\Theta_p) \qquad (2)$$

In the case of a single shot pulse the term for Θ_p reduces to

$$\Theta_p = r(t)$$

and the equation used to calculate peak junction temperature becomes

$$T_{j\,(peak)} = T_{Ambient} + (P_{pk})\,(r(t)) \qquad (3)$$

Allowable Peak Power Dissipation

The allowable peak power dissipation can be derived from the following equation:

$$P_{pk(max)} = \frac{T_{j\,(max)} - T_{Ambient}}{\Theta_p} \qquad (4)$$

Where $T_{j\,(max)}$ is the maximum allowable junction temperature. For the U2TA506, UPTA510 and UPTB520 series the maximum junction temperature is 175°C.

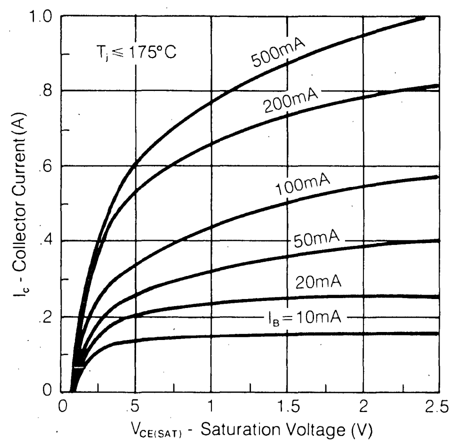


Figure 4. UPTA510 Series. Maximum Saturation Voltage vs. Collector Current

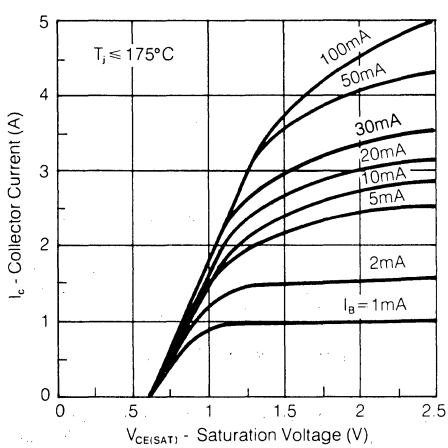


Figure 3. U2TA506 Series. Maximum Saturation Voltage vs. Collector Current

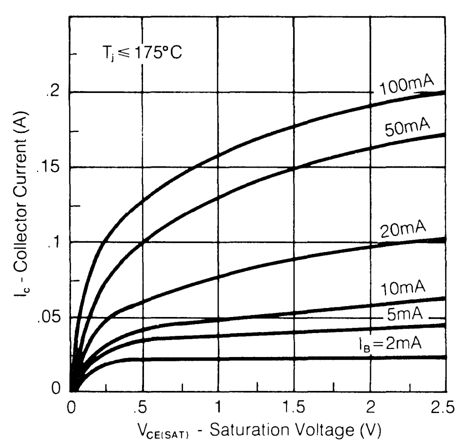


Figure 5. UPTB520 Series Maximum Saturation Voltage vs. Collector Current

Peak Power

The peak power can be expressed as follows:

$$P_{pk} = (V_{CE\,(SAT)})\,(I_{pk}) + (V_{BE\,(SAT)})\,(I_B) \quad \ldots\ldots\ldots\ldots (5)$$

Where I_{pk} is the peak collector current of a square pulse of current equivalent to the applied current pulse, $V_{CE(SAT)}$ is the transistor or Darlington saturation voltage at I_{pk}, $V_{BE(SAT)}$ is the base-to-emitter saturation voltage and I_B is the base current. Figures 3, 4, and 5 are plots of $V_{CE(SAT)}$ for the U2TA506, UPTA510 and UPTB520 series Darlingtons and transistors. Figures 6 and 7 are plots of the $V_{BE(SAT)}$. These curves can be used in determining P_{pk}.

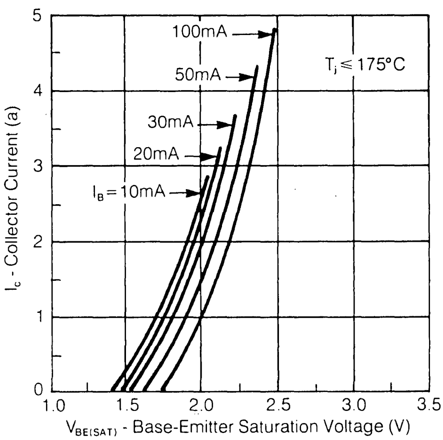


Figure 6. U2TA506 Series Maximum Base to Emitter Saturation Voltage vs. Collector Current

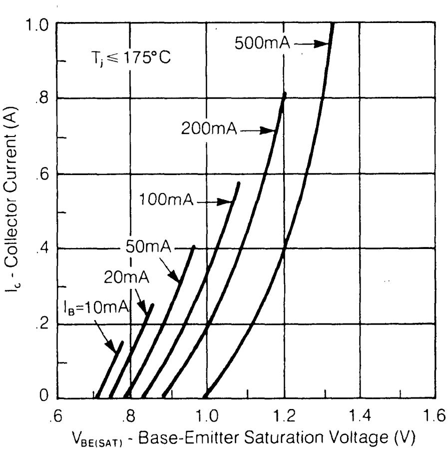


Figure 7. UPTA510, UPTB520 Series. Maximum Base to Emitter Saturation Voltage vs. Collector Current

Design Examples

1. An incandescent lamp is controlled by a U2TA506 Darlington operating from a 12V battery. When switched on the lamp draws an inrush current of 3A which decays exponentially to a steady-state value of 300mA. The time constant of the inrush current is 50 milliseconds and the worst case ambient temperature is 55°C. The Darlington's base drive is 30mA dc.

Problem:
Calculate the peak junction temperature due to the inrush pulse and the steady-state junction temperature.

Solution:
The inrush current can be approximated by a square wave of 3A peak and 50 milliseconds duration. The equivalent square pulse of current will have the same energy as the exponential pulse if the $V_{CE(SAT)}$ of the Darlington is assumed to remain constant. Since the $V_{CE(SAT)}$ will actually drop as the inrush current exponentially decays, the result obtained from using the square wave approximation will be conservative.

Using equations (3) and (5)

$$T_{j(peak)} = T_{Ambient} + (P_{pk})(r(t)) \quad \ldots\ldots\ldots\ldots (3)$$

Where: $T_{Ambient}$ = 55°C
$r(t)$ = r(50mSec) = 17.5°C/W (from Figure 2)
P_{pk} = $(V_{CE(SAT)})\,(I_{pk}) + (V_{BE(SAT)})\,(I_B)$ . . . (5)
= (1.5V) (3A) + (2.15V) (30mA)
(from Figures 3 and 6)
= 4.56W

Therefore:

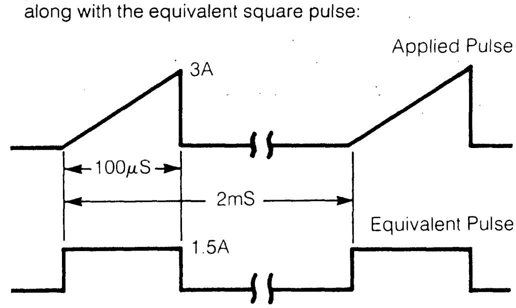
$T_{j(peak)}$ = 55°C + (4.56W) (17.5°C/W) = 135°C

Since 135°C is 40°C less than the maximum operating junction temperature for the U2TA506 ($T_{j(max)}$ = 175°C), the Darlington is operating well within its rating.

The Steady-state junction temperature can be determined as follows:

$T_{j(ss)} = (P_{(ss)})\,(\Theta_{j\text{-}A}) + T_{Ambient}$
= ((.3A)(.73V) + (.03A)(1.60V)) (155°C/W) + 55°C
= 96°C

2. A U2TA508 is used to drive a solenoid load in an impact printer. The collector current waveform is as shown below along with the equivalent square pulse:



The Darlington is switching in a clamped mode so the energy stored in the solenoid inductance during the on-time is dissipated in the clamp and not in the Darlington. The maximum ambient temperature is 80°C and the base drive current is 20mA.

Problem:
Find the worst case junction temperature and determine if it is within the maximum rating of the U2TA508.

Solution:
Use equation (1) to determine Θ_p

$\Theta_p = (\Theta_{j\text{-}A})(D) + (1-D)(r(t+\tau)) - r(\tau) + r(t)$ ....(1)

$\Theta_{j\text{-}A}$ = 155°C/W (from Figure 2)

$D = \frac{.1mSec}{2mSec} = .05$

$r(t+\tau) = r(2.1mSec)$ = 4.2°C/W (from Figure 2)

$r(\tau) = r(2mSec)$ = 4.1°C/W (from Figure 2)

$r(t) = r(.1mSec)$ = 1.1°C/W (from Figure 2)

Therefore:

Θ_p = (155°C/W) (.05) + (.95)(4.2°C/W) − 4.1°C/W
+1.1°C/W
= 8.75°C/W

Using equation (5)

$P_{pk} = (V_{CE(SAT)})(I_{pk}) + (V_{BE(SAT)})(I_B)$ .... (5)

I_{pk} = 1.5A

$V_{CE(SAT)}$ + 2V (from Figure 3)

(The $V_{CE(SAT)}$ value at 3A was chosen to give a conservative answer. If T_j is found to be greater than 175°C it may be necessary to recompute using a closer approximation of the actual $V_{CE(SAT)}$ which varies as the current increases from 0 to 3A.)

I_B = 20mA

$V_{BE(SAT)}$ = 2.1V (from Figure 6)

(Again the $V_{BE(SAT)}$ value at 3A was chosen to give a conservative result.)

Therefore:

P_{pk} = (2V) (1.5A) + (2.1V) (.02A) = 3.04W

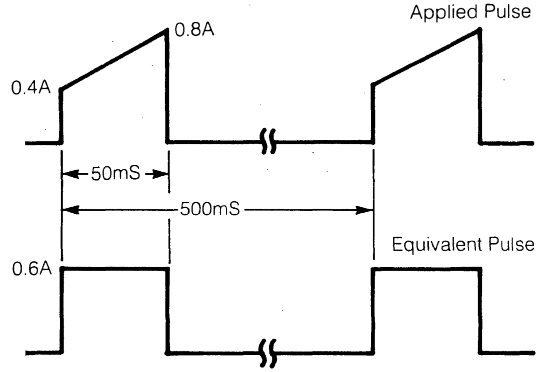
Now T_j can be determined from equation (2)

$T_j = T_{ambient} + (P_{pk})(\Theta_p)$ .... (2)

= 80°C + (3.04W) (8.75°C/W) = 107°C

This is well within the maximum rating of 175°C for the U2TA508.

3. A UPTA530 is used to drive a high voltage DC motor in a display application the current waveform as is shown below:



The base drive is 200 mA and the worst case ambient temperature is 65°C.

Problem:
Determine the junction temperature to insure it is within the maximum rating of 175°C for the UPTA530.

Solution:
Using Equation (1)

Θ_p = (200°C/W) (.1) + (.9) (52°C/W) − 50°C/W + 21°C/W
= 37.8°C/W

From equation (5) and Figures 4 and 7.

P_{pk} = (2.3V (.6A) + (1.2V)(.2A) = 1.6W

(Again $V_{CE(SAT)}$ and $V_{BE(SAT)}$ values at .8A rather than .6A were used to insure a conservative answer).

Therefore, from equation (2)

T_j = 65°C + (1.6W) (37.8°C/W) = 126°C

It becomes readily apparent from these examples that Unitrode's TO-92 transistors and Darlingtons can be operated with significant safety margin in a wide variety of pulsed-power applications.

POWER SWITCHING CAPABILITIES OF IMPROVED TO-92 THYRISTORS

I) Basic Performance Considerations:

The conventional advantage of the TO-92 plastic package over other medium power packages (TO-18, TO-5, etc.) is its low cost. However, in most cases, the performance trade-off required produces low steady-state power handling capability due to relatively high junction-to-case thermal impedance. This is caused by small pellet, low conduction area designs. These conventional design TO-92 devices also have lower pulse power handling capability due to low thermal capacity in the TO-92 package materials. The resulting thermal management problem makes it difficult for conventional planar SCR device designs to exceed 0.8A RMS at 65°C case and 6.0A peak surge current in the TO-92.

As a result of new construction techniques, the Unitrode IP200/2N6681-5 series SCR can handle 1.0A RMS at 65°C case and 8.3 ms surge current pulses of 15A. See Figs. 1A and 1B.

Increased current handling capability, coupled with a high voltage design, permit this device to deliver up to 400W to a steady-state, 60 Hz, 1/2 sinewave load while dissipating less than 1.0W. Proper load configuration can realize this extremely energy efficient design potential.

II) Additional Advantages:

Perhaps the most significant advantage of the IP200/2N6681-5 series over previous TO-92 SCR devices in terms of meeting the needs of existing equipment designs is a considerable improvement in its ability to withstand overloads.

Many applications of such medium power devices are subject to fault conditions in which many times the normal load current is caused to flow in the control device. The curves in Figs. 1B and 1C illustrate the advantage of the IP200/2N6681-5 series surge capability. The thermal management advantages of the IP200/2N6681-5 series also help it to survive fault or spurious circuit conditions which cause the SCR to turn-on without gate drive such as over-voltage or dv/dt triggering. Under these circumstances, only a small pipe-like region of the device is originally brought into conduction. The increased thermal capacity on both the anode and cathode side inherent in the IP200/2N6681-5 series construction provides increased thermal damping right at the surface of the silicon. This keeps the thermal excursion, caused by such high energy density conditions, to a minimum.

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The high voltage capability of the IP200/2N6681-5 series is also a tremendous advantage in equipment fault or transient input conditions.

The combined effect of both of these increased capabilities can allow the finished equipment package to more easily meet severe fault or transient line conditions without permanent damage.

An example of this type of application is in feedback terminated (variable exposure) flash circuits. These circuits are basically an application of Class D inverter circuits. The simplified circuits in Fig. 4 show the use of the IP200/2N6681-5 series as a commutating SCR, quench tube trigger or "Pilot" SCR. These applications, especially the "Pilot" SCR, can find uses other than in flash units.

This capability is also useful in capacitor discharge ignition systems such as the small engine breakerless ignition circuit shown in Fig. 5. In this circuit, a 1.0 μF capacitor, charged to 400V can deliver 0.08 joule of energy to a spark (not counting circuit losses). An example of such a circuit using a 12V automotive ignition coil with the secondary shorted and a 1.0 μF low loss capacitor, produced a peak current of 10A in the SCR at a 400V charging voltage. The IP200/2N6681-5 series case temperature rose to 50°C above free air ambient at 60 Hz rate (3600 RPM for single cylinder engines). Due to the 150°C/W case-to-ambient thermal impedance of this device, the device was dissipating approximately 0.33W or about 7% of the energy being stored in the capacitor.

Other possible applications of the IP200/2N6681-5 series high voltage, pulse handling capability include the direct discharge of capacitors such as small power supply crowbars, and the switching of crystalline optical shutters.

The device also has interest as a source of high voltage PNP transistor action. Even though individual gain is low, darlington configurations are possible.

An example of this type of requirement is available in ground-fault interrupter circuits. In this type of equipment, a TO-92 SCR is frequently used as a relay coil control element. A simplified circuit diagram is shown in Fig. 2. It is evident that any voltage surge applied to the line input will, to an extent, depending on circuit details, be applied to the SCR. The circuit steps necessary to survive such transients will be reduced in proportion to the degree to which the SCRs' overload capability is enhanced.

III) Switching High Power Pulses:

Perhaps one of the fastest design paths for new equipment, taking advantage of the ratings of the IP200/2N6681-5 series, is in the area of pulse power applications involving the transfer of energy from a storage element to a load. For example, since the energy stored in a capacitor is directly proportional to the square of the charging voltage, an 800V device can allow four times the energy storage of a 400V device using the same capacitance.

In some applications, the efficient use of this energy requires its rapid transfer to a load. The same construction techniques which enhance the long pulse surge capability of the IP200/2N6681-5 series by increasing the thermal capacity of the package also give the device a strong advantage at shorter pulse widths. This advantage is demonstrated in Fig. 3.

The upper trace of Fig. 3 shows a short pulse of current (Time: 10 μs/square, Current: 40A/square) which was used to stress each of two different types of TO-92 SCRs. The lower set of traces are the resulting on-state voltage as a function of time for each SCR (Voltage: 5V/square).

The highly non-linear voltage trace is the response of the conventional design TO-92 SCR. The extreme level of heating in this device is indicated by the magnitude of the excursion in on-state voltage.

The other voltage trace is the response of an IP200/2N6681-5 series device. The absence of any thermally generated on-state voltage excursion is evident.

Even though both devices showed no measurable change in electrical characteristics after this test, the small amount of irreversible damage which accumulates with each such surge pulse would be far lower for the IP200/2N6681-5 series.

In fact, in most cases, the IP200/2N6681-5 series can handle an indefinite number of surge pulses at the non-repetitive rating level of previously available TO-92 SCRs. (Refer to Fig. 1C.)

Given this combination of high voltage and high pulse current capability, Fig. 1C indicates that the IP200/2N6681-5 series of devices can deliver energy to a load at a maximum rate of 40,000W and sustain this level for 100μs.

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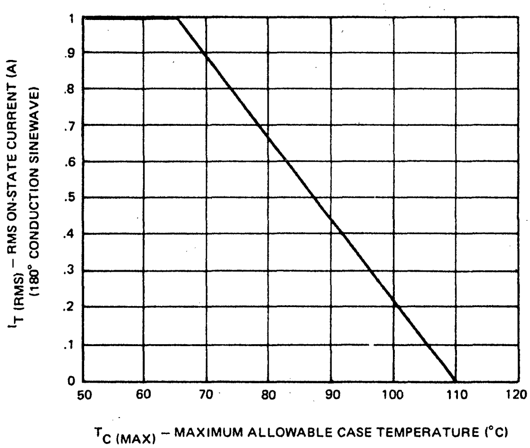


Fig. 1A. Maximum Allowable Case Temperature vs. On-State Current (60 Hz)

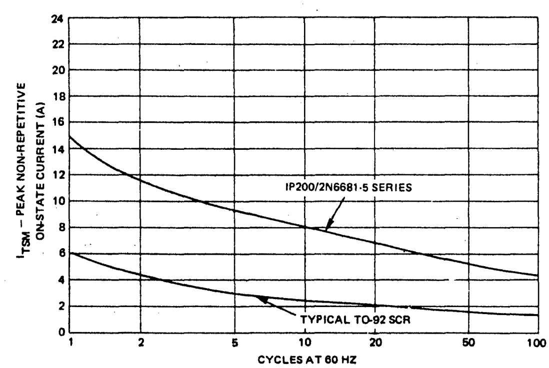


Fig. 1B. Maximum Allowable Non-Repetitive Peak On-State Current Following Rated Load Conditions

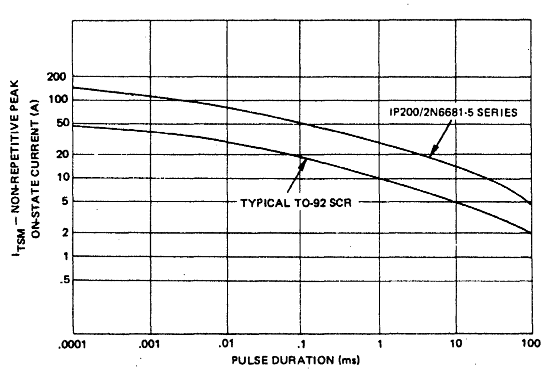


Fig. 1C. Surge Rating vs. Pulse Duration

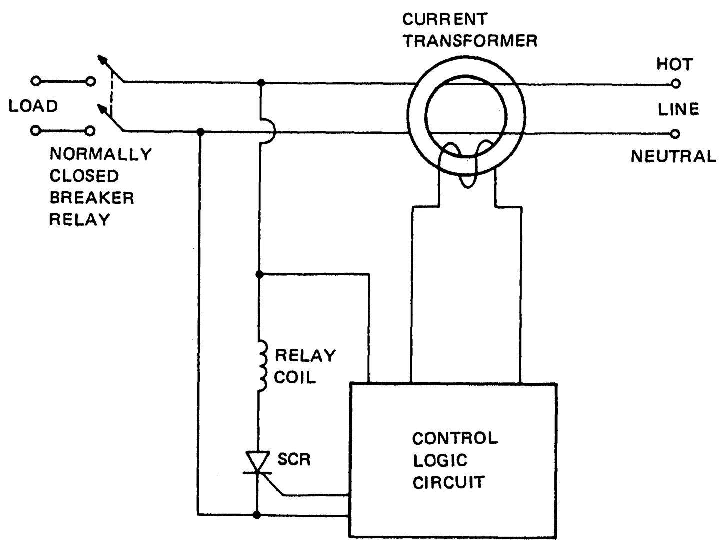
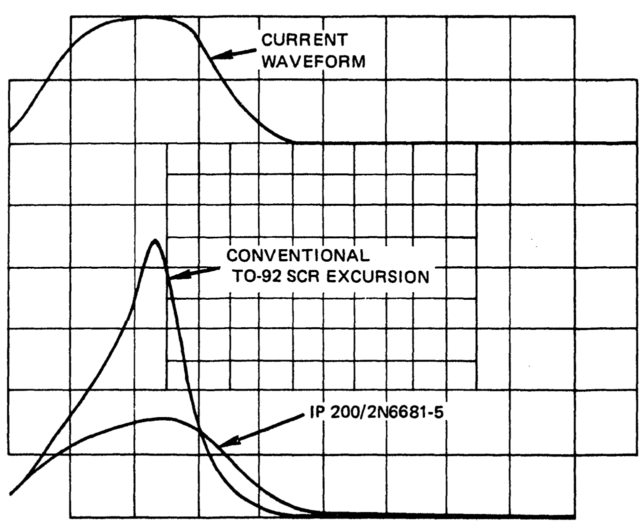


Fig. 2. Ground-Fault Interrupter Circuit



TIME: 10 μS/SQUARE
CURRENT: 40 A/SQUARE (UPPER TRACE)
VOLTAGE: 5 V/SQUARE (LOWER TRACES)

Fig. 3. Response to Short Pulse Surge Stress

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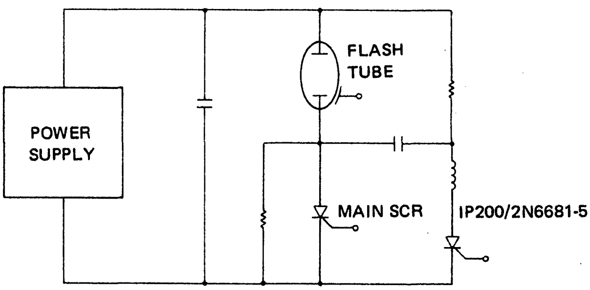

Fig. 4A. Commutating SCR

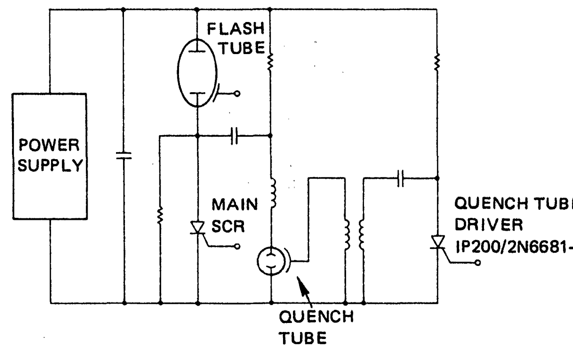

Fig. 4B. Quench Tube Driver

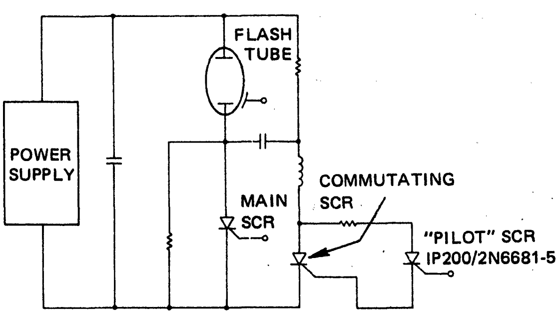

Fig. 4C. "Pilot" SCR

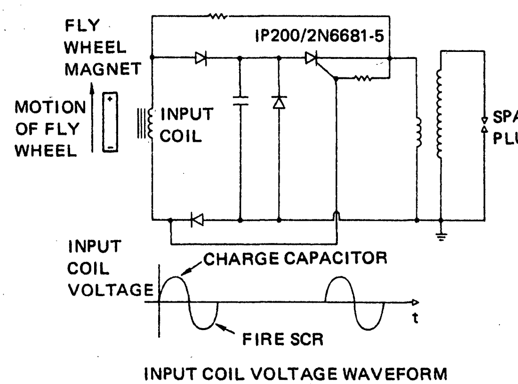

Fig. 5. Small Engine Ignition

GUIDELINES FOR USING TRANSIENT VOLTAGE SUPPRESSORS

1.0 Introduction

During transient periods, system voltages and currents are often many times greater than their steady-state values. These transients must be considered in overall electronic systems design to insure required circuit performance and reliability both during and after the transient.

Transients may result from a variety of causes. The most common of these are: normal switching operations (power supply turn-on and turn-off cycles), routine AC line fluctuations, or abrupt circuit disturbances (faults, load switching, voltage dips, magnetic coupling by electro-mechanical devices, lightning surges, etc.). Voltage transients are a major cause of component failures in semiconductors. Random high voltage transient spikes can permanently damage these voltage sensitive devices and disrupt proper system operation. Catastrophic power supply conditions should not necessarily be the designer's prime concern, since lower level transients can cause improper operation of a system even though no component failures are caused. Normal power supply on-off cycles have the potential of emitting spikes with sufficient energy to destroy an entire semiconductor device chain. Any surviving devices are also suspect. Trouble shooting, isolating, and replacing damaged devices is time consuming and costly; especially when performed in the field.

Unitrode's TVS305 and TVS505 series of transient voltage suppressors (TVS) offer the designer significant price/performance advantages over other protection methods. Their miniature size permits simple "close-in" installation in applications where circuit boards are dispersed throughout one or more electronic racks. Dispersed usage aids system trouble shooting and affords transient voltage protection where internal system disturbances such as those caused by inductive load switching could occur.

In spite of their small size, the TVS305 and TVS505 suppressor series can dissipate 500 watts and 150 watts (respectively) of peak pulse power for 1 millisecond. Response time to transients is just about instantaneous — about 1×10^{-12} seconds. These devices perform to their data sheet specifications without significant degradation throughout their operating life. Unitrode has performed full power pulse life tests for 100,000 pulses with negligible change in characteristics. These devices are suitable for almost any equipment and environment.

2.0 Choosing the Correct Transient Voltage Suppressor for the Application

Certain critical terms must be defined before any discussion of "how to" choose the correct TVS.

1. Stand-Off Voltage (V_R) is the highest reverse voltage at which the TVS will be non-conducting.
2. Min. Breakdown Voltage (BV_{min}) is the reverse voltage at which the TVS conducts 1 mA. This is the point where the TVS becomes a low impedance path for the transient.
3. Max. Clamping Voltage (V_{Cmax}) is the maximum voltage drop across the TVS while it is subjected to the peak pulse current, usually for 1mS.

Figure 1 graphically shows all three terms.

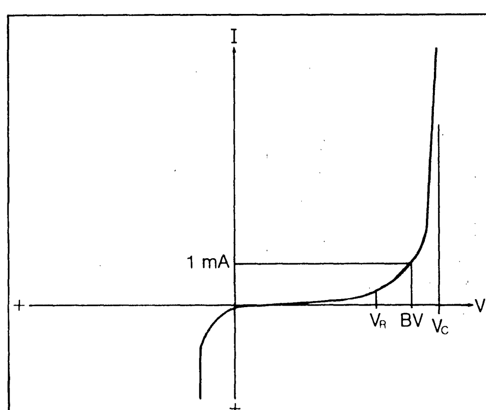

Figure 1 — TVS Characteristics

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2.1 Determining Pulse Power Levels

Since a zener TVS has an almost constant clamping voltage throughout a transient pulse, the transient pulse power (P_p) equals the peak pulse current (I_{pp}) multiplied by the clamping voltage (V_C).

$$P_p = V_C \times I_{pp}$$

2.2 Choosing the Appropriate Transient Voltage Suppressor

The three most important factors in choosing the appropriate TVS for your application, in their order of importance are:

1. Pulse power (P_p) — Choose the TVS series that will handle the Transient Pulse Power. To determine Transient Pulse Power use the simple equation in section 2.1. If I_{pp} is not known or measurable, it can be calculated — see Sections 3 and 4. The pulse duration vs. pulse power graph on the Unitrode TVS305/TVS505 data sheet can then be used to determine the TVS series that will handle the transient. This graph for the TVS505 series is shown in Figure 2.
2. Stand-off voltage (V_R) — From the TVS series selected, choose the device with the stand-off voltage equal to or greater than your normal circuit operating voltage. This insures that the TVS will draw a negligible amount of current from the circuit during normal circuit operation. The electrical specifications for the TVS505 series are shown in Figure 3.
3. Maximum Clamping Voltage (V_{Cmax}) — Determine the clamping voltage of the device chosen for the transient given and be sure it is below the voltage that might damage any components in the protected circuit. See Figure 3.

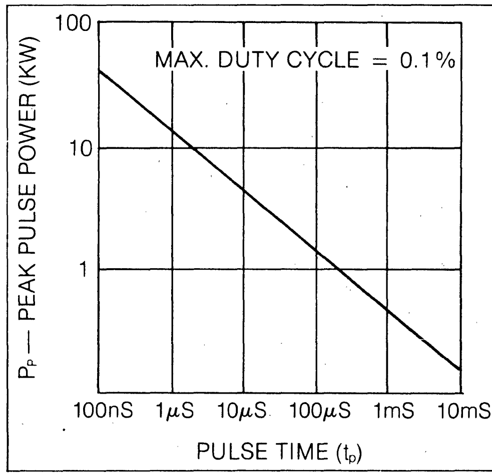

Figure 2 — Peak Pulse Power vs. Pulse Duration

TVS Part No.	Stand-off Voltage V_R	Min. Breakdown Voltage $BV_{(min)}$ @ 1mA	Max. Leakage Current I_R @ V_R	Max. Clamping Voltage V_C @ 1A	Max. Clamping Voltage V_C @ 5A	Max. Clamping Voltage V_C @ 10A	Max. Peak Pulse Current I_{pp}	Max. Clamping Voltage V_C @ I_{pp}
	V	V	μA	V	V		A	V
TVS505	5.0	6.0	300	7.4		7.9	53.7	9.3
TVS510	10.0	11.1	5	13.2		14.4	30.3	16.5
TVS512	12.0	13.8	5	16.5		18.5	23.8	21.0
TVS515	15.0	16.7	5	19.7		22.2	19.8	25.2
TVS518	18.0	20.4	5	23.8	26.0		16.3	30.5
TVS524	24.0	28.4	5	32.4	37.0		11.9	42.0
TVS528	28.0	30.7	5	35.9	41.0		10.7	46.5

Figure 3 — Electrical Specifications @ 25°C

If the actual pulse power and pulse width are different from those listed on the data sheet, the clamping voltage can be calculated. The actual calculation method is beyond the scope of this note. Instead, we offer a graphical approximation using Figure 4. The approximation is based on the ratio of the actual and rated pulse power.

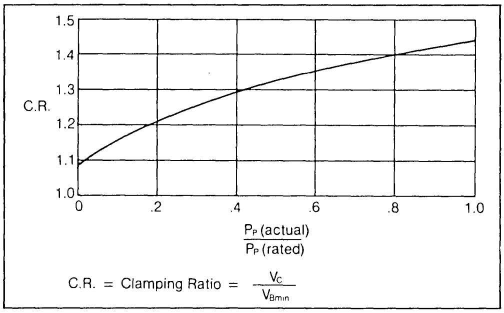

Figure 4 — Graphical Approximation for the Clamping Ratio

The procedure is as follows:

a. Calculate P_p (actual)$\approx 1.3 BV_{min} I_{pp}$.
b. For P_p (rated) use value from TVS data sheet curve (See Fig. 2 for example).
c. Calculate P_p (actual)/P_p (rated).
d. Use Fig. 4 to find corresponding value of C.R.
e. Calculate V_C = C.R. $\times$ BV_{min}.

2.3 Installation Considerations

1. Locate the TVS as close to the device or circuit to be protected as possible.
2. Minimize the "common path" through the TVS to minimize voltage spikes produced by fast risetime transients in lead and wiring stray inductance. See Figure 5.

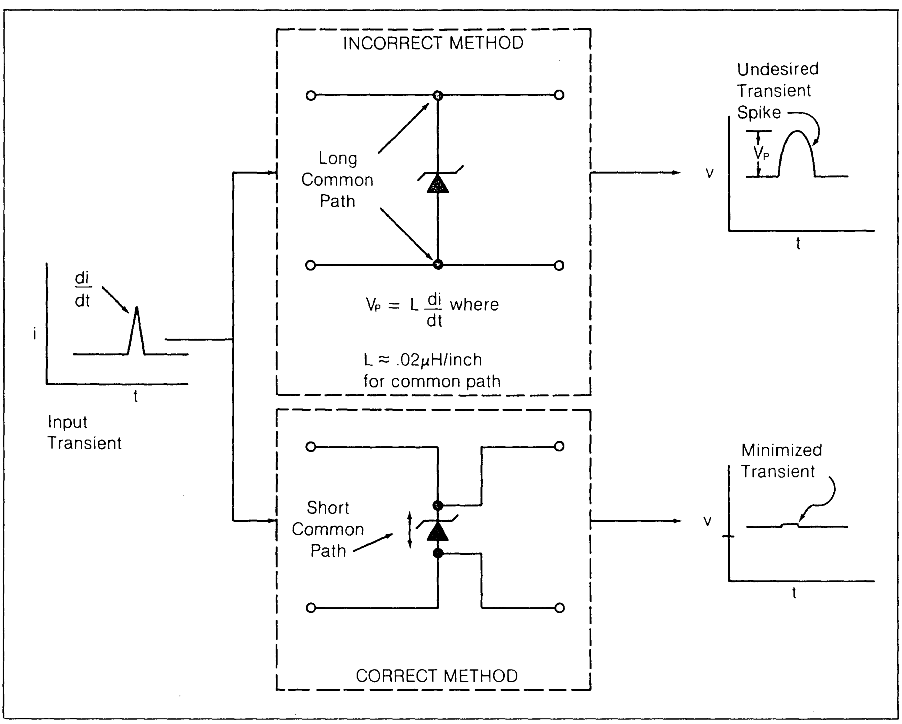

Figure 5 — Minimizing the Common Path

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3.0 Transient Levels and Waveforms

3.1 Voltage, Current and Power Levels

Since TVS tests and specs may be written in terms of voltage, current or power levels, the relationships are shown in Figure 6 for (a) field conditions and (b) test conditions.

In addition to the magnitude of the voltage, current or power, the waveform or pulse width should be specified, as shown in Figure 7, for example.

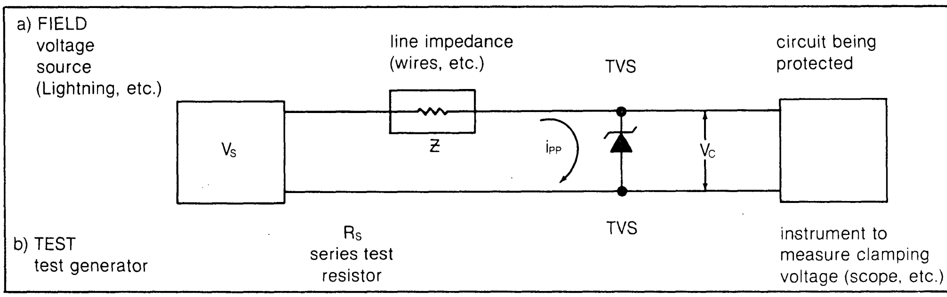

Figure 6 — Equivalent Circuit for Field and Test Conditions

3.2 Typical Transient Levels

Martzloff and Hahn in their paper on transients on 120 volt power lines* produced this table showing the surges recorded at a number of different locations over a two year period. The table indicates two primary causes of transients; load switching within the house and lightning storms.

Table 1*
Detailed Analysis of Recorded Surges

House	Most Severe Surge			Most Frequent Surge				Remarks
	Type†	Crest (volts)	Duration (μs or cycles)	1.5mHz Type†	Crest (volts)	Duration (μs or cycles)	Average Surges per Hour	
1	*A*·1.5	700	10 μs	*A*·1.5	300	10 μs	0.07	
2	*A*·2 0	750	20 μs	*A*·2 0	500	20 μs	0.14	fluorescent light
3	*B*·0.5	600	1 cycle	*B*·0 5	300	1 cycle	0.05	switching
4	*B*·0.5	400	2 cycles	*B*·0 5	300	2 cycles	0.2	
5	*C*	640	5 μs	too few to show typical			10 total	
6	*B*·0 3	400	1 cycle	*B*·0 3	250	1 cycle	0.01	
7	*B*·1	1800	1 cycle	*B*·1 0	800	1 cycle	0.03	lightning storm
8	*C*	1200	10 μs	*B*·0 5	300	4 cycles	0 1	
9	*B*·0.25	1500	1 cycle	same as most severe			0.2	oil burner
10	*B*·0.25	2500	1 cycle	*B*·0 25	2000	1 cycle	0.4	oil burner
11	*B*·0.2	1500	1 cycle	same as most severe			0.15	water pump
12	*B*·0.2	1700	1 cycle	*B*·0.2	1400	1 cycle	0.06	oil burner
13	*B*·0 1	350	1 cycle	too few to show typical			4 total	house next to 12
14	*C*	800	15 μs	—	—	—	1 total	lightning
15	*B*·0.25	800	3 cycles	*B*·0 25	600	3 cycles	0 05	rural area
16	*B*·0 15	400	15 μs	*B*·0 13	200	30 μs	0 4	surges
Street pole	*B*·0 5	5600	4 cycles	*B*·0 3	1000	1 cycle	0 1	lightning stroke nearby
Hospital	*C*	2700	9 μs	*C*	900	5 μs	0.1	lightning storm
Hospital	*B*·0 3	1100	1 cycle	too few to show typical			4 total	
Dept store	*B*·0.5	300	1 cycle	*B*·0 5	300	1 cycle	0.5	
Street pole	*B*·0 2	1400	4 cycles	*B*·0 2	600	4 cycles	0 07	lightning storm

†*A*—long oscillation; *B*—damped oscillation. *C*—unidirectional Number shows frequency in megahertz

*Reprinted from *Surge Voltages in Residential and Industrial Power Circuits* by Francois D. Martzloff, Member, IEEE, and Gerald J. Hahn. Reprinted by permission from *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-89, No. 6, July/August 1970, pp. 1049-1056. Copyright 1970, by the Institute of Electrical and Electronics Engineers, Inc. Printed in U.S.A.

3.3 Commonly Used Test Waveforms

1. The 10 × 1000μS Test Waveform used by many TVS manufacturers, also by incoming inspection departments of users, represents some commonly encountered transients. (See Figure 7).
2. The IEEE Standard (ANSI C 37.90a — 1974) for surge withstand capability. (See Figure 8).

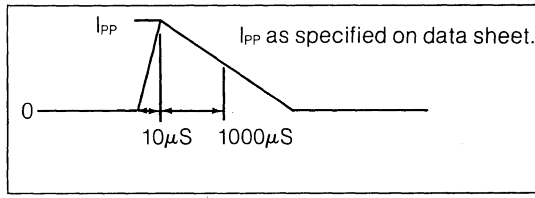

Figure 7 — Commonly Used Test Waveform

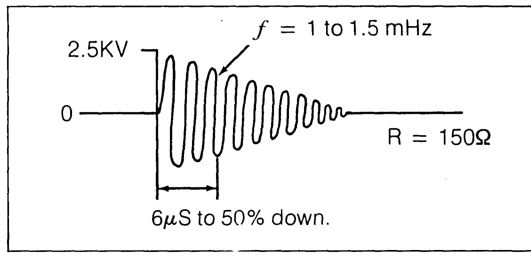

Figure 8 — More Complex Standard Waveform

3.4 Surge Testing

Figure 9 shows a typical test set used to produce an exponentially decaying current pulse of 1mS to 50% down. (10 × 1000μS). The 1mS waveform is used by many manufacturers to test and characterize their TVS devices for pulse power and clamping voltage.

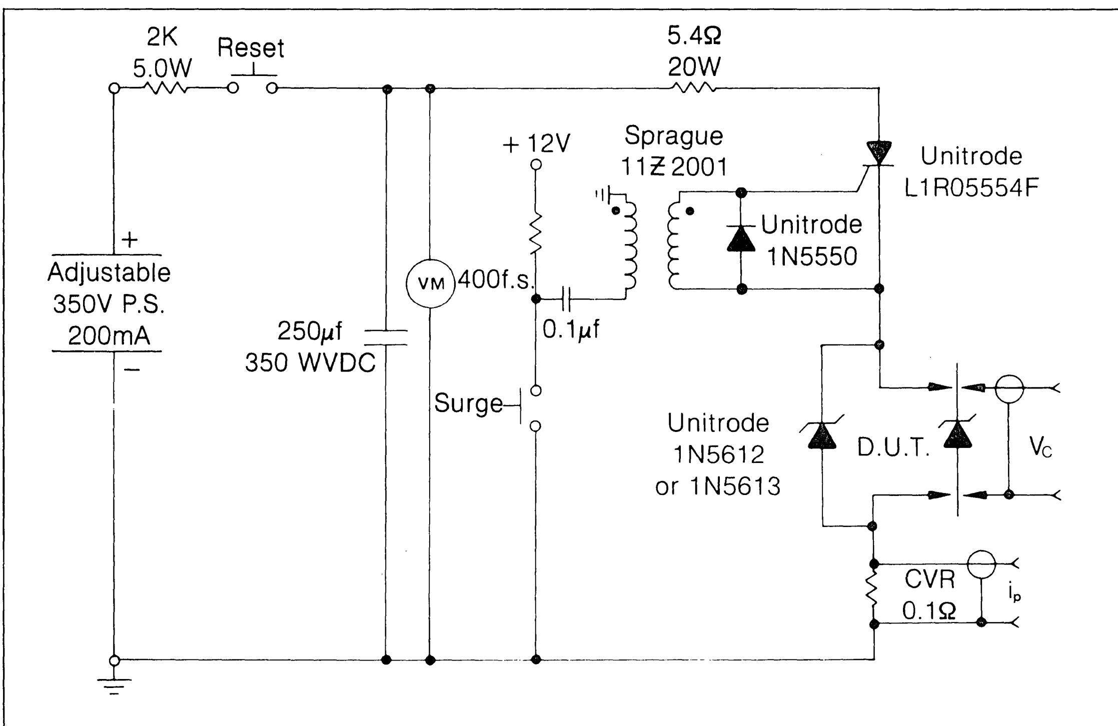

Figure 9 — Suggested Set-up for Surge Testing

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4.0 Examples

4.1 Relay and Solenoid Applications

When the energy stored in the coil inductance of a relay or solenoid is released it can damage contacts or drive transistors. It can also produce EMI interference. A TVS used as shown in Figure 10 will provide reliable operation.

Just before the switch opens, the initial inductor current $I_O = \frac{V_{CC}}{R_L}$.

This is the worst case (maximum) current and assumes the switch was closed long enough for the circuit to reach steady-state.

After the contacts switch at t = 0, $e = -L\frac{di}{dt}$, and when using a TVS the change in coil current, $\frac{di}{dt} = \frac{V_C}{L}$. Referring to Figure 10d, $t_1 = \frac{I_O}{di/dt} = \frac{V_{CC}/R_L}{V_c/L} = \frac{V_{CC}L}{R_L V_c}$. Note that the higher the V_c of the TVS, the shorter the current decay time.

In order to select the proper TVS, determine:

1. Peak pulse power $P_p = I_p \times V_c$, where $I_p = I_o$.
2. Pulse time t_p (@ 50% down point of i_{TVS}) $= \frac{t_1}{2}$.
3. These values of P_p and t_p are used with graphs of pulse power vs. pulse duration provided on the TVS305 and TVS505 data sheet to select proper device. See example in Figure 2.

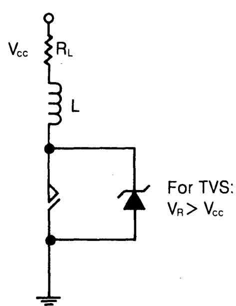

Figure 10a, DC Coil and Contacts.

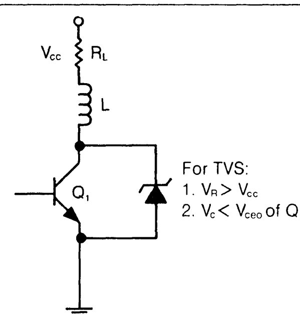

Figure 10b, DC Coil and Transistor.

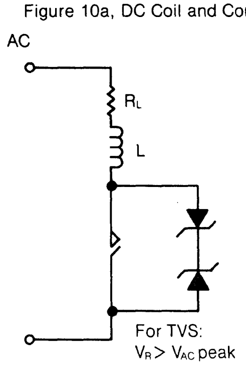

Figure 10c, AC Coil and Contacts.

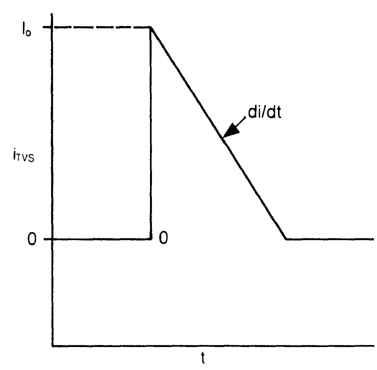

Figure 10d, Simplified Current Waveform in the TVS.

NOTE: In some cases, because of accessibility, the TVS must be located across the coil; in that case a diode should be used in series with the TVS, connected back to back as shown in Figure 11.

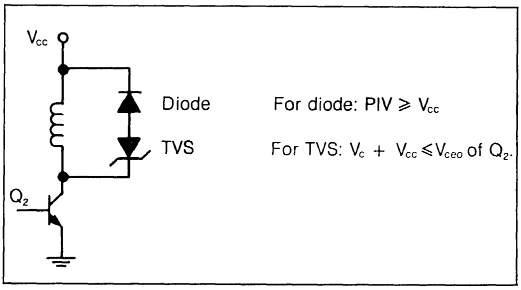

Figure 11 — Using TVS Across Coil

Sample Calculations:

For example, using the circuit of Figure 10a, and sample values of:

$V_{cc} = 14V$, $L = 1mH$, and $R_L = 2\Omega$;

For $V_{cc} = 14V$, the next higher V_R is 15V. (Note that $V_c = 22.2V$ at 10A).

STEP 1: $I_o = \frac{V_{cc}}{R_L} = \frac{14V}{2\Omega} = 7A$

$P_p = I_p \times V_c = 7.0A \times 22.2V = 155W$

STEP 2: $t_1 = \frac{V_{cc}/R_L}{V_C/L} = \frac{14/2}{22.2/10^{-3}} = 0.32mS$

so $t_p = \frac{0.32mS}{2} = 0.16mS = 160\mu S$

STEP 3: From Figure 2, P_{pmax} for $t_p = 160\mu S$ is 1200W, which is well above the circuit value of 155W.

4.2 Protecting Switching Power Supplies

The designer needs to protect against:

1. Load transients
2. Line transients
3. Internally generated transients including those produced by internal faults or failures.

Transients can produce failures because of their own high energy level; and also they can cause improper operation and component failure.

Figure 12 shows a simplified schematic of a typical switching power supply.

Referring to Figure 12, the TVS devices shown protect the following circuit components:

1. the rectifiers.
2. the HV switching transistors.
3. the output rectifiers.
4. the control circuitry.

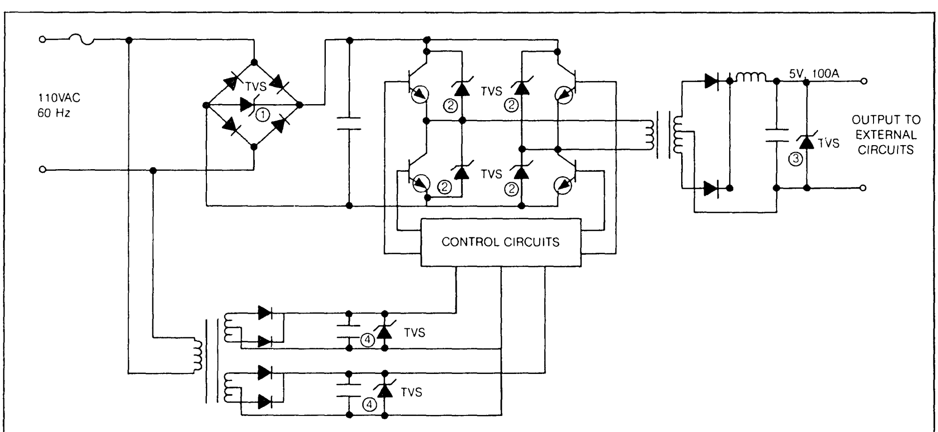

Figure 12 — Typical Switching Power Supply

4.3 Protecting Microprocessor Based Systems

While most microprocessor and IC semiconductor manufacturers design some form of diode-resistive input clamping network on the chip itself, transient voltage protection offered is very minimal — on the order of a few watts of pulse power. Manufacturers are also reluctant to make device performance and reliability claims when power supply operation extends beyond the maximum rated level of the individual device for even relatively short durations such as those that may be encountered during on-off transitions. Therefore, there is a need for some external protective device to suppress voltage transients, as shown in Figure 13.

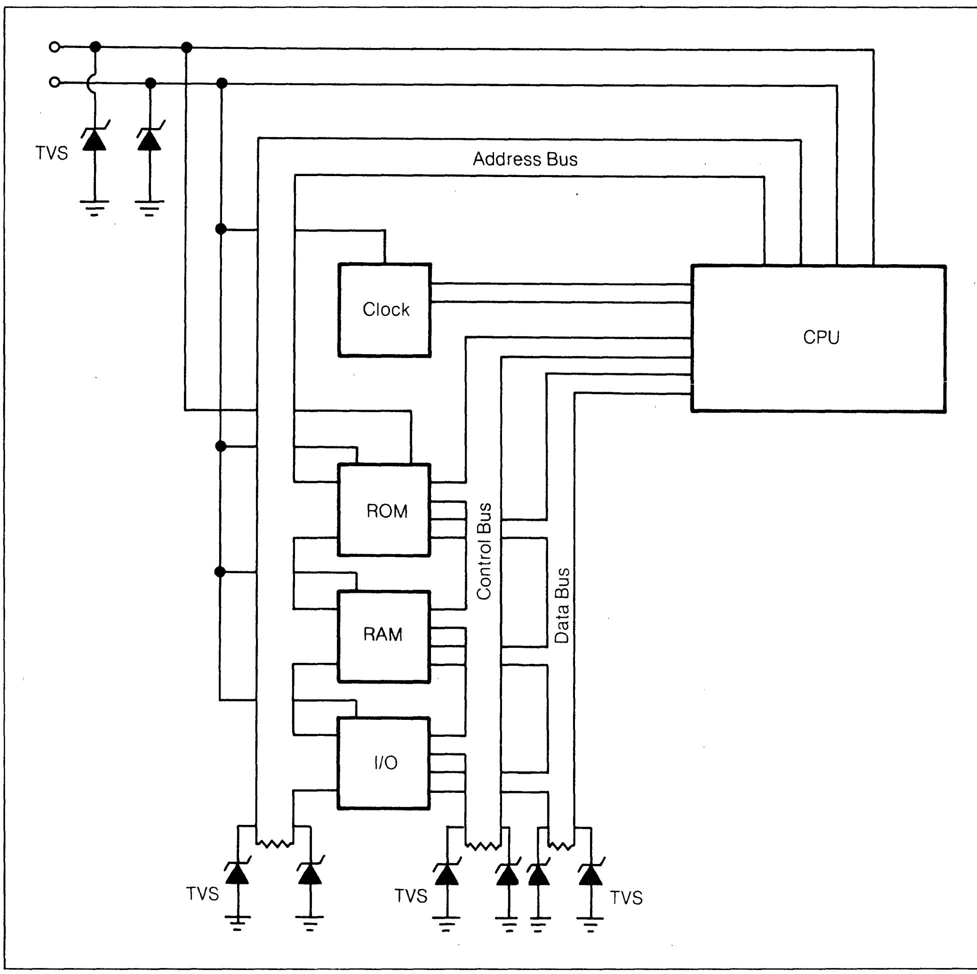

Figure 13 — Protecting Microprocessors

5.0 Alternative Protection Devices

Other protective devices such as MOVs, spark gaps, and crowbars have one common disadvantage when compared to zener TVS products; the response time is from nanoseconds to as much as tens of microseconds as compared to 1 pS for an avalanche zener diode. Even 50nS is long enough to allow a transient to destroy the small junctions used in most integrated circuits, logic, fast transistors, etc.

In circuits where transient pulses are fairly common, device degradation becomes a significant problem. TVS products do not significantly degrade even after 100,000 transients.

In many cases, the zener TVS and one of the alternative devices can complement each other. For example, when used with an SCR crowbar, the zener TVS will keep the voltage during a transient to an acceptable level until the crowbar, which may take 10μS to short the line, can protect the load circuits, and in the case of a heavy transient protect the smaller TVS as well.

OPERATING BUCK TYPE SWITCHING REGULATORS ABOVE 100KHz

1. INTRODUCTION

Until now, most switching regulated power supplies have been designed to operate between 20 and 40KHz, generally because of various device limitations. Because of the recent availability of power MOSFETS, there has been considerable interest shown in operating switching power supplies at much higher frequencies (above 100KHz). The advantages and disadvantages of operating regulators at higher frequencies are discussed in this application note. Important characteristics of MOSFET and bipolar devices are considered for buck type switching regulators. The circuit described presents an economical design of a buck type regulator that operates above 100KHz using bipolar devices (in this case the Unitrode PIC600 switching regulator output stage).

2. SWITCHING REGULATOR HIGH FREQUENCY CONSIDERATIONS

When "Off-Line," including buck type, switching regulators are operated at higher frequencies, the following advantages are achieved:

A. Lower filter cost (L and C)

B. Reduced size and weight

C. Improved transient response

D. Effective, inexpensive and lightweight (aluminum) shielding of noise radiation (EMI)

E. Simpler EMI filtering

F. Improved minimum loading requirements for multiple output voltage tracking

G. Greater control over output ripple

The disadvantages are:

A. Increase in transistor switching losses

B. Increase in magnetic losses

C. Increase in diode reverse recovery losses

Normally the "Off-Line" switching regulator operates at much higher input voltage than the popular "point-of-use" buck type switching regulator. Since switching losses are directly dependent upon the input voltage, switching characteristics become more significant in an "Off-Line" switching regulator.

3. BUCK TYPE SWITCHING REGULATORS (LOW INPUT VOLTAGE)

A buck type switching regulator is normally used to (a) provide regulation of multiple outputs from the output of an "Off-Line" switching regulator, (b) convert unregulated DC input voltage into regulated low voltage output, (c) drive a stepper motor drive, or (d) control the speed of a DC motor.

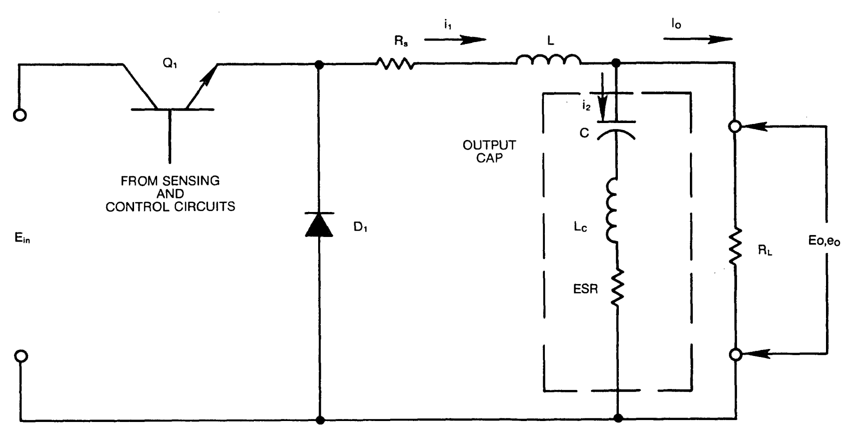

Figure 1 Switching Regulator Basic Configuration (Buck Type)

Since this regulator operates at a lower input voltage than the "Off-Line" version, the power losses during switching are not significant up to 500KHz if the transistors and the catch diode are properly selected.

3.1 Turn-on Time

The shortest possible turn-on time of a pass transistor or MOSFET is limited by the reverse recovery time of the catch diode. Presently the fastest available recovery time of a power P/N junction diode (such as the Unitrode UES1301) is about 20ns. The Schottky diode also has about the same effective reverse recovery time due to its high junction capacitance. To minimize the over-shoot during the current rise time, one must increase the (turn-on) rise time of a MOSFET. A properly selected bipolar device (e.g. PIC600) matches perfectly without controlling current rise time.

Figure 2 shows the reverse recovery characteristics of a Schottky and a P/N junction rectifier in a buck type switching regulator (Figure 1).

Note: The ringing in Figure 2A is due to the large junction capacitance and high Q of the Schottky rectifier which is series resonating with a filter choke. This effect is negligible with a Unitrode P/N junction device.

Thus, the losses during turn-on will remain the same regardless of whether the pass element is a bipolar or a MOSFET device.

The importance of the ratio of reverse recovery time to current rise time is shown in Figure 3. It is obvious that the current rise time of the MOSFET or bipolar transistor should be at least 3 times slower than reverse recovery time of the catch diode. Figure 4 shows the reverse recovery times, and current rise times of commercially available fast switching diodes and transistors.

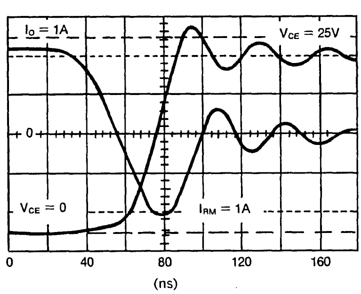

Figure 2A Reverse Recovery of a Schottky Rectifier (SD41)

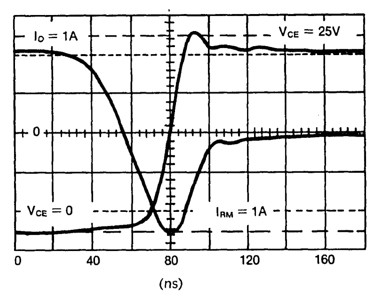

Figure 2B Reverse Recovery of a P/N Junction (UES701)

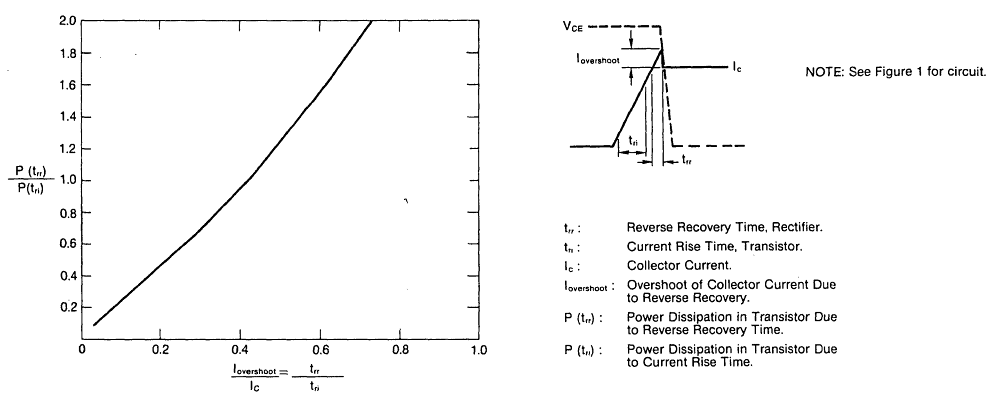

Figure 3 Importance of Current Rise Time of a Transistor and Reverse Recovery of a Rectifier

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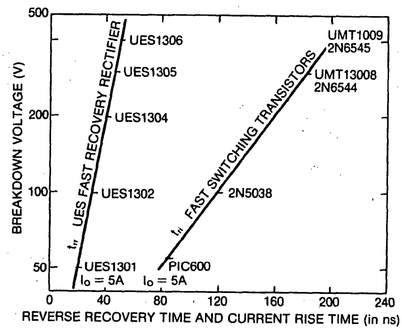

Figure 4 Switching Times vs Breakdown Voltage (Unitrode Rectifiers and Transistors)

3.2 Storage Time

Since the bipolar transistor is a minority carrier device, it has a finite storage time. This time can be significantly reduced if the device is clamped out of saturation. In a low voltage device, there is less majority carrier injection in the collector region, due to its lower collector resistivity, than in high voltage devices. By preventing the output transistor from saturating, significant improvement in the storage time can be achieved. The Unitrode PIC600 series device (see Figure 5) provides a natural clamp. The output device Q_1 which carries the load/current, is kept out of saturation by driver transistor Q_2. The driver transistor operates in saturation mode. At frequencies above 100KHz however, the storage time of the driver transistor Q_2 needs to be reduced.

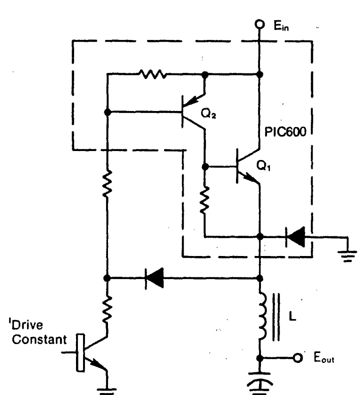

Figure 5 Simple Clamped Circuit

The circuit shown in Figure 5 reduces the overall storage time of the PIC600 to less than 100ns without complicating the drive circuit, at the expense of increased $V_{CE(SAT)}$. When the ratio of the input to output voltage is high (factor of ~3 or more) the DC loss in a transistor is low compared to other losses when operating at frequencies above 100KHz (see Figure 6). The maximum operating frequency is determined by the storage time. In general, the maximum operating frequency of a switching regulator for a given storage time can be determined by the equation;

$$f\ max = \frac{0.2 \times E_{out}}{E_{in(max)} \times t_{s(max)}}$$

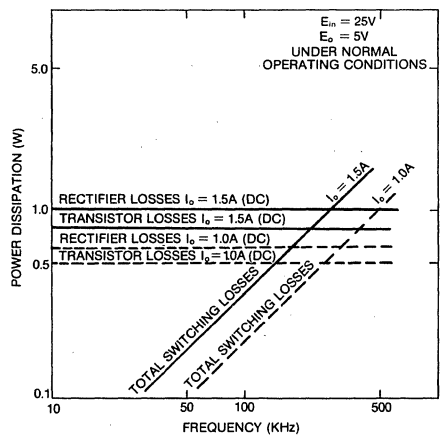

Figure 6 Switching Losses in a Transistor and Rectifier of a PIC600 Switching Regulator Output Stage

For a 100ns storage time, the maximum operating frequency will be 400KHz where E_O = 5V, E_{in} = 25V.

3.3 Fall Time

MOSFET devices will provide faster fall time than bipolar devices providing the drive current is large enough to discharge the input capacitance quickly. However, as pointed out earlier, in a low voltage switching regulator the switching loss during the fall time is a very small percentage of the total power losses.

3.4 $E_{S/B}$ and $I_{S/B}$

Since the inductive load is clamped by diode, the bipolar pass transistor does not experience reverse bias second breakdown ($E_{S/B}$) in a buck switching regulator. Forward bias second breakdown can be prevented by providing adequate drive current and by preventing the core of the inductor from saturating.

3.5 QUASI-SAT LOSSES

The output device of a PIC600 is highly interdigitated which minimizes operating in the QUASI-SAT region. Thus, turn-on losses during QUASI-SAT are avoided.

4. OTHER CONSIDERATIONS

4.1 Magnetics

Generally, hysteresis losses in the magnetic material will increase significantly when an inverter is operating at a higher frequency because of the wide variation of the magnetic flux over the period of a cycle. To minimize the hysteresis losses and leakage inductance losses, proper selection of a core shape magnetic material is required.

However, the hysteresis losses in the magnetic components of a buck type switching regulator are low compared to those in an inverter because the change in the flux is limited over a period of a cycle. Furthermore, there are no leakage inductance losses in the buck regulator. The selection of the inductor and its shape for a buck type switching regulator is, therefore, less critical. To minimize the radiation due to the changing magnetic field in the filter inductor, it is advisable to use a gapped pot core or a toroid.

4.2 Capacitor

The output ripple voltage of a switching regulator depends not only upon the value of the capacitor, but also on its effective series resistance (ESR). The ESR of the capacitor is inversely dependent upon the value of the capacitor. Since the output ripple voltage depends upon the ESR of the capacitor, paralleling capacitors is helpful. This, however, may affect the transient response of the switching regulator.

At higher frequencies, the inductance of the capacitor becomes significant. The equivalent circuit of the capacitor (C_{out}) is shown in Figure 1. The effects of the ESR and inductance of the capacitor can be observed at the instant when an abrupt change in di/dt occurs (see Figure 7). A solid tantalum or electrolytic capacitor has a higher ESR than a high frequency bypass capacitor like metallized polypropylene, polystyrene foil and ceramic. However, the value of the capacitance available in these types is low compared to solid tantalum or electrolytic capacitors. When switching regulators are operated at a higher frequency, the output ripple voltage is more dependent upon the ESR and the inductance of the capacitor than its capacitance.

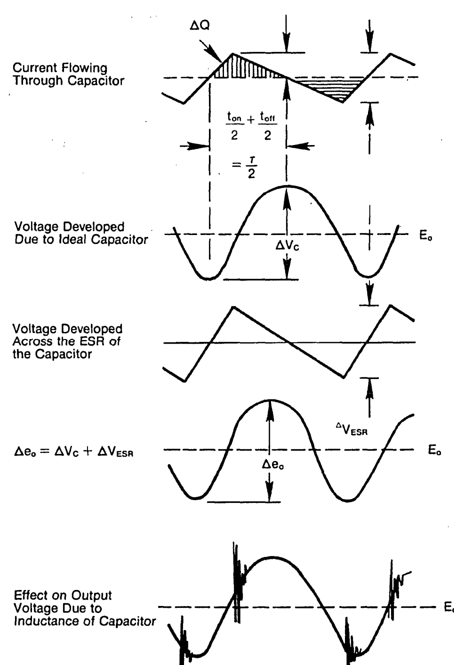

Figure 7 Effect on the Output Ripple Voltage Due to Parasitics of the Output Capacitor

$$\Delta V_C = \frac{\Delta Q}{C} = \frac{\frac{1}{2} \cdot \frac{\Delta I_1}{2} \cdot \frac{T}{2}}{C} = \frac{\Delta I_1}{8fC}$$

$$\Delta V_{ESR} = \Delta I_1 \cdot ESR$$

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4.3 Circuit Layout and RFI

Circuit layout is another important consideration in a high frequency switching regulator. Every inch of wire adds 20nH to the circuit. Any extra lead length of the wire produces unwanted ringing and also radiates energy into the environment. The length of the high di/dt path should be kept to a minimum and, where necessary, bypassed with a ceramic capacitor. Twisting the wire of the transformer and arranging the high current paths such that they oppose each other will reduce the radiated energy to the environment. The layout of the circuit should be designed such that it minimizes the ground loop problems by separating the high current path from the small signal circuit current.

5. CIRCUIT DESCRIPTION

The circuit described in this section provides a simple and economical design of a buck type switching regulator operating at 250KHz with an existing bipolar device (PIC600). The main advantages of operating a switching regulator at a higher frequency are (a) reduction in the size of the inductor required to obtain low output ripple voltage, (b) improved transient response and (c) reduction in cost, size and weight.

The complete circuit is shown in Figure 8. It converts unregulated 25V input voltage into a regulated +5V output voltage. Significant improvement in the storage times and voltage fall time is achieved with a clamping diode D_1 and resistors R_1 and R_2. Since the Unitrode PIC600 operates with a constant current base drive, a fixed voltage drop is developed across R_2.

The voltage is clamped across the collector to emitter of the output device by the clamping diode D_1 and is given by the equation:

$$V_{CE}\ \text{clamped} = I_{drive} \times R_2$$

Under normal operating conditions, the important operating parameters of the PIC600 at output current of 1A and 2A are listed below:

	$I_O = 1A$	$I_O = 2A$
Voltage Rise Time	24ns	24ns
Voltage Fall Time	36ns	56ns
Current Rise Time	28ns	40ns
Current Fall Time	66ns	84ns
Storage Time	76ns	160ns
Diode Forward Drop V_F	0.74V	0.82V
Saturation Voltage $V_{CE(SAT)}$	2.5V	2.5V

The switching losses at 250KHz are less than 0.5W, so that the overall efficiency of the PIC600 is greater than 78%.

The constant base drive current to the PIC600 switching regulator output stage is provided by operating transistor Q_1 and the output transistor of the UC1524 in series as an AND gate. The base of the transistor Q_1 is connected to the reference output voltage (+5V) of the UC1524, PWM voltage regulator integrated circuit. The amount of drive current to the PIC600 is determined by resistor value R_3 and is given by the equation:

$$I_{drive} = \frac{3.5V}{R_3}$$

The current limit is achieved with current sense resistor R_{10} and transistor Q_2.

There is sufficient gain in the error amplifier of the UC1524 to operate up to 500KHz. The fixed dead-band period of the UC1524 is not adversely effected in buck type switching regulator applications.

Capacitor C_3 improves the high frequency response and provides stability in the circuit.

6. CONCLUSION

The circuit described in this application note provides an economical approach to the high frequency buck type switching regulator using a bipolar device instead of a MOSFET device. The circuit operates with a simplified drive circuit and provides improvement in a transient response and reduction in size, cost, and weight. The circuit efficiency is greater than 78% and provides control over output ripple voltage without a large inductor.

The PIC625 switching regulator output stage can be operated at a 5A level at an operating frequency of 250-500KHz.

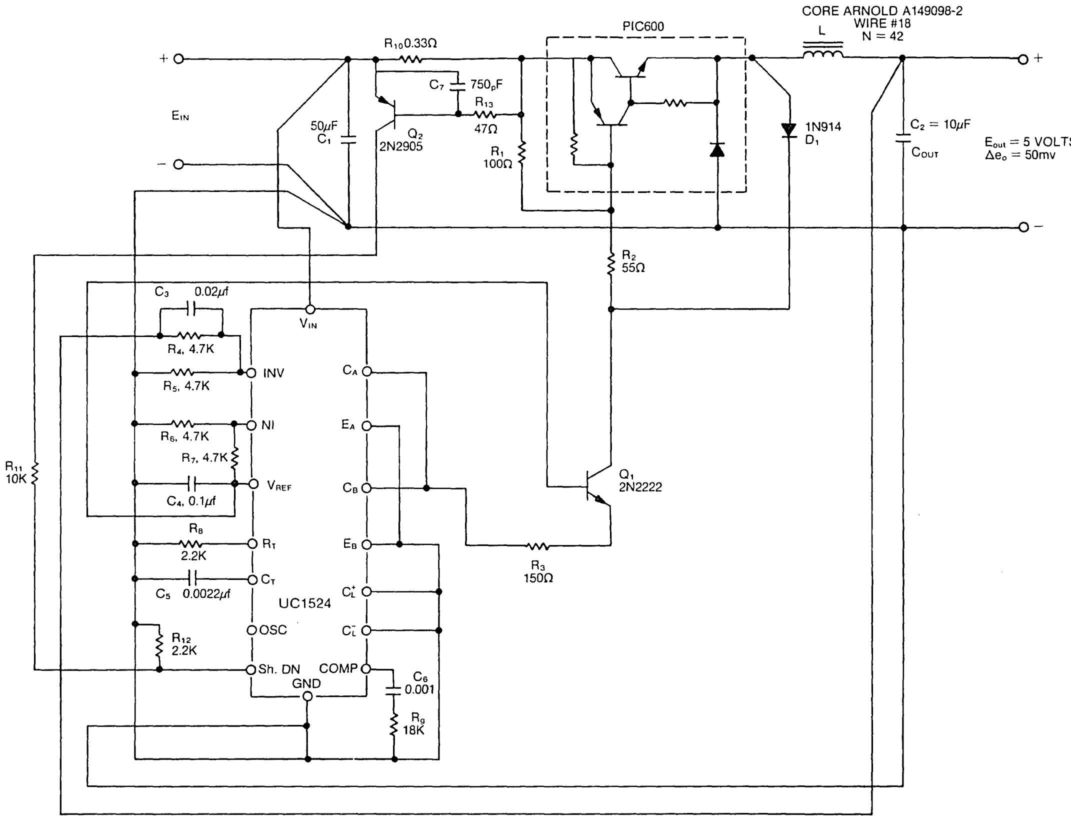

Figure 8 Complete Circuit Diagram

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DETECTING IMPENDING CORE SATURATION IN SWITCHED-MODE POWER CONVERTERS

ABSTRACT

A new low cost concept termed "mismatched flux" has been developed which not only prevents impending saturation of the core but also provides symmetrical switching current in power switches in Pulse Width Modulation switched-mode converters except at low flux density. The detecting signal is obtained by mismatching the flux in the outer legs of an E-E core configuration.

INTRODUCTION

Opposite polarity power pulses are applied to the power transformer in a PWM converter to transfer power from the primary to the secondary windings. The volt-second integral of these pulses averaged over one or more cycles should be zero to avoid any problems with transformer core saturation.

In practice, however, imbalance occurs due to non-ideal characteristics of power switches, mainly the switching times (including storage and delay times) and saturation voltage. Even though the imbalance in the pulse width of the drive current provided by a PWM control circuit is very small compared to power switches, it can drive the core into saturation.

Core saturation in PWM switched-mode converters can cause problems such as secondary breakdown in switching transistors, excessive voltage and current stress on the rectifiers, and EMI problems.

The unique circuit described in this paper develops voltages proportional to the flux density in the core. When the maximum flux densities at the end of the positive and negative cycles in the core are not the same, unequal voltages are produced during the positive and negative cycles. These voltages are fed back to the PWM control circuit which adjusts the widths of its output pulses until the amplitudes of these two voltages are equal.

This technique, which can be applied in push-pull converters as well as bridge type converters, prevents core saturation and provides symmetrical primary current during the positive and negative cycles. It allows the most efficient use of the power transformer. In a buck type regulator, the current limiting function can be performed with this same technique.

THE UNBALANCED PWM CONVERTER

Figure 1 shows the typical push-pull converter and its associated current and voltage waveforms. Due to the difference in switching times and $V_{CE(SAT)}$ of transistors Q_1 and Q_2, the transformer core is driven into saturation. The volt-seconds applied by transistor Q_2 is higher than Q_1 as shown in Figure 1d, even though the secondary current is the same during on-times of transistors Q_1 and Q_2.

Three important observations can be made from these figures:

1. Information concerning the magnitude of the imbalance of the flux can be derived by examining the current in the rectifier diodes (Figures 1e and 1f) during the dead-band period.
2. The slopes of the primary currents when Q_1 and Q_2 are conducting are not the same.
3. The familiar equation $I_{C1}/I_{D1}=N_2/N_1$ is not applicable when the flux density in the transformer is not symmetrical during the positive and negative half-cycle.

Under normal operating conditions and during dead-band period, the path for the current flowing in the output inductor L is provided by diodes D_1 and D_2. The inductor current is divided between these two diodes. The magnetizing current I_{MS} flows in the entire secondary winding. Note that the magnitude of I_{MS} remains the same during the entire dead-band period because the voltage across the secondary winding is zero. The overall result is that one diode conducts more current than the other diode. The current flowing in these diodes is:

$$i_{D_1} = \frac{i_L}{2} + I_{MS} \quad \text{Current in Rectifier Diode } D_1 \qquad (1)$$

$$i_{D_2} = \frac{i_L}{2} - I_{MS} \quad \text{Current in Rectifier Diode } D_2 \qquad (2)$$

Subtracting i_{D_1} from i_{D_2} and rearranging

$$I_{MS} = \frac{i_{D_1} - i_{D_2}}{2} \qquad (3)$$

Thus, the current flowing in diode D_1 and D_2 allows us to determine the exact amount of imbalance in the flux density during the positive and negative half-cycles. Figure 1g, which is calculated from diode current D_1 and D_2, shows the operating flux density of a core in only the 1st quadrant of a B-H curve.

When transistor Q_1 or Q_2 turns on, this magnetizing current is reflected back into the primary winding according to the equation:

$$I_{PM} = \frac{2(N_2)}{N_1} I_{MS} \qquad (4)$$

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The dotted line in Figures 1c and 1d shows the reflected current in the primary winding. Since the flux density is not symmetrical around zero in the B-H curve, the collector current in Transistor Q_1 is lower than in Transistor Q_2. When the magnetizing current (dotted line in Figure 1c) is added to the actual measured collector current (solid line) in Transistor Q_1, it will produce a linear slope compared to the rounded slope of the measured collector current. The equation

$$\frac{I'_{C_1}}{I_{D_1}} = \frac{N_2}{N_1} \qquad (5)$$

will hold true, where I'_{C1} is equal to the magnetizing current reflected into the primary winding plus the actual measured collector current I_{C1}. Similarly, when Transistor Q_2 turns on, the transformer transfers energy from the input power source to the secondary. Some energy is also stored in the core due to the unsymmetrical flux density in the core. The magnetizing current (current level above dotted line in Figure 1d) is subtracted from the measured collector current.

The equation

$$\frac{I'_{C_2}}{I_{D_2}} = \frac{N_2}{N_1} \qquad (6)$$

will hold true, where I_{C2} is equal to the actual measured collector current minus the magnetizing current reflected into the primary winding.

The imbalance in volt-seconds causes the flux density to drift towards one side of the hysteresis loop. This causes an imbalance in the collector currents of the transistor switches. The imbalance in volt-seconds will be compensated, to some extent, by an adjustment in the collector currents of the two transistor switches. As the collector current decreases the storage time increases and $V_{CE(SAT)}$ decreases as shown in Figures 2 and 3. This effectively increases the volt-seconds. The IR drop in the primary winding also helps to balance the volt-seconds in the transformer. These collector currents will vary until the proper volt-second balance is obtained in the transformer. If no corrective scheme is provided to balance current in the switch, the following disadvantages are present:

1. The required current ratings of the transistors and rectifiers must be increased.
2. The $V_{CE(SAT)}$ losses will be increased. Furthermore switching losses will be even higher, especially in high voltage power converters.

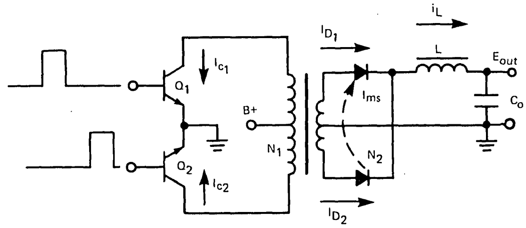

Figure 1a.

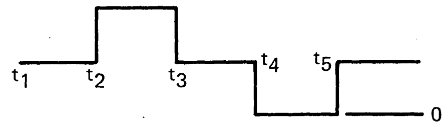

Figure 1b. Voltage Waveform at Collector of Q_2.

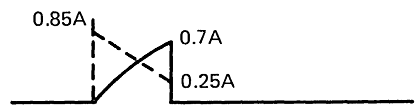

Figure 1c. I_{C_1} Current Flowing in Transistor Q_1.

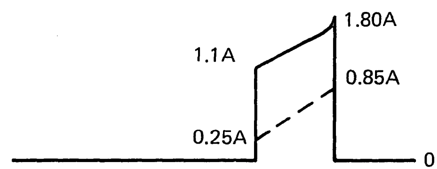

Figure 1d. I_{C_2} Current Flowing in Transistor Q_2.

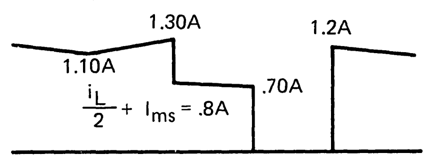

Figure 1e. Load Current in I_{D_1}.

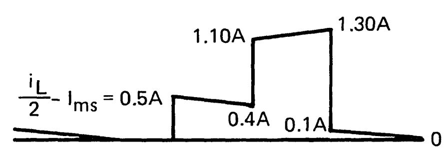

Figure 1f. Load Current in I_{D_2}.

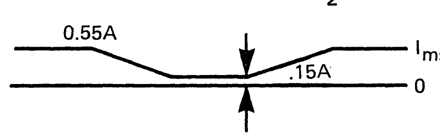

Figure 1g. Magnetizing Current in Secondary.

Figure 1. Gallery of Waveforms of a Push Pull P.W.M. Switching Regulator

3. Losses in the core increase as a function of the square of the maximum operating flux density. As the core temperature goes up, the losses in the core also increase, thus, the potential exists for thermal runaway in the core.
4. The leakage inductance is proportional to the maximum operating flux density. The imbalance causes high leakage inductance, and excess voltage stress across the transistor and rectifier.
5. If the core goes into saturation, it creates excessive current in the power switches, can result in forward bias second breakdown, clamped reverse bias second breakdown, and increased radiated and conducted EMI.

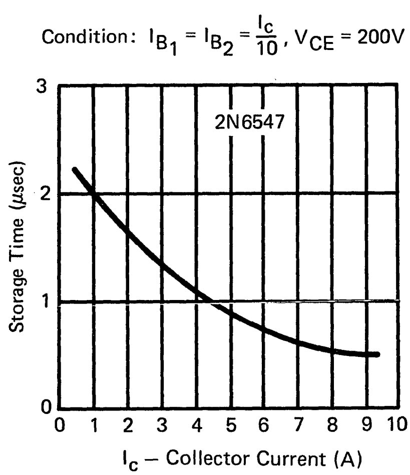

Figure 2. Storage Time vs Collector Current

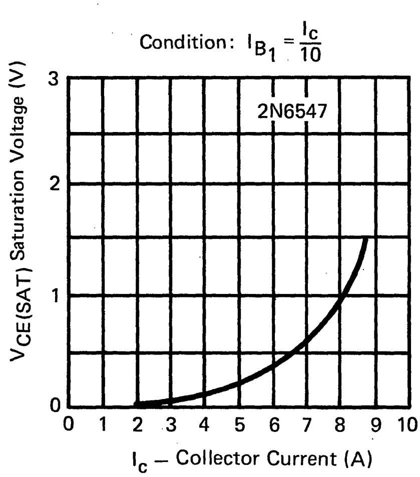

Figure 3. $V_{CE\ (SAT)}$ vs Collector Current

BASIC PRINCIPLE

An air gap in the E-E core can be used to prevent core saturation in PWM converters. The air gap reduces residual flux density in a square loop transformer and prevents core saturation during the start-up condition. However when there is a volt-second imbalance, the air gap does not prevent core saturation.

If the air gap is placed in only one of the outer legs of an E-E or EC core configuration, as shown in Figure 4a, then it allows a means of detecting core saturation, and by using this signal, to provide symmetrical flux swing in the core.

The primary winding and secondary winding are placed in the center leg of the E-E core, while the auxiliary winding is placed in the outer leg which contains the air gap.

The peak output voltage of the auxiliary winding is detected with Diode D_1, D_2 and Capacitor C_1. The Resistor R_1 in parallel with Capacitor C_1 provides the reset for another cycle by discharging the capacitor. The voltage developed across R_1 and C_1 is proportional to the maximum rate of change in flux at the instant when the transistor switch turns on.

The total amount of flux passing through the outer leg with the air gap is inversely proportional to the magnetic length of the opposite side of the leg. As the flux density in the center leg increases, a larger and larger area of the core at the point where the two E cores meet on the opposite side of the leg will become saturated. Note that only the edge of the core will saturate, while the rest of the core (leg with no air gap) will not saturate. As it saturates further, the reluctance of this leg increases, thus its effective magnetic length increases. This phenomenon forces more flux into the leg which has the air gap.

The voltage developed in the auxiliary winding is expressed by Faraday's Law:

$$V = N\left[\frac{d\Phi_2}{dt}\right] \times 10^{-8} \qquad (7)$$

Where N is the number of turns. Thus the magnitude of developed voltage will depend upon the rate of change in flux with respect to time. Since the air gap is in only one leg of the E-E core, the term $|d\Phi_2/dt|$ changes continuously and depends upon the flux density in the center leg. Thus the output voltage from the auxiliary winding also varies with respect to time.

The same results can be obtained with using a core as shown in Figure 4b. The advantage of using this core is that the leakage inductance will be less compared with the previous technique.

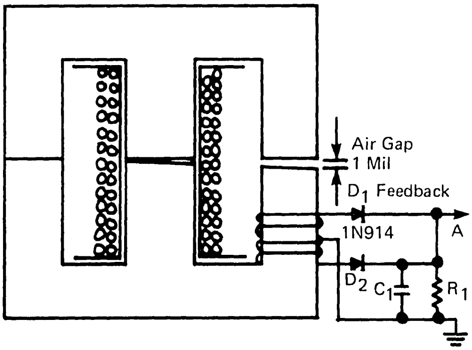

Figure 4a. Air Gap in Only One Leg of E-E Core

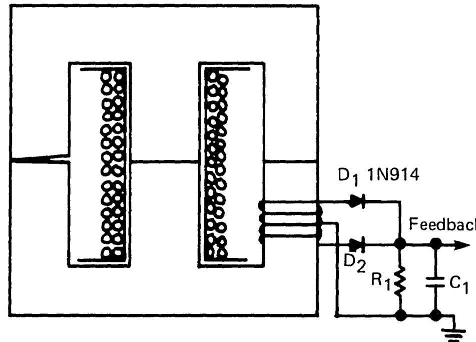

Figure 4b. Tapered Air Gap in One of the Outer Legs of the E-E Core

Figure 5 shows the B-H curve (solid line) of an E-E core with an air gap in only one leg. It lies between the E-E core with an equal air gap in both sides of the outer legs and a core with no air gap. From this figure it is obvious that $|d\Phi/dt|$ changes with the flux density and is a non linear function. Figure 6 shows variation in inductance with magneto-motive forces.

Figures 7 through 9 show the voltage developed in the auxiliary winding at different values of the magnetizing current. The magnetizing current is directly proportional to the maximum flux level for a given transformer. In these waveforms the initial flux density is set at zero and the allowed flux swing is in the 1st quadrant only. The magnitude of the error signal (when the transistor switch turns on) is the same in all three figures since $d\Phi_2/dt$ is the same. As the magnetizing current increases, the developed error signal due to $d\Phi_2/dt$ in the winding around the outer leg (with the air gap) also increases because $d\Phi_2/dt$ increases with flux density. From the shape of the collector current it is obvious that the core is not saturated.

Figure 10 shows the voltage developed across Resistor R_1 from the auxiliary winding and also the current in the two transistors I_{c1} and I_{c2}. The current waveforms show that there is no symmetry in the flux of the core. Figure 11 shows the same output voltage peak detected by paralleling Capacitor C_1 across Resistor R_1. The voltages developed are not symmetrical during the alternative half period of the cycle. Figure 12 shows that when the developed voltage is fed back to the control circuit, it produces flux symmetry in the core. This can be seen by the equal magnitude of the collector currents.

The initial amplitude of the voltage from the auxiliary winding (after the transistor turns on) can be used to further improve performance. This can be accomplished by gating the output voltage of the auxiliary winding with a pulse width of a few microseconds.

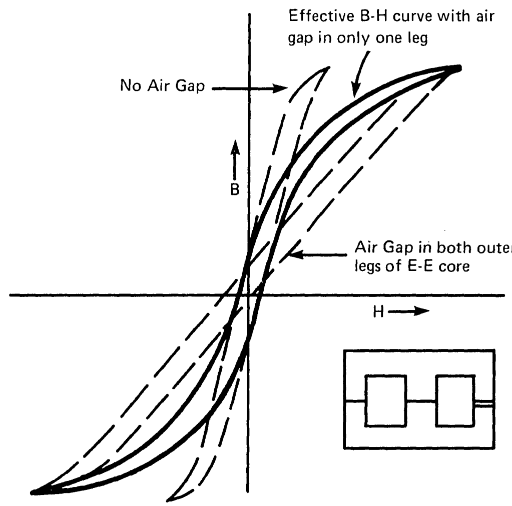

Figure 5. Effects on Hysteresis Curve with Air Gap in Only One Leg of E-E Core

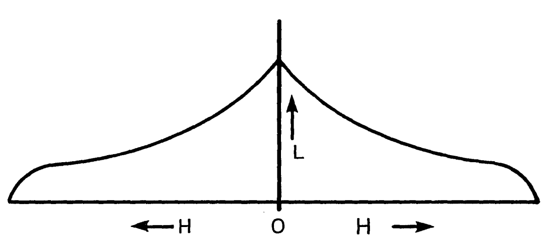

Figure 6. Inductance vs Magnetomotive Force

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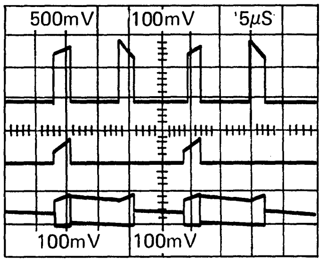

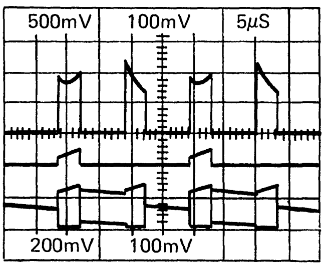

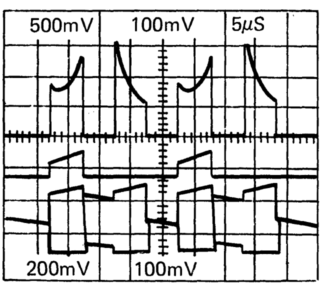

Figure 9. Error Signal Developed at Magnetizing Current = 700 mA

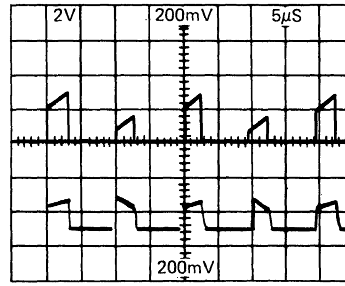

Figure 10. Without a Feedback

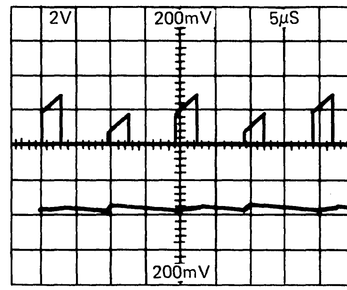

Figure 11. Without a Feedback

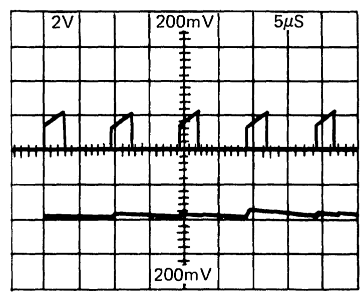

Figure 12. With a Closed Loop

CLOSING THE LOOP

The developed voltage across R_1 and C_1 is fed back to the control circuit (UC3524).

This voltage can be fed into the control circuit in one of three ways:

1. AC coupled into the output of the error amplifier. Since this amplifier is a transconductance design, the output has very high impedance (approximately 5 MΩ). The feedback signal from the auxiliary winding is modulated at this point with the output voltage of the error amplifier. The output pulse width is corrected to provide symmetry as well as to prevent core saturation.
2. Into the non-inverting input. This can be achieved by (a) lifting up 4.7K from ground in the NI circuit, (b) adding 100Ω in series with 4.7K and the other side of 100Ω returning to ground, and (c) adding a feedback signal at the junction of the 100Ω and 4.7K resistors. The peak to peak amplitude of the signal fed into the NI input has to be less than the output ripple voltage fed into the INV input. Feeding signals in the NI or INV inputs will provide flux symmetry in only DC conditions.
3. Feeding the signal at the INV input. This requires an opposite polarity signal, which can be obtained by reversing the diodes in

Figure 4. The modifications required to change the circuit are the same as listed above. Also in this case the peak to peak amplitude of the signal fed into the INV input has to be lower than the peak to peak output ripple voltage fed into the INV input.

To obtain adequate signal at very low input voltages may require a low V_F diode.

PWM PUSH-PULL CONVERTER

A complete schematic of the PWM Push-Pull Converter using this technique is shown in Figure 13. The power switch is a Unitrode hybrid circuit, the PIC636, which is housed in a 4 pin electrically isolated TO-66 package. It provides the advantages of low RFI and ease in heat sinking due to the electrically isolated package. Constant base drive is provided by small signal transistors (2N2905). The output rectifier is a center tap TO-220 fast recovery (35nS) rectifier. The control chip is a UC3524 PWM voltage regulator. The soft start function is performed at the NI input by allowing the reference voltage to come up slowly when the input power supply is turned on. The feedback signal from the auxiliary winding is fed into the compensation terminal (output of the error amplifier) with Resistors R_2, R_3 and Capacitor C_2. The steady state and transient response of the circuit was evaluated: it provides flux symmetry and prevents core saturation under these conditions.

HALF BRIDGE CONVERTER

The method described in this paper can be used for half bridge configurations as shown in Figure 14. It does not require a low ESR, high voltage capacitor in series with the primary of the transformer. The DC balance is provided by Capacitors C_1 and C_2. Thus, this technique offers a low cost solution in preventing core saturation and in providing flux symmetry.

BUCK REGULATOR

In a buck regulator, the method described here can be used to provide the current limiting function without a current sense resistor.

The circuit shown in Figure 15 is a high performance buck regulator. It utilizes the Unitrode power hybrid switching regulator circuit, PIC625. The high performance transistor chip and fast recovery (20nS) rectifier diode are mounted in an electrically isolated 4 pin TO-66 package. The control circuit is a Unitrode Corp. PWM voltage regulator chip. The inductor L utilizes the equal E-E core configuration with unequal air gaps in the side legs. The main winding is placed on the center leg while the two auxiliary windings are wound on the outer legs. The output voltage from these auxiliary windings are compared using Transistor Q_3. The magnitude of the current limiting is adjusted with Resistor R_1. When the current in the hybrid circuit, PIC625, exceeds the set current

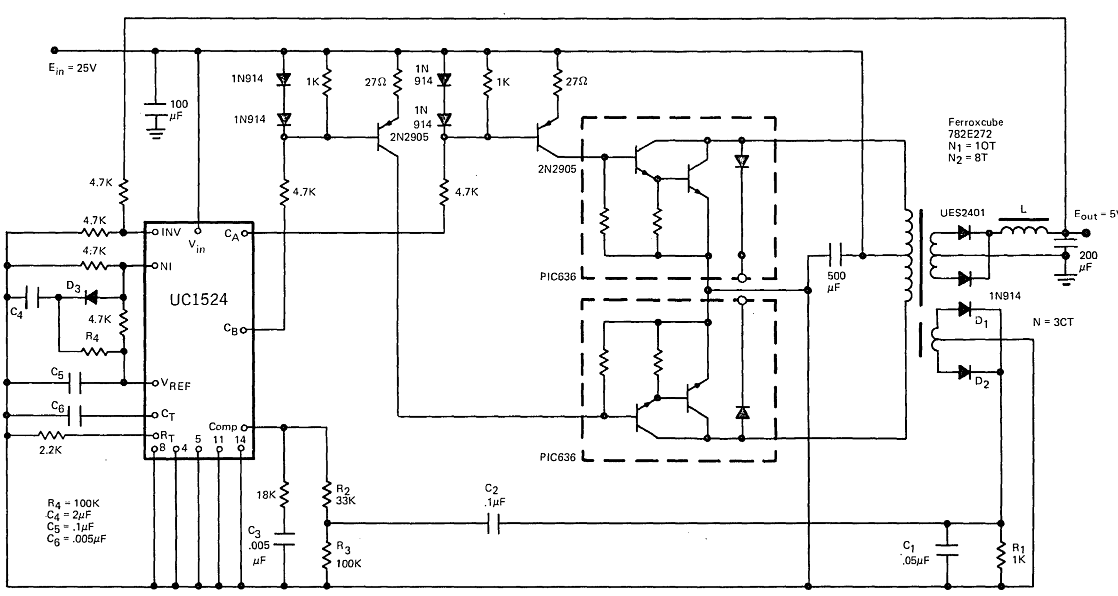

Figure 13. PWM Push-Pull Converter

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limit, Q_3 turns on and the voltage developed across C_1 and R_2 is fed into transistor switches Q_1 and Q_2. The transistor Q_2 removes the drive current from the PIC625 instantaneously. It provides protection during the transient condition. The transistor switch Q_1 provides the function of current foldback by discharging the soft start capacitor C_2. The transient response of this circuit is shown in Figure 16. The current in the switching transistor during short circuit and normal operation mode is shown in Figure 17.

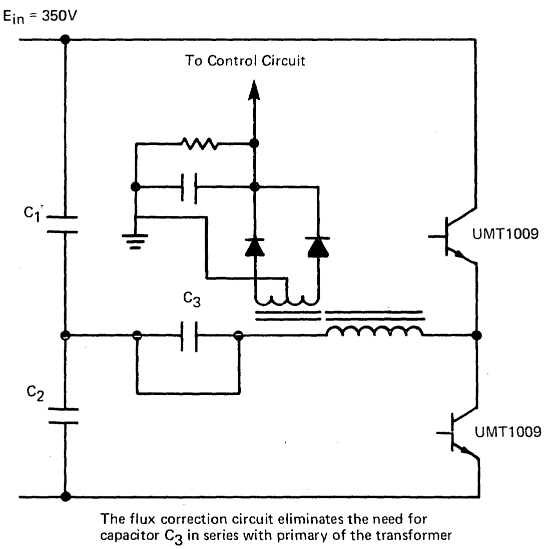


Figure 14. Half Bridge Converter

CONCLUSION

The low cost circuit described in this paper prevents core saturation due to unsymmetrical flux, and provides equal collector current in the transistor switch and in the rectifier diodes. The power dissipation of these switches is kept in balance.

Further advantages of this approach are:

1. a. In a push-pull converter, the need for an inductor is eliminated, thus, the size, cost and weight are reduced.
   b. Transient response time is improved.
2. In a bridge type converter, a capacitor (low ESR, high voltage) in series with the primary of the power transformer is not required. (In conventional designs even with this capacitor, there exists a danger that the core can be driven into saturation under transient conditions).
3. In a buck type converter, it allows the current limiting function to be performed without a current sense resistor, thus improving the performance.
4. Storage time and $V_{CE(SAT)}$ matching of the transistor switches are not required.
5. More efficient use of the transformer, allowing smaller, lower cost magnetics is achieved.
6. In an off-line converter, isolation is maintained.

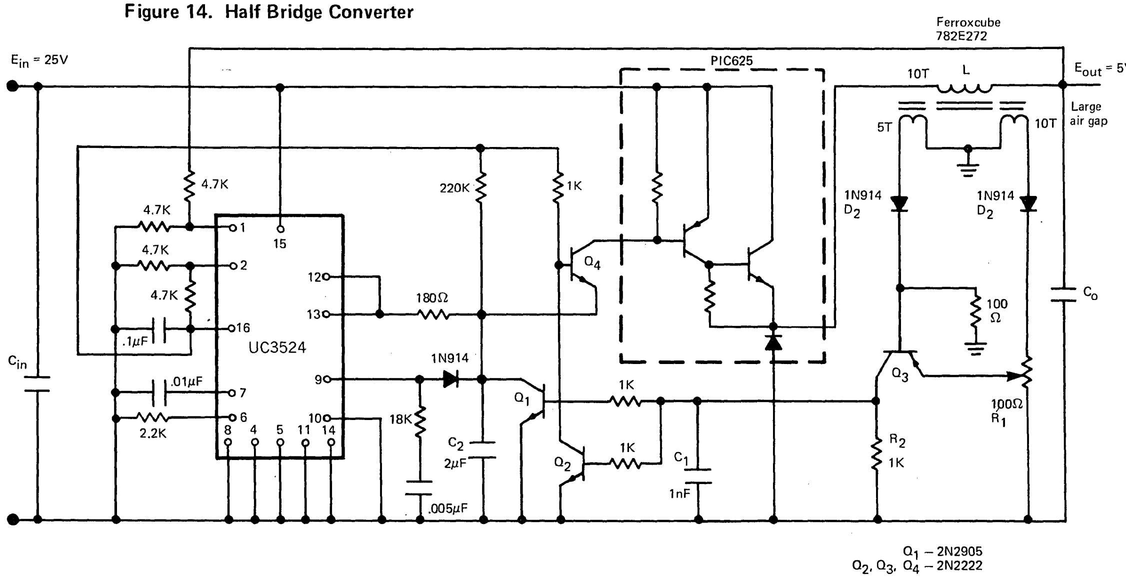
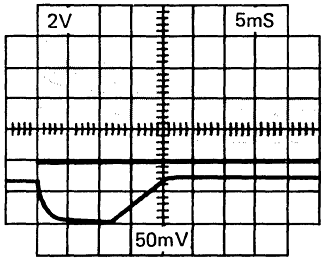
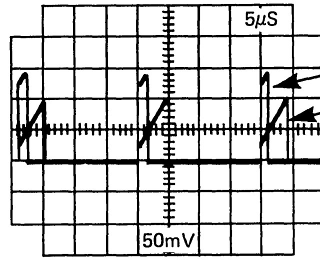


Figure 15. High Performance Buck-Type Switching Regulator



V = 2V/div, H = 5mS/div

Figure 16.
Collector currents for step change in load from 1A to 5A, to 1A.



V = 1A/div, H = 50μS/div

Figure 17.
Collector currents, I_L = 1A and under short circuit conditions.

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1. Walter J. Hirschberg, "A New PWM Control Technique That Eliminates Transformer Unbalance Problems in Power Converters", ACDC Electronics Powercon 6, 1979.
2. John Bullinga, "Transformer with Means of Sensing Impending Saturation", Collins Radio, Powerconversion International, Sept/Oct 1979.

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HYBRID CIRCUITS FOR LOW VOLTAGE SWITCHED-MODE CONVERTERS

ABSTRACT

Hybrid circuits offer many advantages over the conventional discrete approach in switched-mode converters. This paper deals with the construction of the hybrid circuit and its thermal considerations. It examines the efficiency of a buck regulator employing a saturated transistor versus the optimized darlington configuration. Also considered are the effects of reverse recovery of the rectifier and base spreading resistance of the transistor on the efficiency of a switching regulator. Finally, applications of standard hybrid circuits for switched-mode converters are discussed.

I. INTRODUCTION

Recently a rapid increase in the use of hybrid circuits in switched-mode power converters is evident due to their inherent advantages. Some of these advantages are: dc and high frequency electrical isolation, ease in heat sinking multiple power components within the single hybrid package, reduced stray parasitics, and finally, lower overall cost compared to the discrete approach.

The hybrid circuit approach requires careful consideration of thermal design for maximum reliability and proper selection of silicon chips for best electrical performance. This paper provides an overview of the construction of a typical power hybrid switching regulator circuit and its thermal design considerations. Also considered are the effects of the reverse recovery time of the rectifier and the base spreading resistance r_{BB}', of the power switching transistor on the efficiency of the switching regulator. Applications and advantages are also discussed for types of hybrid circuits which are designed for low voltage applications and other types designed for "off-line" switched mode converters.

II. CONSTRUCTION

The power hybrid circuit PIC600 is the power output stage of a buck type switching regulator as shown in Figure 1. It consists of a high speed darlington-connected transistor pair, a commutating diode and two thick film biasing resistors. These components are housed in a 4 pin electrically isolated TO-66 package.

The manufacturing procedure for these devices is divided into two stages. First, a BeO substrate is chosen because of its excellent thermal conductivity, —— 70% as good as copper. The interconnection paths, pad areas for the wire bonds and the thick film resistors are screen printed onto the BeO substrate and then fired in high temperature furnaces. For optimum performance, the tolerances of the thick film resistors are maintained within 10% of their design values. The semiconductor devices used in the circuit are all silicon planar passivated devices and are gold eutectic mounted. Aluminum ultrasonic wire bonding is used for interconnections.

In the second stage the BeO substrate is soft soldered to the header for good heat transfer. A copper slug is interfaced between the BeO substrate and nickel plated steel header. The copper slug is used to relieve mechanical stress between the BeO substrate and the header and to provide heat spreading resulting in lower thermal resistance.

III. THERMAL CONSIDERATIONS

The design of the power hybrid circuit requires careful consideration to optimize important thermal requirements; thermal cycling, resistance, and partitioning. To obtain maximum thermal resistance, overlapping heat flow should be avoided. As shown in Figure 2, heat flow from silicon chips #2 and #3 overlaps, thus reducing the thermal capability. No overlapping heat flow occurs from chip #1.

Thermal resistance of the package can be calculated by the formula:

$$R_T = \rho \frac{t}{A}$$

where t is the thickness of material through which heat flows, ρ is the thermal resistivity of the material and A is the average area through which heat flows.

In making a conservative calculation, it is assumed that heat flux diverges at approximately a 45° angle for all the materials except the copper slug (62.5°) due to high conductivity.

The thermal resistance calculation of a hybrid circuit is shown in Figure 2. The copper slug between the BeO and header reduces the thermal resistance of the package (by about .32°C/W) by spreading the heat flow through a large area of the steel header.

This calculation assumes that no voids are present at the interfaces.

IV. COMPONENT AND CIRCUIT SELECTION

Achieving maximum efficiency in a buck-type regulator requires proper selection of electrical characteristics of the transistor switch and catch diode. Optimum efficiency can be obtained with a

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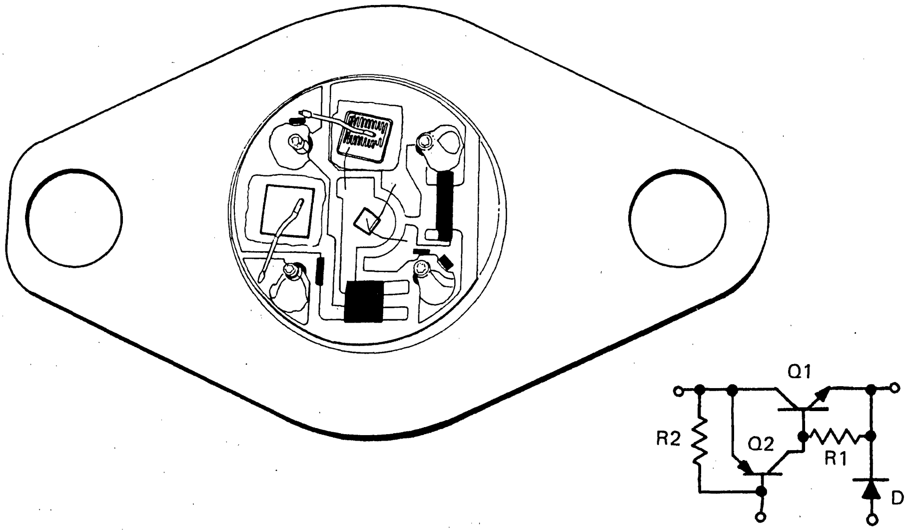
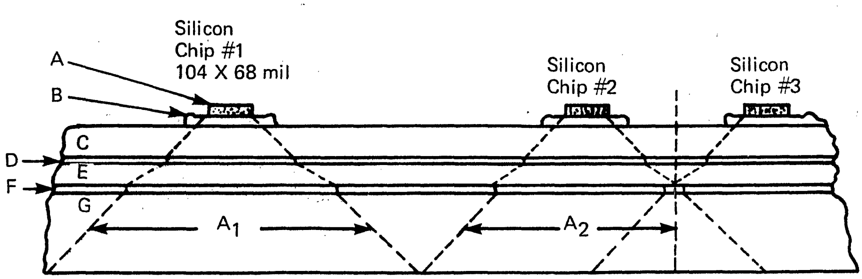


Figure 1. Unitrode power hybrid circuit (PIC600)



DEFINITION:

Material	Temp. Coef. 10^{-6} °C	ρ Rest. °C-in/W	t Thickness in mils		R_T* of PIC625
A – Silicon	4.2	.303	5		.214
B – Si Au Eut.	14	.182	3		.0718
C – BeO	6	.152	20		.249
D – Solder	23	.8	4		.187
E – Copper	16	.104	10		.04614
F – Solder	23	.8	3		.0836
G – Steel	11	.884	65		1.043
				Total	1.8954

$*R_T = \rho \left(\frac{t}{A}\right)$

Figure 2. Heat Flux Line in a Hybrid Circuit

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Schottky rectifier because it has lower forward drop than most PN junction devices. The Schottky rectifier is a majority carrier device and has zero reverse recovery time. However, the Schottky's high junction capacitance (10 times greater than PN junction devices) produces the same effect as the t_{rr} of PN junction devices. Junction capacitance does not change appreciably with temperature, so the effective reverse recovery time remains the same with respect to temperature. Since commercially available Schottky rectifiers have only a 45V PIV rating, the absolute maximum input voltage of the buck type regulator is limited to only 45V.

Ultra fast PN junction devices are available with the same effective reverse recovery as Schottky rectifiers with a higher (up to 400V) PIV capability. The somewhat higher forward drop of the PN junction devices does not degrade efficiency at higher voltages.

The way in which a device recovers from forward conduction is also important. In high voltage (>1000V) power supplies, it is desirable to have abrupt reverse recovery time for optimum efficiency. In low voltage, high current power supplies a soft reverse recovery rectifier is better suited from the RFI viewpoint.

Figure 3 shows the effect of a diode recovery time on transistor power dissipation. The reverse recovery time of the catch diode requires the transistor to conduct higher peak current for a longer duration in the active region. This significantly increases RFI and also increases the power dissipation in the transistor, and may cause second breakdown.

For reliable circuit operation, t_{rr} should be much less than the current rise time of the transistor. This ensures minimum current overshoot in the transistor and also minimizes the amount of time the transistor spends in the active region during turn-on, resulting in lower power dissipation and increased efficiency. However, to obtain maximum efficiency, all switching times, (including current rise time) should be as fast as possible. The rectifier should be selected such that its t_{rr} is one third or less of the current rise time of the transistor. In switching regulator applications, it is also essential that the storage and fall times be as low as possible.

When turn-off is achieved without the assistance of I_{B2}, it is important that the power output transistor have the following characteristics for best performance:

1. Larger emitter periphery area with a triple diffused or double diffused epitaxial construction to provide lowest effective collector series resistance to prevent forward biasing of the collector-base junction.
2. The base spreading resistance, $r_{BB'}$, of the device should be lower than the external biasing resistor. This will provide low storage time and fast fall time.

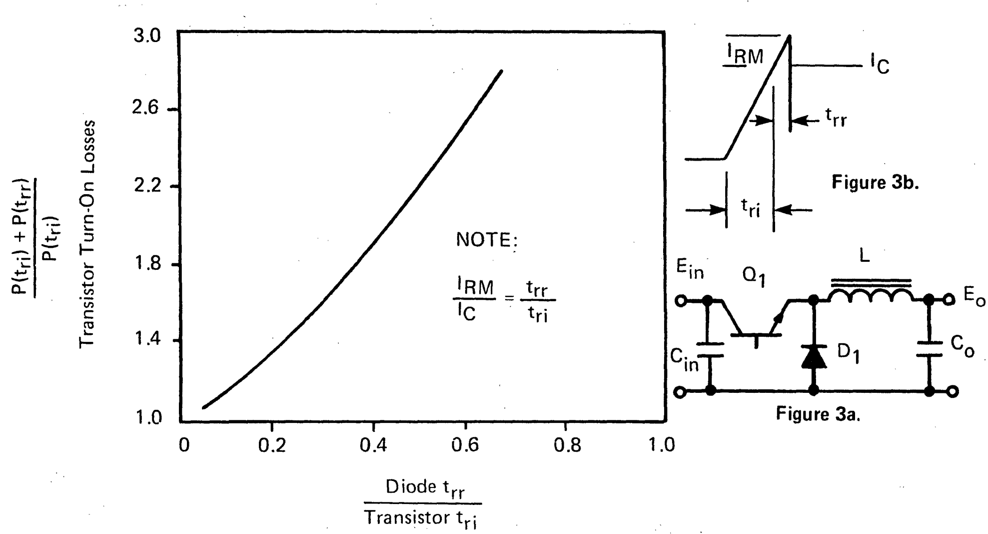

Figure 3. Importance of Reverse Recovery Time of a Rectifier

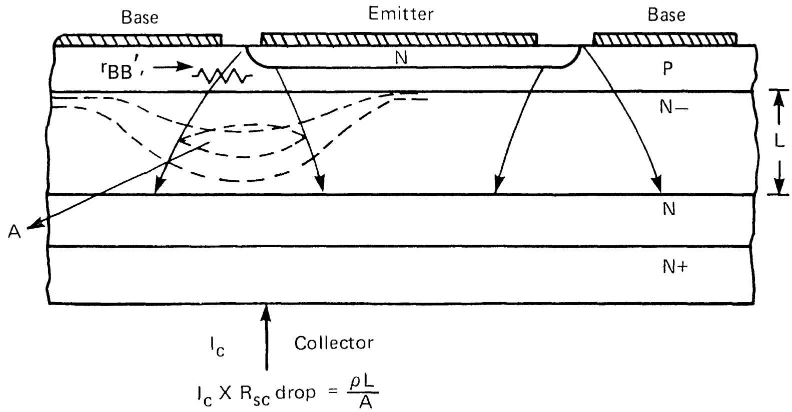

Figure 4. Effect of $r_{BB'}$ on Switching Times and Dynamic Saturation

The resistor turn-on biasing method works satisfactory up to 10A for a low voltage device without affecting the efficiency of the switching regulator. Another advantage of the resistive turn-off circuit is that it limits current crowding during turn-off thus increasing the reliability of the circuit. Since the driver transistor operates in a saturated mode, the device should have a high gain-bandwidth product to minimize overall storage time.

The hybrid circuit PIC600 consists of two transistors connected in a darlington configuration. The internal biasing resistors of these transistors are sufficient for fast turn-off without requiring any I_{B2}.

The table shown in Figure 5 compares the efficiency of a saturated transistor (2N4150) versus the hybrid darlington as the switching element in a 50 kHz buck regulator. In each case, the output device has the same size silicon chip.

Pass Transistor	Power Losses (Watts) $T_j = 25°C$	Efficiency	
		$\frac{E_o}{E_{in}} = 0.5$	$\frac{E_o}{E_{in}} = 0.2$
2N4150 (Saturated)	D.C. Losses . . . . 0.7 Switching Losses . . . . 2.27 Drive Losses . . . . 0.13 Diode Losses 4.76	84.79%	81.66%
PIC625 (Darlington)	D.C. Losses . . . . 1.4 Switching Losses . . . . 1.53 Drive Losses . . . . 0.15 Diode Losses 4.76	82.8%	81.69%

Conditions:
f = 50KHz
$E_o = 5V$
$I_o = 7A$
Same size output device for both cases.

Figure 5. Comparison Between Saturated and Darlington Pass Transistors in a Buck Type Switching Regulator

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In the saturated transistor approach, the transistor is driven with a forced Beta of 5 during turn-on and turn-off. However, in the darlington configuration, no turn-off base drive is employed. Typical measured switching times and saturation voltages are used to calculate losses.

From the table in Figure 5, it is evident that the hybrid darlington approach provides best results in terms of efficiency when the ratio between the output and input voltage is less than 0.25. In a darlington configuration, if the output device is kept out of saturation, then the rise, fall and storage times will be reduced compared with the saturated transistor. Even at higher output/input voltage ratios the loss in efficiency because of higher $V_{CE(SAT)}$ is minimal compared to the complexity and cost of a drive circuit required for a saturated transistor.

The plot in Figure 6 shows dc power dissipation of a PIC625 at various duty cycles and temperatures. The efficiency of the regulator depends heavily upon output voltage. Switching losses of the PIC625 under conditions shown in Figure 6 are:

25°C – 0.875W
-55°C – 0.525W
125°C – 1.476W

V. APPLICATIONS

Different applications of power hybrid circuits are discussed in this section.

Low Voltage Hybrid Circuits (<100V)

Some applications of low voltage hybrid circuits are: low and high current positive and negative buck-type regulators, bidirectional motor driver circuits, PWM push-pull and half bridge converters. Each is discussed briefly as follows:

a. Buck Type Switching Regulator

The schematic of the low cost, free running buck switching regulator is shown in Figure 7. When the output voltage is lower than the reference voltage, transistor Q_2 is off and transistor Q_1 is on and provides the base drive to the power hybrid circuit PIC600. The current in inductor L_1 increases linearly and continues to charge the output capacitor C_o. When the output voltage exceeds the zener voltage of diode D_1 (plus some fixed fraction of V_{BE} of transistor Q_2) transistor Q_2 turns on and removes base drive current from transistor Q_1 and hybrid circuit PIC600. Resistor R_6 and capacitor C_1 are used to provide fast switching times. The output voltage is trimmed with resistor R_3.

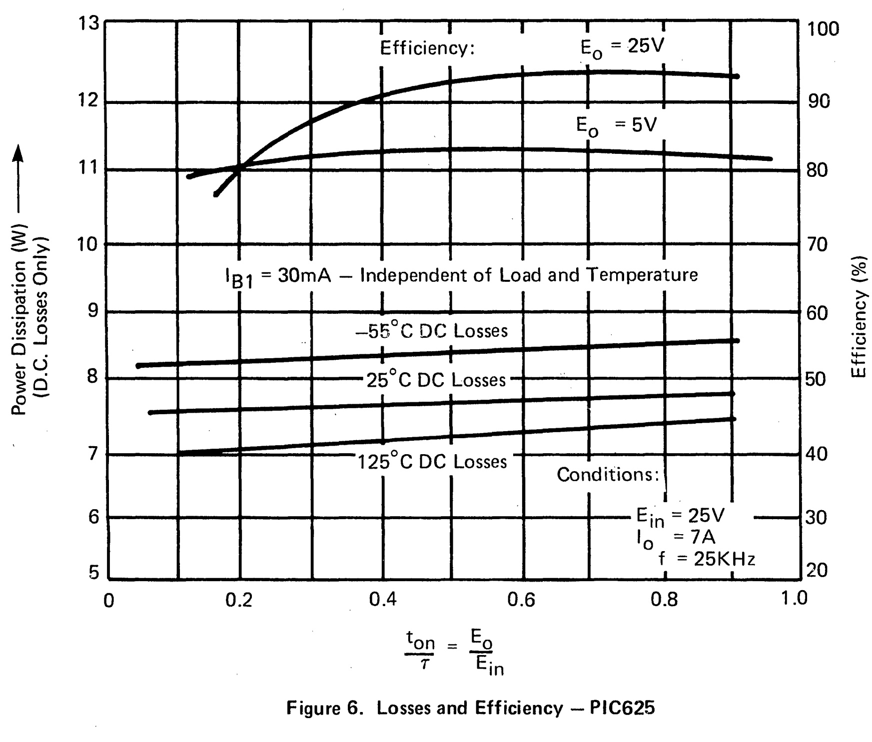

Figure 6. Losses and Efficiency – PIC625

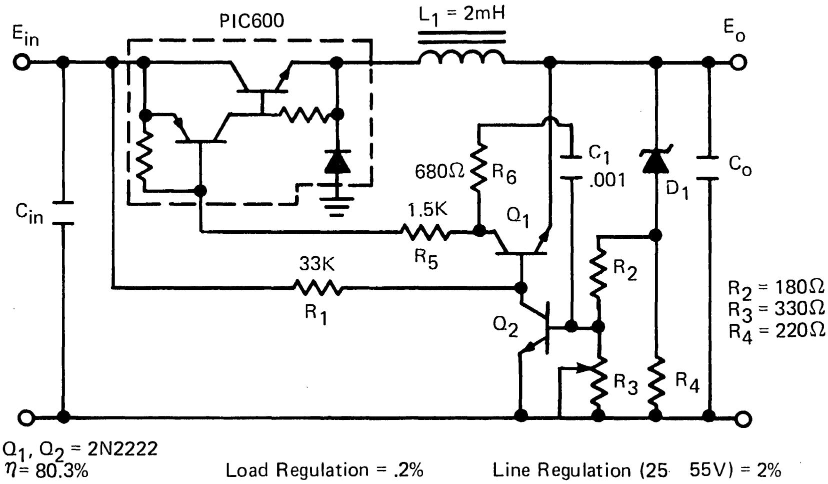

Figure 7. Low Cost Buck Regulator

b. High Frequency Switching Regulator

Low voltage hybrid circuits can be operated as high as 250 kHz due to their fast switching times. When these devices are used above 100 kHz, the storage time of the driver transistor must be reduced. This can be done by using a Baker clamp with resistor R_1 and diode D_1 as shown in Figure 8.

The advantages of operating a buck regulator at higher frequencies are:

- Lower filter cost
- Reduced size and weight
- Improved transient response
- Output ripple voltage less dependent upon ESR of capacitor
- Simpler EMI and RFI filtering

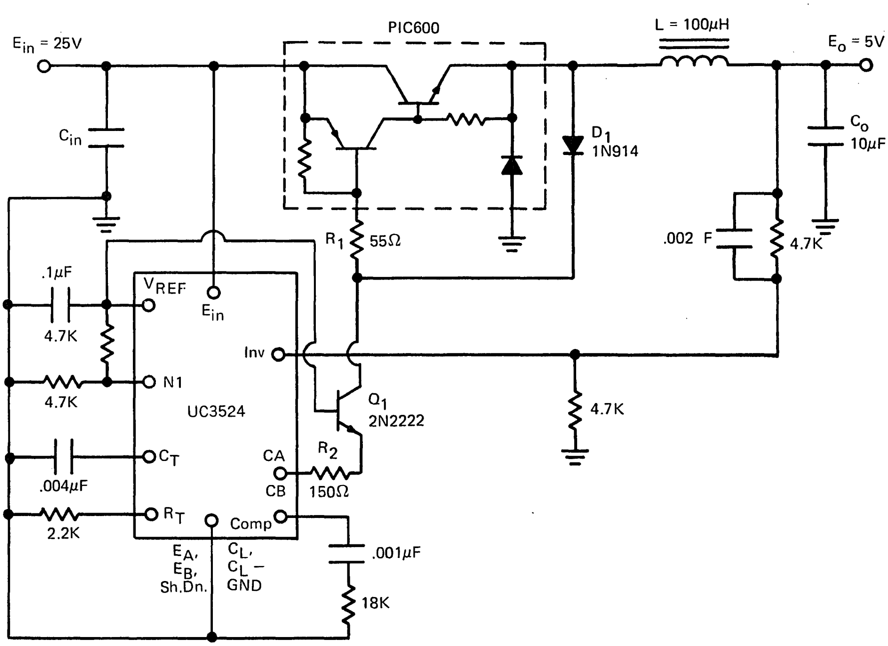

Figure 8. Operating a PWM Buck Regulator Above 100KHz

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c) Extending Output Current Capability up to 20A

The output current capability of a buck regulator can be extended by (1) paralleling the output devices as shown in Figure 9 and (2) the use of a high current device as shown in Figure 10.

The advantages of paralleling output devices are that it allows the device to operate with a relatively simple drive circuit and provides simplicity of heat sinking. On the other hand, proper current sharing during the on-time period and turn-off time is required. The circuit shown in Figure 9 provides the circuit technique to do just that. The only drawback is that it requires a dead-band period which must be greater than 0.1L, where L is the inductance value of the common mode choke L_1.

Another method is to use high current devices like the PIC740, a power output hybrid circuit. It consists of a 25A power output transistor and Schottky rectifier. The device is housed in a 3 pin TO-3 package with copper-core pins. The heat generation is kept to a minimum by using the Schottky rectifier and copper-core pins which allow the use of the TO-3 package for 25A buck type regulators. The limitation of these devices is that the maximum input voltage is only 40V. These devices can be used in high efficiency, high current buck switching regulators. In high current applications, careful consideration should be given to the drive circuit when the output device of the PIC740 is operated in the saturated mode. An increase of up to 5% in efficiency compared to the darlington can be realized at 15A output current.

PWM Push-Pull Converter

The circuit schematic shown in Figure 11 is a width modulated push-pull converter. It utilizes the Unitrode PIC636 power hybrid circuit.

Flux symmetry[5] in the transformer core is provided by introducing an air gap in only one leg of the EE core configuration. The voltage developed across resistor R_1 and capacitor C_1 is proportional to the flux density in the center leg of the EE core. This developed voltage is fed back into the control circuit at the output of the error amplifier. The output pulsewidth is corrected by the developed voltage across C_1 and R_1, providing flux symmetry in the power transformer.

Bidirectional Motor Drive Circuit

These power hybrid circuits can be employed to drive inductive loads, such as DC motors, stepper motors, and hammer drivers. Small inductors L_1 and L_2 limit cross-conduction current during switching times of the two hybrid circuits. The excellent switching properties of the hybrid circuit allow the circuit to be operated with high efficiency up to 100 kHz, improving transient response of the circuit.

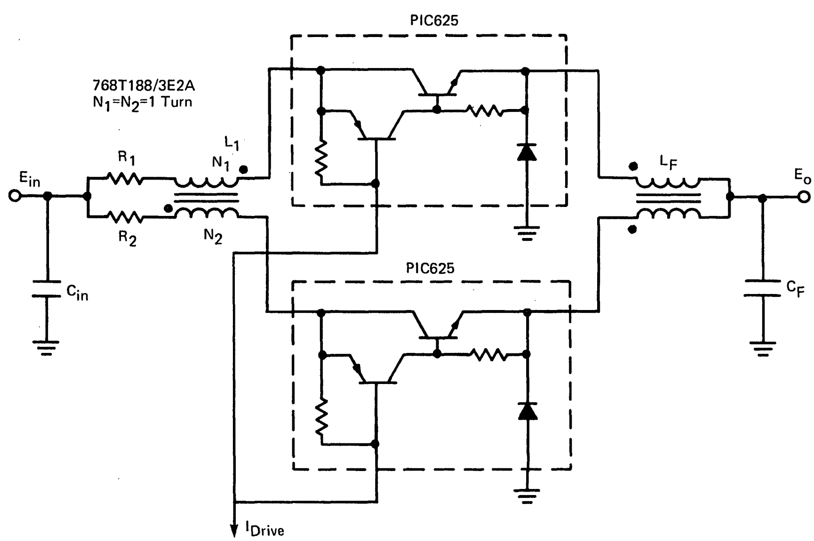

Figure 9. Current Sharing with a Common Mode Choke

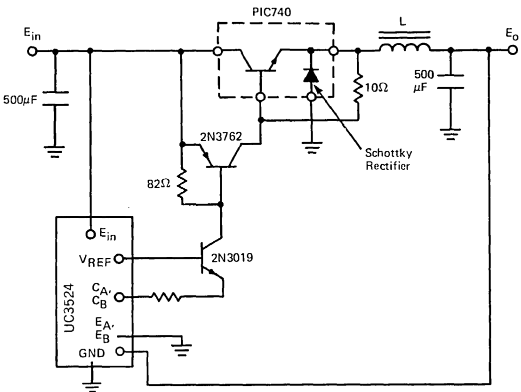

Figure 10. *Simplified Schematic of 20A Buck Type High Efficiency Switching Regulator*

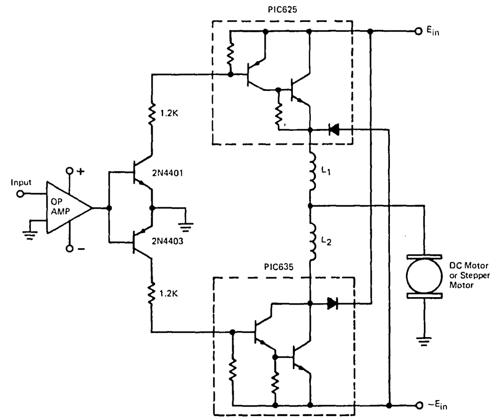

Figure 12. Bidirectional Motor Drive Circuit

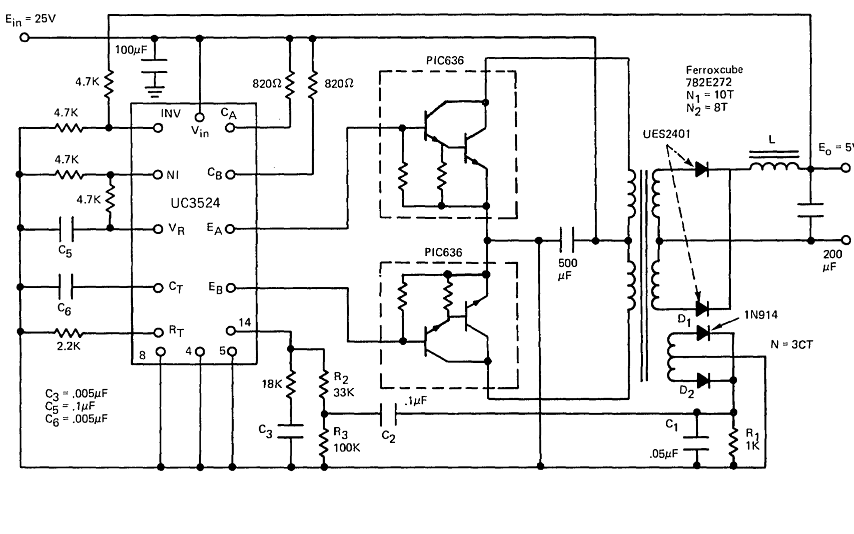

Figure 11. PWM Push-Pull Converter

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VI. CONCLUSION

A wide variety of power hybrid circuits in standard packages for switched-mode converter applications have been developed by Unitrode. Power components were carefully selected for optimum electrical performance. In many instances these hybrid circuits not only provide superior electrical performance but also reduce the overall cost of the power supply by reducing production labor and repair cost.

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SOFT STARTING A POWER SUPPLY IMPROVES RELIABILITY, EFFICIENCY

Active inrush-current limiters—unlike fuses and circuit breakers—prevent dangerous situations instead of only reacting to them. Apply limiting techniques, and you need not employ extra-hefty rectifiers just to ensure rectifier survival during turn on.

The input filter capacitor employed in many power-supply designs creates a potential problem—high inrush current. Fortunately, though, adding a few extra components can prevent inrush current and its associated circuit damage.

How does the input capacitor cause such problems? Intentionally chosen for high storage capacity and low equivalent series resistance (ESR), it behaves like a nearly perfect short circuit when the supply first turns on. The resulting short-duration peak inrush current can reach levels much greater than the tolerable single-cycle ratings of the supply's semiconductor rectifiers (thus destroying them) and still not contain sufficient total energy to open protective fuses or circuit breakers. Additionally, the supply's rapidly rising voltage and current levels could cause dv/dt- or di/dt-sensitive devices in neighboring hardware to fail or malfunction.

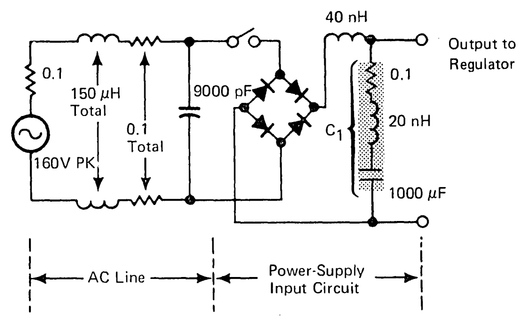
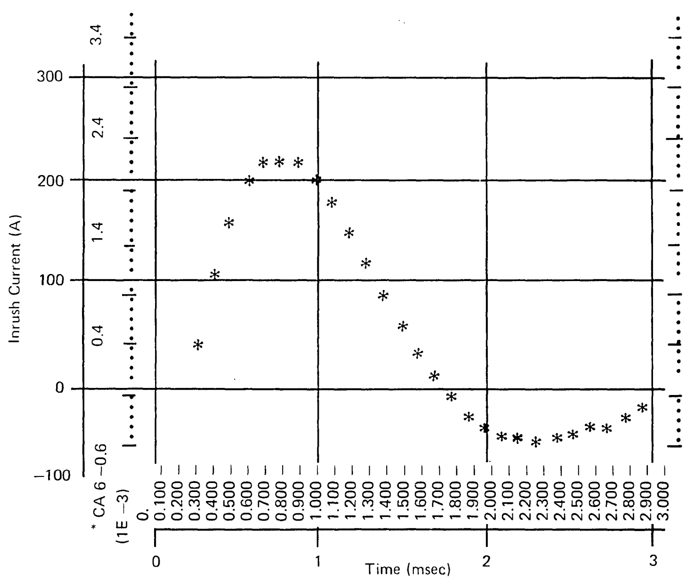


Figure 1. Based upon this generalized model, *analysis indicates the inrush-current problem's magnitude. Chosen for its low ESR, the input filter capacitor (C_1) behaves like a nearly perfect short circuit when the supply first turns on.*




```
ECAP
TRANSIENT ANALYSIS

C
B1    N(0,1), R = .1
B2    N(1,2), L = 150E – 6
B3    N(2,3), R = .1
B4    N(3,0), C = 7000E – 12
B5    N(3,4), R = .001
B6    N(4,5), L = 40E – 9
B7    N(5,6), R = .1
B8    N(6,7), L = 10E – 6
B9    N(7,0), C = 1000E – 6
E1    (1), 0, 0, 0, 160
      TIME STEP = 100E – 6
      FINISH TIME = 3E – 3
      1ERROR = 1
      PRINT NV, CA
      PLOT, (SCALED), CA(6)
      BINARY, NV, CA
```

Figure 2. Peaks greater than 200A *are predicted by ECAP for the circuit model shown in Figure 1.*

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Turn on an analysis before you turn on a power supply

Computer analysis proves useful

To appreciate the inrush-current problem, consider an estimate of its magnitude before examining possible control techniques. Figure 1 depicts a model of the ac-input and rectifier/filter sections for a typical power supply. Although shown in a straight off-the-power-mains configuration, the model should be valid for any other design with the same output-power capability.

An ECAP computer analysis performed for this circuit assumed worst-case conditions: switch closure at 160V (peak voltage). The results (Figure 3) of a typical design. The current pulse's high level and short duration could generate severe, localized hot spots in rectifier junctions or cause false triggering of rate-sensitive devices elsewhere in the circuit.

A standard approach to current limiting is depicted in Figure 4a—a resistor. It's simple, reliable and easy to design in, but efficient it isn't. At any current level, it dissipates power that would otherwise be available to the load. The resistor does perform a surge-current-limiting function, however.

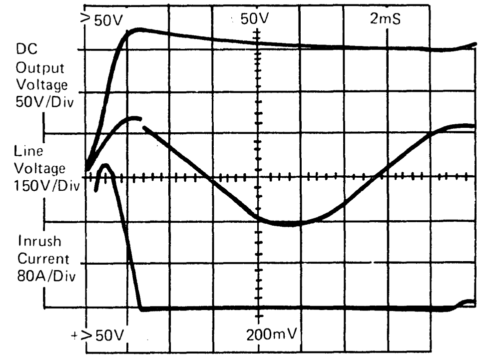


Figure 3. Measured inrush current *appears close to that predicted in Figure 2. This large current inrush could cause junction hot spots and generate troublesome EMI.*

Alternatively, a thermistor-controlled current limiter (Figure 4b) alleviates the resistor's efficiency problems to some extent, but it aggravates the dropout-recovery problem. The same cold-to-hot resistance variation that permits turn-on current limiting and high efficiency at low operating currents fails in dropout-recovery situations: The thermistor's long thermal time constant prohibits fast recovery.

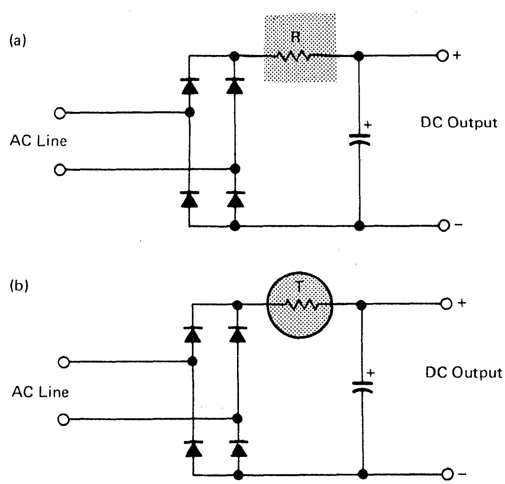
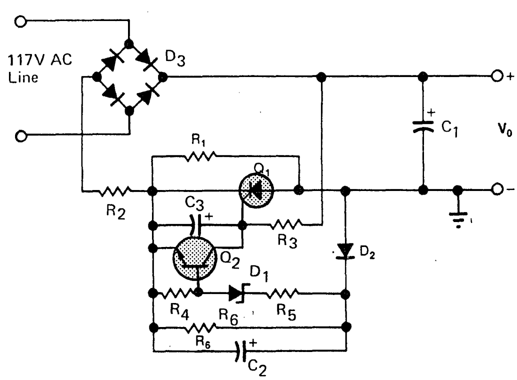


Figure 4. Two common methods *of inrush limiting employ either a resistor (a) or a thermistor (b). But if the resistor is large enough to effectively control surge currents, it also significantly reduces efficiency. The thermistor, while more efficient, offers little protection during dropout recovery because of its long thermal time constant.*



NOTES

R_1: 3, 5W	C_1: 1000 μF	Q_1: L2R06254
R_2: 0.2, 10W	C_2: 10 μF	Q_2: UPT312
R_3: 3k, 5W	C_3: 2 μF	
R_4: 1k	D_1: UZ4715	
R_5: 1k, 2W	D_2: 1N4245	
R_6: 2k	D_3: UT680-4	

Figure 5. SCR soft starting *bypasses the current-limiting resistor (R_1) only when the peak-detected voltage across Q_1 drops below the zener breakdown, i.e., when C_1 becomes almost fully charged through R_1.*

SCR spells efficiency

In view of resistor and thermistor drawbacks, active soft-start designs offer a best-of-both-worlds solution—effective inrush limiting, fast recovery and high operating efficiency. This type of circuit, shown in Figure 5, essentially incorporates a current-limiting resistor (R_1) and a bypass switch (Q_1). At turn on, Q_1 is OFF, and the surge current (I_S) develops a voltage across R_1. This voltage is peak detected by D_2 and stored in C_2. When the voltage exceeds D_1's zener breakdown—an event that should occur almost instantaneously—Q_2 turns on, disabling Q_1's gate-triggering network (R_3C_3). As the power supply's filter capacitor C_1 charges up, the inrush peaks diminish until the detected I_SR_1 voltage falls below D_1's zener breakdown. Q_2 then turns off, and the R_3C_3 network charges up and fires Q_1, bypassing R_1.

This circuit recovers rapidly enough to limit inrush currents that could occur as a result of even short line dropouts. When the ac input voltage goes to zero, the voltage across Q_1 also goes to zero, and Q_1 turns off. When the input voltage reappears, Q_2 keeps Q_1's gate circuit OFF until R_1 has allowed C_1 to become almost fully charged.

Figure 6 graphically depicts this design's inrush-limiting ability. Note how the I_SR_1 voltage level (upper trace) tracks the diminishing inrush-current pulses (lower trace) for the first three cycles. At the 17-msec point (slightly after the third current pulse), the peak detected voltage has dropped below the zener breakdown point, and Q_1 switches on, bypassing R_1. Then R_2 limits inrush currents.

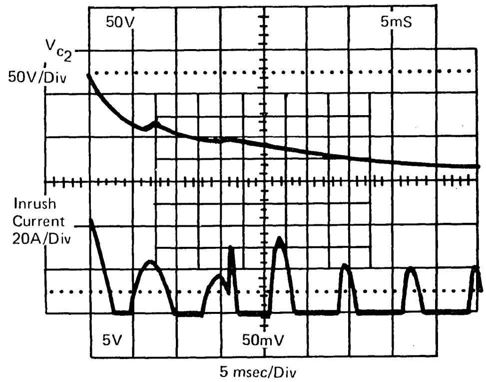


Figure 6. Inrush-current pulses of decreasing magnitude *(bottom trace) lower the SCR's hold-off voltage (upper trace). After 17 msec, the SCR fires.*

After determining your design's maximum continuous dc output current (I_O) and inrush limit (I_S), you can select an appropriate SCR. (The major SCR considerations are the peak repetitive blocking voltages and the maximum average plus peak current levels.) Typical SCRs exhibit a gate-turn-on voltage (V_{GT}) of about 0.6V; typical power-supply circuits exhibit a di/dt of about 1A/μsec—two quantities required for calculating the values of the other critical components:

$$R_1 = \sqrt{2}V_{AC}/I_S$$
$$R_2 = P_{R_2}/I_O^2$$
$$V_Z = I_SR_2$$
$$C3 \geq (2\sqrt{2}\,V_{AC}V_Z)/(R_3V_{GT}R_1(di/dt)).$$

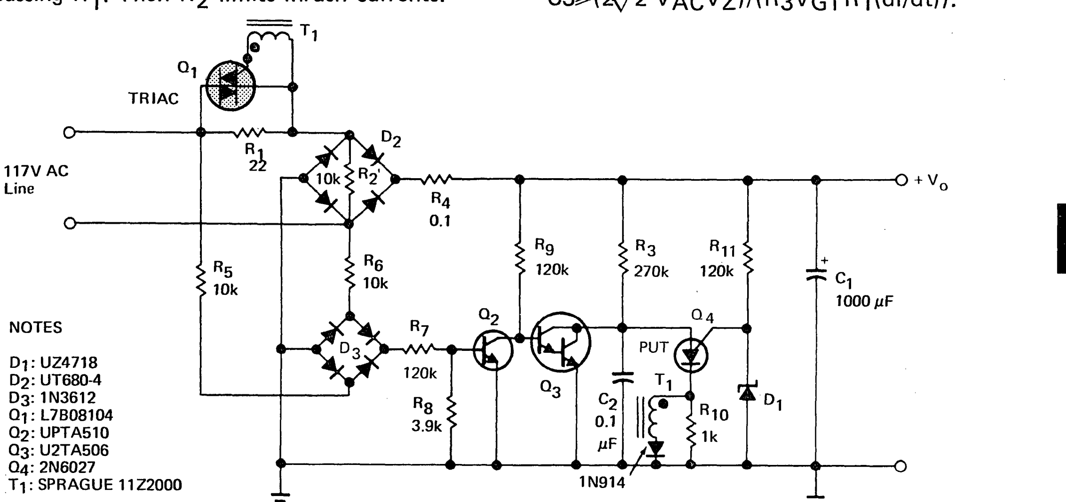


Figure 7. Phase controlling a triac *limits inrush-current pulses' amplitude and duration. Cycle-by-cycle triggering — handled by the PUT comparator — ensures instant recovery from line dropouts.*

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Switch out the limiting resistor when the inrush is over

In the second equation, specify P_{R_2} as the maximum power your requirements allow across R_2.

Another effective inrush-current limiter is the phase-controlled triac design shown in Figure 7, which operates by controlling the conduction time of the current surges. Initially, the dc voltage (V_O) across C_1 builds up slowly because of R_1's current-limiting action. This dc voltage helps establish a reference (via R_{11} and zener diode D_1) for the programmable unijunction transistor (PUT) Q_4 and charges the phase-control timing capacitor C_2 (via R_3). The PUT fires when its trigger point is reached, turning the triac on. Thus, when V_O is initially low, C_2 charges slowly, and the triac triggers on late in the half cycle. As V_O rises Q_1 turns on earlier in each cycle until nearly 100% conduction is achieved.

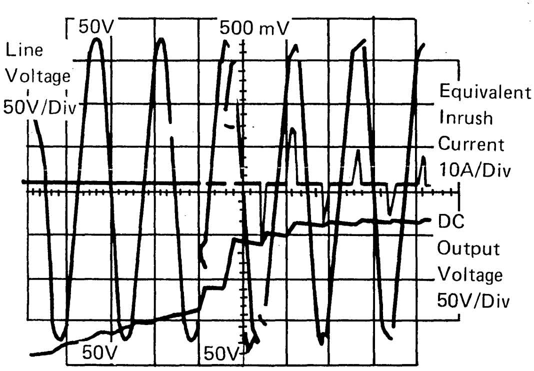

Figure 8. Triac conduction *follows the gradually increasing dc output voltage, decreasing the would-be inrush current. When the output voltage reaches design level, the triac is bypassing the current limiter nearly 100% of the time.*

The remaining circuit components (D_3, Q_2, Q_3, etc) discharge timing capacitor C_2 on each half cycle, thereby assuring cycle-by-cycle current limiting and fast recovery from dropouts. Figure 8 depicts the relationship between the ac input voltage, the dc output voltage and the varying conduction angle of the triac.

HYBRID CIRCUITS FOR OFF-LINE SWITCHING POWER SUPPLIES

1. Introduction

Hybrid circuits offer many advantages over the conventional discrete approach for switching power supplies, which has resulted in a rapid increase in their use. These advantages include ease in heat sinking multiple power components, while maintaining DC and high frequency isolation, reduced stray parasitics and lower overall cost. This application note discusses one of the hybrid circuits built by Unitrode, its components and construction, and two applications in detail, a Forward Converter and a Half-Bridge Converter.

2. "Off Line" Hybrid Circuits

2.1 Advantages

The Unitrode PIC800 series are "Off Line" hybrid circuits consisting of a high voltage power transistor and a fast recovery diode mounted in a 4 pin electrically isolated TO-66 package. The following advantages can be derived by using these power hybrid circuits:

a) Reduced EMI because of
   1. Lower capacitance (10pF instead of 100pF) between the case and active components compared to the conventional TO-66 package, and
   2. faster recovery time of the rectifier (less than 40nSec).
   3. the close proximity of the diode and transistor chip; this also results in reduced ringing.

b) Heat sinking is simple because the package is isolated; devices can be mounted on the same heat sink without any precautions regarding isolation up to 800V.

c) Components are matched for better performance.

2.2 Components

In a high voltage "off line" hybrid circuit a large portion of the power dissipation in the transistor is due to switching losses. The PIC800 series hybrid circuits utilize a Unitrode high voltage transistor which has been computer optimized for fast switching speeds. This optimization and the specially interdigitated structure result in lower r_{bb}' and uniform current injection. The PIC800's rectifier diode, a gold-doped epitaxial device, was chosen for a typical reverse recovery time of 20nSec. This is less than one-third of the transistor's current rise time, to minimize transistor switching dissipation and the generation of spikes and RFI. These power hybrid circuits have the capability of switching up to 8A at 400V and are designed for such applications as high voltage buck type regulators, bridge circuits, forward converters, deflection circuits and DC motor drives.

Type	Peak Output Current	Input, Output Voltage	Polarity	Fall Time Voltage (nS)	Fall Time Current (nS)	On-State Voltage @ I (V) @ I	Package
PIC800 PIC801	8A	350 400	Pos.	200	200	1.5 @ 5	4 PIN TO-66 (Isolated)
PIC810 PIC811	8A	350 400	Neg.	200	200	1.5 @ 5	4 PIN TO-66 (Isolated)

FIG. 1a – PIC800 Series Hybrid Circuits

TYPICAL INDUCTIVE SWITCHING TIMES				
Current	Temp.	t_s μS	t_{fv} nS	t_{fi} nS
$I_c = 5A$	25°C	.9	80	100
	100°C	1.0	190	140

CONDITIONS

$\frac{I_c}{5} = I_{B1} = I_{B2}$

$V_{CC} = 125V$ $V_{(clamp)}$ 350V

FIG. 1b – Unitrode Transistor Switching Times

2.3 Construction

The PIC800 series hybrid circuit is shown in Figure 2. It combines a transistor and a commutating diode in a 4 pin electrically isolated TO-66 package.

Berillium oxide (BEO) is used for the substrate because of its excellent thermal conductivity, 70% as good as copper. The interconnection paths and pad areas for the wire bonds are screen printed on the BEO substrate and fired in high temperature furnaces. The semiconductor devices used in the circuit are gold eutectic mounted, and aluminum ultrasonic wire bonding is used for interconnections.

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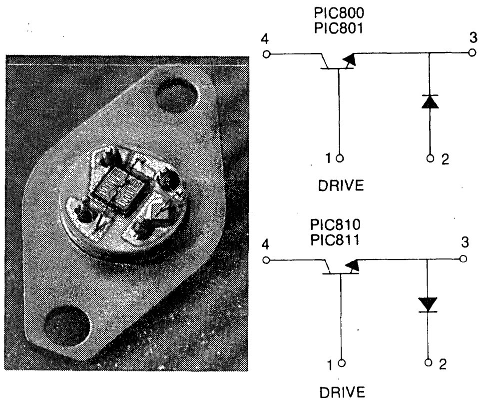
The BEO substrate is soldered to the nickel plated steel header with a copper slug between them. The copper slug relieves mechanical stress between the BEO substrate and the header, and provides heat spreading for lower thermal resistance.



OFF-LINE SWITCHING
REGULATOR OUTPUT CIRCUIT
PIC800-811

Figure 2. PIC800 hybrid circuit

3. Off-Line Forward Converter Application

This section discusses the design for an off-line Forward PWM Converter, 50 watts total to multiple outputs. The design employs such features as soft start, current limiting and protection from output short circuits. The Forward Converter design uses one PIC811 hybrid circuit. The power output transformer uses a demagnetizing winding to prevent core saturation, as does the base drive transformer. The PWM control circuit uses a UC3524 regulator chip. Proportional base drive reduces the power transistor storage time, and an RC snubber limits the turn-off power dissipation.

Section 4 of this application note discusses the design for an off-line half-bridge converter.

Other Unitrode application notes discuss the design of buck, boost, flyback and H-bridge type switching power supplies. (Application Notes U68A, U80, U76 and Design Note DN-8).

3.1 Description of Functional Circuits (see Fig. 3.3)

Current limiting is performed by measuring the collector current of the power transistor Q1 and cutting off the base drive of Q1 instantaneously. Resistor R6 measures the emitter current in Q1; when the voltage developed across R6 becomes greater than V_{BE} of Q4 (0.7V), Q4 turns on and diverts Q1's base current.

Soft start capacitor C11 is at zero volts when the power supply is turned on, and CR26 keeps pin 9 at 0.7V more positive than the voltage on C11, which is being charged slowly by R13.

The maximum pulse width is set by potentiometer R12 and CR24. Storage time of the power transistor Q1 is reduced by using proportional base current drive and by providing large base turn-off current, using transformer T3 and the associated combination of diodes.

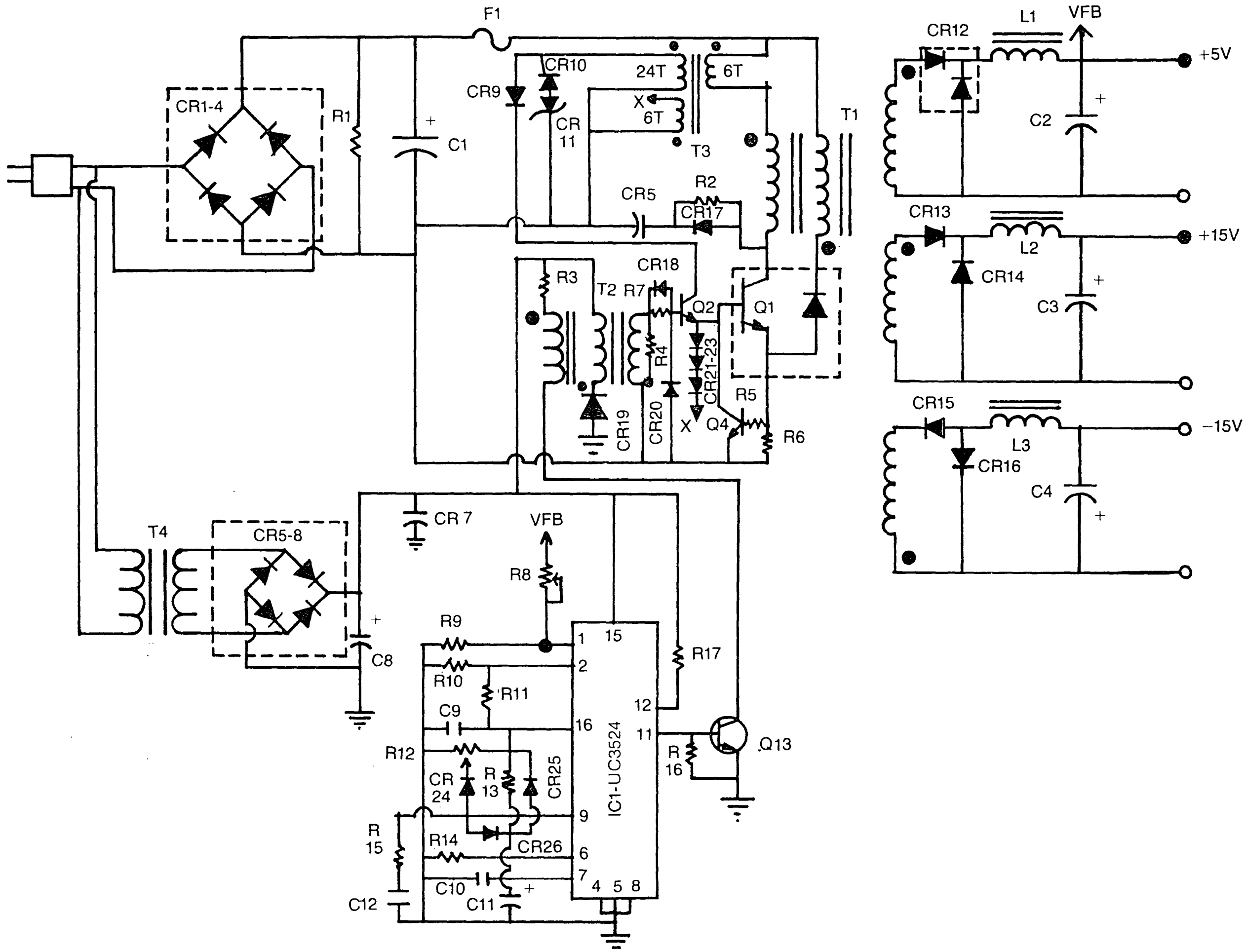
3.2 Specs:

Input – 95 to 135V, 60Hz
Outputs – 5V @ 3A, ±15V @ 1A
Regulation – Line: 0.2% for specified AC input.
– Load (20% to 100%): 5V output, 0.3%; ±15V output, 3%.

Ripple & Noise – 50mV peak to peak for ±15V outputs, 100mV for 5V output.

Frequency – 30KHz
Efficiency – 78%

Features:
Short circuit protected
Soft Start



3.3 Schematic of Forward Converter

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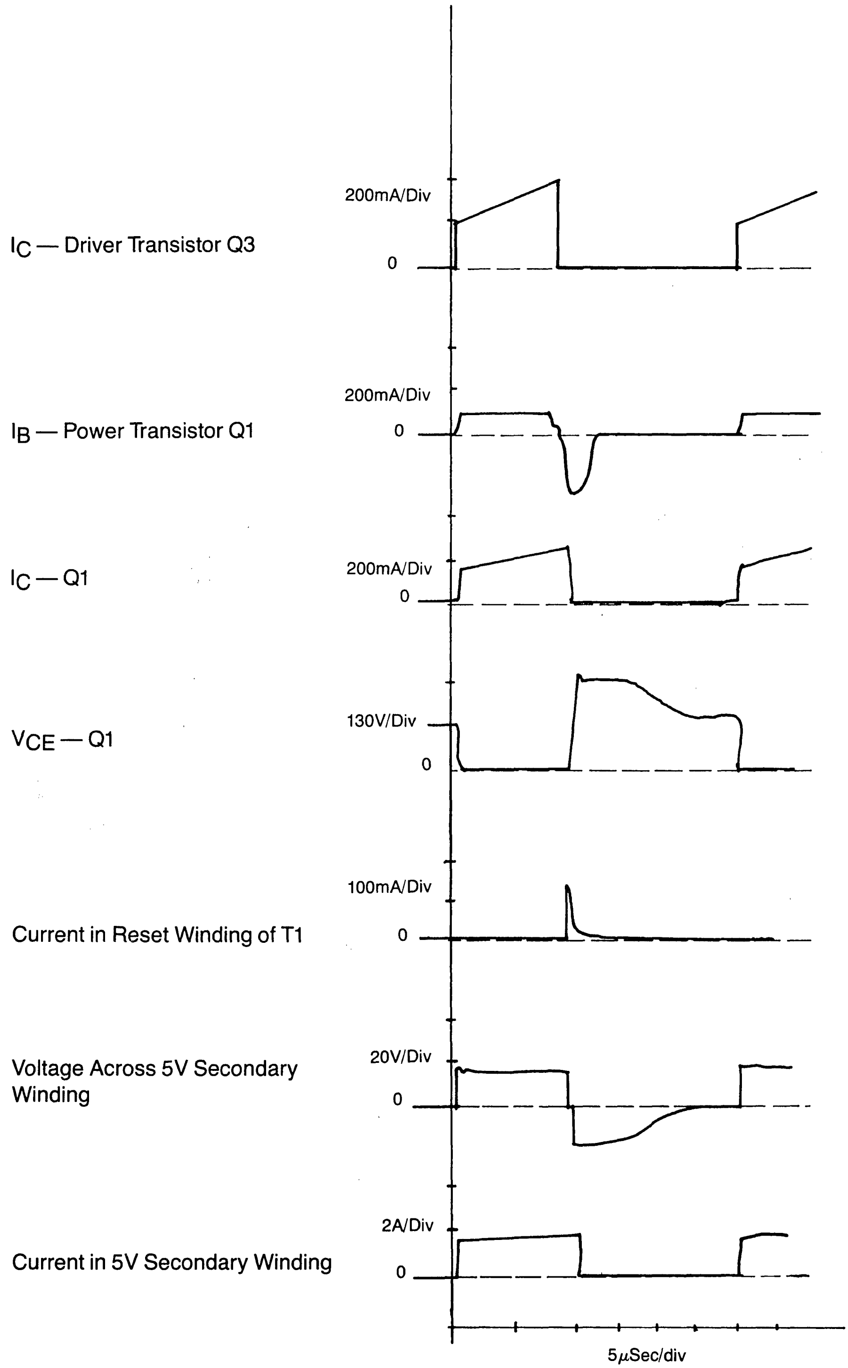
3.4 Waveforms



3.5 Power Transformer Design for Forward Converter

Use an EC-41-3C8 EE core (Ferroxcube).

$$N_p\,(min) = \frac{E_{in}(high) \times 10^8}{2f\,B_{max}\,A_e} = \frac{140\sqrt{2} \times 10^8}{2 \times 25K \times 3.3K \times 1.21}$$

$= 101$ Turns (min) (1)

$$i_{pri} = \frac{P_o/V_{in}}{D.F. \times Eff.} = \frac{50W/165V}{0.45 \times 0.8} = 0.84A$$

For 15% current ramp in primary, $I_{rr} = 0.15 \times 0.84A = 0.14A$

$L_m = E_{in}(high)/(di/dt) = 135V\sqrt{2}/(0.14/15\mu S)$

$= 20mH$ (2)

$$N_p(min) = \left(\frac{L_m \times 10^9}{A1}\right)^{0.5} = \left(\frac{20 \times 10^6}{2800}\right)^{0.5}$$

$= 84$ turns (min) (3)

From (1) and (3) use 120 turns.

Current density in primary; design for 3000A/sq. in. (max) (4)

0.84/3000A/sq. in. = .00028 sq. in. (min)

AWG #24 = .00032 sq. in.

$A_w = 2.5(A_p \times N_p) \times 2 = 2.5(.00032 \times 120) \times 2$

$= 0.17$ sq. in. needed.

EC-41 has $A_w = 0.21$ sq. in. available on bobbin.

For the 5V winding:

$$\frac{N_p}{N_s}(max) = \frac{E_{in}(low) - V_{CE(SAT)}}{2(E_o + V_F + V_{RS})} = \frac{90\sqrt{2} - 1}{2(5 + 0.7 + 0.1)}$$

$= 10.9$ (max); use 9:1 Turns Ratio.

For the 15V Winding:

$$\frac{N_p}{N_s}(max) = \frac{90\sqrt{2} - 1}{2(15 + 0.7 + 0.1)} = 4.3:1 \text{ (max); use } 4:1$$

3.6 Parts List – 50W Forward Converter

IC1 – UC3524

Q1 – PIC811
Q2-3 – 2N2222
Q4 – UPT212

CR1-4 – 697-4
CR5-8 – 673-1
CR9 – UES1101
CR10 – UES1101
CR11 – UZ707
CR12 – UES2401
CR13-14 – UES1304
CR15-16 – UES1304
CR17 – UES1306
CR18 – UES1101
CR19 – UES1304
CR20 – UES1101
CR21-23 – UES1101
CR24-26 – 1N914

TI-4 – See Magnetics Sheet
LI-3 – See Magnetics Sheet

F1 – 2A AGC

C1 – 600μF, 250VDC
C2 – 5000μF, 10VDC
C3 – 1000μF, 25VDC
C4 – 1000μF, 25VDC
C5 – .001μF, 1KV disc ceramic
C7 – 47μF, 35V
C8 – 500μF, 50VDC
C9 – 0.1μF, 50V
C10 – .005μF, 50V disc
C11 – 100μF, 50VDC
C12 – .01μF, 50VDC disc

R1 – 27K, 2W
R2 – 2.2K, 2W
R3 – 27
R4 – 27
R5 – 47
R6 – 0.5
R7 – 33
R8 – 20K pot
R9 – 4.7K
R10 – 4.7K
R11 – 4.7K
R12 – 1K pot
R13 – 100K
R14 – 3.9K
R15 – 22K
R16 – 100
R17 – 330

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3.7 Magnetic Components

T1 – Power Transformer

Core: EC-41-3C8 Core & Bobbin, Ferroxcube

120T	120T	13T	30T	30T
#24 AWG	#30 AWG	#20AWG	#20AWG	#20AWG
(PRI)	(RESET CORE)	(5V SEC)	(15V SEC)	(-15VSEC)

T2 – Base Drive Transformer

Core: 376 B/U 250-3C8 (UI Core), Ferroxcube

60T	60T	15T
#27 AWG	#30 AWG	#24 AWG
(PRI)	(RESET CORE)	(SEC)

T3 – Current Transformer

Core: 846T250-3C8, Ferroxcube

6T	6T	24T
#18 AWG	#18 AWG	#24 AWG
(PRI)	(SEC)	(SEC)

T4 – Isolation Transformer

Stancor PPC-2, 115V/15V, 0.1A

L1 – 5V Output Inductor

Core: 1F31-3C8, Ferroxcube

40T 6 mil air gap in each of the 2 legs.
#18 AWG L1 = 600μH

L2 & L3, 15V Output Inductor

Core: 1F31-3C8, Ferroxcube L3 = L2 = 1.3mH

74T 6 mil air gap in each of the legs.
#18 AWG

4. Off-Line Half-Bridge Converter Application

This portion of the application note discusses the design for an off-line half-bridge PWM converter supplying 100 watts to multiple outputs. Features include soft start and current limiting, and the PWM control circuit uses the UC3524 chip.

Proportional base drive and a special base drive circuit are used to reduce transistor storage time.

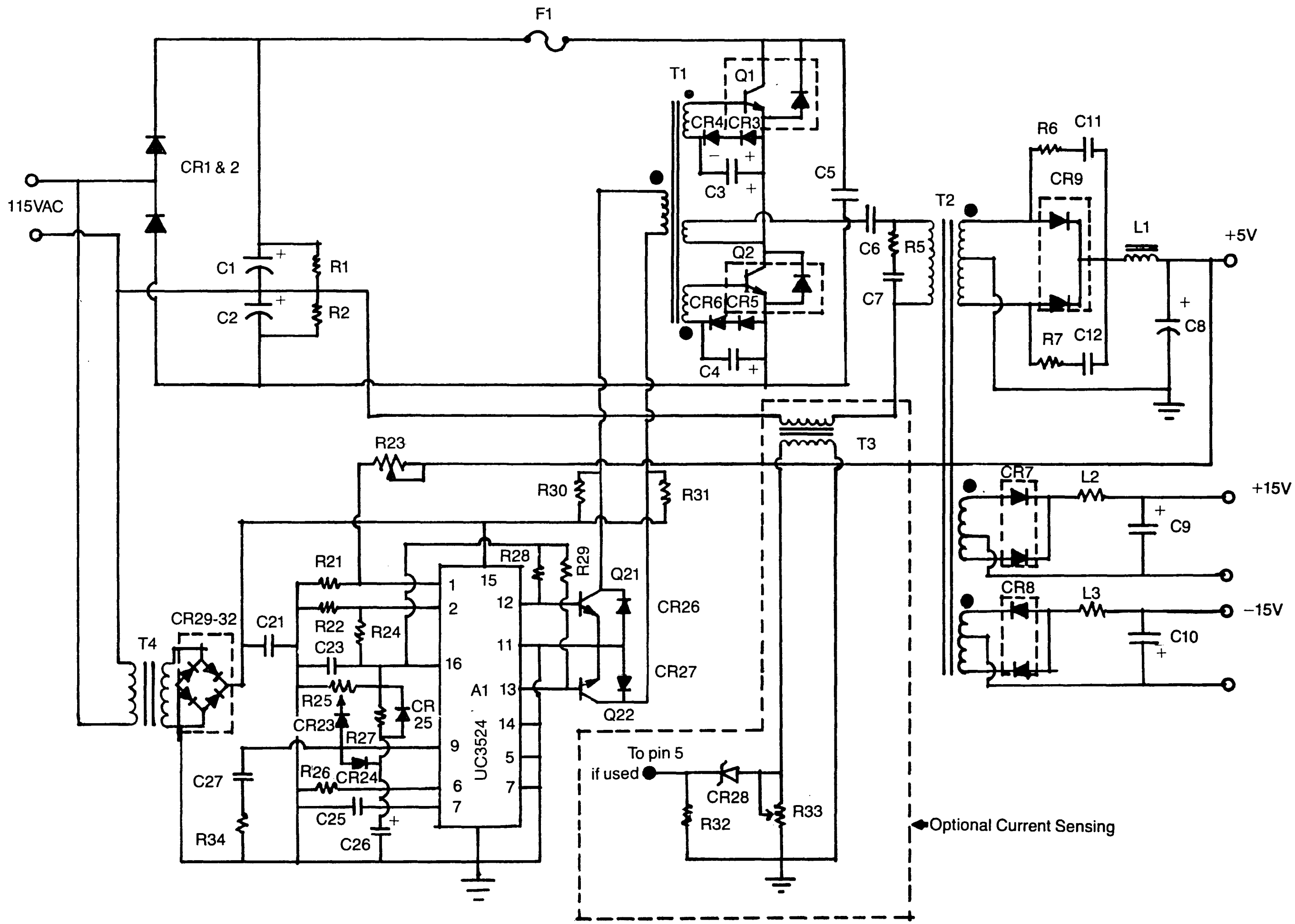
4.1 Circuit Description (see Fig. 4.3

The half-bridge type circuit was chosen for the 100 watt converter design, along with the PIC810 hybrid and fairly simple circuits. The half bridge circuit keeps the transistors' collector voltage, including inductive spikes, from exceeding the DC bus voltage, and the series capacitor C6 prevents core saturation. The base drive circuit is designed to minimize transistor storage time by essentially shorting the primary of the driver transformer T1 during transistor dead-time, providing a low impedance path for I_{B2} of the transistors. This is accomplished by turning on both Q21 and Q22 during the dead-band period. In addition proportional base drive is used.

Soft start capacitor C26 is at zero volts when the power supply is turned on, and CR24 keeps pin 9 at 0.7V more positive than the voltage on C26, which is being charged slowly by R27. The maximum pulse width is set by potentiometer R26 and CR23.

4.2 Specs for Half-Bridge Converter

Input – 95V to 135V, 60Hz
Outputs – 5V @ 15A, ±15V @ 1A
Regulation – Line: 0.3% for specified AC input
Load (20% to 100%): 5V output, 0.5%; ±15V, 2%.
Ripple and Noise – 5V output, 80mV peak to peak.
– ±15V output, 20mV peak to peak.
Frequency – 30KHz
Efficiency – 80%



4.3 Schematic of 100W Off-Line Half-Bridge Converter

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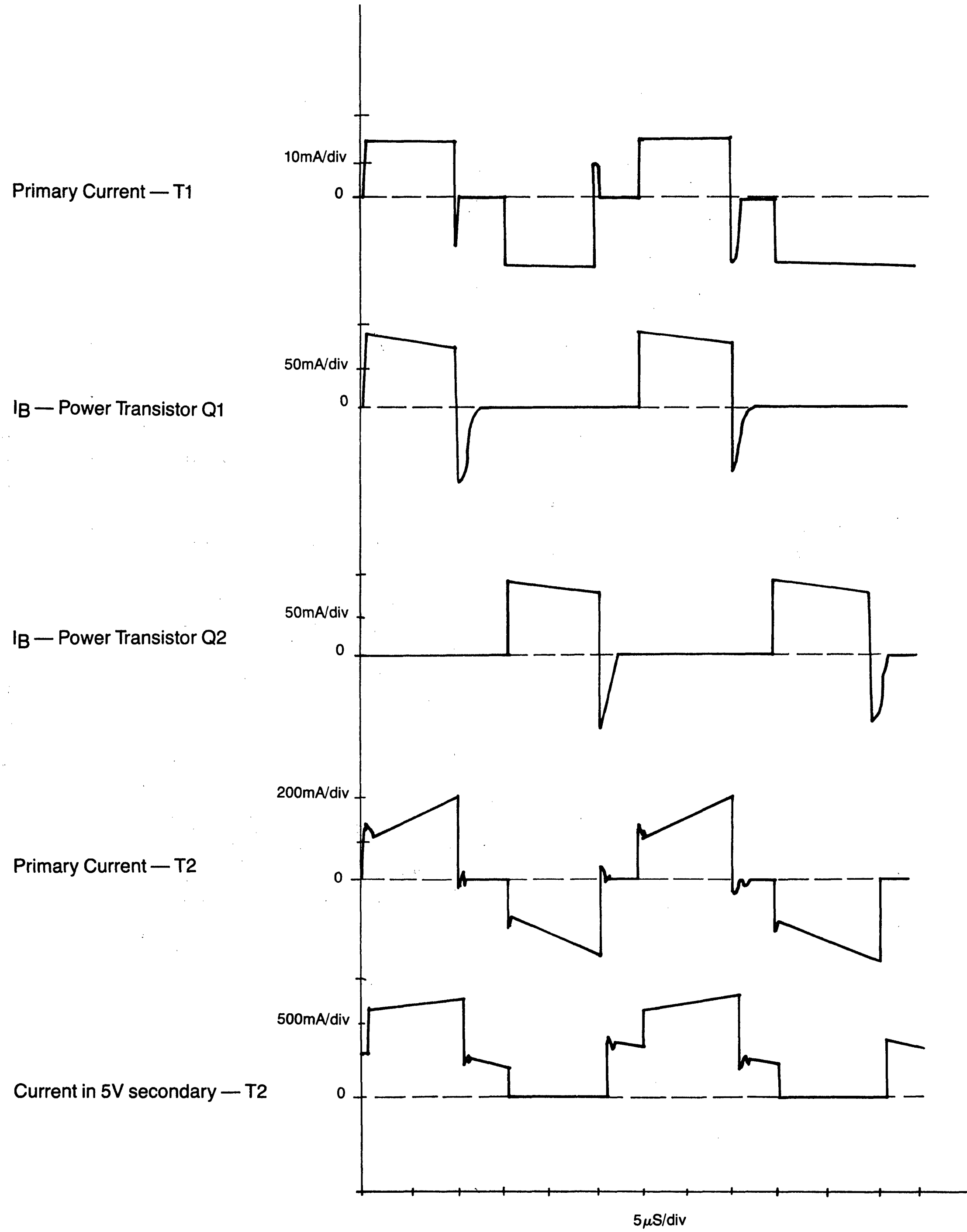
4.4 Typical Waveforms for Half-Bridge Converter



4.5 Power Transformer Design for Half-Bridge

Use EC35-3C8 core and bobbin (E-E configuration)

$$N_p(\text{min}) = \frac{E_{in}(\text{max}) \times 10^8}{4f\, B_{max}\, A_e}$$

$$= \frac{135\sqrt{2} \times 10^8}{4 \times 30K \times 3.3K \times 0.843}$$

= 57 turns (min).

$$i_{pri} = \frac{P_o/V_{in}}{DF \times Eff.} = \frac{100/165}{0.5 \times 0.8} = 1.52A$$

For 25% current ramp in primary:

$Im = 0.25 \times i_{pri} = 0.25 \times 1.52 = 0.38A$

$$Lm = \frac{E_{in}(\text{max})}{Im/ton} = \frac{135\sqrt{2}}{(0.38/12\mu S)} = 5.9mH$$

$$N_p(\text{min}) = \left(\frac{Lm \times 10^9}{A_L}\right)^{0.5} = \left(\frac{5.9 \times 10^6}{1500}\right)^{0.5}$$

= 63 turns (min)

For the 5V winding:

$$\frac{N_p}{N_s}(\text{max}) = \frac{E_{in}(\text{min}) - V_{CE(SAT)}}{E_o + V_F + V_{RS}} \times \frac{T - 2T_{db}}{T}$$

$$= \frac{90\sqrt{2} - 1}{5 + 0.8 + 0.4} \times \frac{33 - 2}{33}$$

= 19.1 (max)

63T/19.1 = 3.3T; use 4 turns

For the 15V winding:

$$\frac{N_p}{N_s}(\text{max}) = \frac{90\sqrt{2} - 1}{15 + 0.8 + 0.4} \times \frac{33 - 2}{33} = 7.3\ (\text{max})$$

19.1/7.3 = 2.62, 2.62 × 4T = 10.48T; use 11 turns.

For primary use 4 × 18 = 72 turns.

Design for current density of 3000A/sq. in. (max).

$A_p(\text{min}) = i_{pri}/\text{max density} = 1.52/3000 = .00050$ sq. in; use #22 AWG = .00050 sq. in.

$AW = 2.5(A_p \times N_p) \times 2 = 2.5(.00050 \times 72) \times 2 =$ 0.17 sq. in. needed. EC35 bobbin has 0.16 sq. in. available. (The first factor of 2.5 is for efficiency of using winding area, the second 2 is for equal primary and secondary winding area).

4.6 Inductor for 5V Output

Selecting an inductor core can be done by first calculating the A_eA_c product (magnetic core area × window winding area) from the known requirements, and then choosing an inductor with an A_eA_c product that is equal or larger.

Using MPP (Magnetics Inc) core material;

$$A_eA_c = \frac{(100/k)\,(L\, I_{max}\, A_t) \times 10^8}{B_{max}}$$

Where k is usable winding area of core in %, and A_t is cross sectional area of wire in sq. cm.

$$= \frac{(100/75)\,(70\mu \times 15 \times 0.033) \times 10^8}{2000}$$

= 2.09 cm^4 needed

Referring to the manufacturer's data sheet, the 55543-A2 core has an $A_eA_c = 0.67 \times 3.1 = 2.1\ cm^4$, which is sufficient.

(A_t = 15A/3000A/sq. in. = .005 sq. in.
= .033 sq. cm)

Then $N = 1000\sqrt{L/L_{1000}} = 1000\sqrt{70\mu H/305mH}$

= 15 Turns

4.7 Magnetics:

Driver Transformer T1
Core: Ferroxcube 2213 P3B7
(1-2) 75 turns, #26 wire
(3-4) (4-5) 12 turns, Bifilar, #24 wire
(6-7) 2 turns, #19 wire

Power Transformer T2
Core: Ferroxcube EC35-3C8 (E-E)
(1-2) 72 turns, #22 wire
(3-4) (4-5) 4 turns, Bifilar, #16
(6-7) (7-8) 11 turns, Bifilar, #18
(9-10) (10-11) 11 turns, Bifilar, #18

Current Transformer T3
Core: Magnetics, Inc. #52056-ID
(1-2) 1 turn, primary winding through core.
(3-4) 34 turns, #24 wire

Filter Inductors
L1
Core: Magnetics, 55543-A2
15 Turns, #12 AWG
L2, L3
Core: Ferroxcube 1F31-3C8
74 turns, #18 AWG

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4.8 Electrical Parts List

Semiconductors

A1 – UC3524
Q1, Q2 – PIC810
Q21, Q22 – UPT212

CR1, CR2 – 1N5551
CR3,4,5,6 – 1N4001
CR7,8 – UES2401
CR9 – SD241
CR21-27 – SES5001
CR28 – 1N4461
CR29-32 –673-1 Bridge

Resistors

R1, R2 – 10K, 2W
R5 – 3Ω, 5W
R6, R7 – 6.8Ω, 2W
R21, R22, R24 – 5.1K
R25 – 1K, 3/4W, Trim Pot
R28, R29 – 510Ω, 1/2W, 5%*
R30, R31 – 1KΩ
R32 – 1K
R33 – 200Ω, 3/4W, Trim Pot
R34 – 20K
R27 – 100K
R26 – 3.9K
R23 – 20K Trimpot

**Adjust for symmetrical base pulses.*

Capacitors

C1, C2 – 430μF, 200V
C3, C4 – 22μF, 6V
C5, C6 – 2μF, 400V
C7 – 0.001μF, 1KV
C8 – 5000μF, 10V
C9, C10 – 1000μF, 25V
C11, C12 – 0.1μF, 100V
C23 – 0.1μF, 25V
C27 – 0.1μF, 100V
C25 – .005μF, 100V
C26 – 100μF, 12V
C21 – 500μF, 25V

Magnetics

L1, L2, L3 – Filter Chokes
T1 – Driver Transformer
T2 – Power Transformer
T3 – Current Transformer
T4 – Stancor PPC-2, 115V/15V, 0.1A

Other

F1 Fuse – 2A-3AG

All resistors ½W, 5% unless otherwise noted.

DESIGN GUIDE — POWER SCHOTTKY RECTIFIERS IN A SWITCHING REGULATOR

1. Introduction

Present technology is stimulating the development of more efficient power supplies. The switching regulated power supply is fast becoming the most popular type especially in industrial and military applications because it offers higher efficiency than a linear power supply.

Schottky rectifiers are widely used in switched-mode converters due to their inherently lower forward voltage characteristics compared with PN junction devices. Losses in the power supply are reduced considerably by the use of Schottky rectifiers, resulting in increased efficiency, improved reliability, and reduced size, weight and cost of the switched-mode converter.

In a +5V T^2L logic power supply, the efficiency of a switched-mode converter is reduced 11 to 15% due to rectifier losses. The trend is for information processing circuits to be operated at even lower voltages, making the forward characteristic of a Schottky rectifier even more important.

Since the Schottky rectifier is a majority carrier device, there is no reverse recovery characteristic caused by minority carrier storage when the devices switch from forward conduction to the blocking state. However, due to the large junction capacitance, Schottky rectifiers will exhibit reverse recovery time like a fast PN junction rectifier.

This application note describes, in brief, the theory of Schottky rectifiers and compares Schottky rectifier characteristics using different barrier metals and their effects on switching regulator efficiency.

The discussion also covers the parasitic elements in the Schottky rectifier and considers the effects of these elements in switched-mode converters. Design rules are derived for optimum snubber networks to protect against transient voltages and minimize RFI. Guidelines are provided for selecting the proper Schottky rectifier for different types of switched-mode converters.

2. Basic Structure

The basic construction of a Schottky rectifier is shown in Figure 1. The starting material is a heavily doped N+ silicon wafer on which an N-type epitaxial layer is deposited. The resistivity of this layer determines the reverse blocking voltage capability of the rectifier. The Schottky barrier is formed by depositing a metal layer on the N-type epitaxial layer, and the junction formed between the metal and the semiconductor is an abrupt junction.

The most commonly used barrier metals or alloys are chromium, platinum, nickel platinum, molybdenum tungsten. A performance comparison of different barrier metals is summarized in Table 1. The chromium barrier provides low forward voltage with a very high leakage current. However, the tungsten barrier provides low leakage current with high forward voltage. Since efficiency is a major consideration in switched-mode converters, the nickel platinum barrier provides the best choice due to its low forward drop with a minimum of leakage current.

3. Theory And Discussion of Parasitic Elements in a Schottky Rectifier

The energy bands of a metal and semiconductor separated by a vacuum are shown in Figure 2a. This system is not in equilibrium. However, if an electrical connection is made between the semiconductor and metal, charge is allowed to flow from the semiconductor to the metal. Equilibrium will be established and the Fermi levels will become aligned.

When intimate contact is made between the metal and semiconductor, Figure 2b, the Fermi levels will line up and there will be an accumulation of positive charges at the surface of the semiconductor. A barrier will exist for electron flow from the metal to semiconductor and the barrier height will be the difference between the work function of the metal and the semiconductor.

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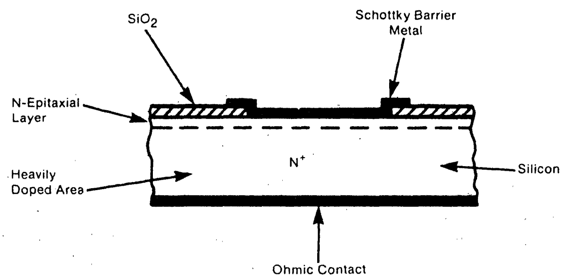

Figure 1 - Cross–Section of a Schottky Barrier Power Rectifier

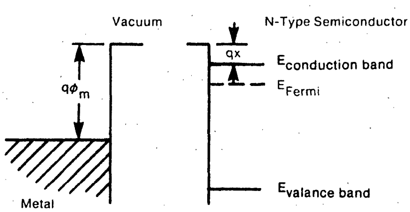

Figure 2a

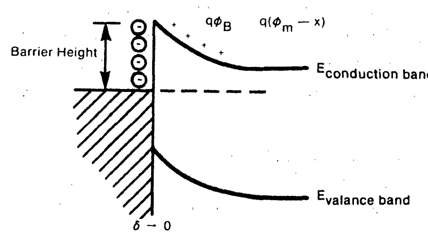

Figure 2b

Figure 2 - Energy Band Diagram of Metal Semiconductor Contact

TABLE 1 — PERFORMANCE COMPARISON OF DIFFERENT BARRIERS

SPECIFICATIONS				POWER LOST IN EACH RECTIFIER	
METAL BARRIER	V_F @ 20A (V) 125°C**	V_F @ 100A (V) 125°C**	LEAKAGE CURRENT (mA) 125°C**	LOSSES DUE TO LEAKAGE (W)*	V_F LOSSES @ 100A (W)*
Chromium	0.35	0.78	280	1.80	33.20
Molybedeum	0.45	0.75	65	0.46	34.07
Platinum	0.51	0.80	10	0.071	35.23
Ni-Platinum	0.433	0.73	30	0.2145	32.70
Tungsten	0.51	0.82	10	0.071	36.79

* Power dissipation calculations are based on 125° C operating junction temperature and a high line input voltage for an off-line PWM converter.

** V_F voltages are for 160 mil^2 die.

3.1 Forward Biased Junction

When the barrier or a junction is forward biased, the energy level of the conduction band in the semiconductor is raised, which allows electrons to flow into the metal as shown in Figure 3a. A small barrier does remain, but the electron energy distribution is sufficient to overcome this remaining barrier. Increased forward bias will overcome the barrier and current flow will be limited only by the series resistance of the device. Most of the forward drop at high current occurs in the high resistivity epitaxial layer which determines the reverse blocking voltage capability.

Schottky rectifier forward drop can be expressed by the following equation:

$$V_F = \frac{\Phi}{q} + \frac{KT}{q} \ln\left(\frac{I_F}{A \times RT^2}\right) + \frac{I_F \cdot \rho \cdot d}{A} \qquad (3.1)$$

+ Voltage drop in ohmic contact of package

Where: I_F = Forward current (A)

A = Barrier area (cm^2)

$\frac{KT}{q}$ = 0.026 at room temperature

Φ = Barrier height - e_v

ρ = Resistivity of epitaxial layer (Ω-cm)

d = Thickness of epitaxial layer (cm)

R = Richardson constant

T = Absolute temperature (° K)

The term $[I_F \cdot \rho \cdot (d/A)]$ in the above equation is the forward drop in the high resistivity epitaxial layer and it is a significant portion of the forward drop at high current levels.

Since holes cannot exist in the metal, none can be injected into it. As a result, conduction is entirely due to electrons. This eliminates the minority carrier related reverse recovery time.

3.2 Reverse Biased Junction

When the device is reverse biased, the conduction band in the semiconductor is lowered by the applied reverse biased voltage as shown in Figure 3b. For any conduction to occur, electrons must surmount the potential barrier created at the metal-semiconductor junction. Some electrons in the metal gain sufficient thermal energy from the lattice structure to overcome the barrier while others are able to tunnel through the barrier. This leakage current is temperature dependent.

3.3 Junction Capacitance

The barrier metal and uniformly doped N-type epitaxial layer create an abrupt junction. This results in at least 5 times higher junction capacitance when compared with similar slightly graded ultra-fast PN junction devices. The depletion capacitance of a Schottky rectifier under reverse biased conditions can be expressed by the equation:

$$C = A \cdot \sqrt{\frac{(43 \cdot 10^{-6})N_D}{V_R + 0.6 + (KT/q)}} \qquad (3.2)$$

Where: N_D = Carrier concentration of an epitaxial layer

$\frac{KT}{q}$ = 0.026 at room temperature

V_R = Applied reverse biased voltage

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As can be seen from the equation, the junction capacitance is inversely proportional to the square root of the applied reverse voltage and is practically independent of temperature at reverse voltages greater than 1V. When the device switches from forward biased condition to the reverse blocking state, current is required to charge the depletion capacitance. The time required to charge up capacitance is determined by the circuit impedance. This charging current has the same effect as the reverse recovery current of a Unitrode fast recovery "UES" PN junction rectifier!

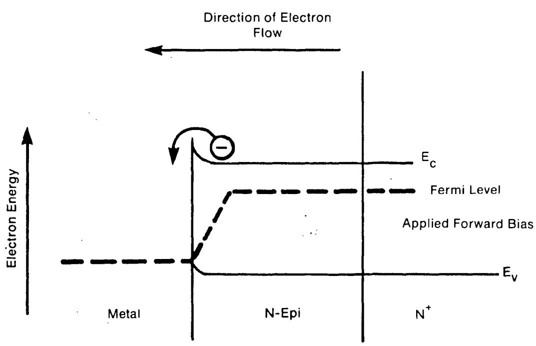


Figure 3a - Rectifier — Forward Biased

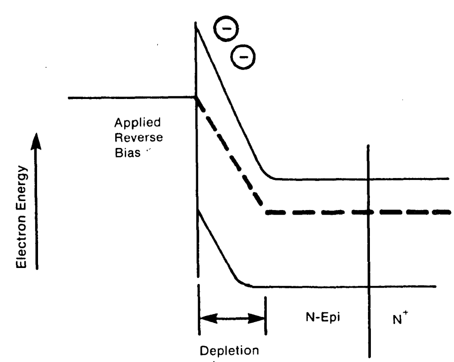


Figure 3b - Rectifier — Reverse Biased

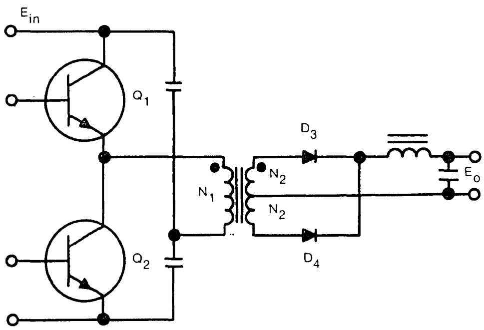
In a switched-mode converter, the apparent reverse recovery time is determined by the leakage inductance of the transformer and the junction capacitance of the Schottky rectifier. Since capacitance does not vary with temperature, the apparent recovery time and current overshoot remain constant with temperature. Ringing resonance of leakage inductance and Schottky capacitance can cause voltage overshoot. In a high frequency switched-mode converter where the transformer is designed with very low leakage inductance, careful consideration must be given in selecting the Schottky rectifier because of dv/dt limitations.

4. Applications of a Schottky Rectifier in Switched-Mode Converters

The simplified power output stage of a half-bridge switched-mode converter is shown in Figure 4a. When switching transistors Q_1 and Q_2 are in the "off" condition, diodes D_3 and D_4 conduct in the forward direction to provide a current path for inductor L_1. Each diode carries half of the load current. When transistor Q_1 turns on, current in diode D_3 starts to change from half the load current to full load current, while current in diode D_4 starts to change from half the load current into the "off" condition. Current transition time in the rectifier will depend on the current rise time of the transistor and the leakage inductance of power transformer T_2. When current in rectifier D_3 increases to full load current, current in rectifier D_4 decreases to zero.

Since a Schottky rectifier is a majority carrier device, it should turn off instantaneously. However, because of the larger junction capacitance of the Schottky rectifier compared with PN junction devices, transistor Q_1 supplies additional current to the secondary winding to charge up this larger junction capacitance. Note that the junction capacitance of the Schottky rectifier varies with reverse bias voltage as shown in Figure 5. Also the capacitance is five times that of equivalent PN junction devices.

As current is increased, the voltage across the junction capacitance of the rectifiers builds up toward the full reverse blocking state. The primary current will be higher than the output load current divided by the transformer turns ratio. During this period, energy is stored in the leakage inductance due to the excessive current on the primary side. As the



$\frac{N1}{N2}$	=	N, transformer turns ratio
R_{PW}	=	Series resistance of primary windings
R_{SW}	=	Series resistance of one half secondary winding
L	=	Leakage inductance of transformer
C_{PW}	=	Primary windings distributed capacitance
C_{SW}	=	One half secondary winding capacitance
C_{ob}	=	Output capacitance of switching transistor
C_j	=	Junction capacitance of rectifier

Figure 4a - Typical Half-Bridge PWM Switching Converter

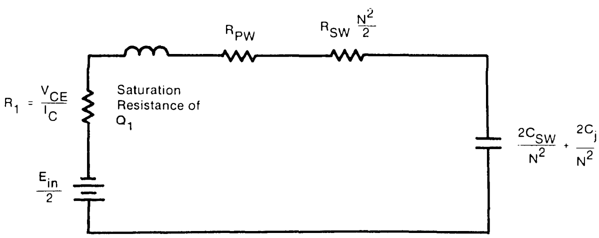


Figure 4b - Equivalent Circuit During Charging of a Junction Capacitance of a Schottky

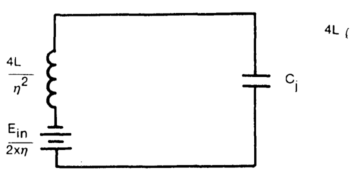


Figure 4c - Simplified Equivalent Circuit Referred Back to Secondary Side

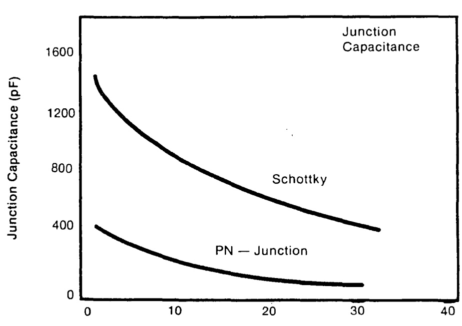


Figure 5 - Comparison of Junction Capacitance ultra-fast PN-Junction vs. Comparable Schottky Rectifier

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voltage across the rectifier reaches full switching voltage, energy stored in the leakage inductance continues to charge up the junction capacitance of the rectifier above the switching voltage reflected back in the secondary. These voltages can force the device into the breakdown region if the proper snubber circuit is not employed.

4.1 Snubber Network Design

The equivalent circuit referred back to the primary side when the junction capacitance is charging up is shown in Figure 4b. The junction capacitance of the Schottky and the leakage inductance of transformer T_2 form a resonant circuit. The winding resistances, R_{PW} and R_{SW}, and saturation resistance, R_1, provide very little damping to this LC tuned circuit. Therefore, its effect on damping can be neglected. The interwinding capacitance of the power transformer is much lower than the junction capacitance of the Schottky rectifier and may be neglected. The simplified circuit referred back to the secondary side is shown in Figure 4c.

Since Schottkys are prone to excessive heating and possible damage in the breakdown mode, a proper snubber is required. The design of the snubber network minimizes voltage spikes and snubber losses. The snubber network also helps to reduce conducted and radiated RFI.

The optimum snubber network should be designed on the basis of critical damping of the LC tuned circuit and limiting the maximum excursion of the voltage below the PIV ratings of the rectifier.

Shown below is the LC tuned circuit with resistor R_{snb} paralleled across the junction capacitance of the Schottky rectifier for a critically damped condition.

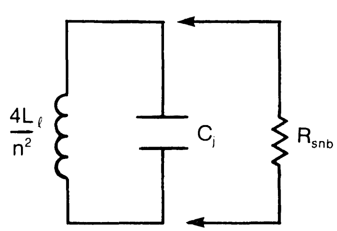

Figure 6 - Damping Resistor R_{snb} Added Across the LC Tuned Circuit for Critical Damping

The loaded Q_L should be 0.5 for a critically damped case to prevent any ringing of the voltage and to provide minimum losses in the snubber resistor. LC tuned circuits will have only real roots. Loaded Q_L can be described by the equation:

$$Q_L = 0.5 = \frac{R_{snb}}{X_L} \tag{4.1}$$

Where: $X_L = j\omega L$

$$\therefore R_{snb} = 0.5 \cdot \omega \cdot L$$

$$= 0.5 \left(\frac{1}{\sqrt{(4L_\ell/n^2)C_j}} \right) \left(\frac{4L_\ell}{n^2} \right)$$

$$R_{snb} = \frac{1}{n}\sqrt{\frac{L_\ell}{C_j}} \tag{4.2}$$

Where: C_j = Junction capacitance of rectifier
L_ℓ = Leakage inductance of power transformer

A capacitor is required in series with the resistor in order to block the dc voltage present. The blocking capacitor should be at least ten times the rectifier junction capacitance:

$$C_{snb} - 10(C_j) \tag{4.3}$$

To transfer the power effectively from the input power source to the output load, the time constant (R_{snb} x C_{snb}) should at at most one-tenth the minimum pulse width of the switched-mode converter. This occurs at maximum input voltage. Therefore:

$$R_{snb} \cdot C_{snb} \leq \frac{(1/20)}{f} (E_{in_{min}}/E_{in_{max}}) \tag{4.4}$$

Where: f is the operating frequency of the switching regulator.

The power dissipation in the snubber resistor R_{snb} can be calculated by the equation:

For Half-Bridge:

$$P_{R_{snb}} = \tfrac{1}{2} C_{snb} \left[\frac{E_{in_{max}}}{n} \right]^2 \cdot f \tag{4.5}$$

For Push-Pull for Full-Bridge:

$$PR_{snb} = \tfrac{1}{2}C_{snb}\left[\frac{2(E_{in_{max}})}{n}\right]^2 \cdot f \qquad (4.6)$$

Where: $E_{in_{max}}$ = Maximum input voltage
n = Primary to secondary turns ratio of power transformer

Every inch of wire represents 20 nanohenries of inductance. When the output current is high, the energy stored in the lead and package inductance in the secondary circuit can generate high voltage spikes across the rectifier during reverse recovery time. To reduce these spikes, two snubber networks are required. One should be placed across each Schottky rectifier as shown in Figure 7 below.

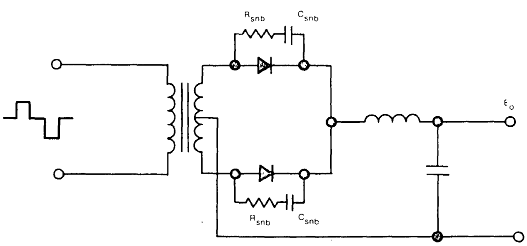

Figure 7 - High Current Outputs

For low current outputs, the snubber network can be connected across the secondary winding as shown in Figure 8.

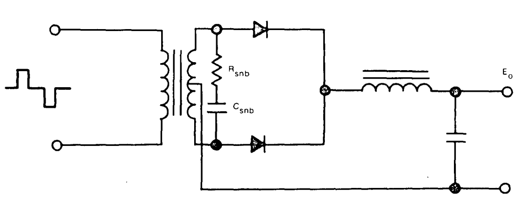

Figure 8 - Low Current Outputs

4.2 *Reverse Recovery Time and Overshoot Current, $I_{RM(REC)}$*

Reverse recovery time is defined as the time required to change a rectifier from the forward conduction state to the reverse blocking state. Although a Schottky rectifier is a majority carrier device, it takes time to "recover" because of its high junction capacitance. In a switched-mode converter, reverse recovery time is, to a large extent, determined by the parasitic leakage inductance of the transformer which resonates with the junction capacitance of the Schottky rectifier. Design equations for reverse recovery time and current overshoot can be derived as shown below.

Reverse Recovery Time:

From basic equations of an LC tuned circuit:

$$\omega = \frac{1}{\sqrt{LC}}$$

Substituting f = 1/τ and rearranging:

$$\tau = 2\pi\sqrt{LC}$$

Since $\tau/2 = t_{rr}$ by definition:

$$t_{rr} = \pi\sqrt{LC} \qquad (4.7)$$

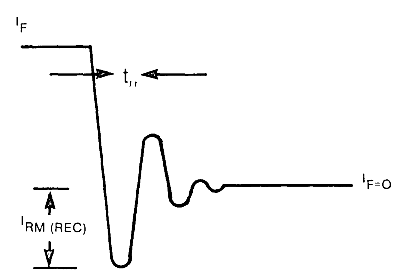

Figure 9 - Reverse Recovery Time of a Rectifier

Assuming the rise time of the transistor is much faster than t_{rr} of the rectifier, and substituting L_ℓ= leakage inductance of the transformer and C_j = junction capacitance of the Schottky rectifier. Neglecting the interwinding capacitance of the transformer, the reverse recovery time (when no snubber network is employed across the rectifier) can be calculated by the equation:

t_{rr} due to junction capacitance:

$$t_{rr} = \frac{2\pi}{n}\sqrt{L_\ell(C_j)} \qquad (4.8)$$

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Where: n = Primary to secondary turns ratio

The ringing frequency can be calculated by the equation:

$$f = \frac{n}{4\pi\sqrt{L_\ell (C_j)}} \quad (4.9)$$

From the characteristic impedance of the LC tuned circuit, overshoot current, I_{RM}, in the Schottky rectifier can be calculated by:

$$I_{RM(REC)} = \frac{E_{in}}{2}\sqrt{\frac{C_j}{L_\ell}} \quad (4.10)$$

4.3 Practical Example

A detailed diagram of a 150W, multiple output switching regulated power supply is shown in Figure 10. The power supply is designed to operate with a line input voltage of 117V ac, 60 Hz or 220V ac, 50 Hz. The regulated output voltages are +5V @ 1A, +12V @ 1.2A, −12V @ 1A and −5V @ 1A. The output voltage is regulated by power switching hybrid circuits Q_1 and Q_2 which are housed in four pin electrically isolated packages.

Since the case is electrically isolated from the active devices, it provides the following advantages:

a) lower conducted and radiated RFI
b) ease in mounting — two devices can be mounted on the same heat sink.

The selected switching transistor provides fast switching time (<100ns) and the diode in the hybrid circuit provides low reverse recovery (<50ns) and forward recovery time. The proportional base drive current to the switching transistor is supplied by the current transformer T_1.

One of the output voltages (+5V) is regulated with a pulse width modulated (PWM) control chip Unitrode's UC3524. The auxiliary voltage to power the control circuit should be electrically isolated from the line voltage. Conventionally, the 60 Hz transformer is utilized to provide isolation and the transformer output voltage is rectified and regulated to supply bias voltage to the control circuit. Transistors, Q_3 and Q_4, provide a low cost approach in developing bias voltage for the control circuit without the use of a 60 Hz transformer. The operation of the circuit is described in detail below.

When the 117V ac input line voltage is applied to the switched-mode converter, capacitors C_1 and C_2 charge up to full input voltage. Meanwhile capacitor C_T charges up slowly through resistor R_T. When the voltage across C_T reaches the anode-gate voltage of the programmable unijunction transistor Q_4, it will turn on and dump the stored charge from capacitor C_T into one of the proportional base drive windings of the transformer T_1. The polarity of the windings is such that it will turn on only transistor Q_2, transferring energy from input capacitor C_2 into the output capacitor C_3 (isolated from the input line) through power transformer T_2. The control circuit LM3524 starts to switch transistor Q_2. At the instant when transistor Q_2 turns on, capacitor C_T will be isolated from current transformer T_1 with the help of transistor Q_3. The programmable unijunction transistor Q_4 now remains off. The capacitor C_3 is now continuously charging up through the secondary winding of the transformer.

The output circuit of the switched-mode converter utilizes coupled inductor L_1 to provide better tracking among all the output voltages, improve transient response and reduce the minimum loading requirement. Coupled inductor L_2 (which is not in the control loop) maintains the sawtooth current in the +5V winding of L_1 (which is in the control loop) providing stability in the control circuit.

Calculations of Snubber Network:

In the 150W switching regulator shown in Figure 10, first calculate the current overshoot $I_{RM(REC)}$, the ringing frequency and the apparent reverse recovery time without the snubber network. Then determine the resistor and capacitor values (for critically damped case) of the network across the Schottky rectifier.

Given: L_ℓ, Leakage inductance of power transformer = 22μH

C_j, Junction capacitance of Schottky = 850pF

f, Operating frequency = 30 KHz

n, Primary to secondary turns ratio = 14

$E_{in_{min}}/E_{in_{max}}$, Ratio of maximum input voltage to minimum input voltage = 400/200 = 2

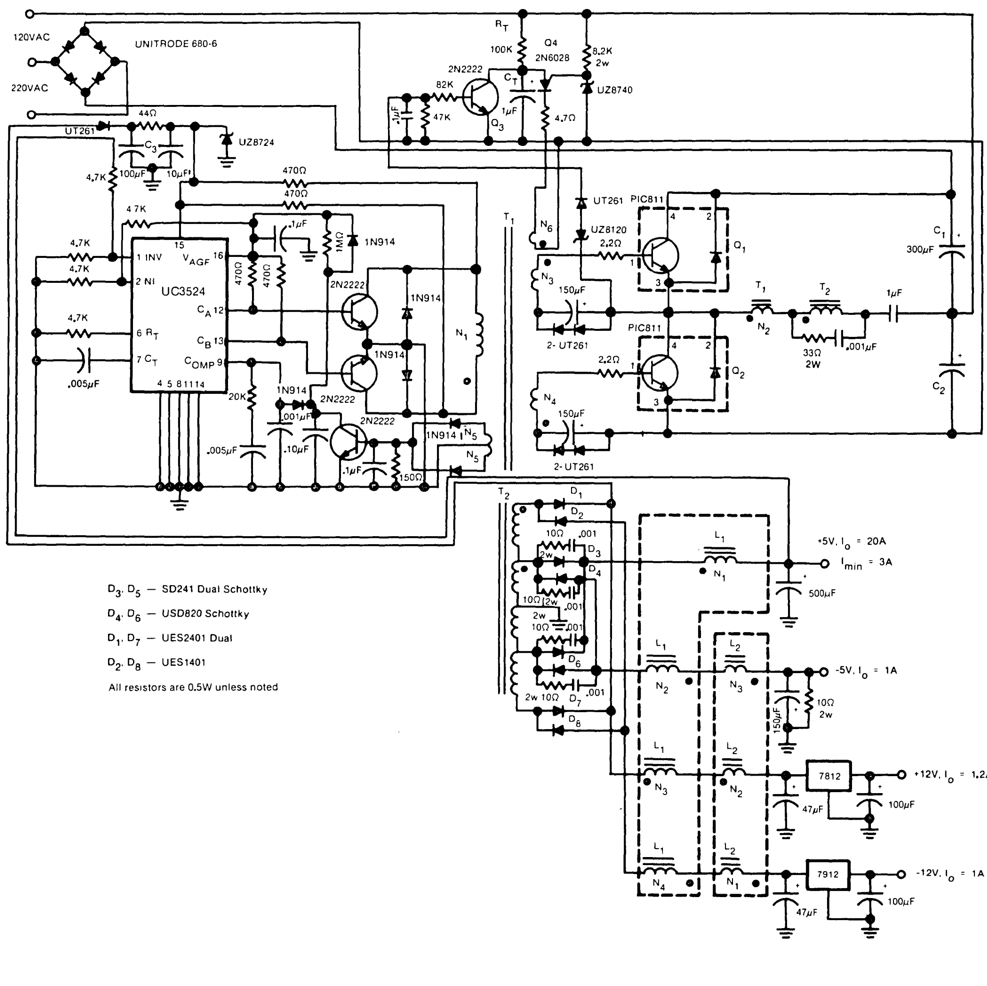

Figure 10 - 150 Watt Multiple Output "OFF Line" Switched-Mode Converter

Solution:

Current overshoot, $I_{RM(REC)}$, from Equation 4.10:

$$I_{RM(REC)} = \frac{E_{in}}{2}\sqrt{\frac{C_j}{l_\ell}}$$

$$= \frac{320V}{2}\sqrt{\frac{850 \times 10^{-12}}{22 \times 10^{-6}}}$$

$$= 1A$$

The ringing frequency from equation 4.9:

$$f = \frac{n}{4\pi\sqrt{L_\ell(C_j)}}$$

$$= \frac{14}{4\pi\sqrt{(22 \times 10^{-6})(850 \times 10^{-12})}}$$

$$= 8.1\ \text{MHz}$$

The apparent reverse recovery time from equation 4.8:

$$t_{rr} = \frac{2\pi}{n}\sqrt{C_j(L_\ell)}$$

$$= \frac{2\pi}{14}\sqrt{(850 \times 10^{-12})(22 \times 10^{-6})}$$

$$= 67ns$$

The value of the snubber resistor from Equation 4.2:

$$R_{snb} = \frac{1}{n}\sqrt{\frac{L_\ell}{C_j}}$$

$$= \frac{1}{14}\sqrt{\frac{22 \times 10^{-6}}{850 \times 10^{-12}}}$$

$$= 10.9\Omega$$

The value of the snubber capacitor from Equation 4.3:

$$C_{snb} = 10(C_j)$$

$$= 10(850 \times 10^{-12})$$

$$= 0.01\mu F$$

The power dissipation in snubber resistor, R_{snb}, from Equation 4.5:

$$P_{R_{snb}} = \tfrac{1}{2}C_{snb}\left[\frac{E_{in_{max}}}{n}\right]^2 \cdot f$$

$$= \tfrac{1}{2}(0.01 \times 10^{-6})\left[\frac{400}{14}\right]^2 \cdot 30 \times 10^3$$

$$= 0.121W$$

∴ The snubber resistor R_{snb} should have at least 0.5W rating.

The criteria for the snubber network should satisfy the conditions below:

$$R_{snb}(C_{snb}) \leq \frac{1}{20f}\left[\frac{E_{in_{min}}}{E_{in_{max}}}\right]$$

$$10\Omega(0.01 \times 10^{-6}) \leq \frac{1}{20(30 \times 10^3)} \cdot \frac{1}{2}$$

$$0.1\mu s \leq 0.993\mu s$$

The voltage across the Schottky rectifier with and without the snubber network in a 150W off-line switched-mode converter is shown in Figures 11a and 11b. Note that the voltage across the Schottky rectifier with a snubber network has no voltage overshoot. Thus, it prevents failure of the Schottky due to large voltage transients during transistor turn-on. The ringing frequency is about 10 MHz without the snubber and is close to calculated values.

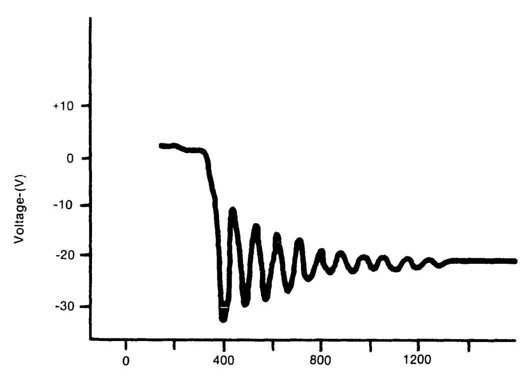

Figure 11a - Voltage Across Rectifier Without Snubber Network

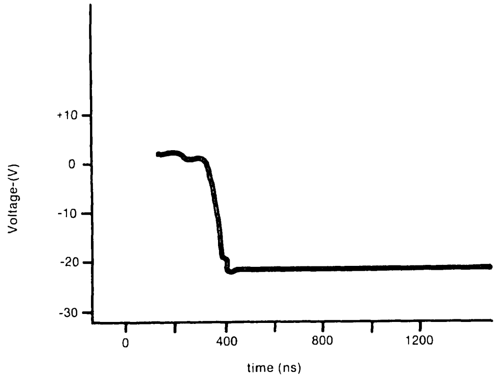

Figure 11b - Voltage Across Rectifier With Snubber Network 10Ω - 0.1μF

4.4 Thermal Stability Considerations

The reverse leakage current of a Schottky rectifier is much higher than PN junction devices because of the Schottky's lower barrier height. The magnitude of this leakage current doubles approximately every ten degrees Centigrade. Since it is temperature sensitive, the thermal stability of the system should be checked over to avoid thermal runaway. In a PWM switched-mode converter (i.e. push-pull, half-bridge, etc.) the rectifier can be operated at 50% duty cycle in the reverse blocking state while the remaining 50% of the time it will operate in the forward conduction mode under worst case conditions. However, forward drop is also a temperature sensitive parameter and this should also be considered when thermal stability calculations are made.

The criteria for thermal stability is defined as: "the rate of change in power pumped into a device with respect to temperature (dP_{in}/dt) should be less than the rate of change in power removed (in the applicable thermal environment) in the form of heat from the device with respect to temperature (dP_{out}/dt)".

In a switched-mode converter, the power dissipated in the device and the power removed can be expressed by:

$$V_R \cdot \frac{I_L(\tau - t_{on})}{\tau} + I_F \cdot V_F \cdot \frac{t_{on}}{\tau} \le \frac{T_J - T_A}{R_{\Theta J-A}} \qquad (4.11)$$

Where: V_R = Applied reverse voltage

I_L = Leakage current at temperature

t_{on} = Rectifier on-time

τ = 1/f, where f is the operating frequency

I_F = Forward current

V_F = Forward voltage at forward current (at temperature)

T_J = Junction temperature

Since both I_L and V_F are temperature sensitive parameters, we can express I_L and V_F as functions of temperature in the above equation for thermal stability and obtain:

$$\left[\left\{\frac{(\tau - t_{on})}{\tau} \cdot V_R \cdot I_o \cdot 2^{\frac{(T_J - T_A)}{y}}\right\} + \left\{I_F \cdot \frac{t_{on}}{\tau} \cdot [V_{F_0} + X(T_J - T_A)]\right\}\right] \le \frac{T_J - T_A}{R_{\Theta JA}} \qquad [4.12]$$

Where: I_o = Leakage current at room temperature

V_{F_0} = Forward voltage drop at room temperature

x = Temperature coefficient for forward voltage at operating current

y = Temperature difference for which leakage current doubles.

Differentiating the above equation:

$$\frac{(\tau - t_{on})}{\tau} \cdot V_R \cdot I_o \cdot 2^{\frac{(T_J - T_A)}{y}} \cdot \frac{1}{y} \cdot \ln 2 + I_F \cdot \frac{t_{on}}{\tau} \cdot X \le \frac{1}{R_{\Theta J-A}} \qquad [4.13]$$

Defining $I_o \cdot 2^{\frac{(T_J - T_A)}{y}}$ as the critical current, $I_{R(crit)}$ at maximum temperature, and solving for $I_{R(crit)}$ we obtain:

$$I_{R(crit)} \le y \left[\frac{(\tau/R_{\Theta J-A}) - I_F \cdot t_{on} \cdot X}{.693\,(\tau - t_{on})V_R}\right] \qquad [4.14]$$

Design Example

In the practical example previously discussed, the maximum reverse voltage across the rectifiers is 30V. Each rectifier is mounted on a heat sink. The thermal resistance of the heat sink is 1° C/W. The Schottky rectifier, SD241, has a maximum thermal resistance of 1.4° C/W from case to junction. Its reverse leakage current doubles every ten degrees Centigrade, while the forward voltage at I_F=20A decreased by 1mV/° C as the junction temperature increases. The designer desires to limit the maximum operating junction temperature of the Schottky rectifier to 125° C under worst case conditions

Calculate the maximum reverse leakage current allowed for these rectifiers at 125° C to prevent thermal instability

Calculation:

$$R_{\theta JA} = (R_{\theta H} + R_{\theta J\text{-}C})\ ^\circ C/W$$
$$= 1^\circ C/W + 1.4^\circ C/W$$
$$= 2.4^\circ C/W$$
$$t_{on} = 16.6\mu s$$
$$t_{off} = 16.6\mu s$$
$$\tau = t_{on} + t_{off} = 33.2\mu s$$

Using equation 4.14:

$$I_{R(crit)} \leq 10^\circ C \times \left[\frac{(33.2 \times 10^{-6})/(2.4^\circ C/W) - (20A)(16.6 \times 10^{-6})(-1 \times 10^{-3}V)}{.693(33.2 \times 10^{-6}\text{ sec} - 16.6 \times 10^{-6})(30V)}\right]$$

$$\leq 410mA$$

From the SD241 specification, the maximum reverse leakage current at 125° C is 100mA; therefore this system will be thermally stable.

4.5 Paralleling Rectifiers

When the output current required is greater than the maximum rated forward current of commercial rectifiers, it becomes necessary to parallel the devices. In some instances, it may be preferable to parallel devices even when a single device of higher current ratings is available. The advantages of paralleling these devices are:

1) Heat is easier to remove when compared to a single device with a higher current rating because the heat is spread between two or more devices.
2) The transformer is easier to wind since the wire size is smaller, using a separate winding for each rectifier.
3) Smaller chip size will have less chance of voids in the chip bond to the package, thus, the reliability of the system is improved.

The disadvantage of paralleling rectifiers is that some kind of circuit technique is required to share the current among the paralleled devices. If the current is not shared equally, the junction temperature of the device which conducts the higher current will increase. The forward voltage of the device will decrease due to its increased temperature and will conduct an even larger share of the load current. If adequate matching is not provided, this regenerative process continues; and if not checked in time, the junction temperature will exceed the maximum rating and the device will be damaged.

In switched-mode converter applications, current sharing can be accomplished by using separate windings for each rectifier and by matching forward drops. The series resistance of each winding acts as a current ballasting impedance.

5. Guidelines for Selecting the Schottky Rectifier in Pulse Width Mode (PWM) Switched-Mode Converter Applications

The minimum required dc blocking voltage of the Schottky rectifier and its maximum power dissipation can be calculated for different types of switched-mode power supplies summarized in Tables II and III. After calculating the maximum power dissipation, the designer can determine the required thermal resistance of the rectifier and the heat sink using the equation:

$$R_{\theta H} + R_{\theta JC} = \frac{T_{jmax} - T_{Amax}}{P_{max}} \qquad [5.1]$$

Where: $R_{\theta JC}$ = Thermal resistance of rectifier

$R_{\theta H}$ = Thermal resistance of heat sink

T_{jmax} = Maximum operating junction temperature of device

T_{Amax} = Maximum ambient temperature

When calculations are made for maximum power dissipation in a rectifier, the voltage drop V_F and leakage current I_R should be taken at the maximum operating junction temperature.

During start up and for step changes in the output load current, the voltage across the rectifier should be limited to below its maximum dc blocking voltage to avoid failures due to transient voltage across the Schottky.

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TABLE 1 — GUIDELINES FOR DETERMINING THE RATING OF A RECTIFIER IN A PWM SWITCHED-MODE CONVERTER

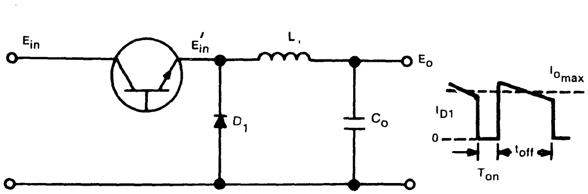
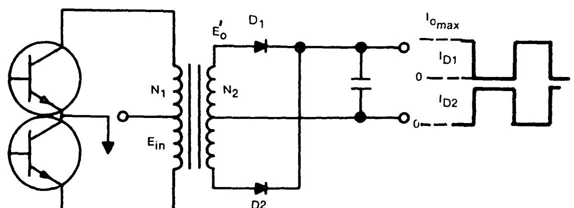
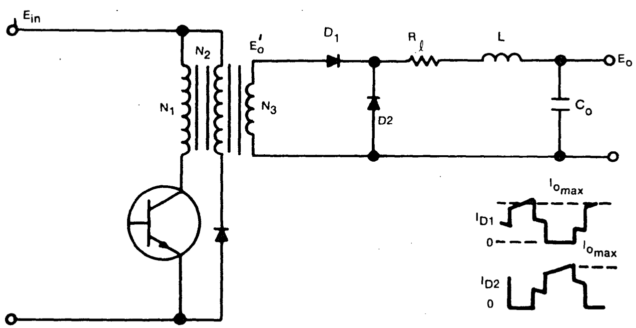
TYPES OF SWITCHING REGULATORS	OUTPUT VOLTAGE	STEADY STATE — POWER DISSIPATION IN RECTIFIERS	MINIMUM DC BLOCKING VOLTAGE REQUIRED
BUCK REGULATOR 	$E_o = E'_{in} \times \frac{t_{on}}{\tau}$ $E_o \approx E_{in} \times \frac{t_{on}}{\tau}$	Power dissipation in Diode D_1 due to forward conduction: $P_{D1_F} = I_{o_{max}} \times V_F \cdot \frac{E_{in_{max}} - E_o}{E_{in_{max}}}$ Power dissipation due to leakage current, I_R: $P_{D1_R} \leq I_R \times E_o,\quad I_R @ E_{in_{max}}$	For Diode D_1: $1.2 \times E_{in_{max}}$
PUSH-PULL CONVERTER (50% Duty Cycle) 	$E'_o = E_o + V_F$ $E_o = E_{in} \times \frac{N_2}{N_1}$	Power dissipation in Rectifier D_1 or D_2 due to forward conduction: P_{D1_F} or $P_{D2_F} = \frac{I_{o_{max}} \times V_F}{2}$ Power dissipation due to leakage current, I_R: P_{D1_R} or $P_{D2_R} = 2.0 \times E_{in_{max}} \times \frac{N_2}{N_1} \times I_R$	For D_1 or D_2: $2.4\,(E_{in_{max}}) \times \frac{N_2}{N_1}$
PWM FORWARD CONVERTER 	$E'_o = E_o + V_F + I_{o_{max}} \times R$ $E_o = E_{in_{min}} \frac{N_3}{N_1 + N_2}$ Where: E_o = dc Output Voltage E'_o = Output of Secondary Winding When D_1 is conducting	Power dissipation due to forward conduction in Rectifier D_1: $P_{D1_F} = I_{o_{max}} \times V_F \frac{N_1}{N_1 + N_2}$ Power dissipation in Rectifier D_2: $P_{D2_F} = I_{o_{max}} \times V_F \left[1 - \frac{N_1}{N_1 + N_2} \cdot \frac{E_{in_{max}}}{E_{in_{min}}}\right]$ Power dissipation due to reverse leakage current: $P_{D1_R} = E_{in_{min}} \cdot I_R \cdot \frac{N_3}{N_1 + N_2}$ $P_{D2_R} = I_R \times \frac{N_3}{N_1 + N_2} \times E_{in_{min}}$	For D_1: $1.2 \times E_{in_{max}} \times \frac{N_3}{N_2}$ For D_2: $1.2 \frac{E_{in_{max}} \times N_3}{N_1}$

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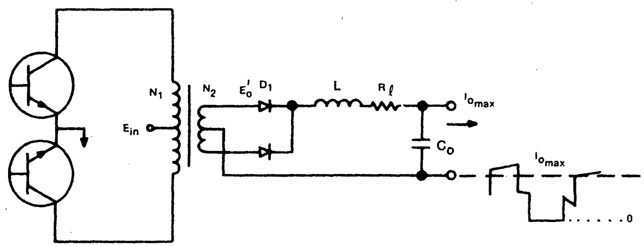
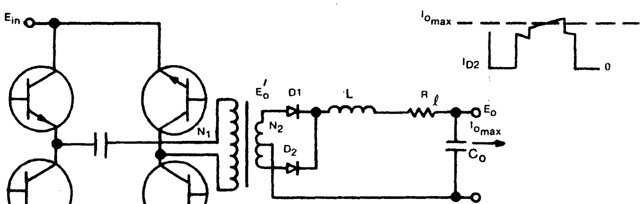
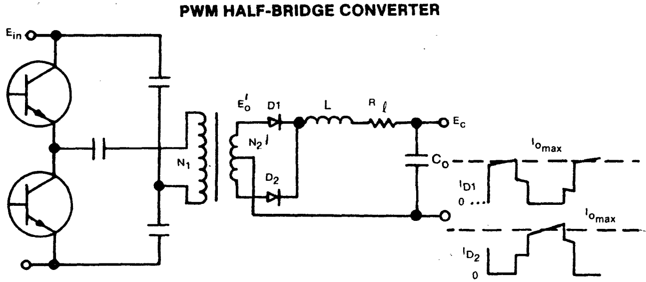
TABLE II

TYPES OF SWITCHING REGULATORS	OUTPUT VOLTAGE	STEADY STATE — POWER DISSIPATION IN RECTIFIERS	MINIMUM DC BLOCKING VOLTAGE REQUIRED
PWM PUSH-PULL CONVERTER   **PWM FULL BRIDGE CONVERTER**	$E_o' = E_o + V_F + I_{o_{max}} \times R_\ell$ $E_o = E_{in_{min}} \times \frac{N_2}{N_1}$ For Push-Pull and Full Bridge	Power dissipation in Rectifier D_1 or D_2 due to forward conduction: P_{D1_F} or $P_{D2_F} = \frac{I_{o_{max}} \times (V_F @ I_{o_{max}})}{2} \times \frac{E_{in_{min}}}{E_{in_{max}}}$ $+ \frac{I_{o_{max}} (V_F @ \frac{I_{o_{max}}}{2})}{2} \times \frac{E_{in_{max}} - E_{in_{min}}}{E_{max}}$ Power dissipation due to leakage current: P_{D1_R} or $P_{D2_R} = I_R(E_{in_{min}})(N_1/N_2)$ NOTE: $I_R @ 2(E_o + V_F + I_{o_{max}} \times R\ell) \times \frac{E_{in_{max}}}{E_{in_{min}}}$	For D_1 or D_2: $2.4 (E_o + V_F + R \times I_{o_{max}}) \times \frac{E_{in_{max}}}{E_{in_{min}}}$
PWM HALF-BRIDGE CONVERTER 	$E_o' = E_o + V_F \times I_{o_{max}} \times R_\ell$ $E_o = \frac{E_{in_{min}}}{2} \times \frac{N_2}{N_1}$ For Half-Bridge	SAME AS ABOVE	SAME AS ABOVE

6 Conclusion

Complete design guidelines for Schottky rectifiers used in switched-mode converters have been provided. The Schottky, when compared to a fast PN junction rectifier, offers the advantages of lower forward voltage and a faster reverse recovery time which is independent of temperature. Efficiency is improved at least 3 to 5% when Schottky rectifiers are used in place of PN junction devices for power rectification in switched-mode converters. Schottky rectifiers are available with a maximum reverse blocking voltage up to only 50 to 60V. Thus, applications of Schottky devices are limited to low output voltages (+5V) in PWM switched-mode converters (except for buck type and 50% duty cycle converters). When the rectifier requires voltage blocking capability of greater than 60V, fast PN junction devices like UES800 series rectifier offers the optimum choice without sacrificing speed and forward voltage.

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SCHOTTKY RECTIFIERS

AVERAGE DC OUTPUT CURRENT		6A	8A	12A[1]	12A	16A[2]	16A	25A	30A	50A	60A[3]	60A	75A
PEAK REVERSE VOLTAGE \ PACKAGE		TO-220 PLASTIC (2-LEAD)	TO-220 PLASTIC (2-LEAD)	TO-220 PLASTIC (3-LEAD)	TO-220 PLASTIC (2-LEAD)	TO-220 PLASTIC (3-LEAD)	TO-220 PLASTIC (2-LEAD)	DO-4 STUD	DO-4 STUD	DO-5 STUD	TO-3	DO-5 DO-5F STUD	DO-5 DO-5F STUD
20V	TYPE V_F I_{FSM}	USD620 .55 @ 6A 150A	USD720 .55 @ 8A 200A	USD620C .65 @ 12A 150A	USD820 .45 @ 12A 200A	USD720C .65 @ 16A 200A	USD920 50 @ 16A 250A		USD420 .55 @ 30A 600A		USD320 .6 @ 20A 400A		USD520 .6 @ 60A 1000A
30V	TYPE V_F I_{FSM}							1N6095 .86 @ 78A 400A		1N6097 .86 @ 157A 800A			
35V	TYPE V_F I_{FSM}	USD635 .55 @ 6A 150A	USD735 .55 @ 8A 200A	USD635C .65 @ 12A 150A	USD835 .45 @ 12A 200A	USD735C .65 @ 16A 200A	USD935 50 @ 16A 250A		USD435 .55 @ 30A 600A		USD335C .6 @ 20A 400A		USD535 .6 @ 60A 1000A
40V	TYPE V_F I_{FSM}	USD640 .55 @ 6A 150A	USD740 .55 @ 8A 200A	USD640C .65 @ 12A 150A	USD840 .45 @ 12A 200A	USD740C .65 @ 16A 200A	USD940 .50 @ 16A 250A	1N6096 86 @ 78A 400A		1N6098 .86 @ 157A 800A			
45V	TYPE " V_F I_{FSM}	USD645 .55 @ 6A 150A	USD745 .55 @ 8A 200A	USD645C .65 @ 12A 150A	USD845 .45 @ 12A 200A	USD745C .65 @ 16A 200A	USD945 50 @ 16A 250A		USD445 SD41[2] 55 @ 30A 600A		USD345C SD241 .6 @ 20A 400A	SD51[4] .6 @ 60A 800A	USD545 .6 @ 60A 1000A

1. CENTER-TAP 6A PER LEG
2. CENTER-TAP, 8A PER LEG
3. CENTER-TAP, 30A PER LEG
4. V_R AT 25° C IS 45V, V_R AT 150° C IS 35V

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A SECOND-GENERATION IC SWITCH MODE CONTROLLER OPTIMIZED FOR HIGH FREQUENCY POWER MOSFET DRIVE

Introduction

Since the introduction of the SG1524 in 1976, integrated circuit controllers have played an important role in the rapid development and exploitation of high-efficiency switching power supply technology. The 1524 soon became an industry standard and was widely second-sourced (it is available from Unitrode as the UC1524). Although this device, as well as the MC3420 and TL494 which followed it, contained all the basic control elements required for switching regulator design; practical power supplies still required other functions which had to be implemented with additional external discrete circuitry.

An additional development within the semiconductor industry was the introduction of practical power FETs which offered the potential of higher efficiencies at higher speeds with resultant lower overall system costs. In order to be able to take full advantage of the speed capabilities of power FETs, it was necessary to provide high peak currents to the gate during turn-on and turn-off to quickly charge and discharge the gate capacitances of 800 to 2000pF present in higher current units.

The development of a second-generation regulating PWM IC, the UC1525A, and its complimentary output version, the UC1527A, was a direct result of the desire to add more power supply elements to the control IC, as well as to optimize the interfacing of high current power devices.

Integrating More Power Supply Functions

Having achieved the greatest level of acceptance among users of first generation control chips, the 1524 became the starting point for expanding IC controller capabilities. This early device, shown in *Figure 1*, contains a fixed-voltage reference source, an oscillator which generates both a clock signal and a linear ramp

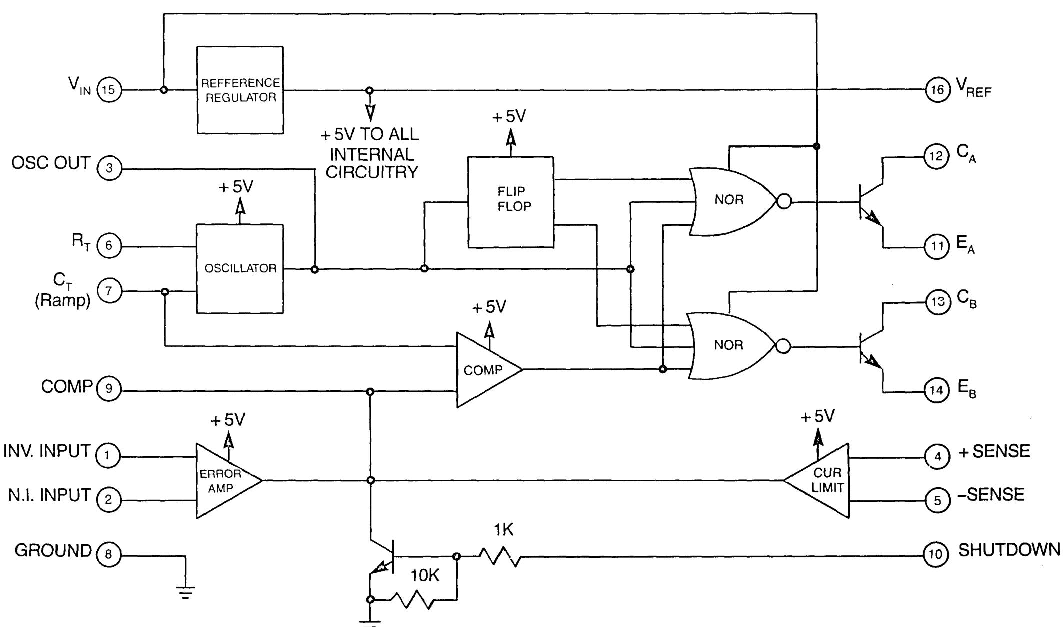

Figure 1. The UC1524 Regulating PWM Block Diagram. This design was the first complete IC control chip for switch mode power supplies.

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waveform, a PWM comparator, and a toggle flip-flop with output gating to switch the PWM signal alternately between the two outputs.

With this circuitry already defined, a two pronged development effort was initiated: 1) to add additional features required by most power supply designs and 2) to improve the utility of features already included within the 1524. The resultant block diagram for the UC1525A is shown in *Figure 2.* Two general comments should be made relative to the overall block diagram. First, in optimizing the output stage for bi-directional, low impedance switching, commitments had to be made as to whether the output should be high or low during the active, or ON state. Since this is application defined there are needs for both output states, so both were developed with the UC1525A device defined by an output configuration which is high during the ON pulse, and the UC 1527A configured to remain high during the OFF state. This difference is implemented by a mask option which eliminates inverter Q_4 (see Figure 3) for the UC1527A. In all other respects, the 1525A and 1527A are identical and any description of the 1525A characteristics apply equally to the 1527A. Second, a major difference between this new controller and the earlier 1524 is the deletion of the current limit amplifier. There are so many system considerations in providing current control that it is preferable to leave this as a user-defined external option and allocate the package pins to other, more universally requested functions. Current limiting possibilities are discussed further under shutdown options.

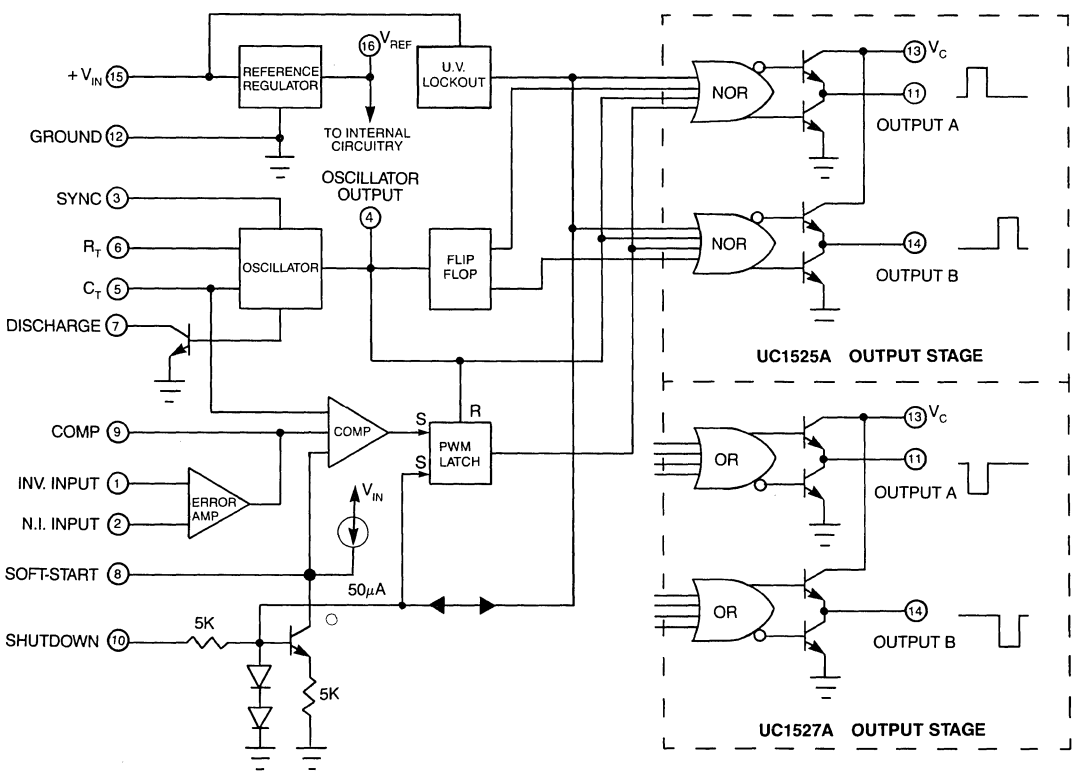

Figure 2. The UC1525A family represents a "second generation" of IC controllers.

"Totem-Pole" Output Stage

One of the most significant benefits in using the UC1525A is its output configuration. For the first time it has been recognized in an IC controller that it is more difficult to turn a power switch off than turn it on. With the UC1525A, a high-current, fast transition, low impedance drive is provided for both turn-on and turn-off of an external power transistor or FET. The circuit schematic of one of the two output stages contained within the device is shown in *Figure 3.* This is a two-state output, either Q_8 is on, forming a low saturation voltage pull-down, or Q_7 is on, pulling the output up to V_C. Note that V_C is a separate terminal from the V_{IN} supply to the rest of the device. This offers the benefits of potentially operating the output drive from a lower supply than the rest of the circuit for power efficiencies, decoupling of drive transients from more sensitive circuits, and a third terminal for extracting a drive signal. Note that even though V_C can be set either higher or lower than V_{IN}, the output cannot rise higher than approximately 1½ volts below V_{IN}.

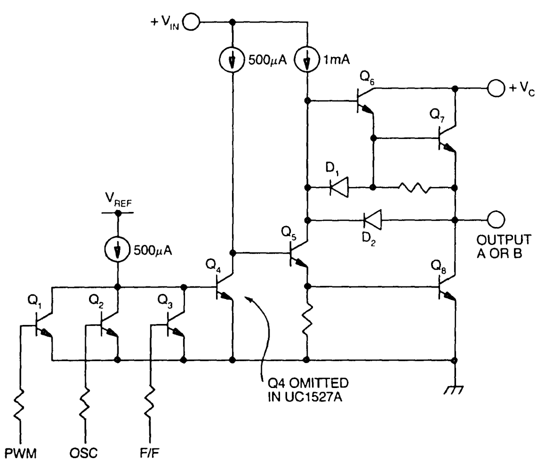

Figure 3. One of two power output stages contained within the UC1525A which conduct alternately due to the internal flip-flop.

During the transition between states, there is a slight conduction overlap between source and sink which results in a pulse of current flowing from V_C to ground. However, due to the high-speed design configuration of this stage, this current spike lasts for only about 100ns. A typical current waveform at V_C is shown in *Figure 4.* This transient will normally be decoupled from the rest of the control power by a 0.1mfd capacitor from V_C to ground but it should not, otherwise, cause a problem unless very high frequency operation is contemplated where it will contribute to overall device power dissipation, by becoming a significant portion of the total duty cycle.

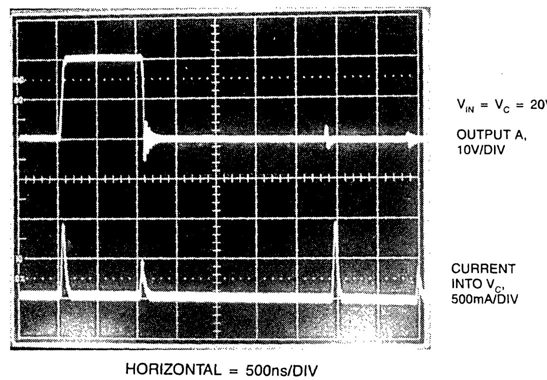

Figure 4. Current "spiking" on the V_C terminal caused by conduction overlap between source and sink is minimized by high-speed design techniques.

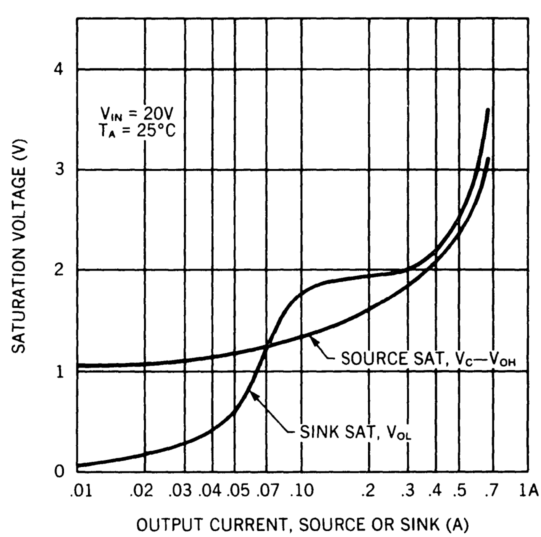

Figure 5. The ouput saturation characteristics of the UC1525A provide both high drive current and low hold-off voltage.

XV

The output saturation characteristics of this stage are shown in *Figure 5.* The source transistor, Q_7, is a straight forward Darlington and its saturation voltage remains between 1 and 2V out to 400mA under the assumption that $V_{IN} \geq V_{CC}$. The sink transistor, Q_8, however, has a non-uniform characteristic which needs explanation. At low sink currents, the 1mA current source through Q_5 insures a very low saturation voltage at the output. As load current increases past 50mA, Q_8 begins to come out of saturation for lack of base drive but only up to about 2V. Here diode D_2 becomes forward biased shunting a portion of the load current through Q_5 to boost the base current into Q_8. With this circuit, the sink transistor can both support high peak discharge currents from a capacitive load, as well as insure the low static hold-off voltage required for bipolar transistors.

A typical output configuration for a push-pull, bipolar transistor power stage is shown in *Figure 6.* With a steady state base drive current from the UC1525A of 100mA, this stage should be able to switch 1 to 5A of transformer primary current, depending upon the choice of transistors. The sum of R_1 and R_2 determine the maximum steady state output current of the UC1525A while their ratio defines the voltage across C_2 which, at turn off, becomes the reverse V_{BE} for Q_1. With the values given, the output current and voltage waveforms are shown in *Figure 7* for a one microsecond pulse. If power FETs are used for the output switches as shown in *Figure 8,* the interfacing circuitry can become even simpler with only a small series gate resistor potentially required to damp spurious oscillations within the FET.

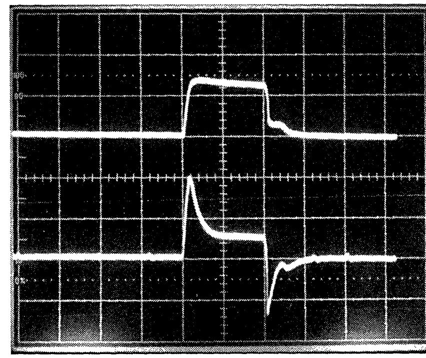

Figure 7. Base current waveforms (Figure 6 circuit) show the enhanced turn-on and turn-off current possible with the UC1525A.

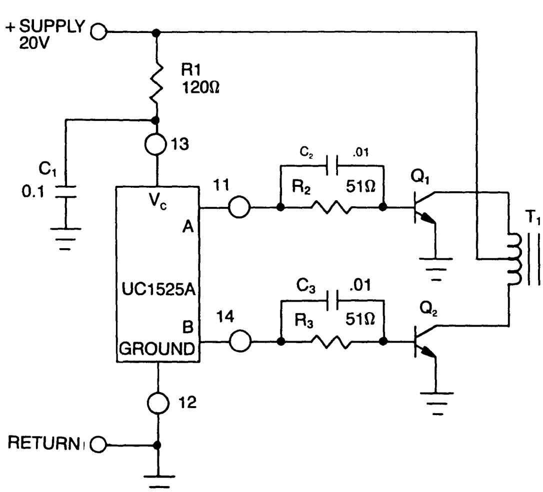

Figure 6. A typical push-pull converter power stage using external bipolar power transistor switches.

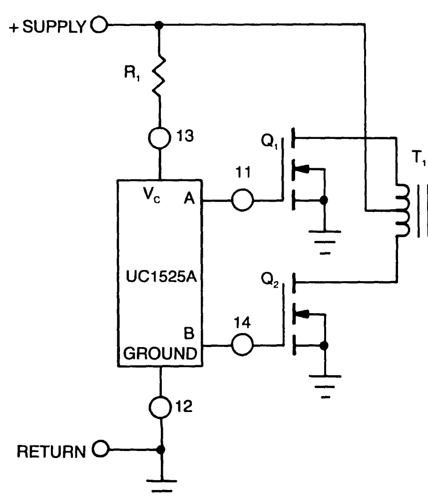

Figure 8. Replacing bipolar transistors with POWER MOSFETs provides even greater simplicity due to the low driving impedances of the UC1525A in each transition.

Push-pull direct transformer drive is also particularly advantageous with UC1525A as shown in *Figure 9.* A version of this configuration is required for isolation when the control circuit is referenced to the secondary side of an off-line power system, and to provide level shifting of drive signals for ½ bridge and full bridge switching. The configuration of *Figure 9* has a couple of important advantages. First, by connecting the drive transformer primary directly between the outputs of the UC1525A, no center-tap is needed and the full primary is driven with opposite polarities. Secondly, between each output pulse, both outputs are pulled to ground which effectively shorts the two ends of the primary winding together coupling a low-impedance turn-off signal to the switching transistors.

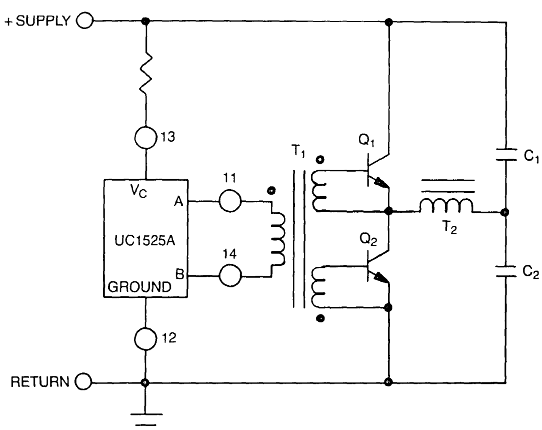

Figure 9. The UC1525A is ideally suited for driving a low-power base drive transformer and eliminates the need for a primary centertap.

A useful single-ended configuration, typical of buck regulators, is shown in *Figure 10.* Here the UC1525A outputs are grounded and the PWM signal is taken from the V_C terminal which switches close to ground during each clock period as the internal source transistors are alternately sequenced.

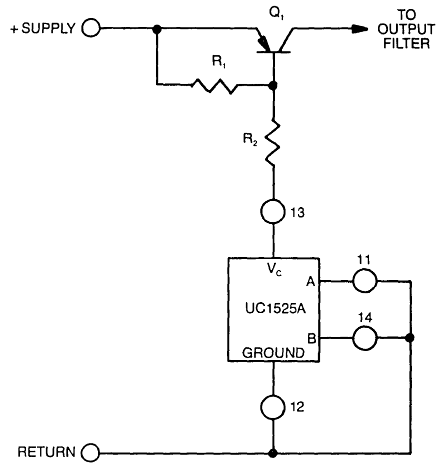

Figure 10. A single-ended, ground-referenced power stage for a flyback or boost regulator.

Controlling Power Supply Start-Up

Although the advantages of the UC1525A's output stage will often be reason enough for its selection, there are several other important and useful features incorporated within this product. One problem previously overlooked in PWM circuits is keeping the output under control as the supply voltage is turned on and off. Undefined states, particularly the possibility of turning on an output before the oscillator is running, can be quite awkward, if not catastrophic. To prevent this, the UC1525A has incorporated an under-voltage lockout circuit which effectively clamps the outputs to the off state with as little as 2½V of supply voltage which is less than the voltage required to turn the outputs on. This clamp is maintained until the supply reaches approximately 8V insuring that all the remaining UC1525A circuitry is fully operational prior to enabling the outputs. The clamp reactivates when the supply is lowered to approximately 7.5V. There is about 500mV of hysteresis built in to eliminate clamp oscillation at threshold.

Another important aspect of power sequencing is restraining the outputs from immediately commanding a 100% duty cycle when they are activated. This is accomplished by a slow turn on (soft-start) which is defined by an internal 50μA current source in conjunction with an externally applied capacitor. The details of this power sequencing system are shown in Figure 11.

Q_3 and Q_4 are the output gates normally driven by the oscillator through D_2 to provide output blanking between pulses. (One of these transistors is shown as Q_2 in Figure 3.) At low supply voltages, Q_2 conducts with base drive from the 20μA current source. Q_2 provides three functions. First, current through R_4 activates the output gates with minimum voltage drop. Second, current through R_5 activates the shutdown transistor Q_5 holding the soft-start capacitor, C_{SS}, discharged. Third, R_2 provides a small bucking voltage across R_3 for hysteresis at the switch point.

When the input voltage becomes high enough to provide a little more than one volt at the base of Q_1, that transistor turns on. This turns off Q_2, activating the outputs and allowing C_{SS} to begin to charge from the internal 50μA current source. The time to reach approximately 50% duty cycle will be

$$t = \left(\frac{2\text{ volts}}{50\mu\text{A}}\right) \text{Css}$$

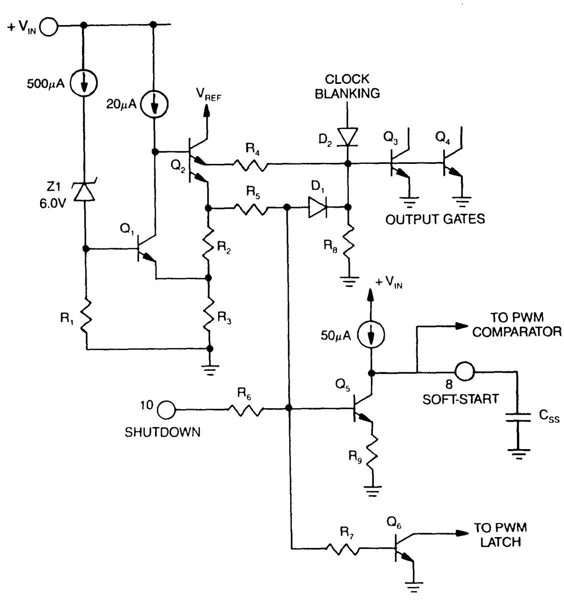

Figure 11. The internal power turn-on, soft-start, and shutdown circuitry of the UC1525A.

Power Supply Shutdown

An important part of any PWM controller is the ability to shut it down at any time for a variety of reasons, including system sequencing requirements or fault protection. Several options are available to the user of the UC1525A, which require an understanding of the capability of the shutdown terminal, pin 10. Referring to *Figure 11,* the base of Q_5 is turned on by a signal which is clamped to approximately 1.4V by the action of D_1 and the V_{BE} of gates Q_3 and Q_4. This holds the outputs off and keeps C_{SS} discharged by Q_5 which, with R9, becomes a 100μA net current sink.

If, during normal operation, pin 10 is pulled high, three things happen. First, the outputs are turned off within 200ns through D_1. Second, the PWM latch is set by Q_6 so that even if the signal at pin 10 were to disappear, the outputs would stay off for the duration of that period, being reset by the next clock pulse. Third, Q_5 is activated commencing a 100μA discharge of C_{SS}. However, if the activation pulse on pin 10 has a duration shorter than ⅓ of the clock period, the voltage on C_{SS} will remain high and soft-start will not be reactivated. Naturally, a fixed signal on pin 10 will eventually discharge C_{SS}, recycling soft-start. Thus, the shutdown pin provides both sequencing capability as well as a convenient port for protective functions, including pulse-by-pulse current limiting.

Regulating PWM Performance Improvements

The UC1525A also offers significant performance and application improvements in almost all of the additional basic functions of a PWM over those obtainable with earlier devices. A general description of these features is outlined below:

Reference Regulator: The output voltage of this regulator is internally trimmed to 5.1V ±1% during manufacture, eliminating the need for adjusting potentiometers in most applications.

Error Amplifier: The UC1525A uses the same basic transconductance amplifier as the UC1524 with an important difference: it is powered by V_{IN} rather than V_{REF}. Now the input common-mode range includes V_{REF} eliminating the need for a voltage divider with its attendant tolerances. An additional feature relative to the error amplifier is that the shutdown circuitry feeds into a separate input to the PWM comparator allowing pulse termination without affecting the output of the error amplifier which might have a slow recovery, depending upon the external compensation network selected. An important benefit of a transconductance amplifier is the ease with which its current mode output can be over-ridden by other external controlling signals.

PWM Comparator: The significant benefit of the UC1525A's PWM comparator is in its following latch. A common problem with earlier devices was that any noise or ringing on the output of the error amplifier would affect multiple crossings of the oscillator ramp signal resulting in multiple pulsing at the comparator's output. The UC1525A's latch terminates the output pulse with the first signal from the comparator, insuring that there can be only a single pulse per period, removing all jitter or threshold oscillation from the system. Another important advantage of this latch is the ability to easily implement digital or pulse-by-pulse current limiting by merely momentarily activating the shutdown circuitry within the UC1525A. This could be as simple as connecting pin 10 to a ground-referenced current sensing resistor. For greater accuracy, some added gain may be advantageous. Once a current signal causes shutdown, the output will remain terminated for the duration of the period, even though the current signal is now gone. An oscillator clock signal resets the latch to start each period anew.

Oscillator: The functions of the oscillator within the UC1525A have been broadened in two important aspects. One is the addition of a synchronization terminal, pin 3, allowing much easier interfacing to an external clock signal or to synchronize multiple UC1525A's together. The other is the separation of the oscillator's discharge network from its charging current source for deadtime control. Reference should be made to the schematic of *Figure 12* for an understanding of the operation of this circuit. The heart of this oscillator is a double-threshold comparator, Q_7 and Q_8, which allows the timing capacitor to charge to an upper threshold by means of the current source defined by R_T and mirrored by Q_1 and Q_2.The comparator then switches to a lower threshold by turning on Q_{10} and discharges C_T through Q_3 and Q_4 with a rate defined by R_D. As long as C_T is discharging, the clock output is high, blanking the outputs. Since the overall oscillator frequency is defined by the sum of the charge and discharge times, there are three elements now in the frequency equation which is approximately:

$$f \approx \frac{1}{C_T\,(.07R_T + 3R_D)}$$

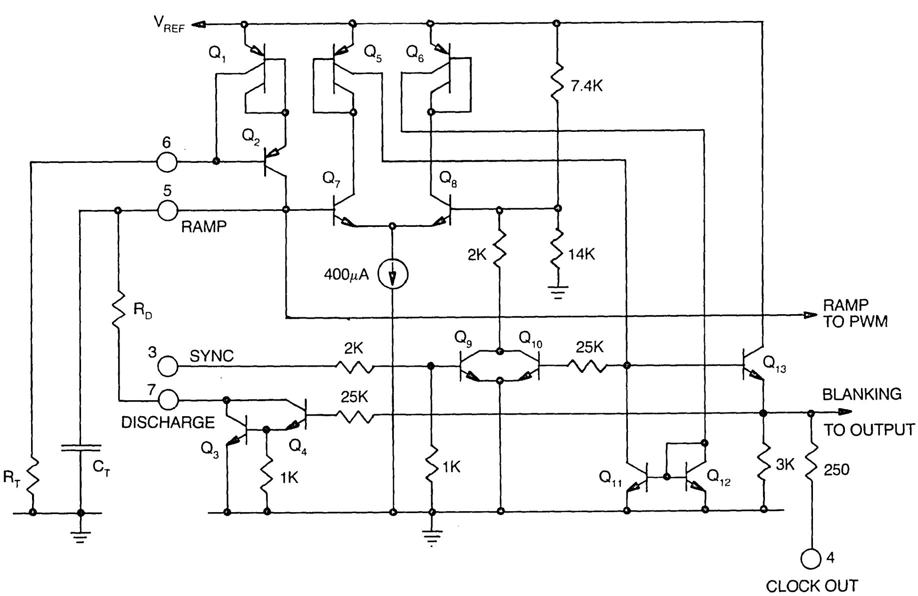

Figure 12. A simplified schematic of the UC1525A's oscillator circuitry.

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External synchronization can easily be accomplished with a 2.8V positive pulse at pin 3. This will turn on Q_9, lowering the comparator threshold below wherever the voltage on C_T may happen to be. Two factors should be considered: First, the voltage on C_T determines the amplitude of the PWM ramp, and if the sync occurs too early, the loop gain will be higher and the resolution may be worse. Second, the sync circuit is regenerative within 200ns; and, while a wider pulse can be used, C_T will not begin to recharge as long as the sync pin is high. For synchronizing multiple UC1525A devices together, one need only to define a master with the correct R_TC_T time constant, connect its output pin to the slave sync pins, and set each slave R_TC_T for a time constant 10–20% longer than the master.

A 200 Watt, Off-Line, Forward Converter

The ease of interfacing the UC3525A into a practical power supply system can be illustrated by the off-line, power converter shown in *Figure 13.* This 200W supply places the control circuitry on the primary side of the power transformer where direct coupling can be used to drive the power switch. While simplifying the drive electronics, this configuration usually requires an isolated voltage feedback signal which is most easily accomplished by an optocoupler driven by some type of voltage regulator IC such as a SG723 or LM305. One other undefined block in *Figure 13* is the auxilliary power supply which suppplies the low voltage, low current bias supply for the UC1525A and the drive for Q_1, the power switch. The choice of the UFN44C2 POWER MOSFET

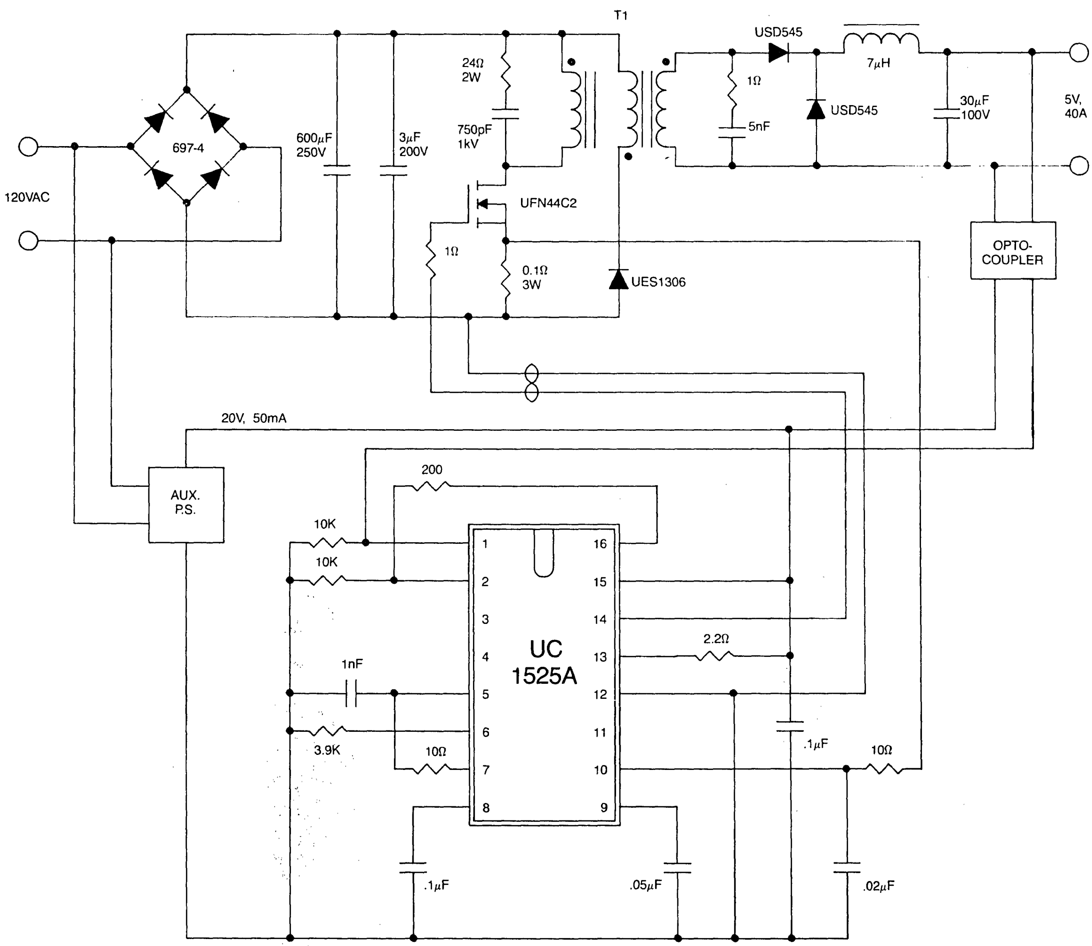


Figure 13. 200W, Off-Line Forward Converter.

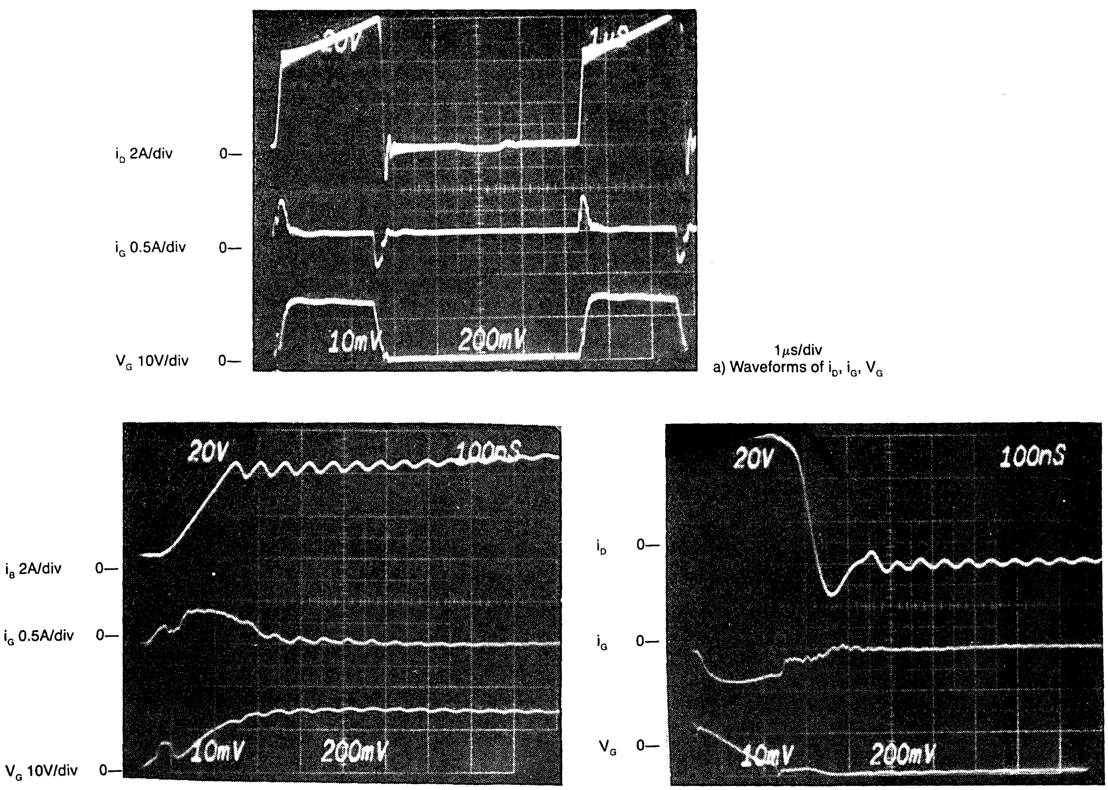
for this switch keeps the total power requirements from the auxiliary supply at less than 1W; readily implemented with a small, line-driven transformer.

This converter is designed to operate at 150kHz which is accomplished by running the UC1525A at 300kHz and using only one of the outputs. This also automatically insures that the duty cycle can never be greater than 50%, a requirement of the power transformer in this configuration. The high operating frequency allows the output filter's roll-off to be set at 12kHz, greatly simplifying the overall loop stability considerations as adequate response can be achieved with only the single-pole compensation of the error amplifier provided by the .05μF capacitor on pin 9.

The totem-pole output of the UC1525A is used to advantage to drive Q_1 by providing a 400mA peak current to charge and discharge the MOSFET's gate capacitance while keeping overall power dissipation low. Waveform photographs of this operation are shown in *Figure 14.*

When operating at full load, the efficiency of this converter is 73% with by far the greatest power losses occurring in the output rectifiers—even though Schottky devices have been selected. Switching losses have been minimized by the fast current transitions, primarily defined by the leakage inductance of the transformer. Although this switching time could probably be even further reduced, there could be problems with current spikes during rise time due to Schottky rectifier capacitance.

Current limiting for this converter is provided by measuring the current in UFN44C2 with the 0.1Ω resistor in series with the source and using this voltage to activate the shutdown circuitry within the UC1525A. While this will provide a fast-acting short circuit protection on a pulse-by-pulse basis, a comparator may need to be added for a more accurate current limit threshold.



b) Risetime
≈90ns

c) Falltime
≈30ns

Figure 14. Current and voltage waveforms for the 200W, Off-Line Forward Converter with a UC1525A direct driven MOSFET Power switch. (Operating frequency is 150kHz with output current equal to 40A.)

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Transformer Winding Data

500 Watt, 100kHz, Off-Line, Half-Bridge Converter

T1 Core: Ferrox 486T250-3C8
Pri: 14T #22AWG
Sec (2): 7T #22AWG

T2 Core: Ferrox EC52-3C8 (EE)
Pri: 14T, 2 layers, 2 #16 AWG in parallel
Sec (2): each 2T, C.T., copper strap .01″ × .8″

T3 Core: Ferrox 486T250-3C8
Pri: 1T
Sec: 20T, C.T. #22AWG

T4 117V/220V, 25V, 0.15A, 50-60Hz

L1 Core: Ferrox IF30-3C8
4 turns, 5 #12AWG in parallel

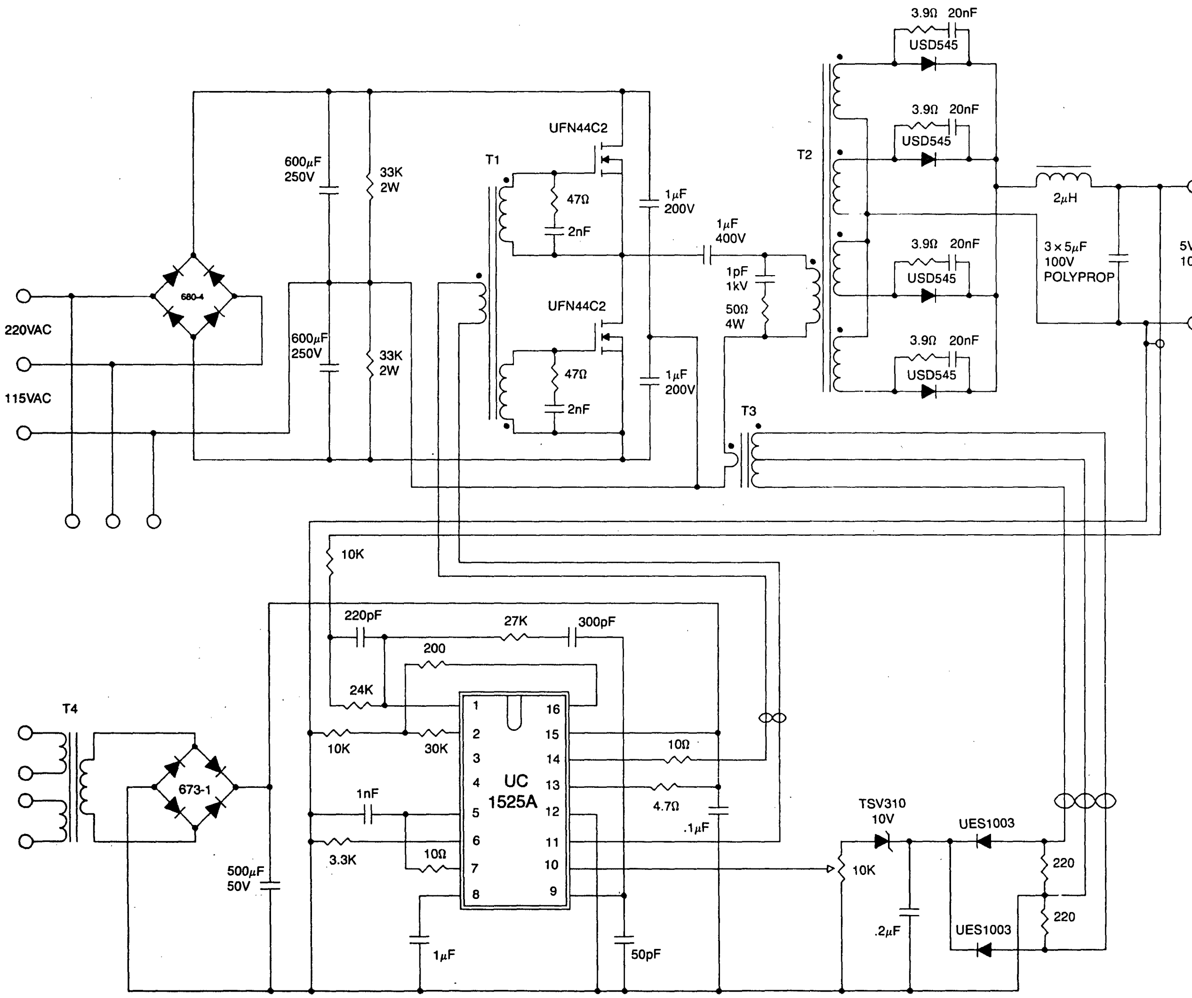

Figure 15. 500W, 100kHz Half-Bridge Schematic.

500 Watt, Off-Line, Half-Bridge Converter

The circuit shown in *Figure 15* uses a pair of Unitrode UFN44C2 POWER MOSFETs in a half-bridge configuration with the UC1525A chip referenced to the secondary side of the power transformer. The MOSFET gates are driven directly from the control chip output through step down and isolation transformer T_1. The UC1525A output terminals (pins 11 and 14) provide active pull-up and pull-down (dual source/sink) for the primary of T_1. This provides the fast, high current turn-on and turn-off pulses needed for the MOSFET gates. In addition, the two ends of the primary windings are shorted to ground during deadtime, which prevents accidental turn-on by transients. Note that the current supplied by the UC1525A outputs drops to a small value when the gate capacitance has been charged or discharged to the desired gate voltage. Damping resistors with series blocking capacitors across the two secondaries of T_1 minimize ringing due to the MOSFET gate capacitance and the inductance of T_1 and lead inductance, particularly during deadtime.

Deadtime for the UC1525A is set very simply by a single resistor between pins 5 and 7. Only a small amount of deadtime is needed since the MOSFETS have no storage time and a very short delay time.

Slow turn-on is accomplished by a single capacitor at pin 8.

Current limiting is provided by current transformer T_3 in series with the primary of the power transformer T_2. The signal is rectified, threshold adjusted and sent to the shutdown terminal, pin 10, of the UC1525A.

Waveforms of the converter are shown in the scope photos of *Figure 16.* Current rise and fall times are 20ns and 10ns. For additional details on this design, see Unitrode Application Note U-87, a 500W, 200kHz Off-Line Power Supply using POWER MOSFETS.

Improved Performance; Less Complexity

Although power supply designers for some time now have had an ever widening inventory of IC components available to ease their design tasks, the final measure of improvement has to be in terms of system performance versus cost. With fewer interface components to the power stages, freedom from potentiometer adjustments, protected start-up and shut-down, a built in soft-start network and several additional system-level features, the UC1525A provides a significant contribution to both performance and costs while simultaneously making the designer's task easier. With these accomplishments, it is clear that this device truly does represent a step-function improvement, introducing a second-generation of power control components.

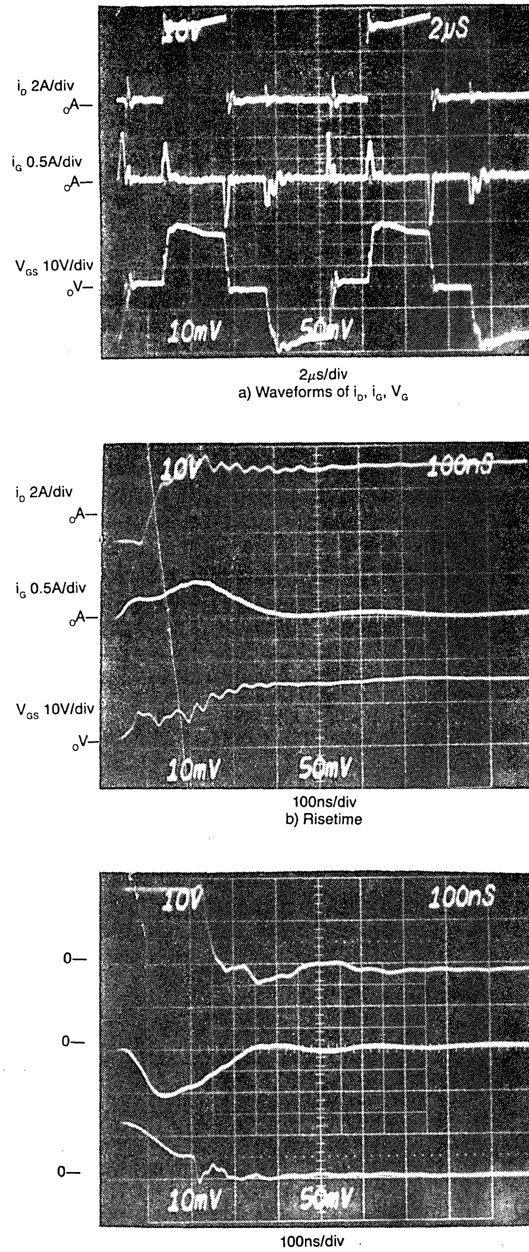

Figure 16. Performance waveforms for the Half-Bridge, 500W, 100kHz Converter with output current of 80A.

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THE UC1524A INTEGRATED PWM CONTROL CIRCUIT PROVIDES NEW PERFORMANCE LEVELS FOR AN OLD STANDARD

Introduction

The application of IC technology to the switching power supply really began with the introduction of the SG1524 in 1976. This device was the first IC to implement all the control blocks necessary for a wide range of PWM power systems. Its straight-forward approach to the classic PWM architecture gave it wide acceptance, and it has become the most commonly used IC controller today.

Even though the 1524 has gained great acceptance and engineers have praised its versatile and easy to understand architecture, they have many times cursed the simplistic, or idealistic, ways its individual blocks were implemented. While one would assume, at first glance, that all control functions necessary for most power supply applications are contained within the 1524, in the real world of practical power systems, additional circuitry is required to interface with the rest of the system, to protect against different types of fault conditions, to adjust for inaccuracies, or to improve control during power sequencing.

Although in the intervening years, many new IC control chips have been introduced which offer certain specialized advantages, it was found that design engineers still preferred the 1524 for its wide versatility and generalized architecture. From this understanding, it became apparent that a new design, which would improve many of the 1524's individual functions by making them more predictable and easier to apply, while retaining the same architecture, could be a winner. Thus, Unitrode undertook this task. The result is the UC1524A.

The UC1524A PWM Controller

A design goal set for the UC1524A was that it not only retain the same architecture but keep the same pin configuration as the 1524 and function equal to or better than the 1524 in most existing applications. In

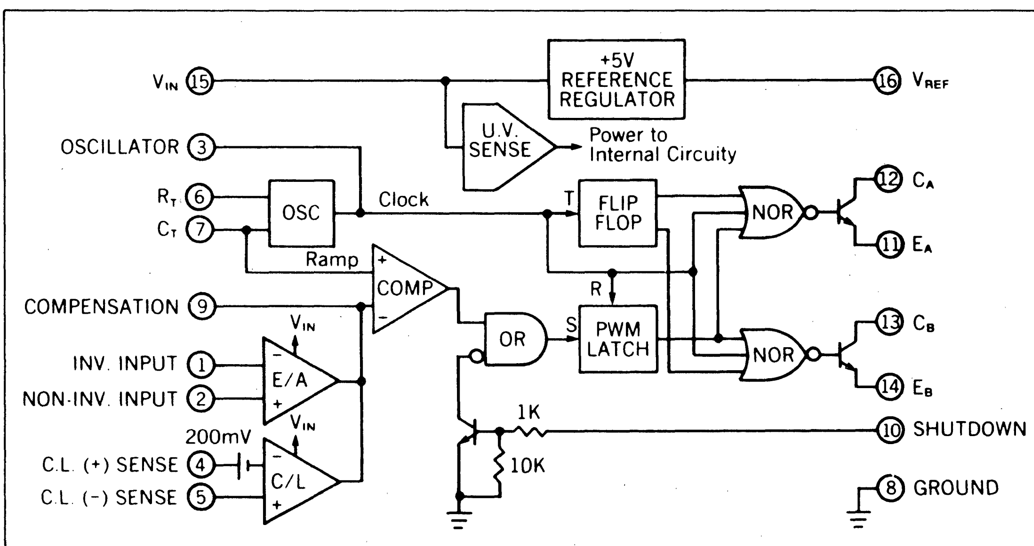

FIGURE 1 —The UC1524A Block Diagram Follows the Same Architecture As the UC1524 But With Several Significant Differences.

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this way, engineers who were familiar with the 1524 could easily understand and evaluate the UC1524A. Performance improvements had to be significant, particularly in reducing the need for discrete support circuitry, so there would be a cost advantage in using the UC1524A in new designs. The block diagram of the UC1524A is shown in Figure 1 which, by intent, appears very similar to that of the older 1524.

The list of the improvements, however, is considerable and includes the following:

1. The 5V reference is now internally trimmed to ±1% accuracy, eliminating the need for potentiometer adjustments.
2. The error amplifier's input range now extends beyond 5V, eliminating the need for a pair of dividers and their attendant tolerances.
3. A high-gain, wide-band, current sense amplifier has been included which is useful for either linear or pulse-by-pulse current limiting in the ground or power supply output lines.
4. An under-voltage lockout circuit has been added which disables all the internal circuitry except the reference until the input voltage has risen to 8V. This holds standby current low until turn-on, greatly simplifying the design of low-power, off-line converters. There is approximately 600mV of hysteresis included for jitter-free activation.
5. A PWM latch has been added insuring freedom from multiple pulsing within a period, even in noisy environments. In addition, the shutdown circuit feeds directly to this latch which will disable the outputs within 200ns of activation.
6. The oscillator circuit is usable to frequencies beyond 500kHz and is easier to synchronize with an external clock pulse.
7. The power capability of the output switches has been boosted by doubling the current capability to 200mA and increasing the voltage rating to 60V.

An understanding of some of these improvements is necessary for ease in application and will now be discussed in greater detail.

Internal Power Turn-on Circuit

The under-voltage lockout and turn-on hysteresis circuit is shown in Figure 2. This circuit requires approximately 2V for activation; but, since nothing else will turn on without at least 3V of supply voltage, lockout is assured. When V_{IN} rises above 2V, R_2 begins to

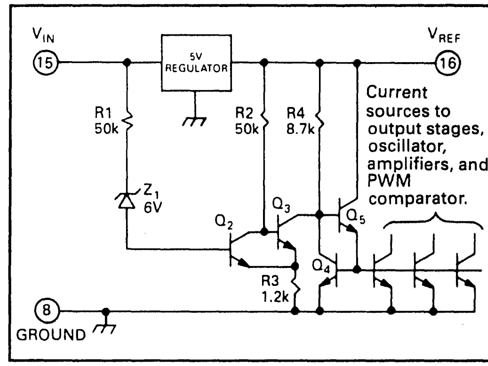

FIGURE 2 — The Under-Voltage Lockout and Power Turn-On Circuitry within the UC1524A.

conduct saturating Q_3 and holding the base of Q_5 too low to allow any of the current sources to conduct. The current through R_4 flows through Q_3 and R_3, developing a 600mV drop across R_3 when V_{REF} reaches 5V. At this level, the only current flowing is that used by the reference regulator and R_2 and R_4, a total of approximately 2.5mA at turn-on threshold.

When the input voltage reaches approximately 8V, diode, Z_1 begins to conduct turning on Q_2 which turns off Q_3 and allows the current sources to activate. Since the current through Q_2 is much less than through Q_3, the voltage across R_3 drops, providing positive feed-

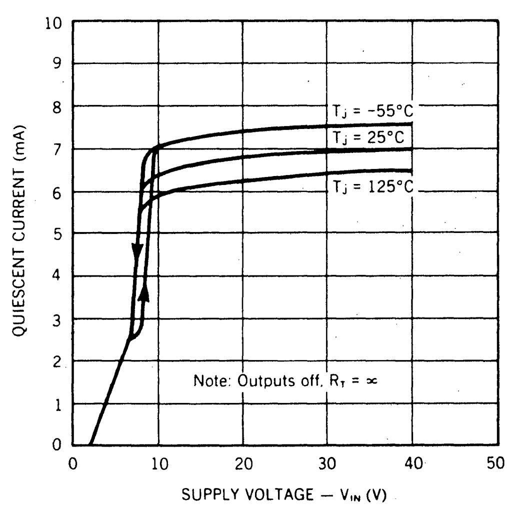

FIGURE 3 — Supply Current for the UC1524A vs. Input Voltage.

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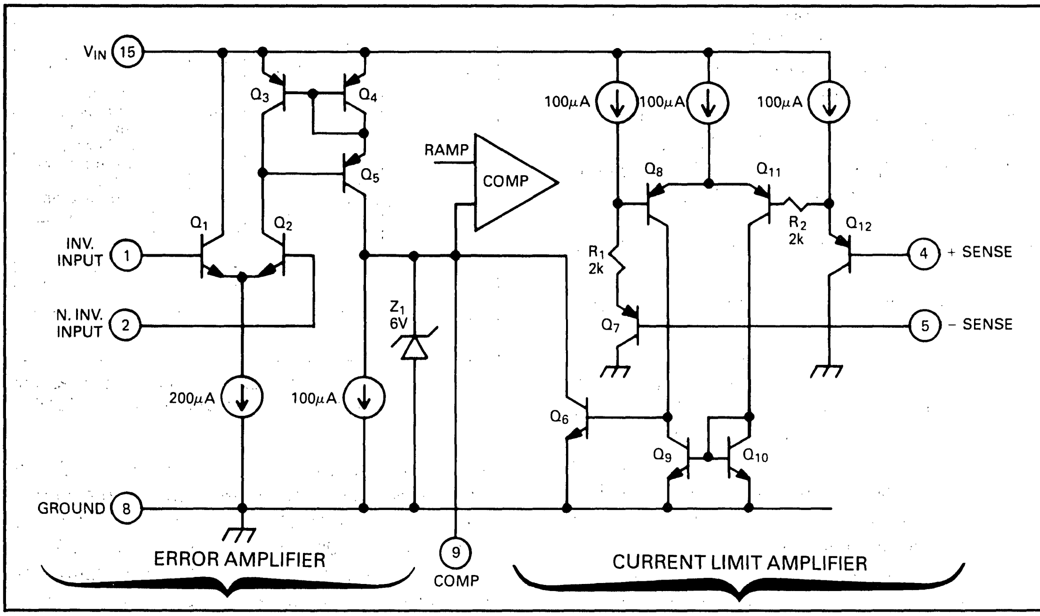


FIGURE 4 —Voltage and Current Sensing Amplifiers Have a Common Output at the Input to the PWM Comparator.

back. This gives about 600mV of hysteresis. This circuit, of course, works in reverse at turn off, insuring that the outputs can only operate when the supply is adequate for fully predictable operation. Figure 3 shows the relationship between quiescent current and input voltage. Designers should find this low current start-up characteristic quite advantageous for off-line, primary-side control with boot-strapped operation after turn on.

A New Current Limit Amplifier

Since the outputs of the current limit amplifier and the voltage-sensing error amplifier are summed at the PWM comparator input, they should be examined together as shown in Figure 4.

Since the error amplifier, consisting of transistors Q_1 through Q_5, must have the lowest priority in controlling the PWM, its output must be easily overruled by current faults or other programming functions, such as soft-start, which would hold pin 9 low. Therefore, a transconductance amplifier similar to that used in the earlier 1524 was again applied to the 1524A with one exception: it is now powered by V_{IN} instead of V_{REF}, so that the input common-mode range extends to within 2V of either rail. Zener diode, Z_1, is used on the output to keep the input level to the PWM comparator below 6 volts.

The error amplifier's output can be considered a 100μA current source or sink (0 - 200μA source with 100μA constant sink). When the current limit circuit activates, Q_6 turns on and can easily pull down pin 9 even though the error amplifier would nominally be calling for a high output at this point.

The current limit circuit consists of Q_6 through Q_{12}. Its differential PNP input stage gives it a common mode range extending from 300mV below ground to within $-2V$ of V_{IN}. Its threshold, or offset, of 200mV is established by the 100μA current source through R_1, with R_2 added to null out the effect of any base current from Q_8.

This current sensing block within the UC1524A can actually be used either as a linear amplifier or as a comparator. The open loop small-signal gain is approximately 80dB while its transition delay with 10% overdrive is 600ns. This can be decreased substantially with additional overdrive. Use of the current sensing block as a comparator is usually preferred from a systems standpoint, since it does not have to be compensated and pin 9 can be dedicated solely to error amplifier compensation. Under this condition, a current signal over the threshold level will pull pin 9 low, terminating the output signal. Recovery is determined by the 100μA pull-up current from the error amplifier in conjunction with any capacitance which may be present on pin 9.

When the current limit circuit is used as a linear amplifier, stabilization is performed by feedback to the inverting input (pin 4) or by capacitance from pin 9 to ground as shown in Figure 5.

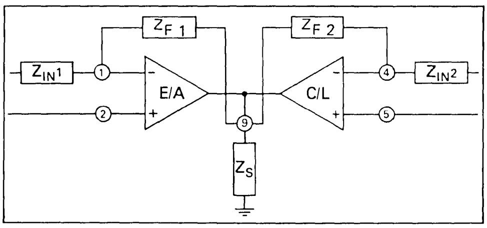


FIGURE 5 — Various Compensation Options Which Are Possible When Both Amplifiers Are Operated in the Linear Mode.

An additional feature of this circuit is its capability to perform as a duty-cycle limiting circuit in the configuration shown in Figure 6. If R_1 is made 100k, there will be minimal effect upon the error amplifier gain.

In current limiting, to achieve the fastest responding pulse-by-pulse control, consideration should be given to the use of the shutdown terminal on pin 10. While the input threshold of this circuit is not as accurately controlled as the current limit amplifier and has a negative temperature coefficient of −2mV/°C and is internally ground referenced; it does feed directly into the PWM latch with only 200ns delay from activation of pin 10 to shutdown of the outputs.

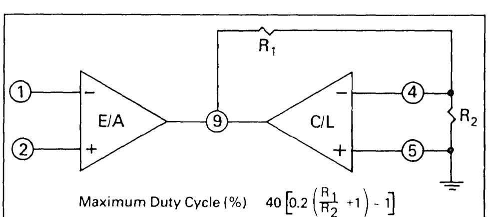


FIGURE 6 — The Fixed 200mV Threshold of the Current Limit Amplifier Can Be Multiplied to Form a Duty-Cycle Clamp or Dead-Band Control.

PWM Comparator and Latch

The PWM latch insures only a single pulse is allowed to reach the appropriate output stage within each period. The latch is reset with the oscillator clock pulse which also serves to blank the outputs. Thus, although the latch is reset at the start of the oscillator clock pulse, it is the termination of the clock pulse which initiates output conduction. The output then stays on until the latch is set, either by a signal from the PWM comparator or from a shutdown command from pin 10. Once the latch is set, it will hold the output off for the duration of the period.

There are several significant advantages to this circuit. First, the latch completely eliminates multiple outputs of the PWM comparator because of noise or ringing on the output of the error amplifier causing multiple crossings of the ramp signal. Second, current limiting can now be performed much more rapidly without instability. Without a latch, significant integration is needed to maintain a turn-off signal after the outputs have turned off. Finally, any instabilities which might potentially be present in the voltage or current loops, or the shutdown signal from pin 10, will cause much less stress on the output stages, since only two transitions through the high-dissipation active region can be made during each period.

The performance of this portion of the UC1524A can be evaluated using a triggerable pulse generator with a variable delay, set up as shown in Figure 7. R_T and C_T are selected for the desired operating frequency. The clock triggers the pulse generator, and the delay is adjusted so the generator output occurs during the PWM period. The output pulse width must be at least 200ns and the amplitude higher than the threshold of the UC1524A input being evaluated. Typical waveform photographs are shown in Figure 8.

Higher Power Output Switches

With the higher current and voltage rating of the UC1524A's output switches, significant economies can now be achieved in interfacing with higher power devices. For low power requirements, a broader range of applications may now be served by the 1524A itself without additional discrete output devices. Regardless of the power supply requirements, more current and voltage from the UC1524A will ease the design tradeoffs. Even with higher current and voltage, the UC1524A offers fast response time. Each output stage contains an anti-saturation network to keep the output transistors out of hard saturation. Although this adds

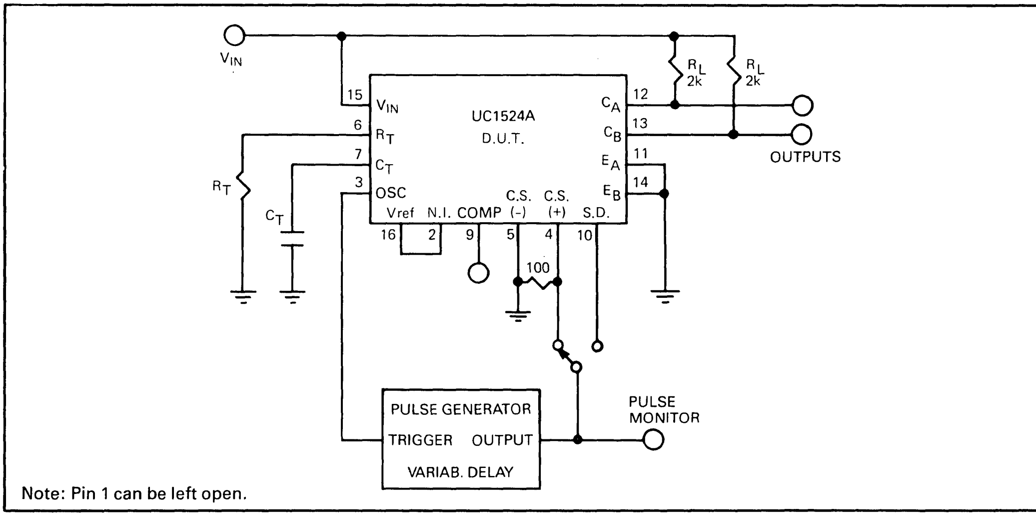
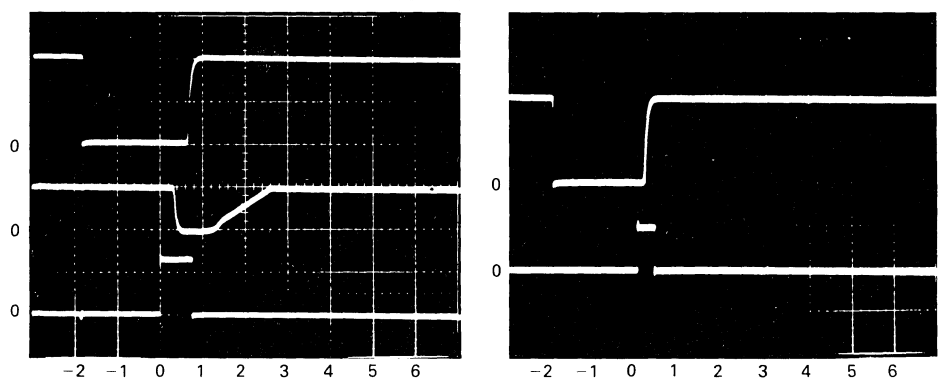


FIGURE 7 — Evaluating the Turn-off Delays of the UC1524A with the Aid of a Triggerable Pulse Generator With Variable Delay.



Top — Output,10V/div
Middle — Comp output, 5V/div
Lower — Current sense input, 200 mV/div
Time — 1 μs/div

Upper — Output, 10V/div
Lower — Shutdown input, 1V/div
Time — 1 μs/div

FIGURE 8 — Typical Turn-off Response From Both the Current Sense and Shutdown Inputs.

somewhat to the saturation voltage, it is more than offset by the benefits in reducing turn-off delay. Saturation voltage as a function of current is shown in Figure 9.

Since both collectors and emitters are available on the UC1524A's output transistors, many different coupling possibilities are offered. One useful configuration for enhanced turn-off is shown in Figure 10. The fast-rising signal appearing at the collector of the output transistor, Q_1, is capacitively coupled to saturate an external transistor, Q_2, greatly reducing the turn-off delay of Q_3 and allowing a much larger value to be selected for R_3. Many variations of this circuit are possible depending upon the power devices to be driven and the voltage levels required.

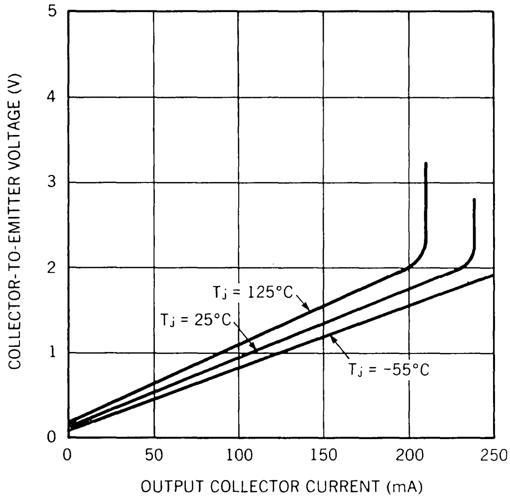


FIGURE 9 —Output Saturation Characteristics for Each of the UC1524A's Outputs.

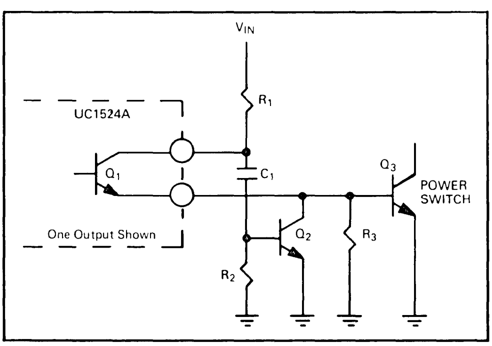


FIGURE 10 — The addition of C_1 and Q_2 Uses the Collector Signal of the UC1524A to Generate an Enhanced Turn-off Command for Q_3

Frequency Synchronization

The oscillator circuit within the UC1524A, shown in Figure 11, has been improved over that of the 1524 with the addition of C_2. Without this component, a synchronizing pulse externally applied to pin 3 had to do all the work of discharging the timing capacitor through Q_4 and Q_5. The simple addition of C_2 couples a positive pulse from pin 3 to the base of Q_{10}, momentarily reducing the threshold of comparator Q_8-Q_9 and regeneratively triggering the oscillator into its discharge state. The circuit is now leading-edge triggered and narrow pulses can be used. This is a consideration when minimum dead time is required, since the outputs are blanked off as long as pin 3 is held high.

As with the 1524, synchronization to an external clock should be done with the R_TC_T time constant set approximately 10 to 20% greater than that determined for the required clock frequency, taking into consideration the expected tolerances of the components. For synchronizing multiple UC1524A devices, all R_T, C_T, and OSC output terminals should be individually connected together and a single R_T and C_T used.

When considering blanking, the pulse on pin 3 may be extended somewhat by the addition of a capacitor of up to 100pF from pin 3 to ground. If narrower blanking pulses are required, adding a resistive load from pin 3 to ground of 1 kohm minimum will reduce the pulse width.

The best way to guarantee a large dead time is still to use a diode to clamp the peak output from the error amplifier to a divider from V_{REF}. This technique is quite accurate due to the accuracy of V_{REF} and the $100\mu A$ fixed current available from the amplifier.

A Simple Buck Regulator Circuit

The application of Figure 12 demonstrates the utility of the UC1524A used with a Unitrode PIC600 hybrid switch. This combination greatly simplifies the design of switching regulators, since the only other active device required is a small-signal 2N2222 which serves to provide a constant drive current to the output switch, regardless of the input voltage level. With the UC1524A, current sensing does not have to be done in the ground line, but will still function when the regulator output is shorted to ground.

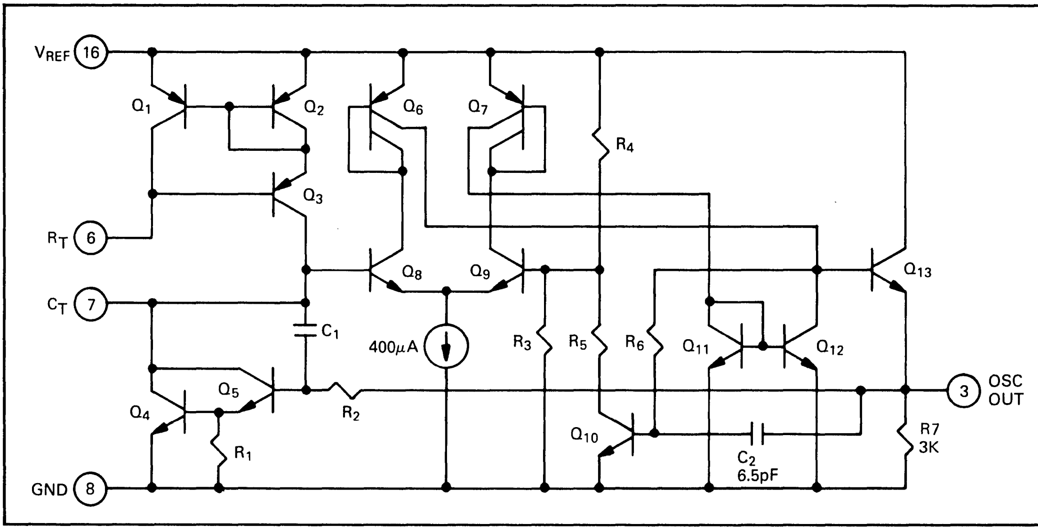


FIGURE 11 — The Oscillator Circuit of the UC1524A Allows Both High Frequency Operation and Ease of External Synchronization.

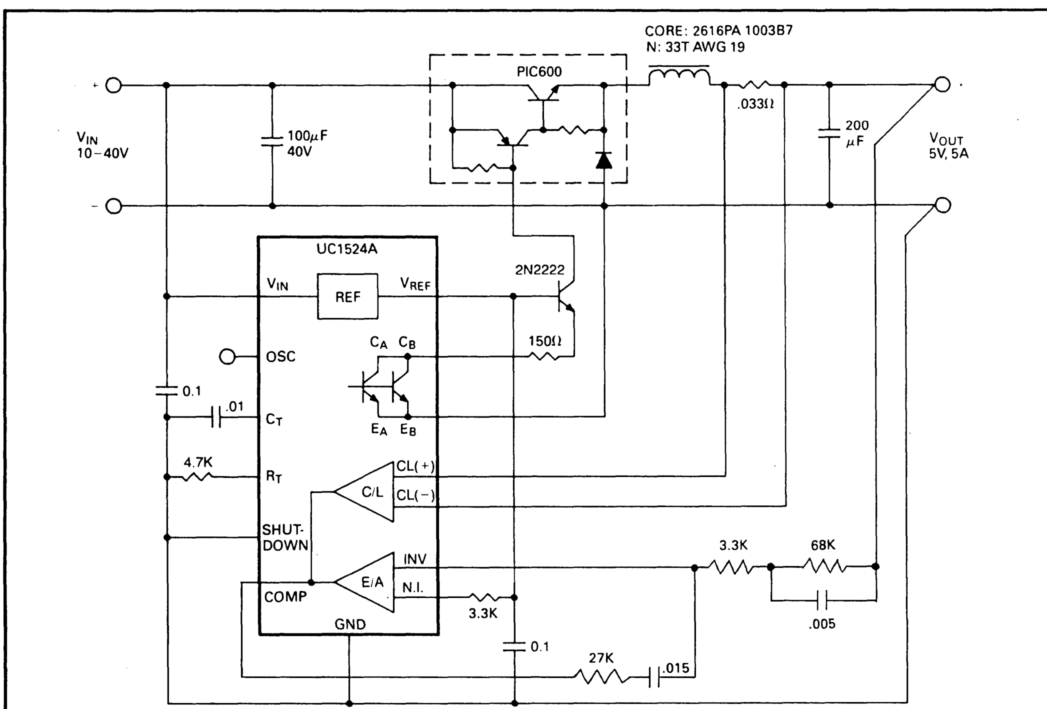


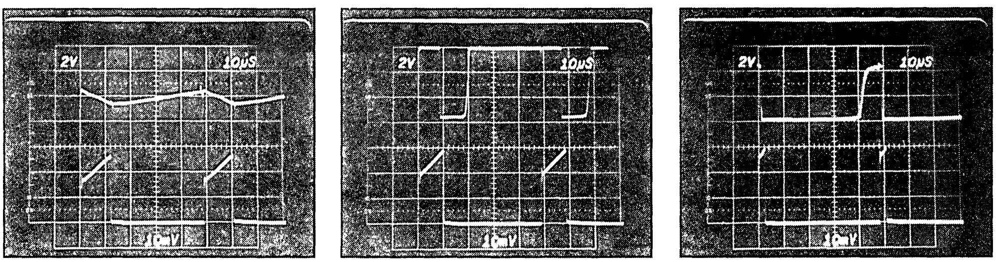
FIGURE 12 — The UC1524A Combines With the PIC 600 Hybrid Switch to Form A Simple But Powerful Buck Regulator.

The waveforms of Figure 13 demonstrate the performance of the current limiting comparator, showing that from the onset of current limiting to a complete short circuit, the peak input current increases from 5.2A to only 5.9A.

A Complete DC-DC Converter with the UC1524A

An important attribute of the new UC1524A family is the higher voltage rating on the output transistors. This now makes it possible to implement a practical 4W DC-DC converter operating from a common 28V bus with no additional output transistors. The schematic of Figure 14 uses a push-pull configuration which imposes a voltage of twice the supply across the "OFF" transistor. This is now within the rating of the UC1524A and, thus, with a 28:7 turns ratio in the transformer, a 5V, ¾A output is achieved with 78% efficiency at a significant minimum parts count.

The fast response of the current limit amplifier within the UC1524A again keeps the device well protected as shown in the waveforms of Figure 15.



A B C

Upper trace is Comp terminal (pin 9), 2 V/div
Lower trace is input current through power switch, 0.2A/div
Time base is 10 µsec/div.

A = Onset of current limiting, I_p = 5.2A
B = Into current limiting, Comp terminal held low until inductor current falls below threshold, Ip = 5.9A
C = Output shorted to ground. Pulse width reduced to 2µs. Ip still 5.9A.

FIGURE 13 — Performance Data for Figure 14's Regulator Shows the Tight Control of Peak Current, Even Under Shorted Output Conditions.

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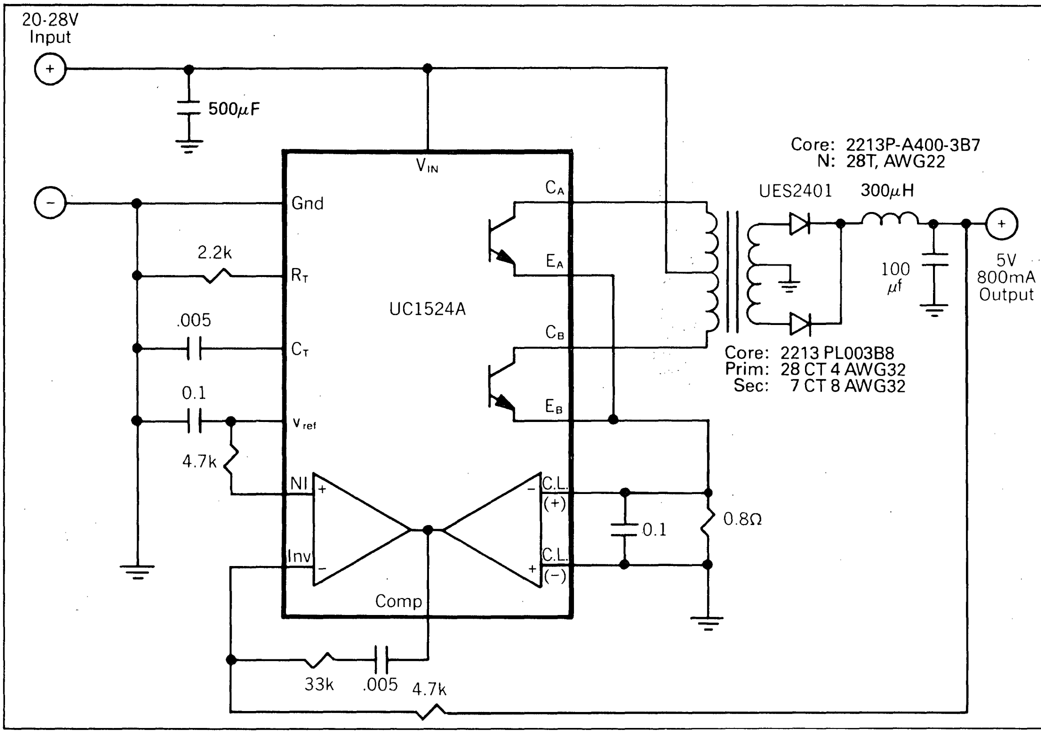
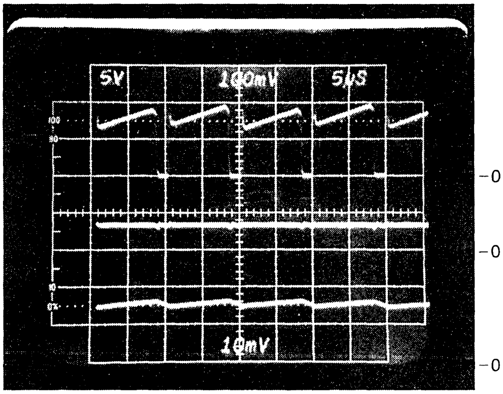
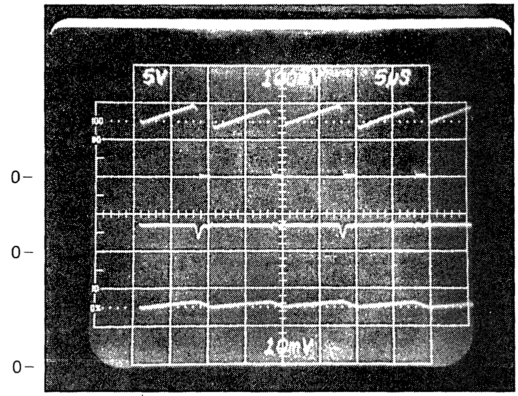


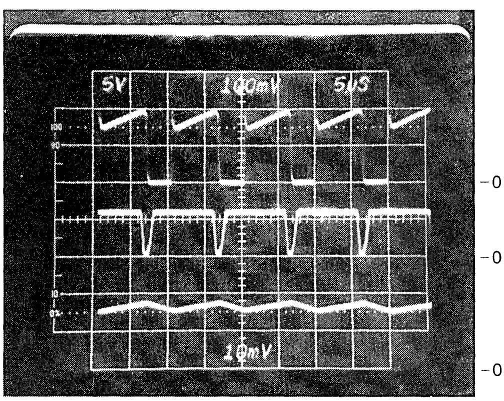
FIGURE 14 — With Higher Output Voltage Capability, the UC1524A can Implement a Complete 4 Watt DC to DC Converter with no Additional Switching Transistors.



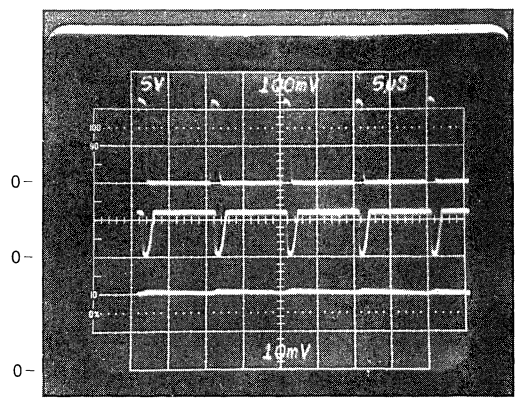
Circuit Under Normal Load



Circuit at Threshold of Current Limiting



Circuit Under Full Current Limit



Circuit Under Short Circuit Conditions

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FIGURE 15 — Operating waveforms for the PWM DC-DC converter (Figure 14)

Upper trace	*= Primary current at 0.1 A/division*
Middle trace	*= Pin 9 voltage at 5V/division*
Lower trace	*= Load current at 0.5A/division*
Time base	*= 5µs/division*

An Off-line Forward Converter

For low to medium power applications, a single-ended flyback or forward converter with all the control on the primary side of the isolation step-down transformer is usually the most economical solution. However there are two complications with this approach. The first is that although the control circuitry can easily be driven from a low-voltage winding on the power transformer, starting energy must be taken from the high-voltage rectified line where, at 170VDC, every 10mA represents a 1.7W loss. The second complication is in obtaining adequate regulation of the output while still meeting isolation requirements from output back to the line.

The 50W forward converter of Figure 16 offers innovative solutions to both these problems. In this circuit, the UC1524A provides all the control with its operating drive power coming from winding N_2. The low-current start-up characteristics of the UC1524A allow starting energy to be developed in C_2 with only approximately 8mA required through R_1.

The problem of isolated feedback control is solved in this application by sampling the 5V output level at the switching frequency by means of the 2N2222 transistor and transformer T_2. With every switching cycle, the output voltage is transferred from N_1 to N_2 where it is peak detected to generate a primary-referenced signal to drive the PWM error amplifier. Diode D_2 is used to temperature compensate for the loss in the rectifier, D_1 and the net result is better than 1% regulation with the main added cost that of a very inexpensive signal transformer.

Some of the other features of this application include a duty-cycle clamp on the PWM formed by diode D_3

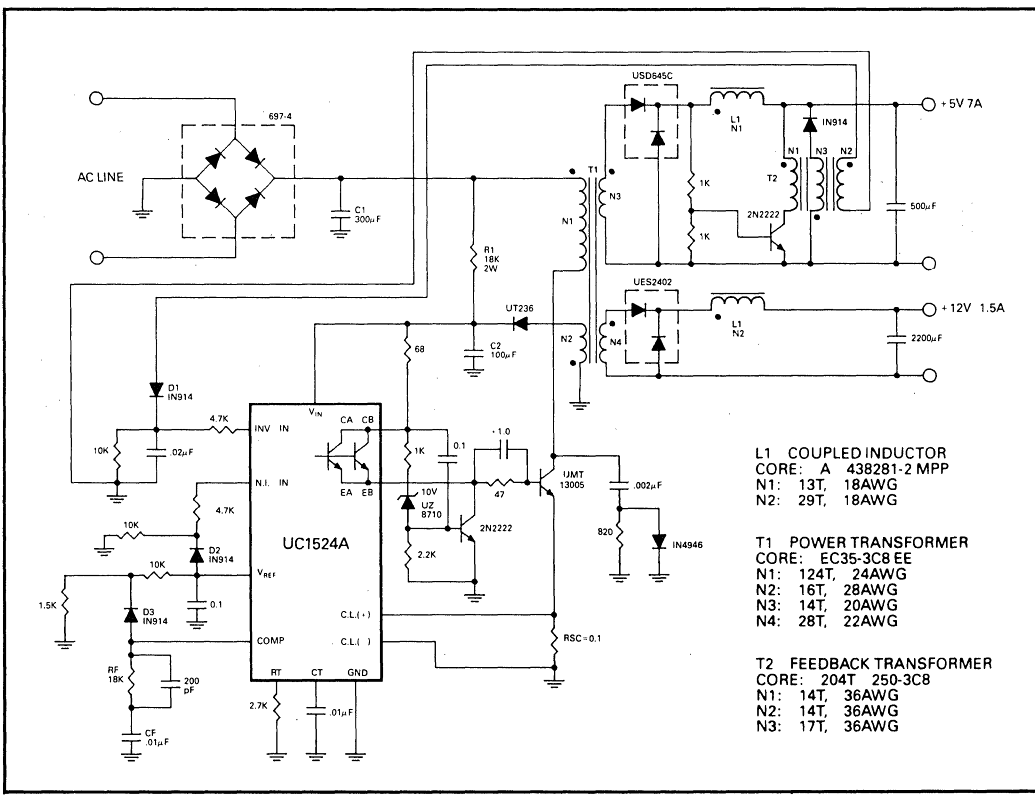


FIGURE 16 —This 50W Off-Line Forward Converter Features Both High Efficiency and Good Regulation while Maintaining Input-Output Isolation.

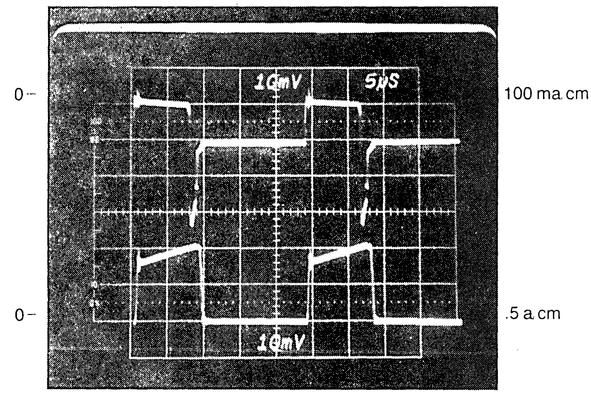
and the 10k - 1.5k divider from V_{REF}. This method of clamping is more effective with the UC1524A since the UV lockout keeps the outputs off until the reference, error amplifier, and oscillator are all operating within specification.

Drive for the UMT13005 high-voltage switch is accomplished by using the emitters of the UC1524A's output transistors for turn-on and the 2N2222 in conjunction with the 1μfd base capacitor to provide a negative base voltage for rapid turn-off as described in Figure 10.

The resultant drive signal is shown in Figure 17. Operating at 40kHz, this regulator provides an isolated 50W of power with an efficiency of 83%, a high degree of regulation, and fast overload protection.

Conclusion

Although there are now many new integrated circuits from which to choose in attempting to build more cost-effective power supplies, it always helps to review well established ideas. In the case of the UC1524A, updating and improving an earlier product has resulted in a significant advancement: providing greater performance and versatility while reducing system costs.



at Full Load (50W)

FIGURE 17 — Base Current (Upper Trace) and Collector Current for the UMT 13005 of Figure 16. The Time Base is 5μs per Division.

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DETERMINING THE CHANGE IN ZENER VOLTAGE WHEN THE CURRENT IS CHANGED

A common question concerning zener diodes is "what will be the zener voltage at a current different from the current now specified?"

The difficulty is that the impedance of a zener is not a constant, and changes with the current, so the zener voltage is a non-linear function of current.

Here is a useful equation that gives a good approximation to the change in zener voltage when the current is changed from one value to another value.

$$\Delta V_Z \doteq k_Z \ln\left(\frac{I_2}{I_1}\right)$$

where $k_Z = I_Z \times Z_Z$ and I_Z is chosen approximately midway between I_1 and I_2

The equation does not include the effect of pulse or dc-heating on the zener voltage. If appreciable junction heating is involved the thermal model must also be used.

Here is an example of how the equation is used.

Question: If the voltage of a UZ5733 is specified as 33V at 40mA, what will be its voltage when measured at 5mA?

Using the graph of Z_Z versus I_Z on the data sheet for this device, and choosing a value of I_Z at 20mA,

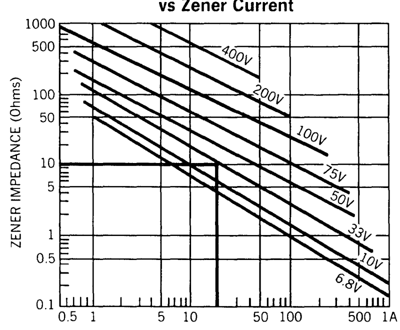
$Z_Z = 10\Omega$

So $k_Z = I_Z \times Z_Z = 20\text{mA} \times 10\Omega = 0.20\text{V}$

$$\Delta V_Z \doteq k_Z \ln\left(\frac{I_2}{I_1}\right) = 0.20 \times \ln\left(\frac{5\text{mA}}{40\text{mA}}\right) = 0.20 \times \ln(0.125) = 0.20\text{V}(-2.08) = -0.42\text{V}$$

Thus the zener voltage at 5mA will be 33V — 0.42V = 32.6V

UZ5706 Series
Typical Zener Impedance
vs Zener Current



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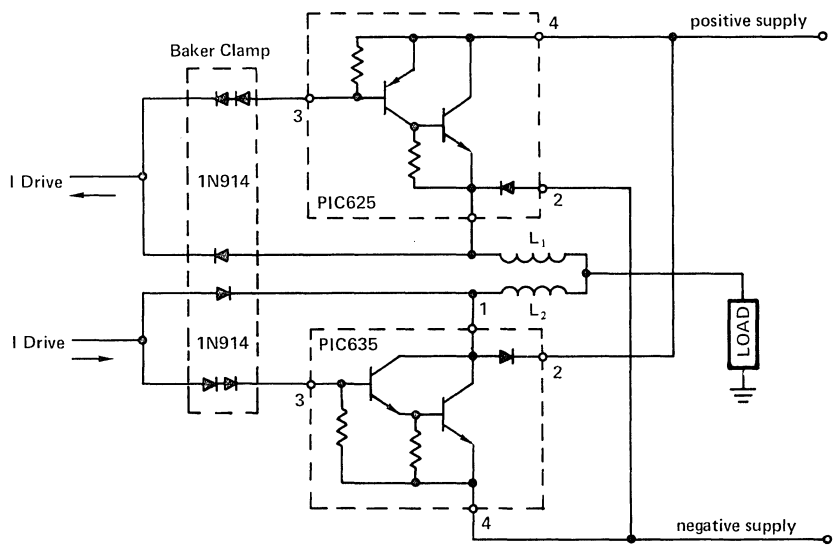
MINIMIZING STORAGE TIME WHEN USING UNITRODE SWITCHING REGULATOR POWER OUTPUT CIRCUITS (PIC600 SERIES)

In some applications (such as a reversing motor drive, for example: stepper motor) where storage time is an important consideration in the design, the normal storage time of PIC600 series (approximately 600ns) can be reduced to acceptable level.

At lower output currents, the excess storage time is a result of the driver stage operating well under saturation, while at higher output currents it is a result of the output transistor operating into quasi-saturation region.

The storage time can be reduced to less than 100ns by utilizing a Baker Clamp technique as shown in the circuit below:



The Baker Clamp will increase the $V_{CE(sat)}$ losses but this disadvantage will be more than offset by the improved switching speed.

The Baker Clamp circuit varies the drive current of the PIC600 series for optimum switching speed at any given load current. The drive current required to the Baker Clamp can be unregulated, as long as it is greater than 30mA.

The small value of the inductor L_1 and L_2 (5 to 10 μH) stops cross conduction during the switching of PIC600 series.

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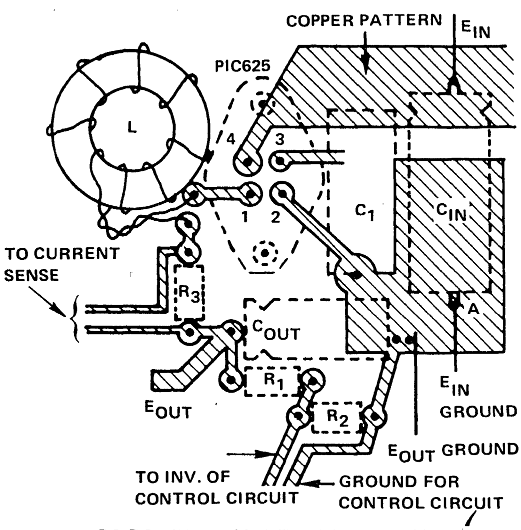
AVOIDING SPURIOUS OSCILLATION WHEN USING UNITRODE SWITCHING REGULATOR POWER OUTPUT CIRCUITS (PIC600 SERIES)

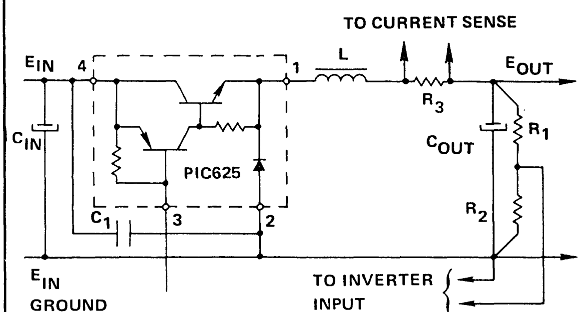
Avoid spurious oscillation due to ground loops and RFI when using a Unitrode Switching Regulator Power Output Circuit (PIC600 Series) in a switching regulator.

The Unitrode switching regulator power output stage (PIC600 Series) is a high frequency fast switching device. Its control circuitry must also operate at high frequency and high gain. Therefore, it is necessary to avoid any ground loops and RFI for stable circuit operation.

The high frequency roll-off of the control circuit should be adjusted properly with a compensation network. The typical layout of the power circuit is shown in the figure below.



PC BOARD LAYOUT OF POWER CIRCUIT



CIRCUIT DIAGRAM

Capacitor C_1 (0.2 μf) reduces the RFI generated due to the reverse recovery current spike of the catch diode, and should be physically located near pin 4 and pin 2 of the PIC625. The capacitor should be a high frequency by-pass capacitor, such as Polystyrene.

The current sense resistor R_3 should be a non-inductive (carbon) type. The current sense signal should be picked up right across this resistor.

If the switching regulator is operated at the higher end of the input voltage, the inductor should be shielded with an electrostatic shield, grounded to Point A. The case of PIC625 should also be connected to Point A.

HOW TO SAFELY CHECK SUSTAINING VOLTAGE ON POWER TRANSISTORS

One of the most important parameters for any power transistor, particularly in switching applications with inductive loads, is the sustaining voltage. Many manufacturers specify only open base sustaining voltage ($V_{CEO(SUS)}$) at a low current level (10 to 200mA); and, even where sustaining voltage with resistive bias ($V_{CER(SUS)}$) or voltage bias ($V_{CEX(SUS)}$) is specified on a data sheet, the chances are that it will not be specified under the exact conditions that will be required by a specific application. Because of this, many designers select a transistor based on its $V_{CEO(SUS)}$ rating, since V_{CER} or V_{CEX} will always be greater than V_{CEO} (see Figure 1 for a graphical explanation of the relationship among V_{CEO}, V_{CER} and V_{CEX}).

By choosing a transistor based upon its V_{CEO} rating, the designer may be using a higher voltage device than necessary. If he could determine the voltage under the actual conditions of his application, it is possible that a lower voltage device could be used, resulting in considerable cost savings. Figure 2 presents a test circuit that can be used to safely measure sustaining voltage under any bias condition at collector currents up to 5A.

PLEASE NOTE: SUSTAINING VOLTAGE SHOULD NEVER BE READ ON A CURVE TRACER, EVEN AT LOW CURRENT LEVELS, SINCE POWER RATING OR REVERSE-BIASED SECOND-BREAKDOWN RATING ($E_{S/b}$) MAY BE EXCEEDED, RESULTING IN PERMANENT DAMAGE TO THE TRANSISTOR.

The test circuit of Figure 2 may also be used to check a transistor's $E_{S/b}$ rating if the zener clamp is removed. $E_{S/b}$, under a specified bias condition of R_{BB} and V_{BB}, is related to collector current and inductance as follows:

$$E_{S/b}\ (\text{joules}) \cong 1/2 L i^2$$

Where i is the peak collector current flowing at the time the transistor is turned-off.

It should be noted, however, that the transistor is not protected without the zener clamp, and the device may be damaged or destroyed if it does not meet its $E_{S/b}$ rating.

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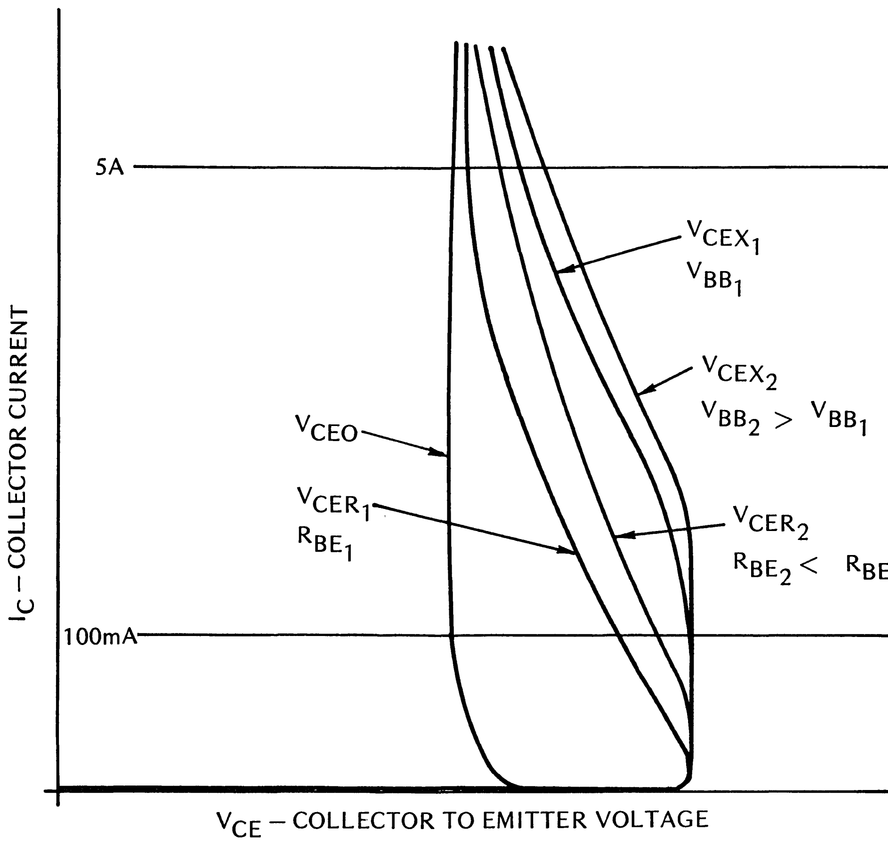
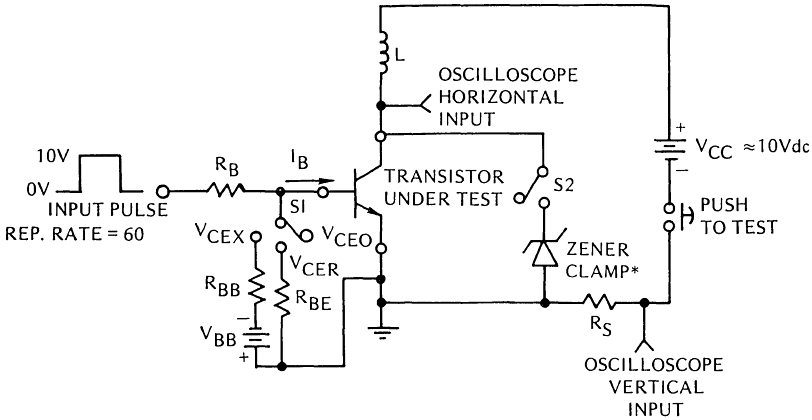


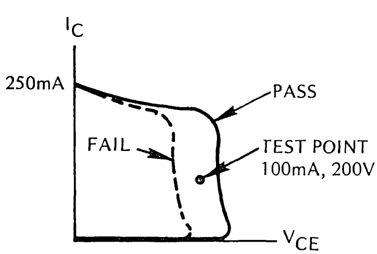
Fig. 1. Relationship among $V_{CEO(SUS)}$, $V_{CER(SUS)}$, $V_{CEX(SUS)}$
(Not to Scale)



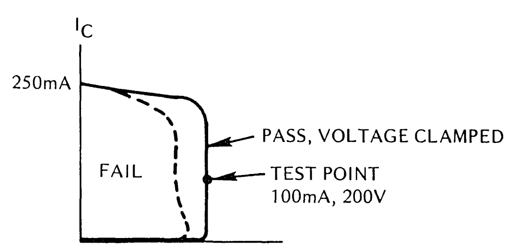
*ZENER CLAMP VOLTAGE SHOULD BE EQUAL TO THE MINIMUM SPECIFIED VALUE OF THE V_{CEO}, V_{CER} OR V_{CEX} VOLTAGE BEING CHECKED.

VOLTAGE RATING (V_{CEO}, V_{CER}, V_{CEX})	TEST CURRENT (I_C)[1]	INDUCTOR (L)	CURRENT SENSE (R_S)	I_B	INPUT PULSE WIDTH
⩽80V	⩽50mA 50mA–200mA 200mA–1.0A 1.0A–5.0A	50mH 20mH 2mH 0.5mH	10Ω 5Ω 1Ω 0.2Ω	0.1(I_C) 0.1(I_C) 0.1(I_C) 0.1(I_C)	350μSec 525μSec 250μSec 325μSec
80V–200V	⩽50mA 50mA–200mA 200mA–1.0A 1.0A–5.0A	100mH 40mH 4mH 1mH	10Ω 5Ω 1Ω 0.2Ω	0.1(I_C) 0.1(I_C) 0.1(I_C) 0.2(I_C)	800μSec 1.0mSec 550μSec 650μSec
⩾200V	⩽50mA 50mA–200mA 200mA–1.0A 1.0A–5.0A	200mH 80mH 10mH 2mH	10Ω 5Ω 1Ω 0.2Ω	0.1(I_C) 0.1(I_C) 0.2(I_C) 0.2(I_C)	1.5mSec 2.0mSec 1.25mSec 1.25mSec

1. THE ZENER CLAMP SHOULD ALWAYS BE USED WHEN TESTING AT COLLECTOR CURRENT VALUES ABOVE 200mA SINCE THE REVERSE-BIASED SECOND-BREAKDOWN ($E_{S/b}$) RATING OF THE TRANSISTOR UNDER TEST MAY BE EXCEEDED.



REPRESENTATIVE SCOPE TRACE FOR UNCLAMPED TEST AT I_C = 100mA



REPRESENTATIVE SCOPE TRACE FOR CLAMPED TEST AT I_C = 100mA

Fig. 2. Test Circuit for $V_{CEO(SUS)}$, $V_{CER(SUS)}$, $V_{CEX(SUS)}$

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OPERATING THE SWITCHING REGULATOR OUTPUT CIRCUIT (PIC600 SERIES) AT LOW FREQUENCIES

The Unitrode switching regulator power output circuit consists basically of a power transistor switch and a catch diode. The appropriate data sheets in the Unitrode Semiconductor Databook provide the necessary information for determining junction temperature and power dissipation at frequencies above 10 kHz.

This Design Note provides a method for determining the junction temperature and maximum allowable power dissipation for the transistor switch and catch diode when the switching regulator is operated at frequencies under 10 kHz, where the switching losses are negligible and can be safely ignored.

The method of determining safe power dissipation requires a detailed transient thermal analysis, since the junctions of the transistor and diode are subjected to temperature excursions due to the applied pulse power.

When the device is subjected to a train of periodical power pulses, the maximum power dissipation and junction temperature can be calculated from the effective pulse thermal resistance (θ_p) as follows:

$$\theta_p = R_T \times D + (1-D)\, r(t+\tau) - r(\tau) + r(t)$$

where: t = pulse width

τ = period

Duty cycle $D = \frac{t}{\tau}$

Peak Power, P_{pk} is peak of an equivalent square power pulse

$r(t+\tau)$ = transient resistance at time $t+\tau$

$r(t)$ = transient thermal resistance at time t

R_T = DC thermal resistance (from data sheets)

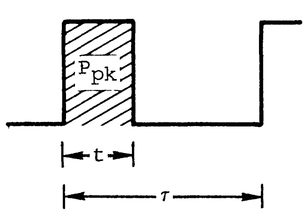

Figure 1. Power Pulses

1. Calculating the Junction Temperatures (Pulse Train)

A. Power Transistor Switch

The peak junction temperature of the transistor switch under repetitive peak power pulse conditions is calculated as follows:

$$T_{j(peak)} = T_{CASE} + P_{pk} \times \theta_p$$

$$T_{j(peak)} = T_{CASE} + V_{CE} \times I_C \times \left[R_T \frac{t_T}{\tau} + \left(1 - \frac{t_T}{\tau}\right) \times r(t_T + \tau) - r(\tau) + r(t_T) \right]$$

The transient thermal impedances $r(t_T + \tau)$, $r(\tau)$, $r(t_T)$ are obtained from the transient thermal impedance plot for the transistor (see Figure 2),

t_T = transistor on-time

B. Catch Diode

The peak junction temperature of the catch diode under repetitive peak power pulse condition is calculated as follows:

$$T_{j(peak)} = T_{CASE} + I_F \times V_F \left[R_T \times \frac{t_D}{\tau} + \left(1 - \frac{t_D}{\tau}\right) r(t_D + \tau) - r(\tau) + r(t_D) \right]$$

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where:

t_D = diode on-time

The Transient thermal impedances $r(t_D + \tau)$, $r(\tau)$, $r(t_D)$, are obtained from the transient thermal impedance plot for the catch diode (see Figure 2).

C. <u>Power Dissipation</u>

The maximum allowable power dissipation in either the transistor or the diode is determined by the maximum junction temperature of 150°C:

$$P_{pk(max)} = \frac{150°C - T_{CASE}}{\theta_p}$$

2. <u>Calculating the Junction Temperature (Single Shot Power Pulse)</u>

For a non-repetitive power pulse, the rise of junction temperature can be calculated as follows:

$$T_j = P_{pk} \times r(t) + T_{CASE}$$

For a pulse with less than 100 millisec, the case temperature is assumed to remain at ambient temperature.

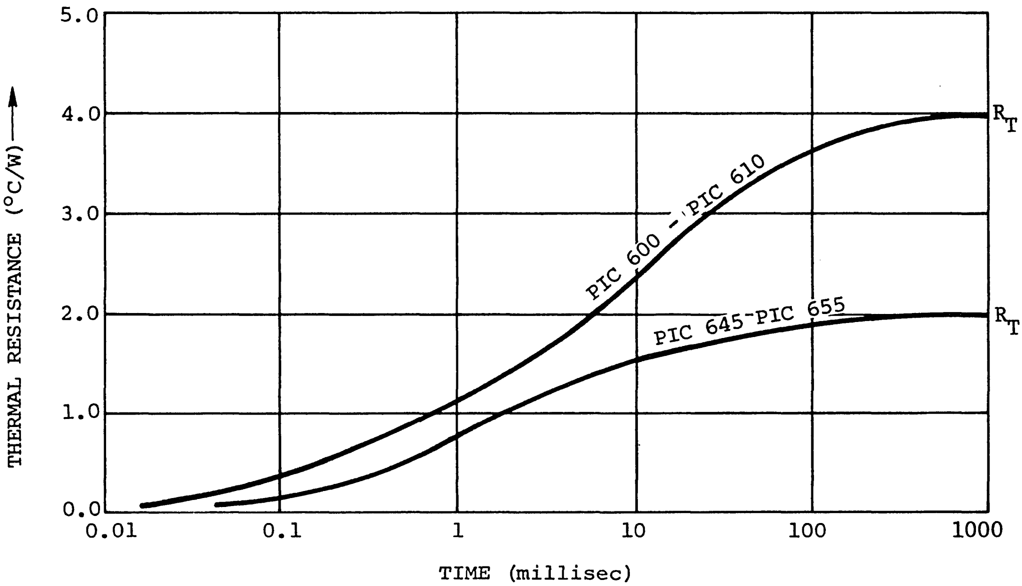

Figure 2. Transient Thermal Resistance — Power Transistor or Catch Diode

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A 350 WATT SWITCHING REGULATED OUTPUT POWER SUPPLY FOR MULTIPLE OUTPUTS UTILIZING UNITRODE SEMICONDUCTOR COMPONENTS

There are many ways a switching power supply can be designed to obtain regulated output voltages. When multiple outputs are desired, such as ±5 volts and ±12 volts, the circuit described below provides the basis for an efficient, economical, and reliable power supply. It consists of a pulse width modulated buck regulator and a synchronized "H" (full bridge) inverter, each leg of which operates at 50% duty cycle. The block diagram of the power supply is shown in Figure 1.

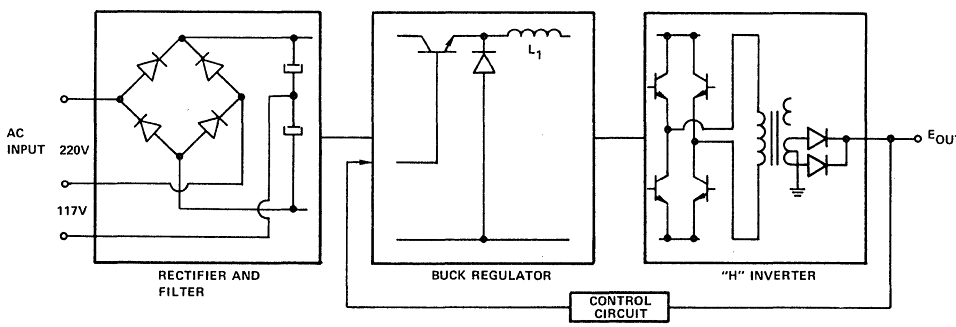


Figure 1. Block Diagram

The advantages of this design approach are as follows:

1. Numerous inductors (normally needed when pulse-width modulating an inverter) are not required. No filter inductor is required in the output which lowers costs. Minimum load bleeder resistors are not needed, thus improving efficiency and excessive heat generation. These features result from the "H" inverter operating at 100% duty cycle.
2. A high voltage, low ESR capacitor in series with the power transformer is not required. The problem of excessive collector current in an "H" inverter stage due to "walking of core flux" on a saturated B-H curve is eliminated.
3. There is no possibility of high current or forward-biased second breakdown in the inverter bridge transistors when they are simultaneously on during switching periods. The "cross-current" is limited by the inductor, L_1, (the buck regulator acts as a constant current source) which increases reliability. Furthermore, the transistors are in saturation during cross conduction again improving efficiency, and reducing heat generation.

4. Only one high voltage switching transistor is required for either 110 or 220V input.
5. There is no possibility of forward-biased second breakdown in the bridge transistor during initial turn-on ("start-up").
6. No expensive high voltage filter capacitor is needed. Filtering is achieved with a low voltage output capacitor.

Description of the Circuit:

The buck regulator, "H" inverter and control circuit is described in brief in this section. The detailed schematic of the circuit is shown in Figure 2.

A. Buck Regulator:

The output stage of a buck regulator consists of a Unitrode Barrier transistor™ UMT1009 and a fast recovery (50 nanoseconds) high voltage catch diode, the Unitrode UES1306. The buck regulator is operated at 50 kHz, twice the operating frequency of the "H" inverter, with very low switching losses. Operating the buck regulator at higher frequency reduces the cost of the filtering inductor, L_1.

The output voltage is regulated in this stage by employing a pulse-width modulation technique using a UC1524. The output of the filter inductor is clamped below the BV_{CEO} of transistors used in an "H" bridge with a Unitrode zener diode UZ4212. This diode absorbs the energy stored in inductor L_1 during the period when energy is not coupled into the secondary due to the leakage inductance of power transformer T_3. Notice that there is no output filter capacitor in the buck regulator. This design feature limits excessive cross conduction collector current in the transistors of the "H" inverter.

The base drive current to the pass transistor is provided with a unique transformer coupled drive circuit. It provides base drive current up to 100% duty cycle if required. Furthermore, a small amount of energy stored in a ferrite bead in the base drive circuit provides assistance in turning off the high voltage pass transistor.

B. "H" Inverter:

The "H" inverter operates at 25 kHz, with a 50% duty cycle in each leg, synchronized with the buck regulator. It utilizes four low voltage 2N6354 transistors. Low voltage transistors offer low $V_{CE(SAT)}$, high gain and fast switching times. Due to high gain, the base drive current required is low.

The switching losses are kept to a minimum by switching the transistors when inductor, L_1, current is at a minimum. The storage time of the transistor is kept to a minimum by reducing the base drive just prior to transistor turn-off. (The base drive current is highest when transistor is turned on and reducing linearly.)

The diodes $D_1 - D_4$ provide the path for magnetizing current at lower output current as well as the path for energy stored in the leakage inductance of the power output transformer.

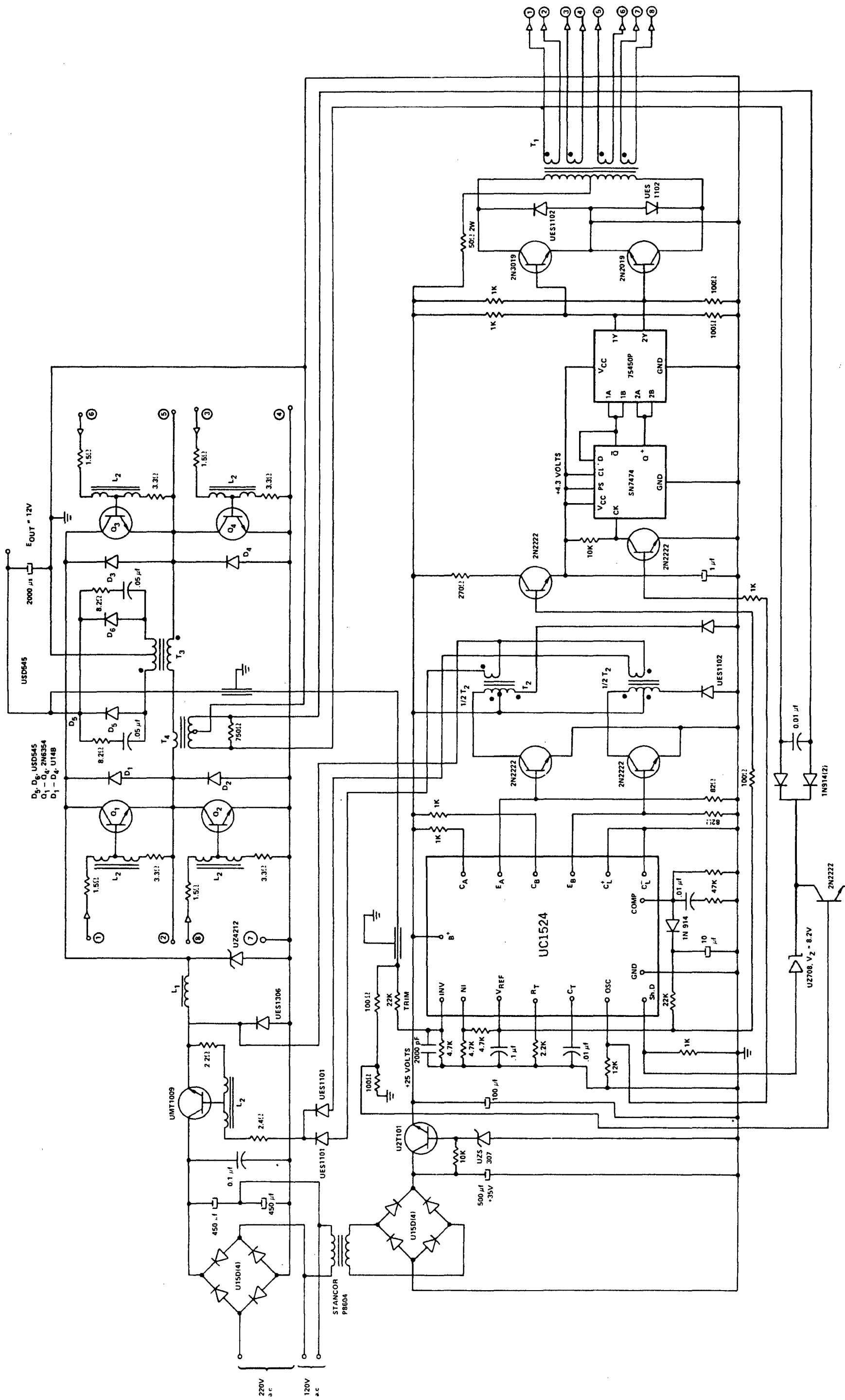


Figure 2. Detailed Schematic of 350 Watt Switching Regulated Output Power Supply

Current limiting is obtained with a current transformer. The level of the current limit is maintained constant regardless of temperature by effectively using two diodes in series with an 8.2 volt zener (Z_2) UZ708. Only one driver transformer is used for all four transistors. The transistor turn-on and turn-off is enhanced with a ferrite bead in the drive circuit.

The output is rectified with Unitrode USD545 Schottky Rectifiers which provide the advantages of low V_F at high current and minimum change in leakage current with temperature. The snubber network across the Schottky diodes prevent reverse bias breakdown from the large voltage spikes due to leakage inductance in the power transformer, and reduces RFI.

C. **Control and Drive Circuits:**

The regulation function is achieved with a UC1524 P.W.M. monolithic integrated circuit. The synchronizing pulses from the integrated circuit drive the D-Flip Flop, SN7474. The output of this D-Flip Flop drives the logic circuit 75450P which provides drive current to low cost 2N3019 NPN transistors. Line isolation is maintaind with a driver transformer.

The control circuit (UC1524) is inhibited in a slow start mode to prevent large current and voltage transients.

The circuit described herein provides conversion efficiency up to 85%. This design approach achieves an efficient and economical switching-regulated power supply when multiple outputs are desired. The output filter capacitor is smaller in size because each leg of the "H" inverter operates at 50% duty cycle.

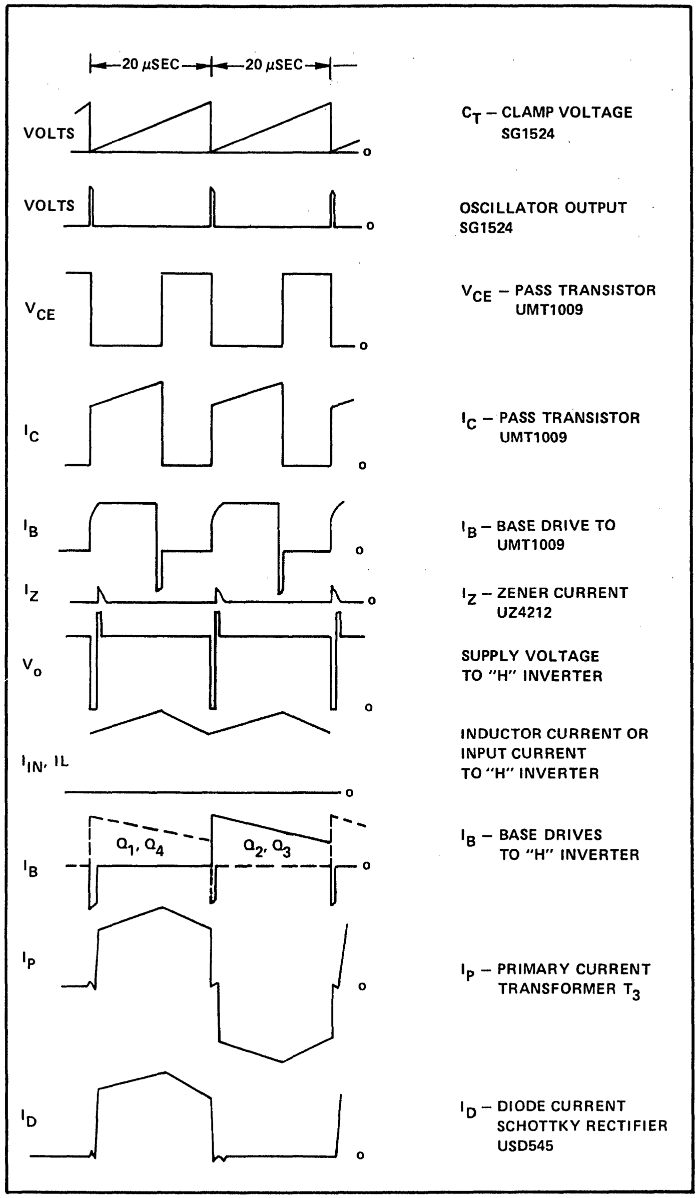
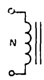


Figure 3. Basic Waveforms

TRANSFORMER AND INDUCTOR DETAILS

L_1. Filter Inductor;

core: Ferroxcube IF-19

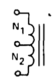


N = 198 turns, wire size AWG #16

Air gap = 0.2 inches

L_2. Ferrite Bead;

core: Stackpole #57-1552 Ferrite Bead

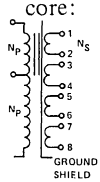


N_1 = 2 turns, wire size #32

N_2 = 2 turns, wire size #32

T_1. "H" Inverter Driver Transformer;

core: Ferroxcube 376U250-3C8, 376UB250-3C8

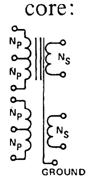


N_P = 90 turns, wire size AWG #32

N_S = 15 turns, wire size AWG #32

T_2. Buck Regulator Driver Transformer;

core: Ferroxcube 78E272-3C8, 782B272-3C8



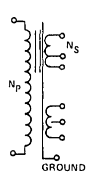
N_P = 90 turns, wire size AWG #34

N_S = 15 turns, wrie size AWG #28

Two transformers wound on same core, over outside legs of E-I core.

T_3. Power Output Transformer;

core: Ferroxcube EC-52



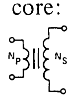
N_P = 32 turns, wire size #16

N_S = 4 turns, wire size #26, 36 wires twisted together

NOTE: Secondary is designed for +12 volts output. For multiple output total copper area of secondary should be 0.30 x Total Window Area.

T_4. Current Transformer;

core: Ferroxcube 376U250-3C8, 376B250-3C8



N_P = 2 turns, wire size AWG #16

N_S = 60 turns, wire size AWG #32

SQUIB-FIRING CIRCUIT PROVIDES FOR RELIABLE FIRING, FROM LOW LEVEL INPUTS

The design of reliable squib-firing circuitry often presents particular problems. Squib functions are typically quite critical, and the initial triggering source for these systems is, by nature, usually minute.

Conventional transistor squib-firing circuits usually require several gain stages, together with a power transistor to handle the squib-firing current. Mechanical squib switches, on the other hand, cannot be operated repetitively to allow for complete testing of the device and associated circuitry during check-out.

The high sensitivity planar Silicon Controlled Rectifier (SCR) can be triggered directly from low-level input circuitry, with significant reduction in circuit complexity and size. Reliability is thus considerably enhanced.

The unique characteristics of the planar SCR have resulted in wide usage of this semiconductor component in squib-firing circuits for rocket engine ignition, detonation, and explosive bolt applications. Compared with conventional transistor techniques or mechanical squib switches, this proven approach has significant reliability advantages, with circuit simplicity, size reduction, mechanical ruggedness and elimination of electrical contacts.

An SCR, with surge current ratings at 100°C of 5 amperes-50 milliseconds or 20 amperes-1 millisecond can easily handle the current required for firing most squibs. Input circuits can be designed to trigger reliably at levels below 100 microamperes and 1.0 Volt, making the SCR particularly well-suited for direct drive from low level control logic circuits and simple RC time delay networks. In addition, the bistable properties of the SCR enable it to be triggered on by a pulse input—remaining in the "ON" state until reset. This inherent "memory" is frequently used to advantage in arming circuits.

Two circuits typical of squib firing applications are shown in Figures 1 and 2. Both will operate from −65°C to over 125°C.

In Figure 1, Capacitor C_1 is charged to +28 Volts through R_1 and stores energy for firing the squib. A positive pulse of 1 mA applied to the gate of SCR_1 will cause it to conduct, discharging C_1 into the squib load X_1. With the load in the cathode circuit, the cathode rises immediately to +28 Volts as soon as the SCR is triggered on. Diode D_1 decouples the gate from the gate trigger source, allowing the gate to rise in potential along with the cathode so that the negative gate-to-cathode voltage rating is not exceeded. This circuit will reset itself after test firing, since the available current through R_1 is less than the holding current of the SCR. After C_1 has been discharged, the SCR automatically turns off—allowing C_1 to recharge.

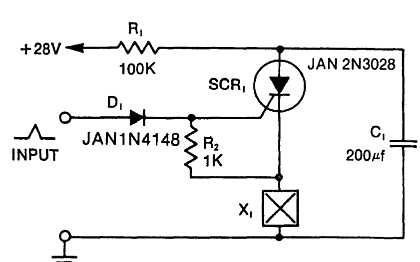


FIGURE 1

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In Figure 2, energy for firing the squib is supplied directly from the +28 Volt supply. Caution must be exercised when arming this type of circuit. If anode voltage is applied too rapidly, the SCR may fire. This dv/dt effect acts through the SCR anode-gate capacitance (15 pf), which couples current to the SCR gate (in proportion to anode dv/dt). The effect is negligible if dv/dt is under 1 Volt/μs—as in Figure 1, where it is limited by the charging of C_1. Faster rates of rise can be safely handled by increasing the SCR gate bias.

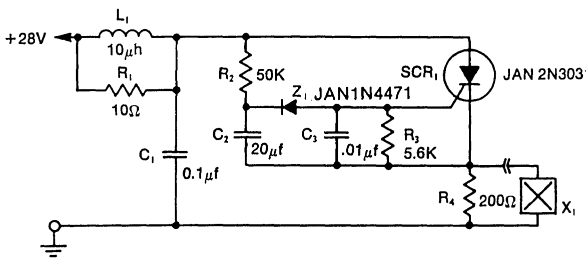

FIGURE 2

In Figure 2, the LRC input network limits the anode dv/dt to a safe value—below 30 Volts/μs. R_1 provides critical damping to prevent voltage overshoot. While a simple RC filter section could be used, the high current required by the squib would dictate a small value of resistance and a much larger capacitor. Resistor R_3 provides DC bias stabilization, while C_3 provides stiff gate bias during the transient interval when anode voltage is applied.

In this circuit the SCR is fired one second after arming by means of the simple R_2 C_2 Z_1 time delay network. R_4 provides a load for the SCR for testing the circuit with the squib disconnected—limiting the current to a level well within the continuous rating of the SCR. The circuit can be reset by opening the +28 Volt supply and then re-arming.

XV

COMBINED AC-DC LOAD CONTROL SIMPLIFIES SCR RESET

Silicon Controlled Rectifiers (SCRs) are finding increased use in a wide variety of control circuit and power switching applications. They offer an economical way to achieve high switching gain, efficiency and blocking voltage.

When the inherent memory or "latching" feature is not desired, AC anode supply is often used, allowing the SCR to turn off automatically upon removal of the gate control signal. With an AC anode supply, an additional benefit is derived—the SCR doubles in function as a rectifying element. Thus, it is possible to operate DC loads directly from an AC power source, often eliminating the need for separate bulky and expensive DC power sources.

When SCR latching action is desired, DC anode supply is commonly employed. Here, however, reset can be a problem, since "brute force" reset techniques must normally be used. This involves an additional switching element, to either open or shunt the load voltage, and current from the SCR.

The circuit of Figure 1 retains the advantages of operating loads directly from an AC power source. Latching action is provided with no need for brute force reset techniques. The DC source needs to provide only a few milliamps of SCR holding current, since load power is drawn from the AC source.

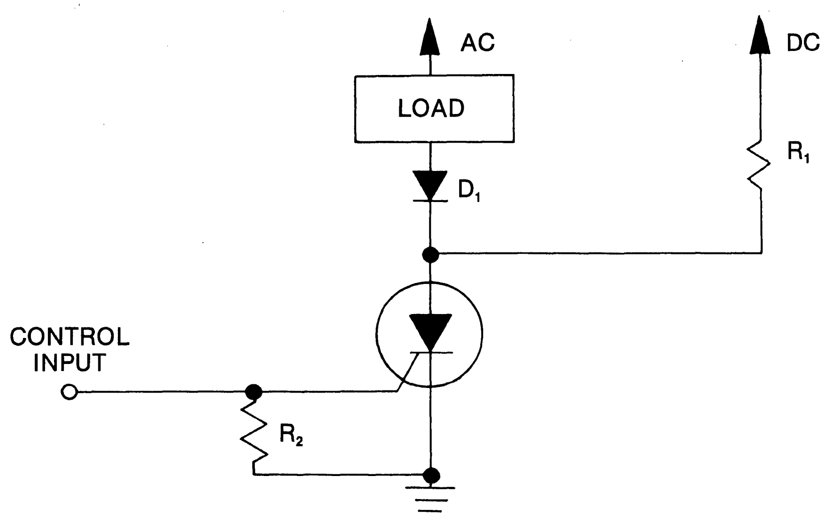

FIGURE 1

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When the SCR is on, a half-wave rectified voltage waveform is applied to the load. During each positive half-cycle of the AC source, diode (or rectifier) D_1 and the SCR conduct the load current as well as the DC holding current provided through R_1. During each negative half-cycle, D_1 blocks the negative voltage from the AC supply, allowing the SCR to remain in conduction. Resistive loads such as heaters and incandescent lamps are driven satisfactorily with the half-wave rectified output of this circuit. DC loads that are less tolerant of this waveform can easily be operated by using shunt capacitors or other filtering methods. Shunt free-wheeling diodes should be employed across inductive loads.

Reset is simply accomplished by interrupting the holding current provided from the DC supply through R_1. The reset interval must, of course, be longer than one half-cycle of the AC line frequency, or it must be timed to occur during the negative half-cycle, since load current will keep the SCR latched on during the entire positive half-cycle. The reset interval must exceed the device gate recovery time which ranges from less than 0.5 μs for the higher speed SCRs to 50 μs for the slower SCRs.

The DC supply voltage level is not critical and can be less than equal to, or greater than the peak AC supply voltage. When it is less than the peak AC, however, D_1 will conduct for a portion of each half-cycle when the SCR is off, causing a current pulse to flow from the AC to the DC supply through R_1.

D_1 must have a blocking voltage capability greater than the sum of the peak AC voltage plus the DC supply voltage. The SCR voltage rating must be at least equal to the peak AC *or* DC supply voltage, whichever of these is greater.

When many identical or similar circuits are used in a single system (as in a band of SCR incandescent lamp drivers), multiple reset is easily accomplished by simultaneously interrupting the DC source and resetting all circuits connected to that source.

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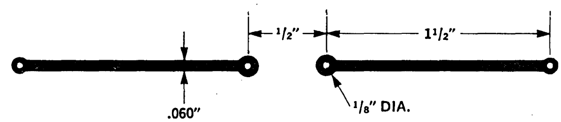
THERMAL DESIGN CONSIDERATIONS FOR LEADED DEVICES

For Lead Mounted Rectifiers and Zeners, for 5 types of mounting.

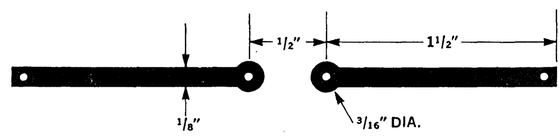
Determining The Power Rating for Your Application.
The information given in this section is presented for straight-forward use by the designer. The value given in this table is $R_{\Theta JA}$, the "Total" thermal resistance of the diode and mounting together; no other graphs or tables are needed.

$$P_{max} = \frac{T_{Jmax} - T_{Amax}}{R_{\Theta JA}}$$

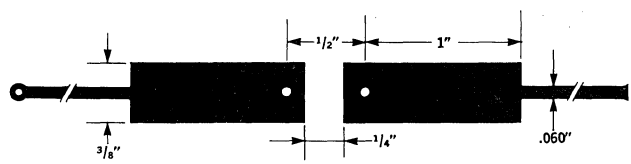
Where: P_{max} is the maximum power that can be dissipated in the device reliably. T_{Jmax} is the maximum of the operating temperature range, usually 175°C, unless derated for a military or hi rel application.
T_{Amax} is the max temp that the ambient reference (air below the device) will reach during operation.
Alternately,
Junction Temp Rise $= PR_{\Theta JA}$



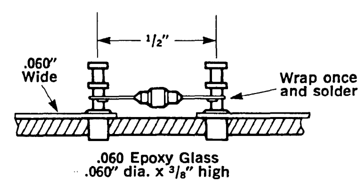
TYPE 1 PC BOARD, LIGHT



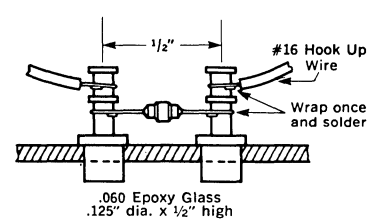
TYPE 2 PC BOARD, MEDIUM



TYPE 3 PC BOARD, HEAVY



TYPE 4 PC BOARD WITH CHESSMEN TERMINALS



TYPE 5 TERMINALS AND HOOK-UP WIRES

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$R_{\theta JA}$
Total Thermal Resistance in Degrees C/Watt

Type	Mounting Type 1	2	3	4	5
1N3611-3614	105	92	75	97	65
1N4245-4249	105	92	75	97	65
1N4461-4489	105	92	75	97	65
1N4736-4764	140	127	110	132	100
1N4942-4946	98	85	68	90	58
1N4954-4996	75	62	45	67	35
1N5063-5117	94	81	64	86	54
1N5186-5189	75	62	45	67	35
1N5186-5190	72	59	42	64	32
1N5550-5553	75	62	45	67	35
1N5614-5622	93	80	63	85	53
1N5802-5806	94	81	64	86	54
1N5807-5811	75	62	45	67	35
TVS 505-528	75	62	45	67	35
UES1101-1106	94	81	64	86	54
UES1301-1306	75	62	45	67	35
UR105-125	142	129	112	134	102
UR205-225	98	85	68	90	58
UT236-347	127	114	97	119	87
UT249-363	110	97	80	102	70
UT251-364	105	92	75	97	65
UT261-268	98	85	68	90	58
UT2005-2060	97	84	67	89	57
UT3005-3060	85	72	55	77	45
UT4005-4060	80	67	50	73	40
UTR01-61	127	114	97	119	87
UTR02-62	98	85	68	90	58
UTR10-60	176	163	146	168	136
UTR2305-2360	97	84	67	89	57
UTR3305-3360	85	72	55	77	45
UTR4305-4360	80	67	50	72	40
UTX105-125	142	129	112	134	102
UTX205-225	98	85	68	90	58
UTX3105-3120	85	72	55	77	45
UTX4105-4120	80	67	50	72	40
UZ706-140	94	81	64	86	54
UZ4706-4120	75	62	45	67	35
UZ5706-5140	75	62	45	67	35
UZ7706L-7710L	73	60	43	65	33
UZ8706-8120	140	127	110	132	100
UZS 306-440	94	81	64	86	54

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DESIGN NOTE DN-13

TURN-OFF METHOD FOR SCRs MINIMIZES EFFECT OF DV/DT

SCRs can be turned off by reducing the magnitude of the anode current to a level below that of the holding current, either by opening the anode circuit or by driving the anode negative. Forward blocking voltage cannot be reapplied until after the minority carrier charge stored in the device as a result of previous forward conduction has been dissipated to a level that can be controlled by the gate bias, otherwise the SCR will self-trigger on again.

In addition, even after the SCRs have recovered, reapplication of anode supply voltage may cause self-triggering due to dv/dt.

Self-triggering of a SCR due to dv/dt is caused by a capacitive current equal to the product of the anode-gate (C_{AG}) capacitance of the SCR and the rate of rise (dv/dt) of applied anode voltage. Sensitivity of a SCR to dv/dt effects can be controlled by the use of a gate-cathode resistor or a current bias. The SCR will self-trigger only if the capacitive current is too large to be controlled by the bias resistor. The smaller the bias resistor, the higher will be the critical rate of rise of anode voltage. However, if the anode-gate capacitance is fully charged before the supply voltage is reapplied across the SCR, the device will be immune to dv/dt effects.

A simple SCR switching circuit is shown in Figure 1. When switch S1 (which can be a relay or a transistor) is in the closed position, the SCR will fire upon the application of a gate trigger pulse of the appropriate magnitude and duration. Switch S1, when opened, will turn off the SCR. After switch S1 is opened, the anode-gate capacitance will charge through the load resistor and the 100K between gate and ground. When the SCR has recovered, S1 can be closed, and no capacitive current will flow since C_{AG} is already charged to the full anode supply voltage.

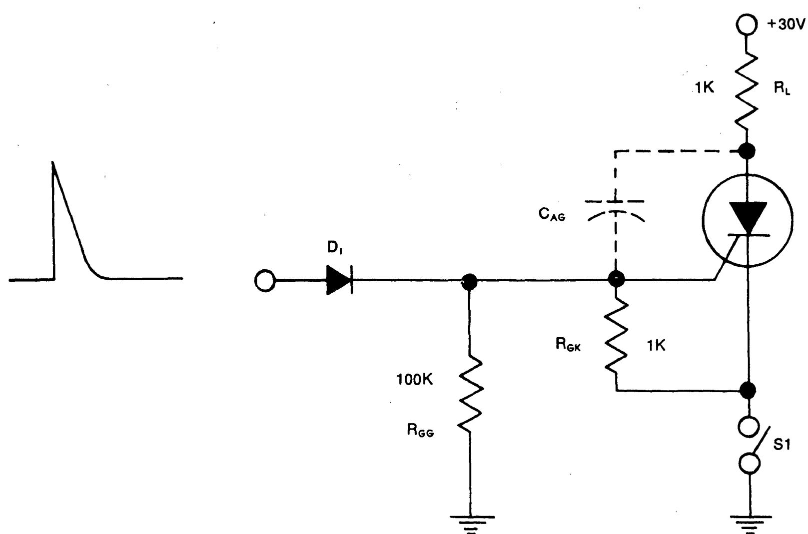

FIGURE 1

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When the cathode circuit of a conducting SCR is initially opened, a large reverse gate current can flow which may damage the gate-cathode junction of the device. Reverse gate current should be limited to 3 ma for safe operation of most SCRs. The bias resistors shown in Figure 1 accomplish this objective, while affording bias stabilization over the operating temperature range. Bias resistor R_{GK} removes all of the internally supplied gate current out through the gate terminal. Under this condition, the internal gate current cannot flow across the gate junction; the device is cut-off, and self-triggering cannot occur. If R_{GK} was connected to the ground side of the switch, when the switch opened the reverse gate current would be about 15 mA — far exceeding the maximum reverse current rating for most SCRs. R_{GG} takes over from R_{GK} when the switch is opened, limiting the reverse gate current to less than 0.3 mA. Diode D_I decouples the gate trigger source from the SCR when the cathode switch is opened. This prevents a low impedance supply from drawing excessive reverse gate current.

For the situation where the anode supply voltage may be subjected to transient pulses or voltage spikes, a small capacitor C_{GK}, connected in parallel with R_{GK} will absorb the transient charging current. If we assume C_{AG} is 100 pf then a C_{GK} of 0.002 μf will form a 20:1 voltage divider requiring a 10V pulse on the anode to result in the required 0.5V (at 25 °C) to trigger the SCR.

XV

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NANOSECOND SCR SWITCH FOR RELIABLE HIGH CURRENT PULSE GENERATORS AND MODULATORS

The design of reliable modulator and pulse generator circuitry often presents the design engineer with seemingly conflicting requirements. In order to obtain fast rise times, "hard tubes" or hydrogen thyratrons are often used. This results in a large system which consumes considerable power and has relatively low conversion efficiency. Reliability, jitter, and stability are also common problems in these systems.

To improve reliability, as well as decrease standby power consumption and improve conversion efficiency, semiconductor devices are a natural choice. However, at the voltage and current levels most often encountered in these applications, conventional semiconductors are usually too slow.

The nanosecond SCR switch developed by Unitrode allows the designer to upgrade high current, high voltage modulator and pulse generator circuitry. A single device (GA201 or GA301*) is capable of operating in circuits with supply voltages up to 100 Volts DC and pulsed load currents in excess of 50 Amperes. It can be triggered directly from logic level signals (1 Volt, 200 microamps) and exhibits a rise time of less than 10 nanoseconds to 1 Ampere with only 10 milliamps of drive signal. Single switches operated in this mode can be used as high current replacements for avalanche transistors, modulators, and harmonic wave form generators.

Special circuity has been developed to apply these nanosecond switches in applications where supply voltages exceed the forward blocking capability of a single device. The simplest of these is shown in Figure 1.

The 1 meg-ohm resistors act as a voltage-sharing network to insure that no single device is overvoltaged because of unequal leakage currents. Turn-on is accomplished by applying a trigger signal to the primary of the pulse transformer, T1. The capacitor, which has been charged to the supply voltage through R_C, discharges through R_L, and the string of SCRs. This circuit is useful until the number of stages used requires a pulse transformer that becomes objectionably bulky. Beyond that point the circuit of Figure 2 or 3 is used.

Figure 2 illustrates an approach that uses a pulse transformer to trigger only part of the string, while the rest of the devices in the string are supplied with gate drive through the zener diodes. With a supply voltage of 360 Volts DC, a 95 Volt $\pm 5\%$ zener diode across each SCR in the string prevents unequal voltage distribution. When SCR_3 and SCR_4 are triggered, 360 Volts appear across SCR_1 and SCR_2 causing zener diodes Z_1 and Z_2 to conduct. Since D_1 and D_2 are back-biased, the current must flow through the gate-to-cathode junctions of SCR_1 and SCR_2, thus driving them on. Up to eight stages can be stacked in this manner using a pulse transformer to drive only the bottom two SCRs in the string. Driving three SCRs with a pulse transformer allows stacking sixteen stages, which can switch a 1440 Volt load using a pulse transformer that needs to have a dielectric isolation rating of less than 300 Volts.

Figure 3 uses no pulse transformer and can be extended to virtually any number of stages. When SCR_1 is triggered, the cathode of SCR_2 drops from +100 to essentially 0 Volts. Capacitor C_1 discharges into the gate of SCR_2 causing it to conduct, and this process is repeated for SCR_3 and SCR_4. This circuit has the added feature of providing negative bias to the SCRs during recharge of the load in order to minimize the effect of dv/dt. As the voltage rises on the anode of SCR_4, current flows through the path consisting of C_4, R_4, C_3, R_3, C_2, R_2, etc. This provides negative bias for the gate-to-cathode junctions of the SCR in the string, making them less sensitive to dv/dt triggering. This allows the use of rapid recharge circuits which permits operation at higher repetition rates. Either resonant recharge or active (SCR) rapid recharge techniques may be used with these circuits.

*GA201 recommended for military, GA301 for commercial applications.

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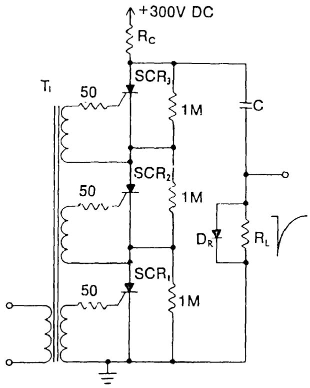

FIGURE 1

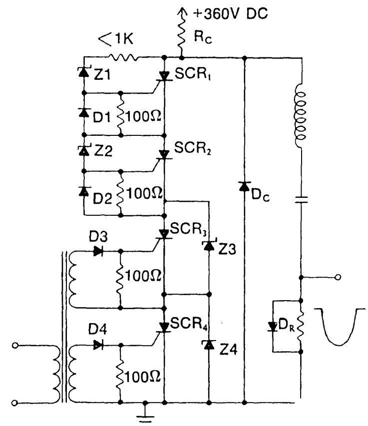

FIGURE 2

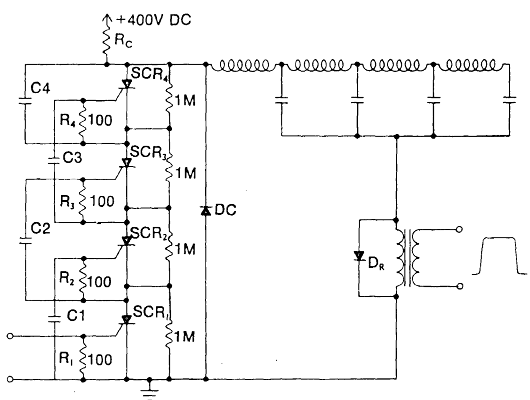

FIGURE 3

If the energy storage element(s) and load consist only of R and C components, the charging resistor must be large enough to limit the DC current to a value less than the minimum holding current of the SCRs in the string. When the load contains an inductive component, as is usually the case in modulator circuits, the network can be designed to "ring" in order to reverse-bias the SCR string momentarily, permitting the SCRs to regain their forward blocking capability even though R_C allows more than the minimum holding current to flow. Diode D_R may be used in all circuits so that the recharge current will not flow through the output element. In Figures 2 and 3, D_R shunts the reverse "ringing" current around the output element. Diode D_C must be used in circuits that contain inductive elements to protect the string from being excessively back-biased due to circuit ringing.

XV

NANOSECOND SCR FOR LASER DIODE PULSE DRIVER

The use of pulsed gallium-arsenide lasers requires a reliable high speed, high current switch to drive these devices. In the past the only solid state devices that could be used in this application were avalanche transistors and fast medium power transistors. Avalanche transistors presented reliability problems, while the standard medium power transistors available were too slow. The GA200 series "Nanosecond SCR" with a rise time capability of 10 nsec to 1 Amp or 20 nsec to 30 Amps provides a solution to both the reliability and the speed problems and appears to be ideal for this type of application.

The circuit shown in Figure 1 utilizes a GA201 device along with a lumped constant delay line to generate the desired square current pulse. For simplicity, a single capacitor could be used instead of the delay line. The delay line, however, has the advantage of producing a square pulse that provides sharp turn-off, which limits the excess power dissipation that would occur in the laser diode if the pulse fell exponentially. The impedance of the delay line ($= \sqrt{L/C}$) is chosen to produce a slight mismatch, which produces overshoot on the trailing edge of the pulse. This overshoot acts as a reverse bias on the anode of the SCR, assisting in turning it off. A typical value for the delay line impedance would be 1 to 2 ohms, which approximates the impedance of the load formed by the SCR and laser diode in series. The time duration of the pulse ($= \sqrt{L/C}$ per section) can be made as short as desired with a value of 50 to 100 nsec being typical.

With the SCR in the off state, the delay line will charge to the supply voltage (100 Volts with GA201). A gate current at the input of as little as 200 μA will trigger the SCR. The delay line will then discharge, producing a square current pulse through the gallium-arsenide laser diode. R_1 and R_{GK} are chosen so that the current, after the delay line discharges, will be less than the holding current of the GA201 (= 3 mA with R_{GK} = 100 ohms.) C_1 should be about .001μf and is necessary to prevent false triggering through noise or through dv/dt commutation. D_2 provides a charging path for the delay line, while $R_2 \cong 50K$ provides a stable ground reference. Diode D_3 insures that the reverse breakover voltage of the GA201 will not be exceeded during the turn-off period.

The forward current level will depend upon the total impedance of the GA201 and the laser diode and the charging voltage used. With a 100 Volt device and a practical minimum circuit impedance of about 1 ohm, it is possible to develop peak currents of up to 100 Amps. (See Figure 2 for Time vs Current curve for GA200/GB200 Series.) Pulse of 60 Amps with rise times of approximately 30 nsec have actually been achieved. For improved performance at high current levels, the SCRs may be operated in parallel or in series. Parallel operation is achieved by providing equal series resistors to the gates of the devices and driving them from the same source. By overdriving the gates with 50 to 100 mA, simultaneous turn-on is guaranteed. Parallel operation results in lower forward voltage drop and faster rise time at high current levels. Series stringing techniques can be used in circuits with a higher total impedance where higher voltages are needed to obtain the desired current levels. For a description of series operation see Design Note 14.

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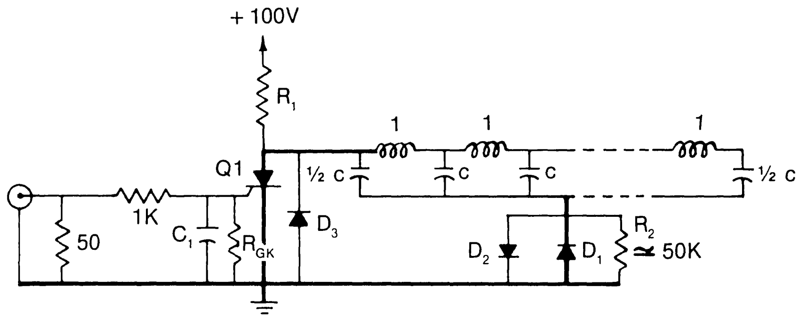


Q1—GA201/GB201, GA301/GB301

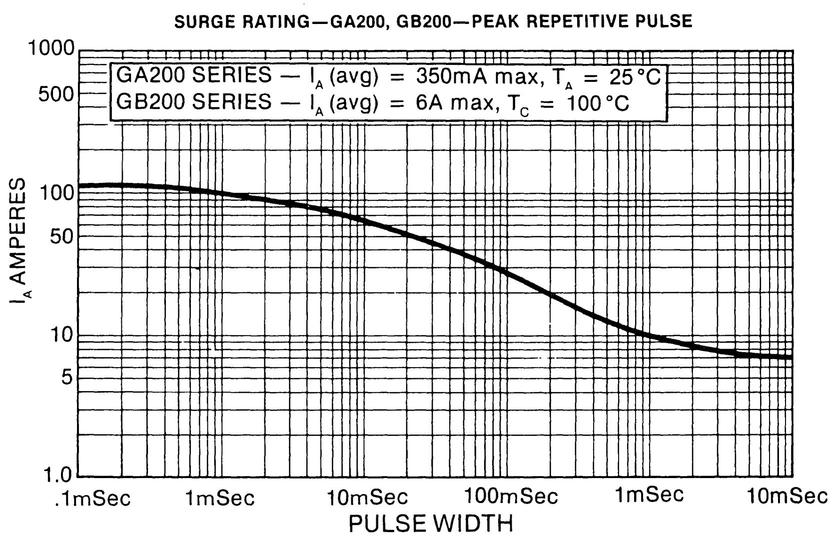
D_1 —Gallium-Arsenide Laser Diode

D_2 —JAN 1N5802 or 1N5807* (Alternative: UES1101 or UES1301)

D_3 —JAN 1N5804 or 1N5809* (Alternative: UES1102 or UES1302)

Note: Heavy lines indicate braided connections for reduced inductance and resistance.

Figure 1



Note: For MIL and high Rel series applications, use GA/GB 200/201 and JAN Diodes.

For high rep rate (high average current), use GB series with 1N5809 or UES1302 rectifiers.

GA300 and UES series are intended for commercial applications.

Figure 2

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LEAD MATERIALS

Unitrode offers a wide choice of lead materials for soldering or welding because the leads are attached to the pins outside the glass seal. Since the leads do not pass through a glass-to-metal seal, there is no need to match the thermal coefficient of expansion of the leads to the glass.

Solderable Leads — Silver plated copper meets the solderability requirements of MIL-STD 202C Method 208A.

Solid silver leads meeting the requirements of MIL-S-13282 Grade A are available on special order.

Weldable Leads — Three types are available to meet the welding requirements of MIL-STD-1276A. The pure grade A nickle leads meet the requirements of type N-1. The gold-plated nickle leads meet the requirements of type N-2. Gold-plating is in accordance with MIL-G-45204, Type 1.

The copper leads (tin-coated) are the standard lead materials. These leads meet the requirements of type C. Types N-2 and C are solderable as well as weldable.

The following table lists standard lead lengths and materials. Weights of the diodes with various leads are also shown. In the event other lead materials are required, please consult Unitrode.

Body	Material	Usage	Lead Length ins	Lead Length mm	Lead Dia ins	Lead Dia mm	Suffix Letter	Typical Weight Body Plus Leads (mg)
.030	Silver plated Copper	Solderable	1.0	25.4	.020	.51	None	—
	Silver plated dumet	Solderable or weldable	1.0	25.4	.014	.36	*	—
A .045	Silver plated Copper	Solderable	1.0	25.4	.028	.71	H	260
	Silver	Solderable	0.7	1.24	.028	.71	M	215
	Copper, tinned (standard)	Solderable or weldable	1.0	25.4	.028	.71	None	260
B .090 and C .125	Silver plated Copper	Solderable	1.0	25.4	.040	1.02	J	740
	Silver	Solderable	1.0	25.4	.040	1.02	P	740
	Copper, tinned (standard)	Solderable or weldable	1.0	25.4	.040	1.02	None	740

* Available on 1N5767 and 1N5957 only.

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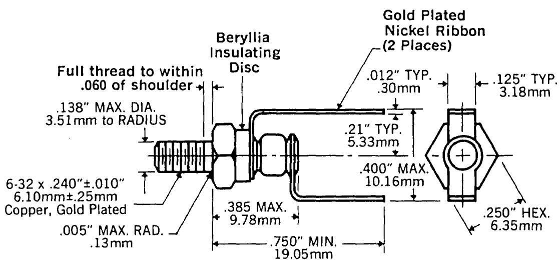
INSULATED STUD PACKAGES

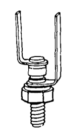
Unitrode's three stud-mounted devices, 10W high-surge zener diodes, 12A standard recovery rectifiers, and 9A fast-recovery rectifiers, are also available as shown here with insulated studs having the same high ratings as the standard non-insulated devices.

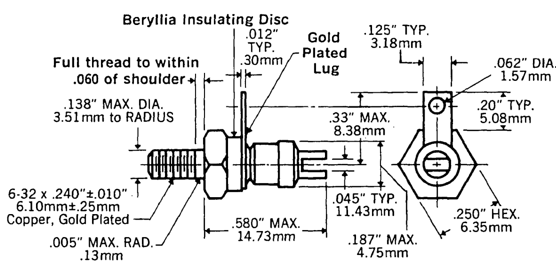
MECHANICAL SPECIFICATIONS



Dimensions in inches.

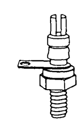
Style W





Dimensions in inches.

Style V



Part Identification: Style W: Part number printed on ribbon lead. Style V: Part number printed on body. Numerals are unique and indicate 10W Zener Series (UZ), 12A rectifier series (UT), or 9A fast-recovery rectifier series (UTR).
Polarity: Cathode to stud end.
Max. Weight: Styles W & V: 2.3 grams.
Installation Precautions: Maximum unlubricated stud torque: 36 inch-ounces.
Note: Do not use a screwdriver in turret slot for installation purposes, or damage may result.

ORDERING INFORMATION

The type numbers that apply to the standard studs also apply to the insulated studs with the addition of suffix W or V for style W or V (see outline drawings). For example, to specify insulated stud style W for a 6.8V zener, order UZ7806W; for a 50V 12A rectifier, order UT8105W; and for a 100V 9A fast-recovery rectifier, order UTR6410W.

XV

HR-201 SCREENING

Unitrode semiconductors are inherently high-reliability devices; however, some users may want the ultimate assurance of reliability. The HR-201 screening specification is intended to satisfy this need. It should be emphasized that, although these tests are not likely to stress a Unitrode device to failure, they are recommended for those applications which require extreme degrees of reliability assurance — such as man-rated space vehicles, special weapons systems, or other critical applications.
Specific screening specifications and the products to which they are applicable follow:

Product	Specification	Specification with Delta's
Rectifiers	HR201	HR201-D
Zeners	HR201Z	HR201Z-D
Surge Suppressors	HR201S	HR201S-D
Transistors	HR201T	
Switching Regulators	UL101T1 & T3*	UL101T3*
	UL102T1 & T3*	UL101T3*

*Includes lot qualification

All units are subject to 100% screening tests per above specifications as follows:

1. **Reverse Bias Operation** — Full rated PIV for rectifiers and switching regulators (80% of minimum voltage for zeners and surge suppressors; 80% of V_{CEO} for transistors) applied for 168 hours at 125°C. Temperature is then reduced to 25°C over a period of not less than one hour with full voltage maintained.
2. **Thermal Fatigue** — Ten cycles. Each cycle consists of 15 minutes at 200°C ambient, immediate transfer to —65°C ambient for 15 minutes, and immediate return to 200°C. For switching regulator temperature extremes are —55°C to 150°C.
3. **Case Integrity** — 100 p.s.i. is applied while submerged in a fluorescent dye such as Zygol ZL-1C for 30 minutes. After rinsing in clear water, the device is examined under ultraviolet light for evidence of a defective seal. For switching regulator, helium and fluorocarbon test methods are used.
4. **Power Operation**
   Rectifiers — Each rectifier is subjected to 5 seconds overload current as follows:
   2A through 0.75A rated, Body A — 5 Adc applied
   4A through 2A rated, Body B — 8 Adc applied
   12A through 7.5A rated, Body C — 8 Adc applied
   Zeners — Each zener diode is subjected to 168 hours of direct current operation in avalanche at $T_A = 25°C$ with sufficient power to raise the junction temperature to 175°C.
   Surge Suppressors — Each device is subjected to 10 pulses at the rate of one pulse per minute at 25°C at rated surge current.
   Transistors — Each device is operated at rated power at 25°C ambient for 168 hours.
   In each of above situations, the device is mounted on 1-inch center clips.
   Switching Regulators — Each device is operated in a pulse circuit at rated free air power rating for 40 hrs.
5. **Room Temperature Measurements** — All parameters are measured to ensure conformance with specification. All diodes are 100% oscilloscope-tested to ensure controlled-avalanche characteristics. Any parts exceeding specified limits or exhibiting unusual characteristics are removed from the lot.

JANTX, and JANTXV DEVICES — A number of rectifiers, zeners, transistors, and SCRs plus some rectifier assemblies and surge suppressors are available with JANTX and JANTXV screening and visual inspections. See the JAN page in the Product Selection Guide, that lists all of Unitrode's qualifications.

HIGH RELIABILITY SEMICONDUCTOR REPORT
Unitrode's High Reliability Semiconductor Report is available upon request. Device design, failure modes, environmental tests and their effects, and stress screening are all presented. A summary of failure rate data is given, as is list of major programs and systems in which Unitrode devices have been used.

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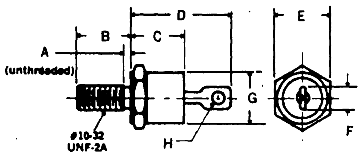
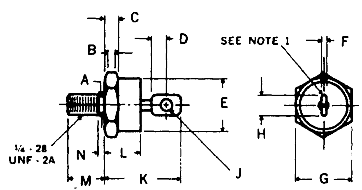
MECHANICAL SPECIFICATIONS XVI

DO-4



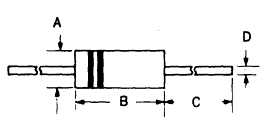
	ins.	mm.
A	.078 MAX.	1.98 MAX.
B	.437±.015	11.10±0.38
C	.405 MAX.	10.29 MAX.
D	.800 MAX.	20.32 MAX.
E	.430±.010	10.92±0.25
F	.250 MAX.	6.35 MAX.
G	.424 MAX.	10.77 MAX.
H	.066 MIN. DIA.	1.68 MIN. DIA.

DO-5



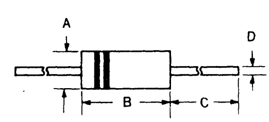
	ins.	mm.
A	.225±.005	5.72±0.13
B	.060 MIN. DIA.	1.52 MIN. DIA.
C	.156±.020	3.96±0.51
D	.156 MIN. FLAT	3.96 MIN. FLAT
E	.667 DIA. MAX.	16.94 DIA. MAX.
F	.090 MAX.	2.29 MAX.
G	.667±.010	17.20±0.25
H	.375 MAX.	9.53 MAX.
J	.140 MIN. DIA.	3.56 MIN. DIA.
K	1.000 MAX.	25.40 MAX.
L	.450 MAX.	11.43 MAX.
M	.438±.015	11.13±0.38
N	.078 MAX.	1.98 MAX.

DO-7



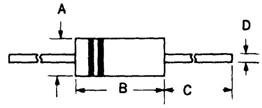
	ins.	mm.
A	.078-.107	1.98-2.72
B	.195-.300	4.95-7.62
C	1.0 MIN.	25.40 MIN.
D	.018-.022	0.46-0.56

DO-34



	INCHES	MILLIMETERS
A	.050 - .065	1.27 - 1.65
B	.080 - .120	2.03 - 3.05
C	1.0 - 1.5	25.4 - 38.1
D	.018 - .022	.46 - .56

DO-35



	ins.	mm.
A	.056-.075	1.42-1.91
B	.140-.180	3.56-4.57
C	1.0 MIN.	25.40 MIN.
D	.018-.022	0.46-0.56

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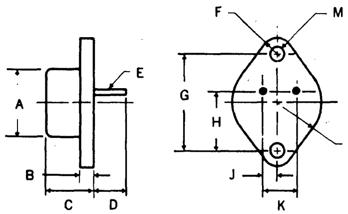
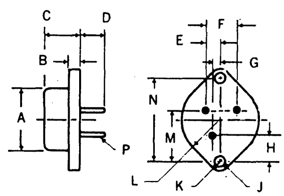
TO-3



	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.038-.043 DIA.*	0.97-1.09 DIA.*
F	.188 MAX. RAD.	4.78 MAX. RAD.
G	1.177-1.197	29.90-30.40
H	.655-.675	16.64-17.15
J	.205-.225	5.21-5.72
K	.420-.440	10.67-11.18
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.151-.161 DIA.	3.84-4.09 DIA.

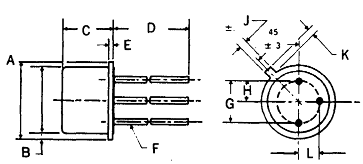
*TO-3 Modified: E = .057"-.063" (1.45mm-1.60mm)

TO-3 (3 PIN)



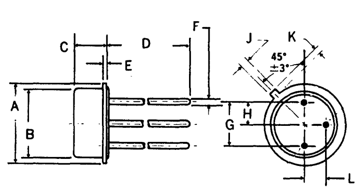
	ins.	mm.
A	.875 MAX.	22.23 MAX.
B	.135 MAX.	3.43 MAX.
C	.250-.450	6.35-11.43
D	.312 MIN.	7.92 MIN.
E	.205-.225	5.21-5.72
F	.420-.440	10.67-11.18
G	.145-.165	3.68-4.19
H	.395-.405	10.03-10.29
J	.151-.161 DIA.	3.84-4.09 DIA.
K	.188 MAX. RAD.	4.78 MAX. RAD.
L	.525 MAX. RAD.	13.34 MAX. RAD.
M	.708-.728	17.98-18.49
N	1.177-1.197	29.90-30.40
P	.038-.043 DIA.	0.97-1.09 DIA.

TO-5



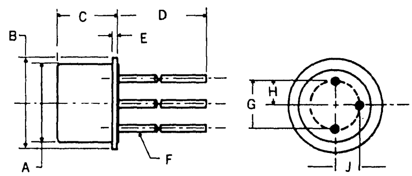
	ins.	mm.
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.240-.260	6.09-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	$.017 \pm {}^{.002}_{.001}$	$.432 \pm {}^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

Pancake TO-5



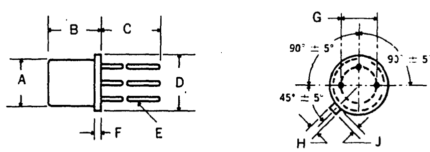
	ins.	mm.
A	.335-.370	8.51-9.40
B	.305-.335	7.75-8.51
C	.165-.185	4.19-4.70
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.254-.762
F	$.017 \pm {}^{.002}_{.001}$	$.432 \pm {}^{.051}_{.025}$
G	.200	5.08
H	.100	2.54
J	.031±.003	.787±.076
K	.029-.045	.736-1.14
L	.100	2.54

TO-9



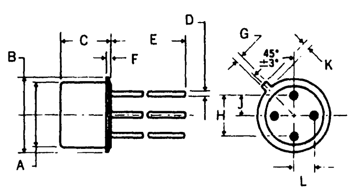
	ins.	mm
A	.275-.335	6.99-7.75
B	.290-.370	7.37-9.40
C	.200-.260	5.08-6.60
D	1.5 MIN.	38.10 MIN.
E	.010-.030	.25-.76
F	.017 ± .002/.001	.432± .051/.025
G	.200	5.08
H	.100	2.54
J	.100	2.54

TO-18



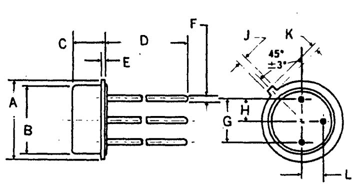
	INCHES	MILLIMETERS
A	.178-.195 DIA.	4.52-4.95 DIA.
B	.170-.210	4.31-5.33
C	.5 MIN.	12.70 MIN.
D	.209-.230 DIA.	5.31-5.84 DIA.
E	.017 ± .002 DIA./.001 DIA.	.432 ± .051/.025
F	.020 MAX.	.508 MAX.
G	.100±.010 DIA.	2.54±.254 DIA.
H	.041±.005	1.04±.127
J	.028-.048	.711-1.22

TO-33



	ins.	mm
A	.305-.335	7.75-8.51
B	.335-.370	8.51-9.40
C	.240-.260	6.10-6.60
D	.017 ± .002/.001	0.43 ± .05/.03
E	1.5 MIN.	38.10 MIN.
F	.018 MAX.	0.46 MAX.
G	.031 ± .003	0.79 ± .08
H	.200	1.02
J	.100	2.54
K	.029-.045	0.74-1.14
L	.100	2.54

TO-39

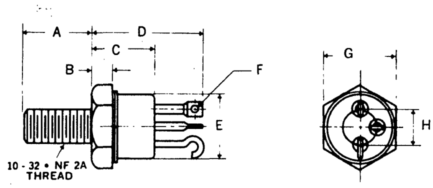


	ins.	mm.
A	.350-.370	8.89-9.39
B	.315-.335	8.00-8.51
C	.240-.260	6.35-6.60
D	.010-.030	.25-.76
E	.5 MIN.	12.70 MIN.
F	.017 ± .002/.001	.432 ± .051/.025
G	.200	5.08
H	.100	2.54
J	.031±.003	.79±.08
K	.029-.045	.74-1.14
L	.100	2.54

XVI

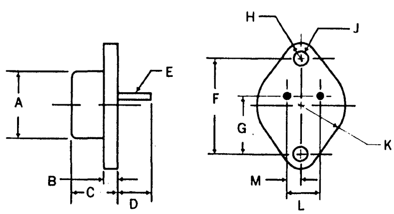
MECHANICAL SPECIFICATIONS

TO-59



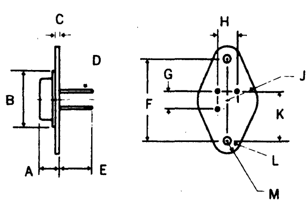
	INCHES	MILLIMETERS
A	.400-.455	10.16-11.56
B	.090-.150	2.28-3.81
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.318-.380	8.07-9.65
F	$.055 \pm {}^{.010}_{.015}$	$1.40 \pm {}^{.254}_{.381}$
G	.424-.437	10.77-11.10
H	.185-.215	4.70-5.46

TO-66



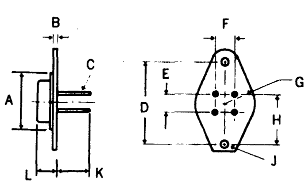
	ins.	mm.
A	.620 MAX.	15.75 MAX.
B	.050-.075	1.27-1.90
C	.250-.340	6.35-8.63
D	.360 MIN.	9.14 MIN.
E	.028-.034 DIA.	.711-0.863
F	.958-.962	24.33-24.43
G	.570-.590	14.47-14.98
H	.145 MAX. RAD.	3.68 MAX. RAD.
J	.142-.152 DIA.	3.60-.386 DIA.
K	.350 MAX. RAD.	8.89 MAX. RAD.
L	.190-.210	4.82-5.33
M	.093-.107	2.36-2.72

TO-66 (3 PIN)



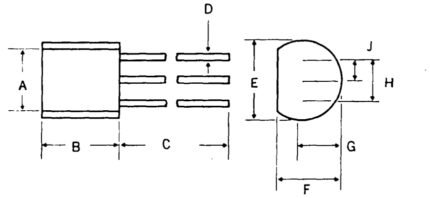
	ins.	mm.
A	.250-.340	6.35-8.64
B	.620 MAX.	15.75 MAX.
C	.050-.075	1.27-1.91
D	.028-.034	0.71-0.86
E	.360 MIN.	9.14 MIN.
F	.958-.962	24.33-24.43
G	.190-.210	4.83-5.33
H	.190-.210	4.83-5.33
J	.350 MAX. RAD.	8.89 MAX. RAD.
K	.570-.590	14.48-14.99
L	.142-.152	3.61-3.86
M	.145 MAX. RAD.	3.68 MAX. RAD.

TO-66 (4 PIN)



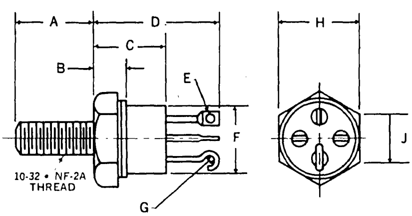
	ins.	mm.
A	.620 MAX.	15.75 MAX.
B	.050-.075	1.27-1.91
C	.028-.034	0.71-0.86
D	.958-.962	24.33-24.43
E	.190-.210	4.82-5.33
F	.190-.210	4.82-5.33
G	.350 MAX. RAD.	8.89 MAX. RAD.
H	.570-.590	14.48-14.99
J	.142-.152 DIA.	3.61-3.86 DIA.
K	.360 MIN.	9.14 MIN.
L	.250-.340	6.35-8.64

TO-92



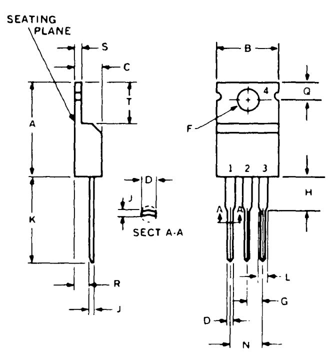
	ins.	mm.
A	.135 MIN.	3.42 MIN.
B	.170-.210	4.31-5.33
C	.500 MIN.	12.70 MIN.
D	.016-.019	.406-.482
E	.175-.205	4.44-5.21
F	.125-.165	3.17-4.19
G	.080-.105	2.03-2.66
H	.095-.105	2.41-2.66
J	.045-.055	1.14-1.40

TO-111



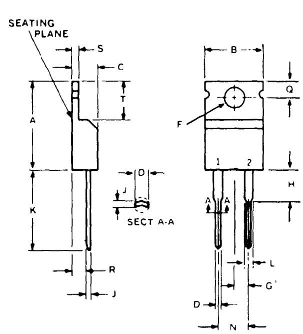
	ins.	mm.
A	.400-.455	10.16-11.55
B	.090-.250	2.28-6.35
C	.320-.468	8.13-11.88
D	.570-.763	14.48-19.38
E	.065-.090	1.65-2.28
F	.313-.318	7.95-8.07
G	.070-.090	1.77-2.28
H	.423-.438	10.74-11.12
J	.135-.215	3.43-5.46

TO-220AB



	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9 66	10.66	0.380	0.420
C	3 56	4.82	0.140	0.190
D	0 51	1.14	0.020	0.045
F	3.531	3 733	0 139	0.147
G	2 29	2.79	0.090	0.110
H	—	6 35	—	0.250
J	0.38	0.64	0 015	0.025
K	12 70	14 27	0 500	0.562
L	1 14	1.77	0 045	0 070
N	4 83	5 33	0 190	0 210
Q	2.54	3.04	0 100	0.120
R	2.04	2.92	0 080	0.115
S	1.14	1.39	0 045	0 055
T	5 85	6.85	0.230	0.270

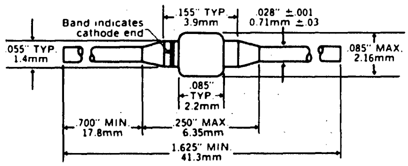
SIMILAR TO-220



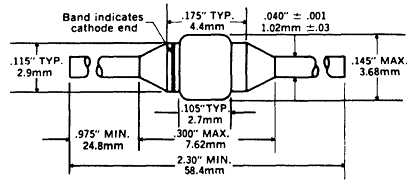
	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	14.23	15.87	0.560	0.625
B	9.66	10.66	0.380	0.420
C	3.56	4.82	0.140	0.190
D	0.51	1.14	0.020	0.045
F	3.531	3.733	0.139	0.147
G	2.29	2.79	0.090	0.110
H	—	6.35	—	0.250
J	0.38	0.64	0.015	0.025
K	12.70	14.27	0.500	0.562
L	1.14	1.77	0.045	0.070
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.92	0.080	0.115
S	1.14	1.39	0.045	0.055
T	5.85	6.85	0.230	0.270

MECHANICAL SPECIFICATIONS

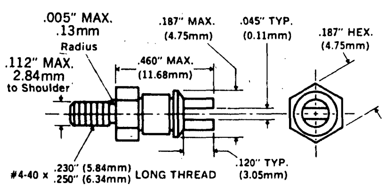
A



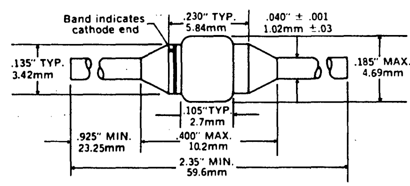
B



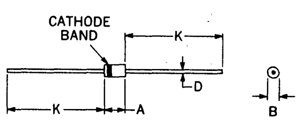
C



CL

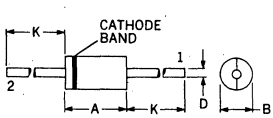


ASA



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.160	0.260	4.06	6.60
B	0.110	0.120	2.79	3.05
D	0.030	0.034	0.76	0.86
K	1.100	—	27.94	—

ASB



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.370	0.380	9.40	9.65
B	0.190	0.210	4.83	5.33
D	0.048	0.052	1.22	1.32
K	1.062	1.072	26.97	27.23

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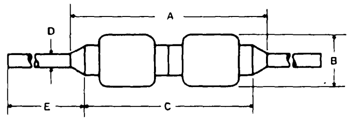
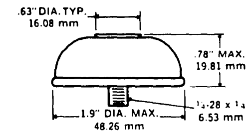
AA, BB, CCL

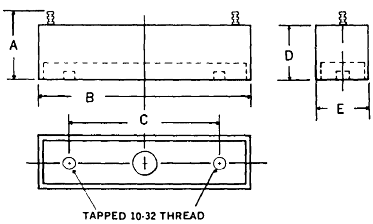


	AA ins.	AA mm.	BB ins.	BB mm.	CCL ins.	CCL mm.
A	450 MAX.	11.43 MAX	500 MAX.	12 70 MAX	600 MAX	15 24 MAX
B	.085 MAX.	2.16 MAX.	.145 MAX.	3 68 MAX.	185 MAX	4.70 MAX
C	275 TYP.	6.99 TYP.	.325 TYP.	8.26 TYP.	430 TYP	10 92 TYP
D	.028± 001	0.71±0 03	040± 001	1 02±0 03	040± 001	1 02±0 03
E	700 MIN	17.78 MIN.	.975 MIN.	24 77 MIN	.925 MIN.	23 50 MIN

DD

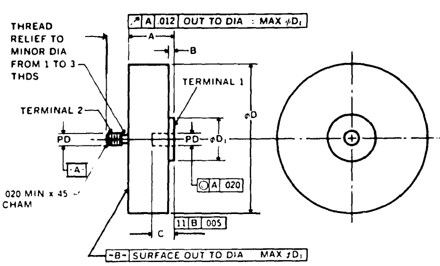


BE



	ins.	mm.
A	1.140 MAX.	28.96 MAX.
B	2.985-3.015	75.82-76.58
C	2.110-2.140	53.59-54.36
D	.740-.770	18.80-19.56
E	.720-.750	18.29-19.05

DE, DF



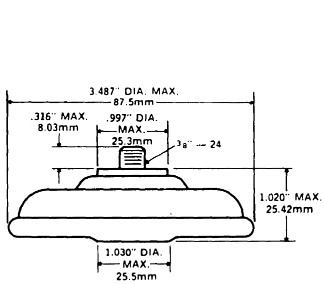
DE

Ltr	Dimensions in inches with metric equivalents (mm) in parentheses		NOTES
	Minimum	Maximum	
A	.73 (18.54)	.83 (21.08)	8
B		.080 (2.03)	
C	.240 (6.10)	.264 (6.71)	2,6
C_1	.265 (6.73)	.400 (10.16)	4
ϕD	1.85 (46.99)	1.95 (49.53)	
ϕD_1	.57 (14.48)	.67 (17.02)	

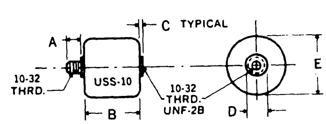
DF

Ltr	Dimensions in inches with metric equivalents (mm) in parentheses		NOTES
	Minimum	Maximum	
A	.970 (24.64)	1.020 (25.91)	8
B	.050 (1.27)	.080 (2.03)	
C	.307 (7.80)	.317 (8.05)	3
C_1	.318 (8.08)	.400 (10.16)	5,7
ϕD	3.450 (87.63)	3.650 (92.71)	
ϕD_1	.95 (24.13)	1.250 (31.75)	

DG



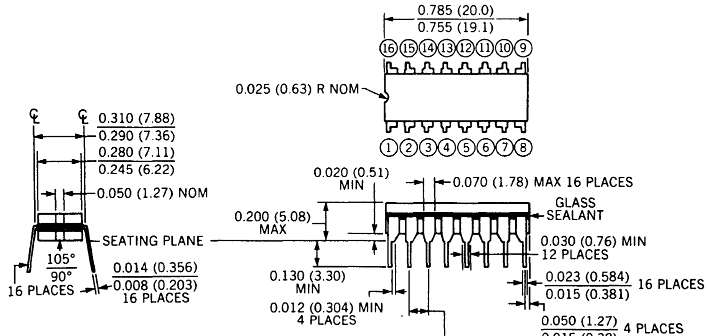
DH



	ins.	mm.
A	.230-.235	5.84-5.97
B	.980-1.10	24.89-27.94
C	.020-.040	0.51-1.02
D	.320-.330	8.13-8.38
E	.97-1.00	24.64-25.40

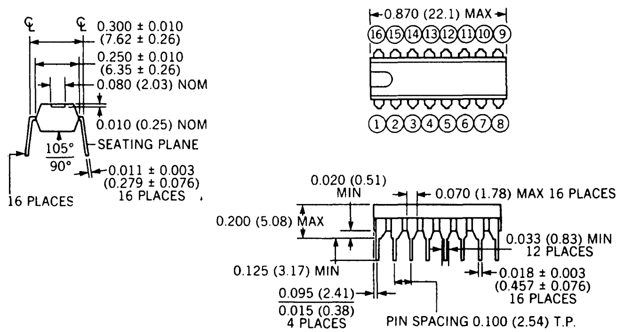
XVI

DIL-16 (J)



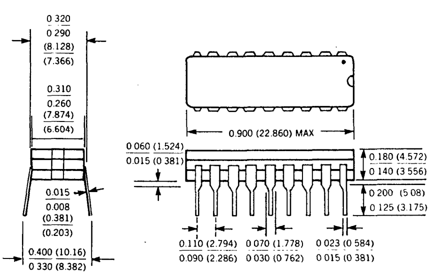
Dimensions in inches and (millimeters)

DIL-16 (N)

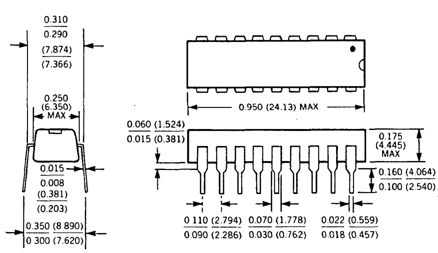


Dimensions in inches and (millimeters)

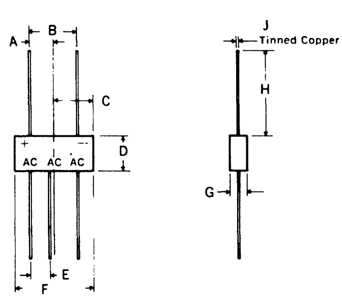
DIL-18 (J)



DIL-18 (N)



F



	ins.	mm.
A	.310	7.87
B	.621	15.77
C	.512 REF.	13.0 REF.
D	.460 MAX.	11.68 MAX.
E	.255	6.48
F	1.030 MAX.	26.16 MAX.
G	.220 MAX.	5.59 MAX.
H	.875	22.23
J	.028 DIA.	0.71 DIA.

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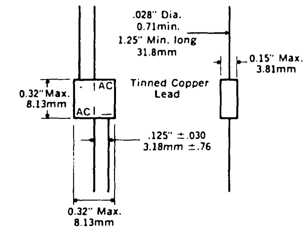
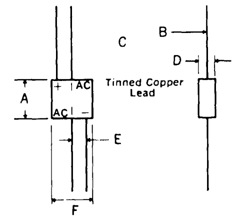
G

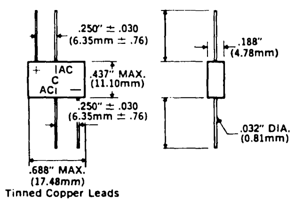


GA

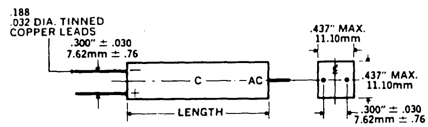


	ins.	mm.
A	0.50±.01	12.70±.25
B	.032 DIA	0.81 DIA.
C	1.0 MIN.	25.4 MIN.
D	.250 MAX	6.35 MAX.
E	.150 TYP.	3.81 TYP.
F	0.50±.01	12.70±.25

GH



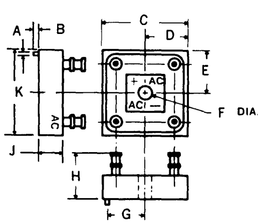
HJ, HK, HL, HM, HN, HO, HP



MAX. LENGTHS

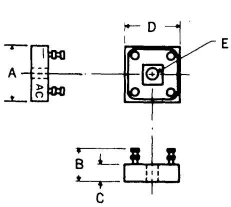
J	K	L	M	N	O	P
.562" 14.27mm	.688" 17.48mm	.875" 22.23mm	1.125" 28.58mm	1.25" 31.75mm	1.375" 34.92mm	1.625" 41.28mm

MA



	ins.	mm.
A	.056-.066	1.42-1.68
B	.052-.072	1.32-1.83
C	1.115-1.135	28.32-28.83
D	.552-.572	14.02-14.53
E	.552-.572	14.02-14.53
F	.180-.200 DIA.	4.57-5.08 DIA.
G	.490-.510	12.45-12.95
H	.750 MAX.	19.05 MAX.
J	.302-.322	7.67-8.18
K	1.115-1.135	28.32-28.83

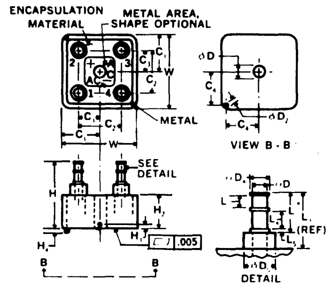
MB



	ins.	mm.
A	.735-.755	18.67-19.18
B	.570 MAX.	14.48 MAX.
C	.226-.246	5.74-6.25
D	.735-.755	18.67-19.18
E	.130-.150 DIA.	3.30-3.81

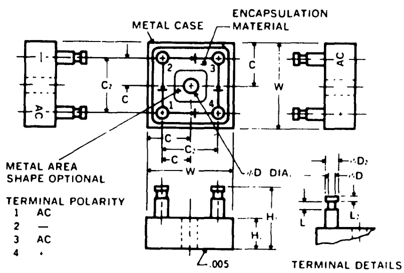
XVI

MC



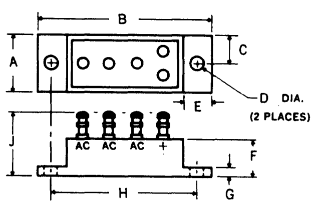
Ltr	Dimensions			
	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
C_1	.552	.572	14.02	14.53
C_2	.624	.760	15.85	19.30
C_3	.312	.380	7.92	9.65
C_4	.495	.512	12.57	13.00
ϕD_1	.189	.195	4.80	4.95
ϕD_2	.057	.067	1.45	1.70
ϕD_3	.108	.118	2.74	3.00
ϕD_4	.141	.151	3.58	3.84
ϕD_5	.225	.235	5.72	5.97
H_1	.669	1.060	17.53	26.92
H_2	.300	.500	7.62	12.70
H_3	.040	.060	1.02	1.52
H_4	.042	.062	1.07	1.57
L_1	.370	.560	9.40	14.22
L_2	.307	.365	7.80	9.27
L_3	.089	.099	2.26	2.49
L_4	.132	.142	3.35	3.61
L_5	.026	.036	.66	.91
W	1.104	1.144	28.04	29.06

MD



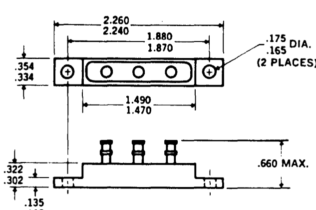
Ltr	Dimensions			
	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
C_1	.367	.375	9.32	9.53
C_2	.350	.450	8.89	11.43
C_3	.175	.225	4.45	5.72
ϕD_1	.139	.149	3.53	3.78
ϕD_2	.091	.101	2.31	2.57
ϕD_3	.066	.076	1.68	1.93
H_1		.570		14.48
H_2		.370		9.40
L_1	.088	.098	2.24	2.49
L_2	.020	.030	.51	.76
W	.735	.750	18.67	19.05

ME

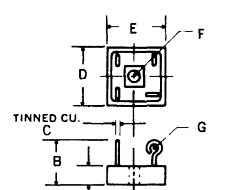


	ins.	mm.
A	.740-.760	18.80-19.30
B	2.240-2.260	56.90-57.40
C	.365-.385	9.27-9.78
D	.164-.174 DIA.	4.17-4.42 DIA.
E	.370-.390	9.40-9.91
F	.486-.506	12.34-12.85
G	.115-.135	2.92-3.43
H	1.870-1.880	47.50-47.75
J	.820 MAX.	20.83 MAX.

MF



NA



Typical Weight
10 grams

	ins.	mm.
A	.240 MAX.	6.10 MAX.
B	.57 MAX.	14.45 MAX.
C	.040 TYP.	1.02 TYP.
D	.750 MAX.	19.05 MAX.
E	.750 MAX.	19.05 MAX.
F	.140 DIA.	3.56 DIA.
G	.09 DIA. TYP.	2.29 DIA. TYP.

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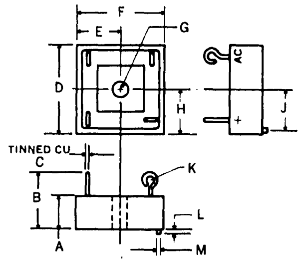
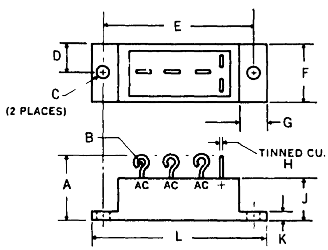
NB



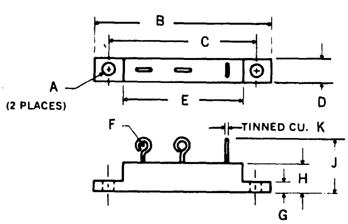
	Ins.	mm.
A	.328 MAX.	8.33 MAX.
B	.750 MAX.	19.05 MAX.
C	.040 TYP.	1.02 TYP.
D	1.125 MAX.	28.58 MAX.
E	.562	14.27
F	1.125 MAX.	28.58 MAX.
G	.193	4.90
H	.562	14.27
J	.500	12.70
K	.09 DIA. TYP.	2.29 DIA. TYP.
L	.062	1.57
M	.062	1.57

NC



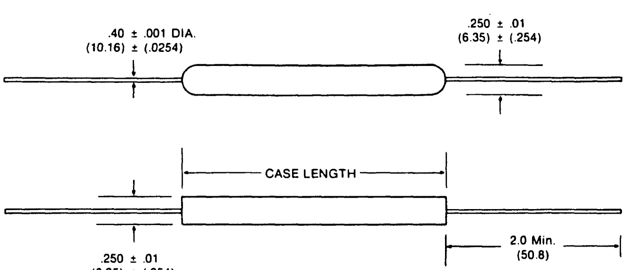
	Ins.	mm.
A	.820 MAX.	20.83 MAX.
B	.09 DIA. TYP.	2.29 DIA. TYP.
C	.164-.174 DIA.	4.17-4.42 DIA.
D	.365-.385	9.27-9.78
E	1.870-1.880	47.50-47.75
F	.740-.760	18.80-19.30
G	.370-.390	9.40-9.91
H	.040 TYP.	1.02 TYP
J	.486-.506	12.34-12.85
K	.115-.135	2.92-3.43
L	2.240-2.260	56.90-57.40

ND



	Ins.	mm.
A	.165-.175 DIA.	4.19-4.45 DIA.
B	2.240-2.260	56.90-57.40
C	1.870-1.880	47.50-47.75
D	.334-.354	8.48-8.99
E	1.480-1.490	37.59-37.85
F	.09 DIA. TYP.	2.29 DIA. TYP.
G	.115-.135	2.29-3.43
H	.302-.322	7.67-8.18
J	.660 MAX.	16.76 MAX.
K	.040 TYP.	1.02 TYP.

PA



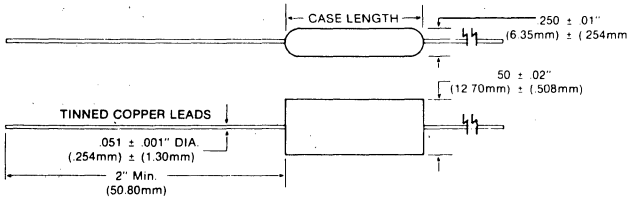
CASE LENGTH	
Ins.	MM
1.5 ± .02	38.1 ± .508
2.0 ± .02	50.8 ± .508
2.5 ± .02	63.5 ± .508
3.0 ± .02	76.2 ± .508
3.5 ± .02	88.9 ± .508

Dimensions in inches and (millimeters)

XVI

MECHANICAL SPECIFICATIONS

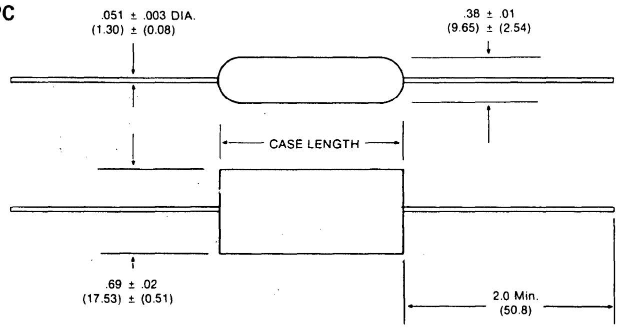
PB



CASE LENGTH	
Ins.	MM
1.125 ± .02	28.58 ± .508
1.625 ± .02	41.28 ± .508
2.000 ± .02	50.80 ± .508
2.375 ± .02	60.33 ± .508
2.750 ± .02	69.80 ± .508
3.500 ± .02	88.90 ± .508
4.250 ± .02	107.95 ± .508

Dimensions in inches and (millimeters)

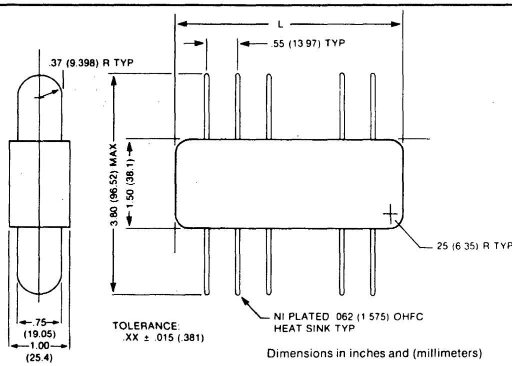
PC



CASE LENGTH	
Ins.	MM
1.5 ± .03	38.10 ± 0.76
2.5 ± .03	63.50 ± 0.76
3.5 ± .03	88.90 ± 0.76
4.5 ± .03	114.30 ± 0.76
5.5 ± .03	139.70 ± 0.76
6.5 ± .03	165.10 ± 0.76

Dimensions in inches and (millimeters)

PMA

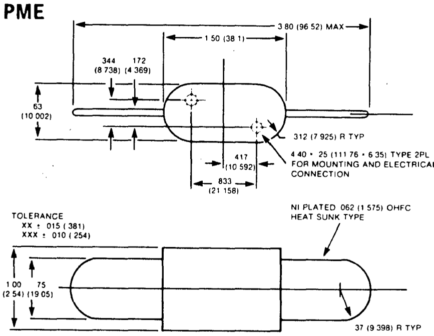


Dimensions in inches and (millimeters)

CASE LENGTH	
Ins.	MM
1.65 ± .030	41.91 ± 0.76
2.20 ± .030	55.88 ± 0.76
2.75 ± .030	69.85 ± 0.76
3.85 ± .030	97.79 ± 0.76
4.95 ± .030	125.73 ± 0.76
6.05 ± .030	153.67 ± 0.76
7.15 ± .030	181.61 ± 0.76
8.25 ± .030	209.55 ± 0.76
9.35 ± .030	237.49 ± 0.76
10.45 ± .030	265.43 ± 0.76
11.55 ± .030	293.37 ± 0.76
13.75 ± .030	349.25 ± 0.76

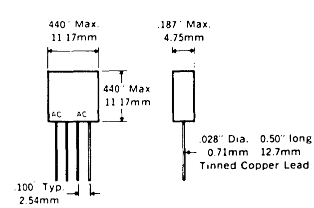
For mounting and electrical spacing, refer to individual data sheets.

PME



Dimensions in inches and (millimeters)

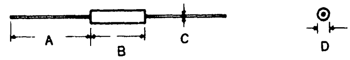
S



SA

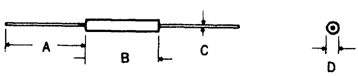
	ins.	mm.
A	.75 MIN.	19.05 MIN.
B	.50 MAX.	12.70 MAX.
C	.028 DIA.	.71 DIA.
D	.187 MAX.	4.75 MAX.

SB



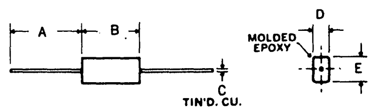
	ins.	mm.
A	1.25 MIN.	31.75 MIN.
B	0.85 MAX.	21.59 MAX.
C	.032 DIA.	.81 DIA.
D	.187 MAX.	4.75 MAX.

SC



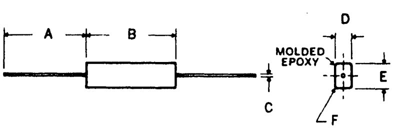
	ins.	mm.
A	1.25 MIN.	31.75 MIN.
B	1.125 MAX.	28.58 MAX.
C	.032 DIA.	.81 DIA.
D	.187 MAX.	4.75 MAX.

SD



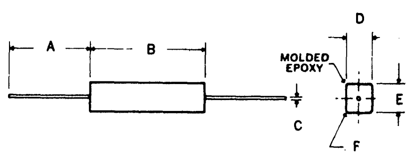
	ins.	mm.
A	1.25 MIN.	31.75 MIN.
B	.875 MAX.	22.23 MAX.
C	.032 DIA.	.81 DIA.
D	.250 MAX.	6.35 MAX.
E	.375 MAX.	9.53 MAX.

SE



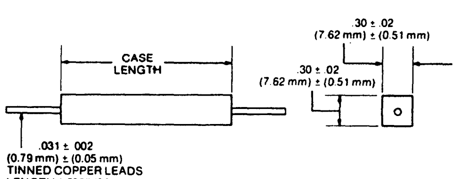
	ins.	mm.
A	1.25 MIN.	31.75 MIN.
B	1.375 MAX.	34.93 MAX.
C	.032 DIA.	.81 DIA.
D	.250 MAX.	6.35 MAX.
E	.375 MAX.	9.53 MAX.
D	.078	1.98

SF



	ins.	mm.
A	1.25 MIN.	31.75 MIN.
B	1.75 MAX.	44.45 MAX.
C	.032 DIA.	.81 DIA.
D	.400 MAX.	10.16 MAX.
E	.400 MAX.	10.16 MAX.
D	.078	1.98 MAX.

SP



CASE LENGTH	
Ins.	MM
1.50 ± .03	38.1 ± 0.76
2.00 ± .03	50.8 ± 0.76
2.50 ± .03	63.5 ± 0.76

Dimensions in inches and (millimeters)

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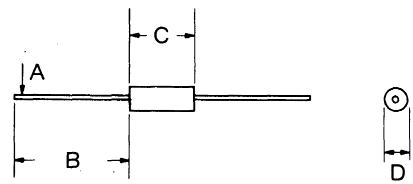
MECHANICAL SPECIFICATIONS

SG, SH, SJ, SK
SL, SM, SN

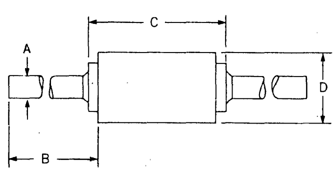


Dimensions in inches and (millimeters)

	SG		SH		SJ		SK	
	Ins.	MM	Ins.	MM	Ins.	MM	Ins.	MM
A	.020 ± .001	0.51 ± 0.03	.020 ± .001	0.51 ± 0.03	.031 ± .002	0.79 ± 0.05	.031 ± .002	0.79 ± 0.05
B	.73	18.54	.73	18.54	1.12	28.4	1.12	28.4
C	.400 ± .005	10.16 ± 0.13	.225 ± .005	5.72 ± 0.13	.410 ± .005	10.41 ± 0.13	.200 ± .005	5.08 ± 0.13
D	.125 ± .002	3.18 ± 0.05	.090 ± .002	2.29 ± 0.05	.140 ± .005	3.57 ± 0.13	.100 ± .005	2.54 ± 0.13

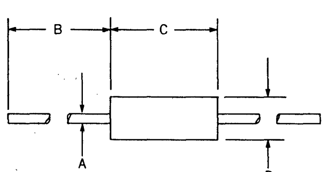
	SL		SM		SN	
	Ins.	MM	Ins.	MM	Ins.	MM
A	.040 ± .003	1.016 ± 0.76	.093 ± .003	2.36 ± 0.76	.020 ± .001	0.51 ± 0.03
B	.40	10.16	.40	10.16	.60	15.24
C	.400 ± .015	10.16 ± .381	.375 ± .015	9.52 ± .381	1.500 ± .015	38.1 ± .381
D	.300 ± .015	7.62 ± .381	.500 ± .015	12.7 ± .381	.235 ± .005	5.97 ± 0.13

TG



	INCHES	MILLIMETERS
A	.020 ± .002	.508 ± .051
B	1.0 MIN.	25.4 MIN.
C	.285 ± .015	7.239 ± .381
D	.095 ± .01	2.413 ± .254

TM



	INCHES	MILLIMETERS
A	.025 ± .003	.635 ± .076
B	1.0 MIN.	25.4 MIN.
C	.405 ± .015	10.287 ± .381
D	.14 ± .015	3.556 ± .381

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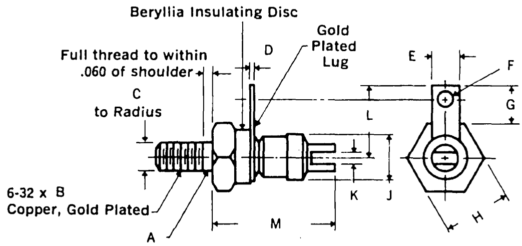
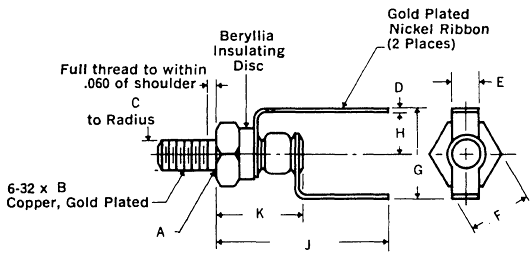


	ins.	mm.
A	.005 MAX.RAD.	.13 MAX.RAD.
B	.240±.010	6.10±.25
C	.138 MAX. DIA.	3.51 MAX. DIA.
D	.012 TYP.	.30 TYP.
E	.125 TYP.	3.18 TYP.
F	.062 DIA.	1.57 DIA.
G	.20 TYP.	5.08 TYP.
H	.250 HEX.	6.35 HEX.
J	.187 MAX.	4.75 MAX.
K	.045 TYP.	11.43 TYP.
L	.33 MAX.	.8.38 MAX.
M	.580 MAX.	14.73 MAX.

W



	ins.	mm.
A	.005 MAX.RAD.	.13 MAX.RAD.
B	.240±.010	6.10±.25
C	.138 MAX. DIA.	3.51 MAX. DIA.
D	.012 TYP.	.30 TYP.
E	.125 TYP.	3.18 TYP.
F	.250 HEX.	6.35 HEX.
G	.400 MAX.	10.16 MAX.
H	.21 TYP.	5.33 TYP.
J	.750 MIN.	19.05 MIN.
K	.385 MAX.	9.78 MAX.

LEAD MATERIALS

Unitrode offers a wide choice of lead materials for soldering or welding because the leads are attached to the pins outside the glass seal. Since the leads do not pass through a glass-to-metal seal, there is no need to match the thermal coefficient of expansion of the leads to the glass.

Solderable Leads — Silver plated copper meets the solderability requirements of MIL-STD 202C Method 208A.

Solid silver leads meeting the requirements of MIL-S-13282 Grade A are available on special order.

Weldable Leads — Three types are available to meet the welding requirements of MIL-STD-1276A. The pure grade A nickle leads meet the requirements of type N-1. The gold-plated nickle leads meet the requirements of type N-2. Gold-plating is in accordance with MIL-G-45204, Type 1.

The copper leads (tin-coated) are the standard lead materials. These leads meet the requirements of type C. Types N-2 and C are solderable as well as weldable.

The following table lists standard lead lengths and materials. Weights of the diodes with various leads are also shown. In the event other lead materials are required, please consult Unitrode.

Body	Material	Usage	Lead Length ins	Lead Length mm	Lead Dia ins	Lead Dia mm	Suffix Letter	Typical Weight Body Plus Leads (mg)
.030	Silver plated Copper	Solderable	1.0	25.4	.020	.51	None	—
	Silver plated dumet	Solderable or weldable	1.0	25.4	.014	.36	*	—
A .045	Silver plated Copper	Solderable	1.0	25.4	.028	.71	H	260
	Silver	Solderable	0.7	1.24	.028	.71	M	215
	Copper, tinned (standard)	Solderable or weldable	1.0	25.4	.028	.71	None	260
B .090 and C .125	Silver plated Copper	Solderable	1.0	25.4	.040	1.02	J	740
	Silver	Solderable	1.0	25.4	.040	1.02	P	740
	Copper, tinned (standard)	Solderable or weldable	1.0	25.4	.040	1.02	None	740

* Available on 1N5767 and 1N5957 only.

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PRINTED IN U.S.A.