The Power Semiconductor Data Book

for

Design Engineers

European Edition

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IMPORTANT NOTICES

THE POWER SEMICONDUCTOR DATA BOOK

From the earliest days of transistors, semiconductor circuit designers have needed devices capable of handling the *power* functions of their equipment.

The past twenty years in the semiconductor industry have brought extensive development of power products— germanium power transistors, silicon power transistors, thyristors, triacs, rectifiers, regulators and bridges. The future will certainly bring even further developments in power devices and functions.

Along with advancements in integrated circuit technology, improvements in power devices will aid equipment design engineers in their efforts toward continual enhancement of functional utility, cost effectiveness, and reliability of designs.

In this data book, Texas Instruments is pleased to catalogue important power semiconductor products available in the industry, and to present technical information on TI's broad line of power products.

You will find essential design information on silicon power transistors, SCR's, triacs, rectifiers, regulators and bridges. In silicon power, TI's extensive product line encompasses high-voltage as well as low-voltage, high-safe-operating-area (SOA) designs, power Darlingtons, fast switching types, radiation tolerant designs, JAN and JANTX types, and both metal can and plastic package types.

Most of the silicon power devices, as well as a broad range of SCR's and triacs, are offered in TI's specially designed plastic packages. These designs incorporate glass-passivated junctions with thermally matched epoxy and piece- parts, for high reliability—plus the adaptability for high-volume, cost-effective production.

We sincerely hope you will find this Power Semiconductor Data Book for Design Engineers a valuable addition to your technical library. It represents TI experience since the early 1950's in the design and manufacture of power semiconductor products.

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selection by current and voltage

Device Type		$I_C$cont	V_{CEO} $*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
BF457		0.2	160	25	0.03	1.0	0.03	12.5	25	SOT-32
BF458		0.2	250	25	0.03	1.0	0.03	12.5	25	SOT-32
BF459		0.2	300	25	0.03	1.0	0.03	12.5	25	SOT-32
TIP29	TIP30	1.0	40	40	0.2	0.7	1.0	30.0	25	TO-66 PLASTIC
BD135	BD136	1.0	45	40	0.15	0.5	0.5	6.5	25	SOT-32
TIP29A	TIP30A	1.0	60	40	0.2	0.7	1.0	30.0	25	TO-66 PLASTIC
BD137	BD138	1.0	60	40	0.15	0.5	0.5	6.5	25	SOT-32
TIP29B	TIP30B	1.0	80	40	0.2	0.7	1.0	30.0	25	TO-66 PLASTIC
BD139	BD140	1.0	80	40	0.15	0.5	0.5	6.5	25	SOT-32
TIC29C	TIC30C	1.0	100	40	0.2	0.7	1.0	30.0	25	TO-66 PLASTIC
2N3583		1.0	175	40	0.5	0.5	1.0	20.0	100	TO-66
TIP47		1.0	250	30	0.3	1.0	1.0	40.0	25	TO-66 PLASTIC
TIP48		1.0	300	30	0.3	1.0	1.0	40.0	25	TO-66 PLASTIC
P7029		1.0	300	30	0.05	–	–	20.0	25	SOT-32
BD410		1.0	325	30	0.05	0.5	0.1	20.0	25	SOT-32
TIP49		1.0	350	30	0.3	1.0	1.0	40.0	25	TO-66 PLASTIC
TIP50		1.0	400	30	0.3	1.0	1.0	40.0	25	TO-66 PLASTIC
TIP65		1.5	*1200	–	–	5.0	1.0	40.0	75	TO-3 PLASTIC
TIP66		1.5	*1400	–	–	5.0	1.0	40.0	75	TO-3 PLASTIC
2S721		2.0	30	20	1.0	5.0	1.0	85.0	25	TO-53
2S723		2.0	30	40	1.0	3.0	1.0	85.0	25	TO-53
BD239	BD240	2.0	45	15	1.0	0.7	1.0	30.0	25	TO-66 PLASTIC
BD633	BD634	2.0	45	25	1.0	0.6	1.0	30.0	25	TO-66 PLASTIC
2S722		2.0	60	20	1.0	5.0	1.0	85.0	25	TO-53
2S724		2.0	60	40	1.0	3.0	1.0	85.0	25	TO-53
BD239A	BD240A	2.0	60	15	1.0	0.7	1.0	30.0	25	TO-66 PLASTIC
BD635	BD636	2.0	60	25	1.0	0.6	1.0	30.0	25	TO-66 PLASTIC
†TIP110	TIP115	2.0	60	1000	1.0	2.5	2.0	50.0	25	TO-66 PLASTIC
2N5333		2.0	80	30	1.0	0.45	1.0	15.0	100	TO-5
2N4998	2N4999	2.0	80	30	1.0	0.85	2.0	20.0	100	TO-59
2N5000	2N5001	2.0	80	70	1.0	0.85	2.0	20.0	100	TO-59
2N5148	2N5147	2.0	80	30	1.0	0.85	2.0	4.0	100	TO-39
2N5150	2N5149	2.0	80	70	1.0	0.85	2.0	4.0	100	TO-39
2N5152		2.0	80	30	2.5	0.75	2.5	6.7	100	TO-39
2N5154		2.0	80	70	2.5	0.75	2.5	6.7	100	TO-39
BD239B	BD240B	2.0	80	15	1.0	0.7	1.0	30.0	25	TO-66 PLASTIC
BD637	BD638	2.0	80	25	1.0	0.6	1.0	30.0	25	TO-66 PLASTIC
†TIP111	TIP116	2.0	80	1000	1.0	2.5	2.0	50.0	25	TO-66 PLASTIC
BD239C	BD240C	2.0	100	15	1.0	0.7	1.0	30.0	25	TO-66 PLASTIC
†TIP112	TIP117	2.0	100	1000	1.0	2.5	2.0	50.0	25	TO-66 PLASTIC
TIP503		2.0	120	40	1.0	0.6	1.0	20.0	100	TO-66
TIP505		2.0	120	40	1.0	0.6	1.0	20.0	100	TO-59
TIP504		2.0	150	40	1.0	0.6	1.0	20.0	100	TO-66
TIP506		2.0	150	40	1.0	0.6	1.0	20.0	100	TO-59
	TIP507	2.0	150	30	1.0	1.5	2.0	20.0	100	TO-59
	TIP508	2.0	150	30	1.0	1.5	2.0	4.0	100	TO-39
†TIP150		2.0	200	500	1.5	2.0	1.5	65.0	25	TO-66 PLASTIC
	TIP521	2.0	200	20	1.0	2.5	2.0	20.0	100	TO-59
	TIP522	2.0	200	20	1.0	2.5	2.0	4.0	100	TO-39

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PRODUCT SELECTION GUIDE
TRANSISTORS

Device Type		$I_C$cont	V_{CEO} $*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
2N3584		2.0	250	8	1.0	0.75	1.0	20.0	100	TO-66
2N3585		2.0	300	8	1.0	0.75	1.0	20.0	100	TO-66
2N4240		2.0	300	10	0.75	1.0	0.75	20.0	100	TO-66
†TIP151		2.0	300	500	1.5	2.0	1.5	65.0	25	TO-66 PLASTIC
†TIP152		2.0	400	500	1.5	2.0	1.5	65.0	25	TO-66 PLASTIC
BUY71		2.0	*2200	–	–	10.0	1.5	40.0	25	TO-3
2N3902		2.5	400	30	1.0	0.8	1.0	67.0	100	TO-3
BU105		2.5	*1500	–	–	5.0	2.5	10.0	90	TO-3
TIP31	TIP32	3.0	40	25	1.0	1.2	3.0	30.0	25	TO-66 PLASTIC
BD241	BD242	3.0	45	10	3.0	1.2	3.0	40.0	25	TO-66 PLASTIC
TIP31A	TIP32A	3.0	60	25	1.0	1.2	3.0	30.0	25	TO-66 PLASTIC
BD241A	BD242A	3.0	60	10	3.0	1.2	3.0	40.0	25	TO-66 PLASTIC
2N3418		3.0	60	10	1.0	0.25	1.0	15.0	100	TO-5
2N3420		3.0	60	15	1.0	0.25	1.0	15.0	100	TO-5
TIP31B	TIP32B	3.0	80	25	1.0	1.2	3.0	30.0	25	TO-66 PLASTIC
BD241B	BD242B	3.0	80	10	3.0	1.2	3.0	40.0	25	TO-66 PLASTIC
2N3419		3.0	80	10	1.0	0.25	1.0	15.0	100	TO-5
2N3421		3.0	80	15	1.0	0.25	1.0	15.0	100	TO-5
TIP31C	TIP32C	3.0	100	25	1.0	1.2	3.0	30.0	25	TO-66 PLASTIC
BD241C	BD242C	3.0	100	10	3.0	1.2	3.0	40.0	25	TO-66 PLASTIC
TIP51		3.0	250	10	3.0	1.5	3.0	100.0	25	TO-3 PLASTIC
TIP529		3.0	300	25	1.5	2.5	3.0	67.0	100	TO-61
TIP530		3.0	300	25	1.5	2.5	30.0	20.0	100	TO-66
TIP52		3.0	300	10	3.0	1.5	3.0	100.0	25	TO-3 PLASTIC
TIP554		3.0	300	10	3.0	1.5	3.0	100.0	100	TO-3
TIP53		3.0	350	10	3.0	1.5	3.0	100.0	25	TO-3 PLASTIC
TIP555		3.0	350	10	3.0	1.5	3.0	100.0	100	TO-3
TIP54		3.0	400	10	3.0	1.5	3.0	100.0	25	TO-3 PLASTIC
TIP556		3.0	400	10	3.0	1.5	3.0	100.0	100	TO-3
2N5157		3.5	500	30	1.0	0.8	1.0	67.0	100	TO-3
BD733	BD734	4.0	25	50	2.0	1.1	2.0	40.0	25	TO-66 PLASTIC
BD735	BD736	4.0	35	40	2.0	1.1	2.0	40.0	25	TO-66 PLASTIC
BD737	BD738	4.0	45	40	2.0	1.1	2.0	40.0	25	TO-66 PLASTIC
TIP509		4.0	120	40	2.0	0.6	2.0	30.0	100	TO-3
TIP511		4.0	120	40	2.0	0.6	2.0	30.0	100	TO-61
TIP510		4.0	150	40	2.0	0.6	2.0	30.0	100	TO-3
TIP512		4.0	150	40	2.0	0.6	2.0	30.0	100	TO-61
BD253		4.0	200	15	1.0	2.0	3.0	50.0	25	TO-3
BD253A		4.0	250	15	1.0	2.0	3.0	50.0	25	TO-3
BD253B		4.0	300	15	1.0	2.0	3.0	50.0	25	TO-3
BD253C		4.0	400	15	1.0	2.0	3.0	50.0	25	TO-3
BD539	BD540	5.0	40	30	1.0	0.8	3.0	45.0	25	TO-66 PLASTIC
2N4913	2N4904	5.0	40	25	2.5	1.5	5.0	50.0	100	TO-3
2N5067	2N4901	5.0	40	20	1.0	1.5	5.0	87.5	25	TO-3
BD539A	BD540A	5.0	60	30	1.0	0.8	3.0	45.0	25	TO-66 PLASTIC
2N4914	2N4905	5.0	60	25	2.5	1.5	5.0	50.0	100	TO-3
2N5068	2N4902	5.0	60	20	1.0	1.5	5.0	87.5	25	TO-3
†TIP120	TIP125	5.0	60	1000	3.0	4.0	5.0	65.0	25	TO-66 PLASTIC
†TIP620	TIP625	5.0	60	1000	3.0	2.0	3.0	90.0	25	TO-3

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Device Type			V_{CEO} $^*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
2N5869	2N5867	5.0	60	20	1.5	2.0	3.0	87.5	25	TO-3
BD539B	BD540B	5.0	80	30	1.0	0.8	3.0	45.0	25	TO-66 PLASTIC
	2N5385	5.0	80	20	2.0	0.6	2.0	30.0	25	TO-111
2N5069	2N4903	5.0	80	20	1.0	1.5	5.0	87.5	25	TO-3
2N4915	2N4906	5.0	80	25	2.5	1.5	5.0	87.5	25	TO-3
2N5870	2N5868	5.0	80	20	1.5	2.0	3.0	87.5	25	TO-3
2N3996		5.0	80	40	1.0	0.25	1.0	30.0	100	TO-111
2N3997		5.0	80	80	1.0	0.25	1.0	30.0	100	TO-111
2N3998		5.0	80	40	1.0	0.25	1.0	30.0	100	TO-111
2N3999		5.0	80	80	1.0	0.25	1.0	30.0	100	TO-111
	2N5384	5.0	80	20	2.0	0.6	2.0	30.0	100	TO-111
2N5002	2N5003	5.0	80	30	2.5	0.75	2.5	33.3	100	TO-59
2N5004	2N5005	5.0	80	70	2.5	0.75	2.5	33.3	100	TO-59
	2N5151	5.0	80	70	2.5	0.75	2.5	6.7	100	TO-39
	2N5153	5.0	80	70	2.5	0.75	2.5	6.7	100	TO-39
†TIP121	TIP126	5.0	80	1000	3.0	4.0	5.0	65.0	25	TO-66 PLASTIC
†TIP621	TIP626	5.0	80	1000	3.0	2.0	3.0	90.0	25	TO-3
BD539C	BD540C	5.0	100	30	1.0	0.8	3.0	45.0	25	TO-66 PLASTIC
†TIP122	TIP127	5.0	100	1000	3.0	4.0	5.0	65.0	25	TO-66 PLASTIC
†TIP622	TIP627	5.0	100	1000	3.0	2.0	3.0	90.0	25	TO-3
BD539D	BD540D	5.0	120	30	1.0	0.8	3.0	45.0	25	TO-66 PLASTIC
	TIP513	5.0	150	30	2.5	1.0	2.5	30.0	100	TO-59
	TIP514	5.0	150	30	2.5	1.0	2.5	20.0	100	TO-66
	TIP523	5.0	200	20	2.5	1.5	2.5	30.0	100	TO-59
	TIP524	5.0	200	20	2.5	1.5	2.5	6.0	100	TO-39
TIP525		5.0	200	30	2.5	1.2	2.5	60.0	100	TO-3
TIP526		5.0	200	30	2.5	1.2	2.5	60.0	100	TO-61
†TIP160		5.0	200	500	3.0	1.5	3.0	125.0	25	TO-3 PLASTIC
†TIP161		5.0	300	500	3.0	1.5	3.0	125.0	25	TO-3 PLASTIC
†TIP162		5.0	400	500	3.0	1.5	3.0	125.0	25	TO-3 PLASTIC
2N5241		5.0	400	10	3.5	0.7	2.5	125.0	62.5	TO-3
BU108		5.0	*1500	–	–	5.0	4.5	12.5	95	TO-3
BU208		5.0	*1500	–	–	5.0	4.5	12.5	95	TO-3
BU308		5.0	*1500	–	–	5.0	4.5	12.5	95	TO-3
BDX32		5.0	*1700	–	–	5.0	3.5	40.0	25	TO-3
TIP41	TIP42	6.0	40	30	0.3	1.5	6.0	65.0	25	TO-66 PLASTIC
BD243	BD244	6.0	45	15	3.0	1.5	6.0	65.0	25	TO-66 PLASTIC
TIP41A	TIP42A	6.0	60	30	0.3	1.5	6.0	65.0	25	TO-66 PLASTIC
BD243A	BD244A	6.0	60	15	3.0	1.5	6.0	65.0	25	TO-66 PLASTIC
TIP41B	TIP42B	6.0	80	30	0.3	1.5	6.0	65.0	25	TO-66 PLASTIC
BD243B	BD244B	6.0	80	15	3.0	1.5	6.0	65.0	25	TO-66 PLASTIC
TIP41C	TIP42C	6.0	100	30	0.3	1.5	6.0	65.0	25	TO-66 PLASTIC
BD243C	BD244C	6.0	100	15	3.0	1.5	6.0	65.0	25	TO-66 PLASTIC
	TIP544	6.0	100	25	3.0	1.0	3.0	85.0	100	TO-3
2N5758		6.0	100	25	3.0	1.0	3.0	85.0	100	TO-3
	TIP545	6.0	120	20	3.0	1.0	3.0	85.0	100	TO-3
2N5759		6.0	120	20	3.0	1.0	3.0	85.0	100	TO-3
	TIP546	6.0	140	15	3.0	1.0	3.0	85.0	100	TO-3
2N5760		6.0	140	15	3.0	1.0	3.0	85.0	100	TO-3

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PRODUCT SELECTION GUIDE
TRANSISTORS

Device Type		$I_C$cont	V_{CEO} $^*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
BU126		6.0	*750	15	1.0	2.0	2.0	50.0	25	TO-3
2N5873	2N5871	7.0	60	20	2.5	2.0	5.0	115.0	25	TO-3
2N5874	2N5872	7.0	80	20	2.5	2.0	5.0	115.0	25	TO-3
2S024		7.5	32	20	2.0	0.8	2.0	100.0	25	TO-53
TI1135		7.5	50	30	2.0	1.0	2.0	50.0	100	TO-61
TI1136		7.5	50	15	2.0	1.0	2.0	50.0	100	TO-61
TI1155		7.5	50	20	5.0	2.5	5.0	50.0	100	TO-61
TI1156		7.5	50	10	5.0	2.5	5.0	50.0	100	TO-61
2S025		7.5	60	20	2.0	0.8	2.0	100.0	25	TO-53
TI1133		7.5	75	30	2.0	1.0	2.0	50.0	100	TO-61
TI1134		7.5	75	15	2.0	1.0	2.0	50.0	100	TO-61
TI1153		7.5	75	20	5.0	2.5	5.0	50.0	100	TO-61
TI1154		7.5	75	10	5.0	2.5	5.0	50.0	100	TO-61
TI1131		7.5	100	30	2.0	1.0	2.0	50.0	100	TO-61
TI1132		7.5	100	15	2.0	1.0	2.0	50.0	100	TO-61
TI1151		7.5	100	20	5.0	2.5	5.0	50.0	100	TO-61
TI1152		7.5	100	10	5.0	2.5	5.0	50.0	100	TO-61
2S026		7.5	100	20	2.0	0.8	2.0	100.0	25	TO-53
2N5387		7.5	200	25	2.0	2.0	5.0	100.0	100	TO-61
TIP535		7.5	200	20	5.0	1.2	5.0	100.0	100	TO-3
2N5388		7.5	250	25	2.0	2.0	5.0	100.0	100	TO-61
TIP55		7.5	250	20	5.0	2.5	7.5	125.0	25	TO-3 PLASTIC
TIP536		7.5	300	20	5.0	1.2	5.0	100.0	100	TO-3
2N5389		7.5	300	25	2.0	2.0	5.0	100.0	100	TO-61
TIP56		7.5	300	20	5.0	2.5	7.5	125.0	25	TO-3 PLASTIC
TIP57		7.5	350	15	5.0	2.5	7.5	125.0	25	TO-3 PLASTIC
TIP537		7.5	400	20	5.0	1.2	5.0	100.0	100	TO-3
TIP58		7.5	400	15	5.0	2.5	7.5	125.0	25	TO-3 PLASTIC
BD543	BD544	8.0	40	40	3.0	0.5	5.0	70.0	25	TO-66 PLASTIC
BD543A	BD544A	8.0	60	40	3.0	0.5	5.0	70.0	25	TO-66 PLASTIC
TIP130	TIP135	8.0	60	1000	4.0	3.0	6.0	70.0	25	TO-66 PLASTIC
BD543B	BD544B	8.0	80	40	3.0	0.5	5.0	70.0	25	TO-66 PLASTIC
†TIP131	TIP136	8.0	80	1000	4.0	3.0	6.0	70.0	25	TO-66 PLASTIC
†TIP132	TIP137	8.0	100	1000	4.0	3.0	6.0	70.0	25	TO-66 PLASTIC
BD543C	BD544C	8.0	100	40	3.0	0.5	5.0	70.0	25	TO-66 PLASTIC
BD543D	BD544D	8.0	120	40	3.0	0.5	5.0	70.0	25	TO-66 PLASTIC
	TIP519	8.0	150	30	4.0	1.0	4.0	50.0	100	TO-3
	TIP520	8.0	150	30	4.0	1.0	4.0	50.0	100	TO-61
	TIP527	8.0	200	20	4.0	1.5	4.0	60.0	100	TO-3
	TIP528	8.0	200	20	4.0	1.5	4.0	60.0	100	TO-61
TIP33	TIP34	10.0	40	20	3.0	4.0	10.0	80.0	25	TO-3 PLASTIC
BD245	BD246	10.0	45	4	10.0	4.0	10.0	80.0	25	TO-3 PLASTIC
TIP542		10.0	45	40	5.0	0.8	10.0	40.0	100	TO-59
TIP33A	TIP34A	10.0	60	20	3.0	4.0	10.0	80.0	25	TO-3 PLASTIC
BD245A	BD246A	10.0	60	4	10.0	4.0	10.0	80.0	25	TO-3 PLASTIC
†TIP140	TIP145	10.0	60	1000	5.0	3.0	10.0	125.0	25	TO-3 PLASTIC
†TIP640	TIP645	10.0	60	500	10.0	3.0	10.0	175.0	25	TO-3
2N5877	2N5875	10.0	60	20	4.0	3.0	8.0	150.0	25	TO-3
2N3713	2N3789	10.0	60	25	1.0	4.0	10.0	150.0	25	TO-3

† Darlington

PRODUCT SELECTION GUIDE
TRANSISTORS

Device Type		$I_C$cont	V_{CEO} $^*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
2N3715	2N3791	10.0	60	50	1.0	4.0	10.0	150.0	25	TO-3
TIP543		10.0	65	40	5.0	0.8	10.0	40.0	100	TO-59
TIP33B	TIP34B	10.0	80	20	3.0	4.0	10.0	80.0	25	TO-3 PLASTIC
BD245B	BD246B	10.0	80	4	10.0	4.0	10.0	80.0	25	TO-3 PLASTIC
†TIP141	TIP146	10.0	80	1000	5.0	3.0	10.0	125.0	25	TO-3 PLASTIC
†TIP641	TIP646	10.0	80	500	10.0	3.0	10.0	175.0	25	TO-3
2N5878	2N5876	10.0	80	20	4.0	3.0	8.0	150.0	25	TO-3
2N3714	2N3790	10.0	80	25	1.0	4.0	10.0	150.0	25	TO-3
2N3716	2N3792	10.0	80	50	1.0	4.0	10.0	150.0	25	TO-3
2N4301		10.0	80	30	5.0	0.4	5.0	50.0	100	TO-61
TIP33C	TIP34C	10.0	100	20	3.0	4.0	10.0	80.0	25	TO-3 PLASTIC
BD245C	BD246C	10.0	100	4	10.0	4.0	10.0	80.0	25	TO-3 PLASTIC
†TIP142	TIP147	10.0	100	1000	5.0	3.0	10.0	125.0	25	TO-3 PLASTIC
†TIP642	TIP647	10.0	100	500	10.0	3.0	10.0	175.0	25	TO-3
BUY70C		10.0	200	15	1.0	5.0	4.0	75.0	25	TO-3
BUY69C		10.0	200	15	2.5	3.3	8.0	100.0	25	TO-3
BUY70B		10.0	325	15	1.0	5.0	4.0	75.0	25	TO-3
BUY69B		10.0	325	15	2.5	3.3	8.0	100.0	25	TO-3
BU124		10.0	*350	–	–	0.5	4.0	50.0	25	TO-3 PLASTIC
BUY70A		10.0	400	15	1.0	5.0	4.0	75.0	25	TO-3
BUY69A		10.0	400	15	2.5	3.3	8.0	100.0	25	TO-3
	2N5386	12.0	80	20	6.0	0.6	6.0	50.0	100	TO-61
TIP515		12.0	120	40	6.0	0.8	6.0	80.0	100	TO-3
TIP517		12.0	120	40	6.0	0.8	6.0	80.0	100	TO-61
TIP516		12.0	150	40	6.0	0.8	6.0	80.0	100	TO-3
TIP518		12.0	150	40	6.0	0.8	6.0	80.0	100	TO-61
BU361		12.0	*800	–	–	3.5	8.0	70.0	25	TO-3
BU137		12.0	*1000	–	–	5.0	7.5	70.0	25	TO-3
BD545	BD546	15.0	40	25	5.0	1.0	10.0	85.0	75	TO-3 PLASTIC
BD545A	BD546A	15.0	60	25	5.0	1.0	10.0	85.0	75	TO-3 PLASTIC
2N3055		15.0	60	20	4.0	8.0	10.0	115.0	25	TO-3
2N5881	2N5879	15.0	60	20	6.0	4.0	12.0	160.0	25	TO-3
TIP3055	TIP2955	15.0	70	5	10.0	3.0	10.0	90.0	25	TO-3 PLASTIC
2N5882	2N5880	15.0	80	20	6.0	4.0	12.0	160.0	25	TO-3
BD545B	BD546B	15.0	80	25	5.0	1.0	10.0	85.0	25	TO-3 PLASTIC
BD545C	BD546C	15.0	100	25	5.0	1.0	10.0	85.0	25	TO-3 PLASTIC
BD545D	BD546D	15.0	120	25	5.0	1.0	10.0	85.0	25	TO-3 PLASTIC
TIP538		15.0	200	20	7.5	0.75	7.5	125.0	100	TO-3
TIP539		15.0	300	20	7.5	0.75	7.5	125.0	100	TO-3
TIP531		15.0	300	20	7.5	1.5	15.0	150.0	100	TO-3
TIP533		15.0	300	20	7.5	1.5	15.0	150.0	100	TO-63
TIP540		15.0	400	20	7.5	0.75	7.5	125.0	100	TO-3
TIP532		15.0	400	20	7.5	1.5	15.0	150.0	100	TO-3
TIP534		15.0	400	20	7.5	1.5	15.0	150.0	100	TO-63
2N3772		20.0	60	15	10.0	4.0	20.0	150.0	25	TO-3
2N5039		20.0	75	20	10.0	2.5	20.0	80.0	100	TO-3
2N5303		20.0	80	15	10.0	1.5	15.0	114.0	100	TO-3
2N5038		20.0	90	20	12.0	2.5	20.0	80.0	100	TO-3
2N3846		20.0	200	10	10.0	0.75	10.0	150.0	100	TO-63

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PRODUCT SELECTION GUIDE
TRANSISTORS

Device Type		I_C cont	V_{CEO} $*V_{CBO}$	h_{FE} @ I_C		$V_{CE(sat)}$ Max @ I_C		P_T @ T_C		Package
NPN	PNP	A	V	min	A	V	A	W	°C	
2N3847		20.0	300	10	10.0	0.75	10.0	150.0	100	TO-63
TIP35	TIP36	25.0	40	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
BD249	BD250	25.0	45	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
TIP35A	TIP36A	25.0	60	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
BD249A	BD250A	25.0	60	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
2N5885	2N5883	25.0	60	20	10.0	4.0	20.0	200.0	25	TO-3
2N5886	2N5884	25.0	80	20	10.0	4.0	20.0	200.0	25	TO-3
TIP35B	TIP36B	25.0	80	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
BD249B	BD250B	25.0	80	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
TIP35C	TIP36C	25.0	100	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
BD249C	BD250C	25.0	100	10	15.0	4.0	25.0	125.0	25	TO-3 PLASTIC
	2N4398	30.0	40	15	15.0	1.0	15.0	114.0	100	TO-3
2N5301		30.0	40	15	15.0	2.0	20.0	114.0	100	TO-3
2N3771		30.0	40	15	15.0	4.0	30.0	150.0	25	TO-3
	2N4399	30.0	60	15	15.0	1.0	15.0	114.0	100	TO-3
2N5302		30.0	60	15	15.0	2.0	20.0	114.0	100	TO-3
2N6326	2N6329	30.0	60	12	15.0	3.0	30.0	200.0	25	TO-3
2N4002		30.0	80	20	15.0	1.2	30.0	100.0	100	TO-63
2N6270		30.0	80	20	15.0	1.0	15.0	150.0	100	TO-3
2N6272		30.0	80	20	15.0	1.0	15.0	150.0	100	TO-63
2N6327	2N6330	30.0	80	12	15.0	3.0	30.0	200.0	25	TO-3
2N5671		30.0	90	20	15.0	0.75	15.0	140.0	25	TO-3
2N4003		30.0	100	20	15.0	1.2	30.0	100.0	100	TO-63
2N6271		30.0	100	20	15.0	1.0	15.0	150.0	100	TO-6
2N6273		30.0	100	20	15.0	1.0	15.0	150.0	100	TO-63
2N6328	2N6331	30.0	100	12	15.0	3.0	30.0	200.0	25	TO-3
2N5672		30.0	120	20	15.0	0.75	15.0	140.0	25	TO-3
2N6322		30.0	200	40	5.0	1.5	20.0	200.0	100	TO-3
2N6323		30.0	200	40	5.0	1.5	20.0	200.0	100	TO-63
2N6324		30.0	300	30	5.0	1.5	20.0	200.0	100	TO-3
2N6325		30.0	300	30	5.0	1.5	20.0	200.0	100	TO-63
2N5685	2N5683	50.0	60	15	25.0	1.0	25.0	171.0	100	TO-3
2N5686	2N5684	50.0	80	15	25.0	1.0	25.0	171.0	100	TO-3

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PRODUCT SELECTION GUIDE
THYRISTORS

SCR's

Type No.	I_T	V_{DRM}	I_{TSM}	I_{GT} MAX	V_{GT} MAX	I_H MAX	V_T MAX @ I_T		PACKAGE
	A	V	A	mA	V	mA	V	A	
2N3005	0.35	30	6	0.2	0.8	5	1.2	0.35	(TO-18)
2N3006	0.35	60	6	0.2	0.8	5	1.2	0.35	(TO-18)
2N3007	0.35	100	6	0.2	0.8	5	1.2	0.35	(TO-18)
2N3008	0.35	200	6	0.2	0.8	5	1.2	0.35	(TO-18)
TIC44	0.6	30	6	0.2	0.8	5	1.4	0.3	(TO-92 PIN CIRCLE)
TIC45	0.6	60	6	0.2	0.8	5	1.4	0.3	(TO-92 PIN CIRCLE)
TIC46	0.6	100	6	0.2	0.8	5	1.4	0.3	(TO-92 PIN CIRCLE)
TIC47	0.6	200	6	0.2	0.8	5	1.4	0.3	(TO-92 PIN CIRCLE)
2N5060	0.8	30	6	0.2	0.8	5	1.7	1.2	(TO-92)
2N5061	0.8	60	6	0.2	0.8	5	1.7	1.2	(TO-92)
2N5062	0.8	100	6	0.2	0.8	5	1.7	1.2	(TO-92)
2N5063	0.8	150	6	0.2	0.8	5	1.7	1.2	(TO-92)
2N5064	0.8	200	6	0.2	0.8	5	1.7	1.2	(TO-92)
TIC106Y	5	30	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC106F	5	50	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC106A	5	100	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC106B	5	200	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC106C	5	300	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC106D	5	400	30	0.2	1.0	5	1.7	5	TO-66 PLASTIC
TIC116F	8	50	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116A	8	100	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116B	8	200	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116C	8	300	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116D	8	400	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116E	8	500	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC116M	8	600	80	20.0	1.5	40	1.7	8	TO-66 PLASTIC
TIC126F	12	50	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126A	12	100	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126B	12	200	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126C	12	300	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126D	12	400	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126E	12	500	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC
TIC126M	12	600	100	20.0	1.5	40	1.4	12	TO-66 PLASTIC

PRODUCT SELECTION GUIDE
THYRISTORS

plastic triacs

Type No.	$I_{T(RMS)}$	V_{DRM}	I_{TSM}	I_{GT} Max I,II,III†	I_{GT} Max IV†	V_{GT} Max I,II,III†	V_{GT} Max IV	V_{TM} @ I_{TM} Max		I_H Max	Package
	A	V	A	mA	mA	V	V	V	A	mA	
TIC206A	3	100	20	5	10	2.0	2	2.2	4.2	30	TO-66 PLASTIC
TIC206B	3	200	20	5	10	2.0	2	2.2	4.2	30	TO-66 PLASTIC
TIC206D	3	400	20	5	10	2.0	2	2.2	4.2	30	TO-66 PLASTIC
TIC216A	6	100	60	5	10	2.2	3	1.7	8.4	30	TO-66 PLASTIC
TIC216B	6	200	60	5	10	2.2	3	1.7	8.4	30	TO-66 PLASTIC
TIC216D	6	400	60	5	10	2.2	3	1.7	8.4	30	TO-66 PLASTIC
TIC226B	8	200	70	50		2.5		2.1	12.0	60	TO-66 PLASTIC
TIC226D	8	400	70	50		2.5		2.1	12.0	60	TO-66 PLASTIC
TIC236B	12	200	100	50		2.5		2.1	17.0	50	TO-66 PLASTIC
TIC236D	12	400	100	50		2.5		2.1	17.0	50	TO-66 PLASTIC
TIC246B	16	200	125	50		2.5		1.7	22.5	50	TO-66 PLASTIC
TIC246D	16	400	125	50		2.5		1.7	22.5	50	TO-66 PLASTIC
TIC253B	20	200	150	50		2.5		1.7	28.2	50	TO-3 PLASTIC
TIC253D	20	400	150	50		2.5		1.7	28.2	50	TO-3 PLASTIC
TIC253E	20	500	150	50		2.5		1.7	28.2	50	TO-3 PLASTIC
TIC253M	20	600	150	50		2.5		1.7	28.2	50	TO-3 PLASTIC
TIC263B	25	200	175	50		2.5		1.7	35.2	50	TO-3 PLASTIC
TIC263D	25	400	175	50		2.5		1.7	35.2	50	TO-3 PLASTIC
TIC263E	25	500	175	50		2.5		1.7	35.2	50	TO-3 PLASTIC
TIC263M	25	600	175	50		2.5		1.7	35.2	50	TO-3 PLASTIC

PRODUCT SELECTION GUIDE
RECTIFIERS

Type No.	CV Approved	BS Approved	Identification	I_O A	V_R V	V_F V	I_R µA	I_{FSM} A	t_{rr} ns	Package
1N1130			R	0.3	1500	15.0	50.0	1.0	–	SO-10
1N1131			R	0.3	1500	15.0	50.0	1.0	–	SO-10
1N550			R	0.5	100	1.1	0.5	4.0	–	SO-10
1N551			R	0.5	200	1.1	1.0	40.0	–	SO-10
1N552			R	0.5	300	1.1	1.5	40.0	–	SO-10
1N553			R	0.5	400	1.1	2.5	4.0	–	SO-10
1N554			R	0.5	500	1.1	3.5	4.0	–	SO-10
1N555			R	0.5	600	1.1	5.0	4.0	–	SO-10
1N560			R	0.5	800	1.1	5.0	35.0	–	SO-16
1N561			R	0.5	1000	1.1	5.0	35.0	–	SO-16
1N588			R	0.5	1500	1.5	50.0	10.0	–	SO-16
1N589			R	0.5	1500	1.5	50.0	10.0	–	SO-16
1N536			R	0.75	50	1.0	10.0	35.0	–	SO-16
1S030			R	0.75	50	1.25	2.0	40.0	–	SO-16
1N537			R	0.75	100	1.0	10.0	35.0	–	SO-16
1N4364			R	0.75	100	1.1	1.0	35.0	–	SO-16
1S031			R	0.75	100	1.25	2.0	40.0	–	SO-16
1S100	●		R	0.75	100	1.25	1.0	40.0	–	SO-16
1N538			R	0.75	200	1.0	10.0	35.0	–	SO-16
1N4365			R	0.75	200	1.1	1.0	35.0	–	SO-16
1S032			R	0.75	200	1.25	2.0	40.0	–	SO-16
1S101	●		R	0.75	200	1.25	1.0	40.0	–	SO-16
1N539			R	0.75	300	1.0	10.0	35.0	–	SO-16
1N4366			R	0.75	300	1.1	1.0	35.0	–	SO-16
1N540			R	0.75	400	1.0	10.0	35.0	–	SO-16
1N4367			R	0.75	400	1.1	1.0	35.0	–	SO-16
1S034			R	0.75	400	1.25	2.0	40.0	–	SO-16
1S103	●		R	0.75	400	1.25	1.0	40.0	–	SO-16
1N1095			R	0.75	500	1.0	10.0	35.0	–	SO-16
1N4368			R	0.75	500	1.1	1.0	35.0	–	SO-16
1N547			R	0.75	600	1.0	10.0	35.0	–	SO-16
1N1096			R	0.75	600	1.0	10.0	35.0	–	SO-16
1N4369			R	0.75	600	1.1	1.0	35.0	–	SO-16
1S036			R	0.75	600	1.25	2.0	40.0	–	SO-16
1S105	●		R	0.75	600	1.25	1.0	40.0	–	SO-16
1S038			R	0.75	800	1.25	2.0	40.0	–	SO-16
1S107	●		R	0.75	800	1.25	1.0	40.0	–	SO-16
1S109			R	0.75	1000	1.25	1.0	40.0	–	SO-16
1N4374			R	0.75	1500	1.5	100.0	15.0	–	SO-16
1N607/A			R	0.8	50	1.5	1.0	10.0	–	SO-10
1N608/A			R	0.8	100	1.5	1.0	10.0	–	SO-10
1N609/A			R	0.8	150	1.5	1.0	10.0	–	SO-10
1N610/A			R	0.8	200	1.5	1.0	10.0	–	SO-10
1N611/A			R	0.8	300	1.5	1.0	10.0	–	SO-10
1N612/A			R	0.8	400	1.5	1.5	10.0	–	SO-10

R. . .Rectifier
R.A. . .Avalanche Rectifier
●Full approval

*R. . .Fast Rectifier
RS. . .Soft-recovery Fast Rectifier
0 Pending Approval

PRODUCT SELECTION GUIDE
RECTIFIERS

Type No.	CV Approved	BS Approved	Identification	I_O A	V_R V	V_F V	I_R μA	I_{FSM} A	t_{rr} ns	Package
1N613/A			R	0.8	500	1.5	2.0	10.0	–	SO-10
1N614/A			R	0.8	600	1.5	2.5	10.0	–	SO-10
ED1			R	1.0	50	1.5	20.0	25.0	–	SO-16
1SX170			*R	1.0	60	1.2	10.0	30.0	350	DO-41
1SX171			*R	1.0	100	1.2	10.0	30.0	350	DO-41
1SX172			*R	1.0	200	1.2	10.0	30.0	350	DO-41
1SX173			*R	1.0	300	1.2	10.0	30.0	350	DO-41
1SX174			*R	1.0	400	1.2	10.0	30.0	350	DO-41
1SX175			*R	1.0	500	1.2	10.0	30.0	350	DO-41
BYW10-50/R		O	*RS	1.5	50	1.4	15.0	35.0	400	SO-16
BYW10-100/R		O	*RS	1.5	100	1.4	15.0	35.0	400	SO-16
1S020		O	R	1.5	100	1.25	1.0	125.0	–	SO-16
BYW10-200/R		O	*RS	1.5	200	1.4	15.0	35.0	400	SO-16
1S021		O	R	1.5	200	1.25	1.0	125.0	–	SO-16
BYW10-300/R		O	*RS	1.5	300	1.4	15.0	35.0	400	SO-16
BYW10-400/R		O	*RS	1.5	400	1.4	15.0	35.0	400	SO-16
1S023		O	R	1.5	400	1.25	1.0	125.0	–	SO-16
BYW10-600/R		O	*RS	1.5	600	1.4	15.0	35.0	400	SO-16
1S025		O	R	1.5	600	1.25	1.0	125.0	–	SO-16
BYX45-600/R			RA	1.5	600	1.45	100.0	125.0	–	SO-16
BYW10-800/R		O	*RS	1.5	800	1.4	15.0	35.0	400	SO-16
1S027		O	R	1.5	800	1.25	1.0	125.0	–	SO-16
BYX45-800/R			RA	1.5	800	1.45	100.0	125.0	–	SO-16
1AS027	●		RA	1.5	800	1.25	1.0	125.0	–	SO-16
BYW10-1000/R		O	*RS	1.5	1000	1.4	15.0	35.0	400	SO-16
1S029		O	R	1.5	1000	1.25	1.0	125.0	–	SO-16
BYX45-1000/R			RA	1.5	1000	1.45	100.0	125.0	–	SO-16
1AS029	●		RA	1.5	1000	1.25	1.0	125.0	–	SO-16
1S441/R			RA	3.0	12	1.5	–	40.0	–	SO-10
1S442/R			RA	3.0	20	1.5	–	40.0	–	SO-10
1S443/R			RA	3.0	40	1.5	–	40.0	–	SO-10
1S430/R			R	3.0	50	1.6	5.0	15.0	–	SO-10
1S444/R			RA	3.0	60	1.5	–	40.0	–	SO-10
1S445/R			RA	3.0	80	1.5	–	40.0	–	SO-10
BY205-100			*RS	3.0	100	1.5	100.0	35.0	850	TO-220
1S431/R			R	3.0	100	1.6	5.0	15.0	–	SO-10
1S410/R	●		R	3.0	100	1.6	5.0	15.0	–	SO-10
BY205-200			*RS	3.0	200	1.5	100.0	35.0	850	TO-220
1S446/R			RA	3.0	120	1.5	–	40.0	–	SO-10
1S432/R			R	3.0	200	1.6	5.0	15.0	–	SO-10
1N1124/R			R	3.0	200	1.1	10.0	25.0	–	SO-10
1S411/R	●		R	3.0	200	1.6	5.0	15.0	–	SO-10
1N1125/R			R	3.0	300	1.1	10.0	25.0	–	SO-10
BY205-400			*RS	3.0	400	1.5	100.0	35.0	850	TO-220
1S434/R			R	3.0	400	1.6	5.0	15.0	–	SO-10

R. . .Rectifier

RA. . .Avalanche Rectifier

●Full approval

*R. . .Fast Rectifier

RS. . .Soft-recovery Fast Rectifier

0 Pending Approval

PRODUCT SELECTION GUIDE
RECTIFIERS

Type No.	CV Approved	BS Approved	Identification	I_O A	V_R V	V_F V	I_R μA	I_{FSM} A	t_{rr} ns	Package
1S413/R	●	●	R	3.0	400	1.6	5.0	15.0	–	SO-10
1N1126/R			R	3.0	400	1.1	10.0	25.0	–	SO-10
1N1127/R			R	3.0	500	1.1	10.0	25.0	–	SO-10
BY205-600			*RS	3.0	600	1.5	100.0	35.0	850	TO-220
1S436/R			R	3.0	600	1.6	5.0	15.0	–	SO-10
1S415/R	●		R	3.0	600	1.6	5.0	15.0	–	SO-10
1N1128/R			R	3.0	600	1.1	10.0	25.0	–	SO-10
BY205-800			*RS	3.0	800	1.5	100.0	35.0	850	TO-220
1S417/R	●		R	3.0	800	1.6	5.0	15.0	–	SO-10
1S438/R			R	3.0	800	1.6	5.0	15.0	–	SO-10
BY205-1000			*RS	3.0	1000	1.5	100.0	35.0	850	TO-220
1S419/R			R	3.0	1000	1.6	5.0	15.0	–	SO-10
1N1612			R	5.0	50	1.5	10.0	100.0	–	SO-10
1N1613			R	5.0	100	1.5	10.0	100.0	–	SO-10
1N1614			R	5.0	200	1.5	10.0	100.0	–	SO-10
1N1615			R	5.0	400	1.5	10.0	100.0	–	SO-10
1N1616			R	5.0	600	1.5	10.0	100.0	–	SO-10
BYW11-50/R		O	*RS	6.0	50	1.4	15.0	75.0	400	SO-10
1N3879/R		●	*R	6.0	50	1.4	15.0	75.0	200	SO-10
BYW11-100/R		O	*RS	6.0	100	1.4	15.0	75.0	400	SO-10
1N3880/R		●	*R	6.0	100	1.4	15.0	75.0	200	SO-10
BYW11-200/R		O	*RS	6.0	200	1.4	15.0	75.0	400	SO-10
1N3881/R		●	*R	6.0	200	1.4	15.0	75.0	200	SO-10
BYW11-300/R		O	*RS	6.0	300	1.4	15.0	75.0	400	SO-10
1N3882/R		●	*R	6.0	300	1.4	15.0	75.0	200	SO-10
BYW11-400/R		O	*RS	6.0	400	1.4	15.0	75.0	400	SO-10
1N3883/R		●	*R	6.0	400	1.4	15.0	75.0	200	SO-10
BYW11-600/R		O	*RS	6.0	600	1.4	15.0	75.0	400	SO-10
BYW11-800/R		O	*RS	6.0	800	1.4	15.0	75.0	400	SO-10
BYW11-1000/R		O	*RS	6.0	1000	1.4	15.0	75.0	400	SO-10
1S420/R			R	10.0	100	1.5	50.0	200.0	–	SO-10
1S421/R	●	●	R	10.0	200	1.5	50.0	200.0	–	SO-10
1S423/R	●	●	R	10.0	400	1.5	50.0	200.0	–	SO-10
1S425/R	●	●	R	10.0	600	1.5	50.0	200.0	–	SO-10
1S427/R	●	●	R	10.0	800	1.5	50.0	200.0	–	SO-10
1S429/R	●	●	R	10.0	1000	1.5	50.0	200.0	–	SO-10
1N1199A/RA			R	12.0	50	1.35	3000.0	240.0	–	SO-10
1N3889/R		O	*R	12.0	50	1.5	25.0	150.0	200	SO-10
1N1200A/RA			R	12.0	100	1.35	2500.0	240.0	–	SO-10
1N3890/R		O	*R	12.0	100	1.5	25.0	150.0	200	SO-10
1N1201A/RA			R	12.0	150	1.35	2250.0	240.0	–	SO-10
1N3891/R		O	*R	12.0	200	1.5	25.0	150.0	200	SO-10
1N1202A/RA			R	12.0	200	1.35	2000.0	240.0	–	SO-10
1N3892/R		O	*R	12.0	300	1.5	25.0	150.0	200	SO-10
1N1203/RA			R	12.0	300	1.35	750.0	240.0	–	SO-10

R. . .Rectifier	*R. . .Fast Rectifier
RA. . .Avalanche Rectifier	RS. . .Soft-recovery Rectifier
●Full Approval	0 Pending Approval

TEXAS INSTRUMENTS

PRODUCT SELECTION GUIDE RECTIFIERS

Type No.	CV Approved	BS Approved	Identification	I_O A	V_R V	V_F V	I_R μA	I_{FSM} A	t_{rr} ns	Package
1N3893/R		O	*R	12.0	400	1.5	25.0	150.0	200	SO-10
1N1204A/RA			R	12.0	400	1.35	1500.0	240.0	–	SO-10
1N1205A/RA			R	12.0	500	1.35	1500.0	240.0	–	SO-10
1N1206A/RA			R	12.0	600	1.35	1500.0	240.0	–	SO-10
BYW12-50/R		O	*RS	15.0	50	1.4	15.0	150.0	400	SO-10
BYW12-100/R		O	*RS	15.0	100	1.4	15.0	150.0	400	SO-10
BYW12-200/R		O	*RS	15.0	200	1.4	15.0	150.0	400	SO-10
BYW12-300/R		O	*RS	15.0	300	1.4	15.0	150.0	400	SO-10
BYW12-400/R		O	*RS	15.0	400	1.4	15.0	150.0	400	SO-10
BYW12-600/R		O	*RS	15.0	600	1.4	15.0	150.0	400	SO-10
BYW12-800/R		O	*RS	15.0	800	1.4	15.0	150.0	400	SO-10
BYW12-1000/R		O	*RS	15.0	1000	1.4	15.0	150.0	400	SO-10

R. . .Rectifier

RA. . .Avalanche Rectifier

•Full Approval

*R. . .Fast Rectifier

RS. . .Soft-recovery Rectifier

0 Pending Approval

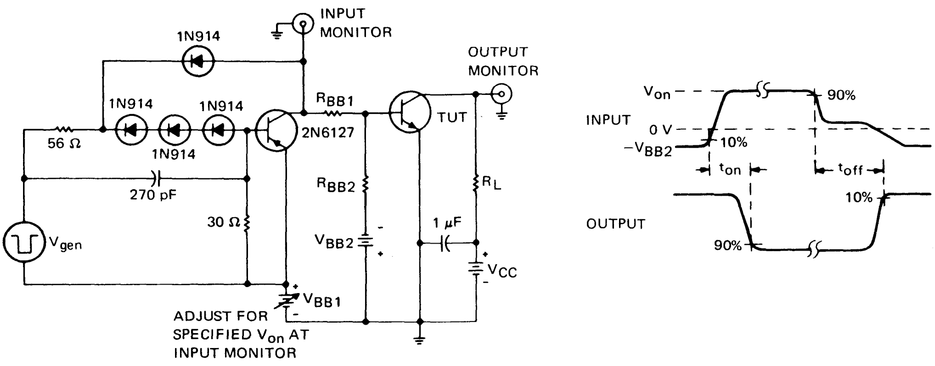
Nominal Breakdown
Voltage (Vz) (Tolerances are nominal)

6.8
7.5
8.2
9.1
10
11
12
13
15
16
18
20
22
24
27
30
33
36
39
43
47
51
56
62
68
75
82
91
100
110
120
130
150
160
180
200

1.3 Watts at 25°C amb	1.5 Watts at 25°C amb CV & BS approved ON ± 5%	10 Watts at 100°C Stud	10 Watts at 100°C Stud	10 Watts at 50°C Stud
1S3000A	**1S4000**	**1S5000** Characterised at 25°C stud temperature	**1S6000** Characterised at 100°C stud temperature	**1N2970 Thru 1N3015**
DO-41 ± 5%	SO-16 BS approval in progress on ± 5% ±10% available	SO-10 ± 5%; ±10% Normal & Reverse	SO-10 ± 5% Full CV & BS approved Normal & Reverse ± 10% available	SO-10 ± 5% ± 10% ± 20% Normal & Reverse

Data Sheets

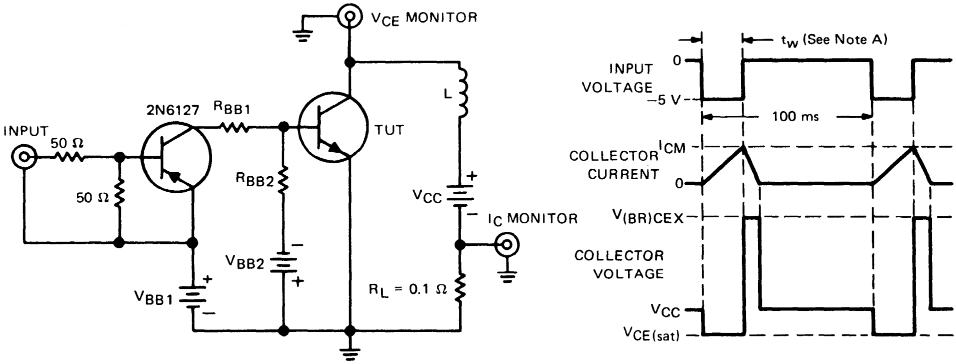
The circuits shown below are used to test many of the silicon power transistors manufactured by Texas Instruments. They are taken from the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$ $t_w = 5\ \mu s$, duty cycle ⩽ 5%.
C. Waveforms are monitored on an ocsilloscope with the following characteristics: $t_r \leqslant 10$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.
F. Circuit shown is for testing n-p-n transistors. For p-n-p transistors, all voltage supplies and waveforms are reversed and the driver transistor is type 2N6128.

FIGURE 1—SWITCHING TIMES



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
A. Input pulse width is increased until the peak collector current reaches the specified value of I_{CM}.
B. Circuit shown is for testing n-p-n transistors. For p-n-p transistors, all voltage supplies and waveforms are reversed and the driver transistor is type 2N6128.

FIGURE 2—INDUCTIVE LOAD SWITCHING

BD 135
NPN EPITAXIAL PLANAR SILICON TRANSISTOR

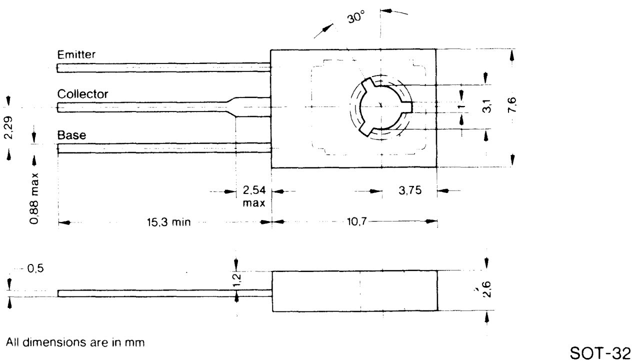
REVISED SEPTEMBER 1975

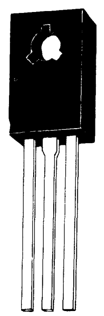
DESIGNED FOR COMPLEMENTARY USE WITH BD136

- Driver Stages
- Active Convergence
- Control Circuits
- Switching Application
- P_{tot} = 6.5 W at T_C = 60 °C
- $h_{FE} > 40$ at I_C = 150 mA
- $V_{CE(sat)} \leqslant 0.5$ V at I_C = 0.5 A

These components are tested according to the appropriate test method of MIL-STD-750. By special agreement, they can also be tested additionally to MIL- or DIN-specifications.

mechanical data





Transistors in SOT-32 package can also be supplied with mica insulating washers or heat sinks for 1.5 up to 2.5 Watts. Separate datasheet available.

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	45 V
Collector-Emitter Voltage (See Note 1)	45 V
Emitter-Base Voltage	5 V
Continuous Collector Current	1 A
Peak Collector Current	1.5 A
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 2)	1 W
Continuous Device Dissipation at (or below) 60 °C Case Temperature (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. $\Theta_{JA} \leqslant 100$ °C/W
3. $\Theta_{JC} \leqslant 10$ °C/W

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

BD135
NPN EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\,\mu A$,	$I_E = 0$		45		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 20\,mA$,	$I_B = 0$	See Note 4	45		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\,\mu A$,	$I_C = 0$		5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30\,V$,	$I_E = 0$			100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2\,V$,	$I_C = 5\,mA$		25		
		$V_{CE} = 2\,V$,	$I_C = 150\,mA$		40	250	
		$V_{CE} = 2\,V$,	$I_C = 500\,mA$		25		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2\,V$,	$I_C = 500\,mA$			1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 50\,mA$,	$I_C = 500\,mA$			0.5	V
f_T	Transition Frequency	$V_{CE} = 5\,V$,	$I_C = 50\,mA$	f = 20 MHz	50		MHz

NOTE: 4. These parameters must be measured using pulse techniques. $t_p = 300\,\mu s$, duty cycle $\leqslant 2$ %.

BD 136

PNP EPITAXIAL PLANAR SILICON TRANSISTOR

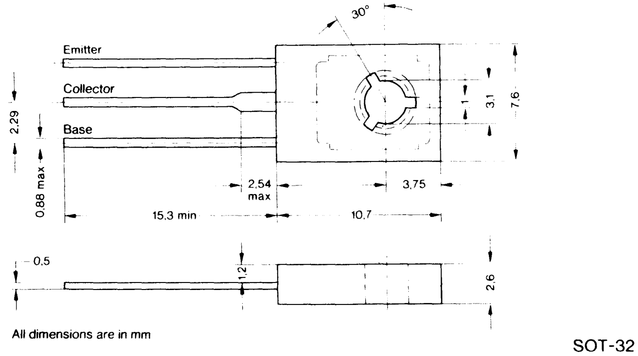
REVISED SEPTEMBER 1975

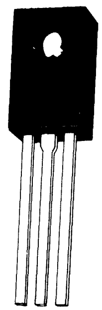
DESIGNED FOR COMPLEMENTARY USE WITH BD135

- Driver Stages
- Active Convergence
- Control Circuits
- Switching Application
- P_{tot} = 6.5 W at T_C = 60 °C
- $h_{FE} > 40$ at I_C = −150 mA
- $V_{CE(sat)} \leqslant 0.5$ V at I_C = −0.5 A

These components are tested according to the appropriate test method of MIL-STD-750. By special agreement, they can also be tested additionally to MIL- or DIN-specifications.

mechanical data





Transistors in SOT-32 package can also be supplied with mica insulating washers or heat sinks for 1.5 up to 2.5 Watts. Separate data-sheet available.

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−45 V
Collector-Emitter Voltage (See Note 1)	−45 V
Emitter-Base Voltage	−5 V
Continuous Collector Current	−1 A
Peak Collector Current	−1.5 A
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 2)	1 W
Continuous Device Dissipation at (or below) 60 °C Case Temperature (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. $\Theta_{JA} \leqslant 100$ °C/W
3. $\Theta_{JC} \leqslant 10$ °C/W

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD 136
PNP EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$,	$I_E = 0$		−45		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -20$ mA,	$I_B = 0$	See Note 4	−45		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\ \mu A$,	$I_C = 0$		−5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -30$ V,	$I_E = 0$			−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V, $V_{CE} = -2$ V, $V_{CE} = -2$ V,	$I_C = -5$ mA $I_C = -150$ mA $I_C = -500$ mA		25 40 25	 250 	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V,	$I_C = -500$ mA			−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -50$ mA,	$I_C = -500$ mA			−0.5	V
f_T	Transition Frequency	$V_{CE} = -5$ V,	$I_C = -50$ mA,	f = 20 MHz	50		

NOTE: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leqslant 2$ %.

BD 137

NPN EPITAXIAL PLANAR SILICON TRANSISTOR

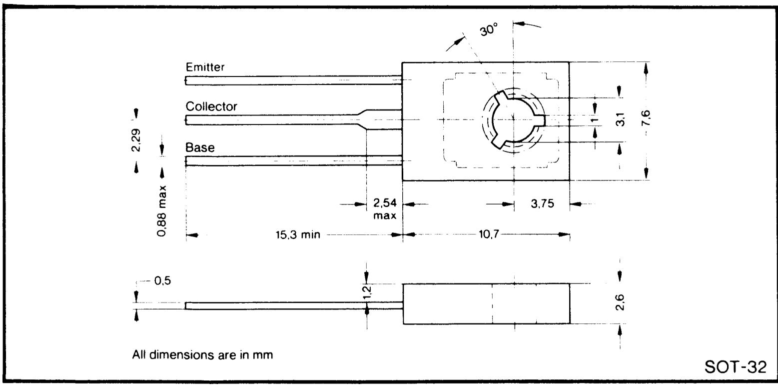
REVISED SEPTEMBER 1975

DESIGNED FOR COMPLEMENTARY USE WITH BD138

- Driver Stages
- Active Convergence
- Control Circuits
- Switching Application
- P_{tot} = 6.5 W at T_C = 60 °C
- $h_{FE} > 40$ at I_C = 150 mA
- $U_{CE(sat)} \leqslant 0.5$ V at I_C = 0.5 A

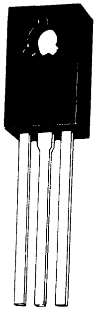
These components are tested according to the appropriate test method of MIL-STD-750. By special agreement, they can also be tested additionally to MIL- or DIN-specifications.

mechanical data



All dimensions are in mm

SOT-32



Transistors in SOT-32 package can also be supplied with mica insulating washers or heat sinks for 1.5 up to 2.5 Watts. Separate data-sheet available.

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	60 V
Collector-Emitter Voltage (See Note 1)	60 V
Emitter-Base Voltage	5 V
Continuous Collector Current	1 A
Peak Collector Current	1.5 A
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 2)	1 W
Continuous Device Dissipation at (or below) 60 °C Case Temperature (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. $\Theta_{JA} \leqslant 100$ °C/W.
3. $\Theta_{JC} \leqslant 10$ °C/W.

BD137
NPN EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$,	$I_E = 0$		60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 20$ mA,	$I_B = 0$	See Note 4	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$,	$I_C = 0$		5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 30$ V,	$I_E = 0$			100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V,	$I_C = 5$ mA		25		
		$V_{CE} = 2$ V,	$I_C = 150$ mA		40	160	
		$V_{CE} = 2$ V,	$I_C = 500$ mA		25		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V,	$I_C = 500$ mA			1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 50$ mA,	$I_C = 500$ mA			0.5	V
f_T	Transition Frequency	$V_{CE} = 5$ V,	$I_C = 50$ mA	f = 20 MHz	50		MHz

NOTE: 4. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leqslant 2$ %.

BD138
PNP EPITAXIAL PLANAR SILICON TRANSISTOR

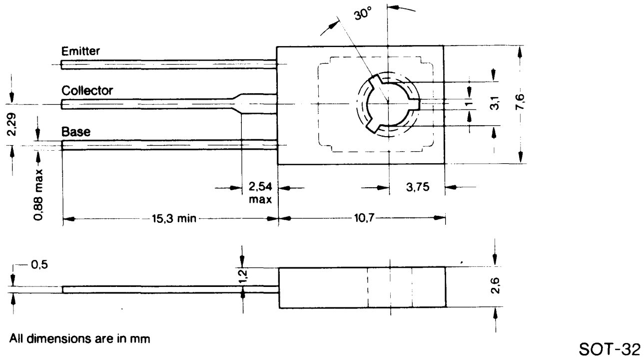
REVISED SEPTEMBER 1975

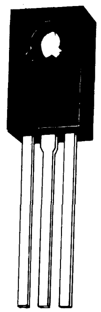
DESIGNED FOR COMPLEMENTARY USE WITH BD137

- Driver Stages
- Active Convergence
- Control Circuits
- Switching Application
- $P_{tot} = 6.5$ W at $T_C = 60$ °C
- $h_{FE} > 40$ at $I_C = -150$ mA
- $V_{CE(sat)} \leqslant -0.5$ V at $I_C = 0.5$ A

These components are tested according to the appropriate test method of MIL-STD-750. By special agreement, they can also be tested additionally to MIL- or DIN-specifications.

mechanical data





Transistors in SOT-32 package can also be supplied with mica insulating washers or heat sinks for 1.5 up to 2.5 Watts. Separate data-sheet available.

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−60 V
Collector-Emitter Voltage (See Note 1)	−60 V
Emitter-Base Voltage	−5 V
Continuous Collector Current	−1 A
Peak Collector Current	−1.5 A
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 2)	1 W
Continuous Device Dissipation at (or below) 60 °C Case Temperature (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. $\Theta_{JA} \leqslant 100$ °C/W
3. $\Theta_{JC} \leqslant 10$ °C/W

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD 138
PNP EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\,\mu A$,	$I_E = 0$		−60		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -20$ mA,	$I_B = 0$,	See Note 4	−60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\,\mu A$,	$I_C = 0$		−5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -30$ V,	$I_E = 0$			−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V,	$I_C = -5$ mA		25		
		$V_{CE} = -2$ V,	$I_C = -150$ mA		40	160	
		$V_{CE} = -2$ V,	$I_C = -500$ mA		25		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V,	$I_C = -500$ mA			−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -50$ mA,	$I_C = -500$ mA			−0.5	V
f_T	Transition Frequency	$V_{CE} = -5$ V,	$I_C = -50$ mA	f = 20 MHz	50		MHz

NOTE: 4. These parameters must be measured using pulse techniques. $t_p = 300\,\mu s$, duty cycle $\leqslant 2$ %.

BD139
NPN EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Base Breakdown Voltage	I_C = 100 µA,	I_E = 0	80		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 20 mA,	I_B = 0, Note 4	80		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 µA,	I_C = 0	5		V
I_{CBO}	Collector Cutoff Current	V_{CB} = 30 V,	I_E = 0		100	nA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V,	I_C = 5 mA	25		
		V_{CE} = 2 V,	I_C = 150 mA	40	160	*
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V,	I_C = 500 mA	25		
V_{BE}	Base-Emitter Voltage	V_{CE} = 2 V,	I_C = 500 mA		1	V
$V_{CE(sat)}$	Collector-Emitter-Saturation Voltage	I_B = 50 mA,	I_C = 500 mA		0.5	V
f_T	Transition Frequency	V_{CE} = 5 V, f = 20 MHz	I_C = 50 mA	50		MHz

* The following h_{FE}-groups are available:

BD 139/6	h_{FE} @ V_{CE} = 2 V, I_C = 150 mA	40 - 100
BD 139/10		63 - 160
BD 139/16		100 - 250

NOTE: 4. These parameters must be measured using pulse techniques. t_p = 300 µs, duty cycle ⩽2%

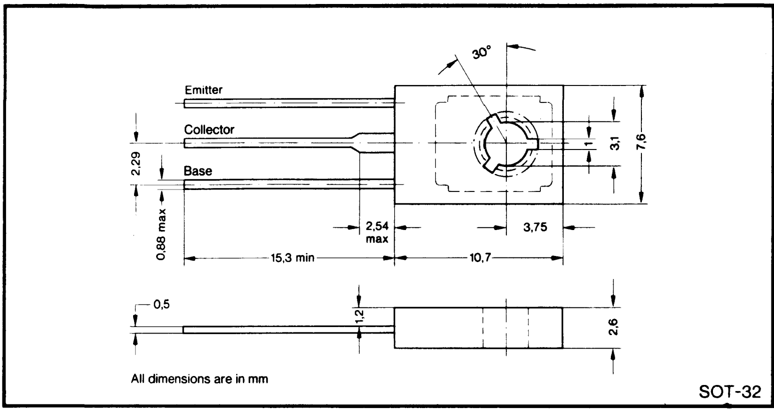
BD139

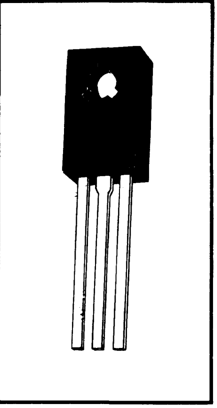
NPN EPITAXIAL PLANAR SILICON TRANSISTOR

REVISED SEPTEMBER 1975

- Driver for Audio Amplifier
- Active Convergenz
- Regulators
- Power Switching
- P_{tot} = 6.5 W at T_G = 60 °C
- $h_{FE} > 40$ at I_C = −150 mA
- $V_{CE(sat)} \leqslant -0.5$ V at I_C = −0.5 A

mechanical data





absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	−80 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−5 V
Continuous Collector Current	−1 A
Peak Collector Current	−1.5 A
Continuous Device Dissipation at T_U = 25 °C (See Note 2)	1 W
Continuous Device Dissipation at T_G = 60 °C (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. $R_{thJU} \leqslant 100$ °C/W
3. $R_{thJG} \leqslant 10$ °C/W

PRELIMINARY DATA SHEET: Supplementary data may be published at a later date.

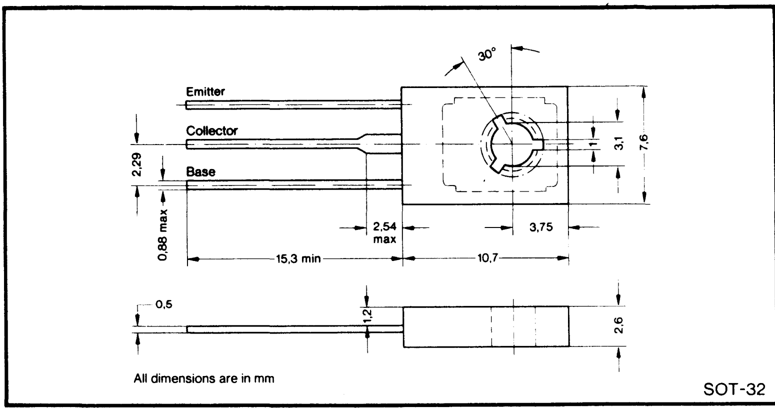
TEXAS INSTRUMENTS

BD140
PNP EPITAXIAL PLANAR SILICON TRANSISTOR

REVISED SEPTEMBER 1975

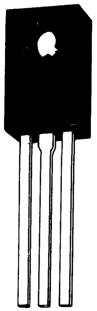
- **Driver for Audio Amplifier**
- **Active Convergenz**
- **Regulators**
- **Power Switching**
- **P_{tot} = 6.5 W at T_G = 60 °C**
- **$h_{FE} > 40$ at I_C = 150 mA**
- **$V_{CE(sat)} \leqslant 0.5$ V at I_C = 0.5 A**

mechanical data



All dimensions are in mm

SOT-32



absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Collector-Base Voltage	80 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	5 V
Continuous Collector Current	1 A
Peak Collector Current	1.5 A
Continuous Device Dissipation at T_U = 25 °C (See Note 2)	1 W
Continuous Device Dissipation at T_G = 60 °C (See Note 3)	6.5 W
Storage Temperature Range	−55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. $R_{thJU} \leqslant 100$ °C/W
3. $R_{thJG} \leqslant 10$ °C/W

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD140
PNP EPITAXIAL PLANAR SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\,\mu A$,	$I_E = 0$		−80		V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -20$ mA,	$I_B = 0$,	Note 4	−80		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -10\,\mu A$,	$I_C = 0$		−5		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -30$ V,	$I_E = 0$			−100	nA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V,	$I_C = -5$ mA		25		
		$V_{CE} = -2$ V,	$I_C = -150$ mA		40	160	*
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V,	$I_C = -500$ mA		25		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V,	$I_C = -500$ mA			−1	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -50$ mA,	$I_C = -500$ mA			−0.5	V
f_T	Transition Frequency	$V_{CE} = -5$ V, f = 20 MHz	$I_C = -50$ mA		50		MHz

* The following h_{FE}-groups are available:

BD 140/6	h_{FE} @ $V_{CE} = 2$ V, $I_C = 150$ mA	40 - 100
BD 140/10		63 - 160
BD 140/16		160 - 250

NOTE: 4. These parameters must be measured using pulse techniques. $t_p = 300\,\mu s$, duty cycle $\leqslant 2\%$

BD239, BD239A, BD239B, BD239C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

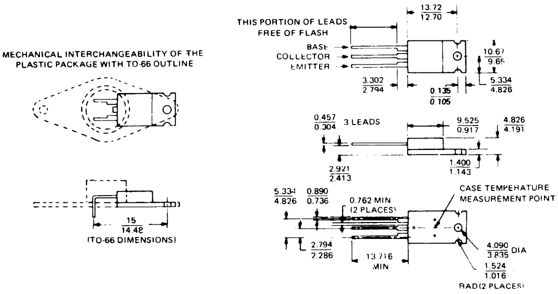
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD240A-C

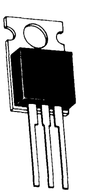
- **30 W at 25 °C Case Temperature**
- **2 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 200 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD239	BD239A	BD239B	BD239C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	55 V	70 V	90 V	115 V
Collector-Emitter Voltage (See Note 1)	45 V	60 V	80 V	100 V
Emitter-Base Voltage	5 V			
Continuous Collector Current	2 A			
Peak Collector Current (See Note 2)	4 A			
Continuous Base Current	0.6 A			
Safe Operating Region at (or below) 25 °C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	30 W			
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	32 mJ			
Operating Collector Junction Temperature Range	−65 °C to 150 °C			
Storage Temperature Range	−65 °C to 150 °C			
Lead Temperature 3.2mm from Case for 5 Seconds	250 °C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.24 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

BD239, BD239A, BD239B, BD239C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD239		BD239A		BD239B		BD239C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	I_C = 30 mA, See Note 6	I_B = 0,	45		60		80		100		V
I_{CEO}	V_{CE} = 30 V,	I_B = 0		0.3		0.3					mA
	V_{CE} = 60 V,	I_B = 0						0.3		0.3	
I_{CES}	V_{CE} = 45 V,	V_{BE} = 0		0.2							mA
	V_{CE} = 60 V,	V_{BE} = 0				0.2					
	V_{CE} = 80 V,	V_{BE} = 0						0.2			
	V_{CE} = 100 V,	V_{BE} = 0								0.2	
I_{EBO}	V_{EB} = 5 V,	I_C = 0		1		1		1		1	mA
h_{FE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 0.2 A	40		40		40		40		
	V_{CE} = 4 V, See Notes 6 and 7	I_C = 1 A,	15		15		15		15		
V_{BE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 1 A,		1.3		1.3		1.3		1.3	V
$V_{CE(sat)}$	I_B = 200 mA, See Notes 6 and 7	I_C = 1 A,		0.7		0.7		0.7		0.7	V
h_{fe}	V_{CE} = 10 V, f = 1 kHz	I_C = 0.2 A,	20		20		20		20		
$\|h_{fe}\|$	V_{CE} = 10 V, f = 1 MHz	I_C = 0.2 A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2 %.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

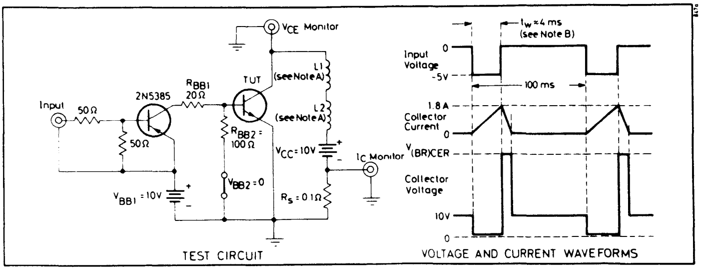
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	4.17	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

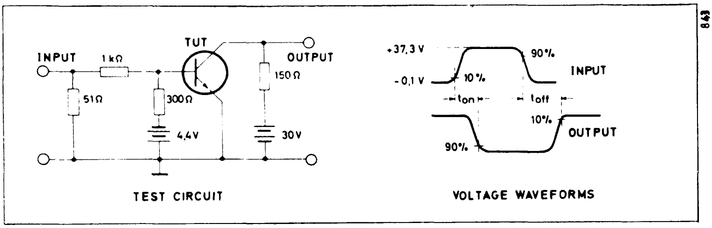
switching characteristics at 25 °C case temperature

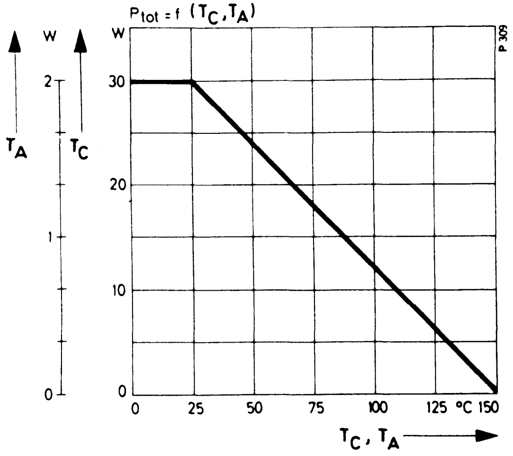
PARAMETER	TEST CONDITIONS +			TYP	UNIT
t_{on}	I_C = 200 mA,	$I_{B(1)}$ = 20 mA,	$I_{B(2)}$ = 20 mA,	0.3	μs
t_{off}	$V_{BE(off)}$ = −3.4 V, R_L = 150 Ω,		See Figure 1	0.8	

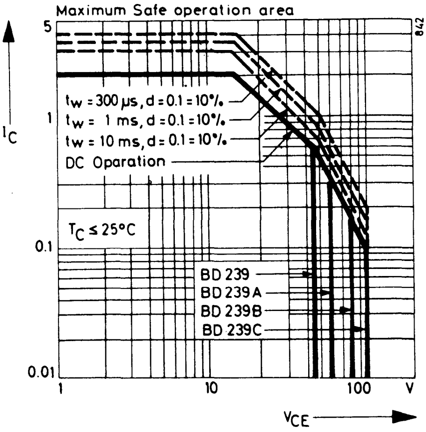
+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD239, BD239A, BD239B, BD239C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

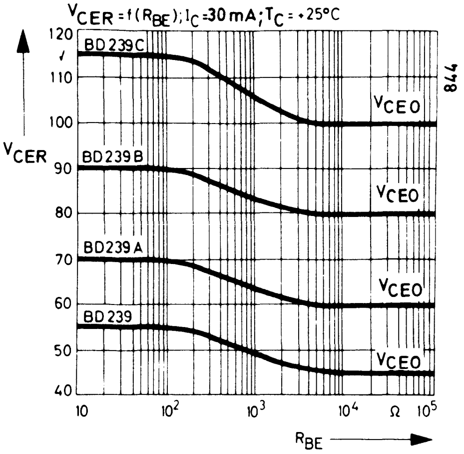


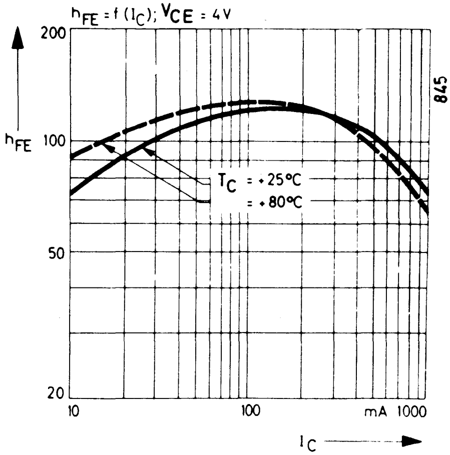


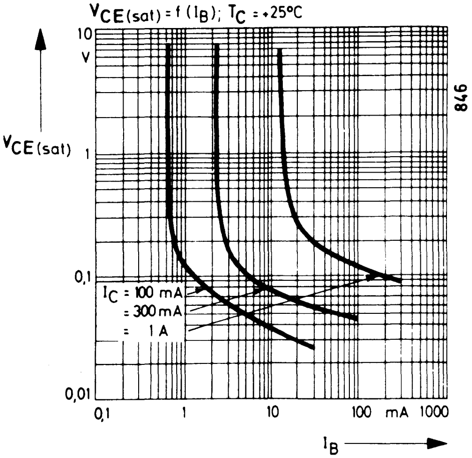


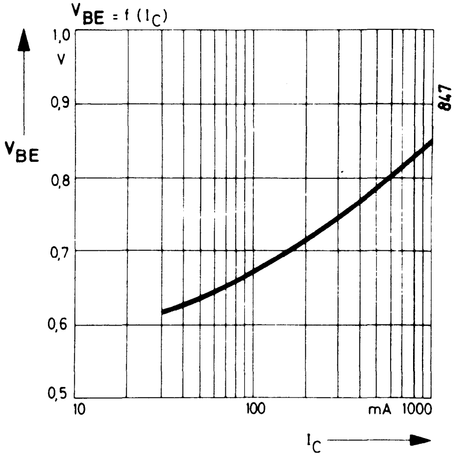


BD239, BD239A, BD239B, BD239C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD240, BD240A, BD240B, BD240C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

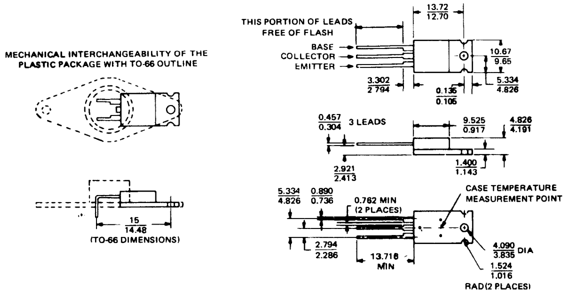
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD239A-C

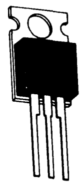
- **30 W at 25 °C Case Temperature**
- **2 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 200 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD240	BD240A	BD240B	BD240C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	−55 V	−70 V	−90 V	−115 V
Collector-Emitter Voltage (See Note 1)	−45 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	← −5 V →			
Continuous Collector Current	← −2 A →			
Peak Collector Current (See Note 2)	← −4 A →			
Continuous Base Current	← −0.6 A →			
Safe Operating Region at (or below) 25 °C Case Temperature	← See Figure 5 →			
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	← 30 W →			
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	← 2 W →			
Unclamped Inductive Load Energy (See Note 5)	← 32 mJ →			
Operating Collector Junction Temperature Range	← −65 °C to 150 °C →			
Storage Temperature Range	← −65 °C to 150 °C →			
Lead Temperature 3.2mm from Case for 5 Seconds	← 250 °C →			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.24 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy $\approx I_C{}^2L/2$.

BD240, BD240A, BD240B, BD240C
PNP SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD240		BD240A		BD240B		BD240C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	$I_C = -30$ mA, See Note 6	$I_B = 0$,	−45		−60		−80		−100		V
I_{CEO}	$V_{CE} = -30$ V,	$I_B = 0$		−0.3		−0.3					mA
	$V_{CE} = -60$ V,	$I_B = 0$						−0.3		−0.3	
I_{CES}	$V_{CE} = -45$ V,	$V_{BE} = 0$		−0.2							mA
	$V_{CE} = -60$ V,	$V_{BE} = 0$				−0.2					
	$V_{CE} = -80$ V,	$V_{BE} = 0$						−0.2			
	$V_{CE} = -100$ V,	$V_{BE} = 0$								−0.2	
I_{EBO}	$V_{EB} = -5$ V,	$I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -0.2$ A,	40		40		40		40		
	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -1$ A,	15		15		15		15		
V_{BE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -1$ A,		−1.3		−1.3		−1.3		−1.3	V
$V_{CE(sat)}$	$I_B = -200$ mA, See Notes 6 and 7	$I_C = -1$ A,		−0.7		−0.7		−0.7		−0.7	V
h_{fe}	$V_{CE} = -10$ V, f = 1 kHz	$I_C = -0.2$ A,	20		20		20		20		
$\|h_{fe}\|$	$V_{CE} = -10$ V, f = 1 MHz	$I_C = -0.2$ A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leqslant 2$ %.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	4.17	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

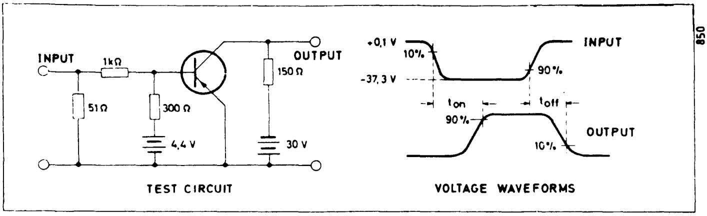
switching characteristics at 25 °C case temperature

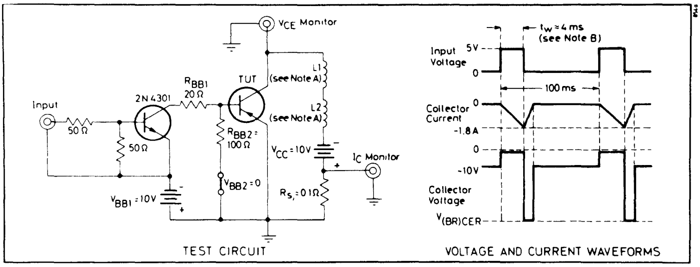
PARAMETER	TEST CONDITIONS +			TYP	UNIT
t_{on}	$I_C = -200$ mA,	$I_{B(1)} = -20$ mA,	$I_{B(2)} = 20$ mA,	0.2	μs
t_{off}	$V_{BE(off)} = 3.4$ V,	$R_L = 150\ \Omega$,	See Figure 1	0.4	

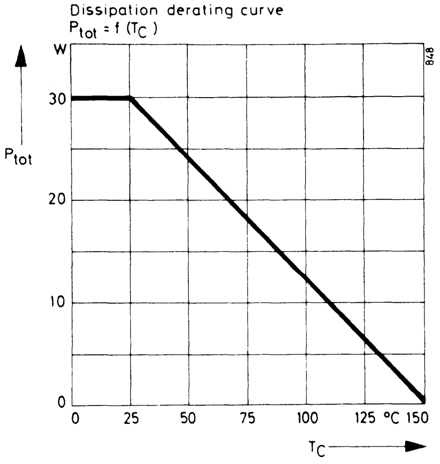
+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

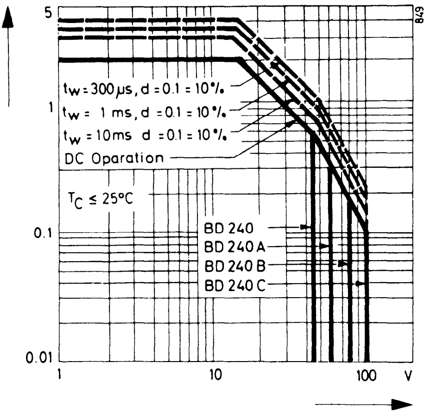
BD240, BD240A, BD240B, BD240C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

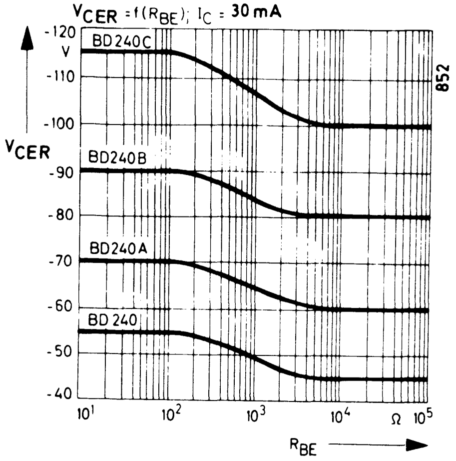


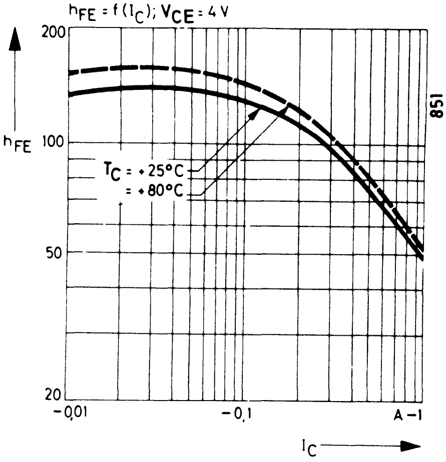


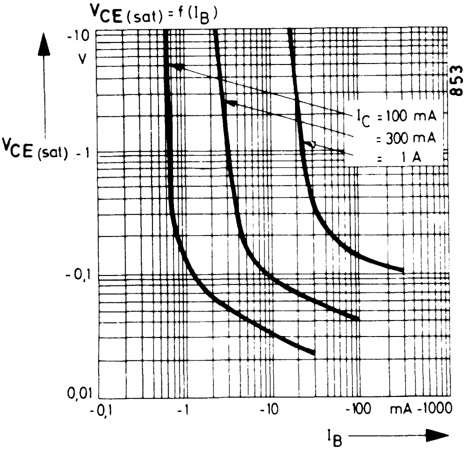


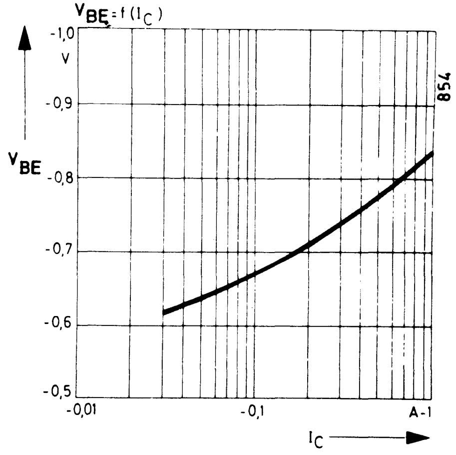


BD240, BD240A, BD240B, BD240C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD241, BD241A, BD241B, BD241C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

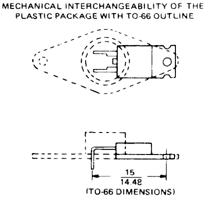
REVISED SEPTEMBER 1975

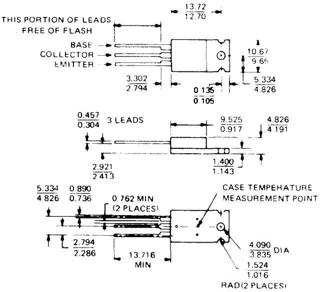
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD242A-C

- 40 W at 25 °C Case Temperature
- 3 A Rated Collector Current
- Min f_T of 3 MHz at 10 V, 500 mA

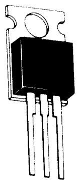
mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD241	BD241A	BD241B	BD241C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	55 V	70 V	90 V	115 V
Collector-Emitter Voltage (See Note 1)	45 V	60 V	80 V	100 V
Emitter-Base Voltage	← 5 V →			
Continuous Collector Current	← 3 A →			
Peak Collector Current (See Note 2)	← 5 A →			
Continuous Base Current	← 1 A →			
Safe Operating Region at (or below) 25 °C Case Temperature	← See Figure 5 →			
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	← 40 W →			
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	← 2 W →			
Unclamped Inductive Load Energy (See Note 5)	← 32 mJ →			
Operating Collector Junction Temperature Range	← −65 °C to 150 °C →			
Storage Temperature Range	← −65 °C to 150 °C →			
Lead Temperature 3.2mm from Case for 5 Seconds	← 250 °C →			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.32 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD241, BD241A, BD241B, BD241C NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD241		BD241A		BD241B		BD241C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	I_C = 30 mA, See Note 6	I_B = 0,	45		60		80		100		V
I_{CEO}	V_{CE} = 30 V,	I_B = 0		0.3		0.3					mA
	V_{CE} = 60 V,	I_B = 0						0.3		0.3	
I_{CES}	V_{CE} = 45 V,	V_{BE} = 0		0.2							mA
	V_{CE} = 60 V,	V_{BE} = 0				0.2					
	V_{CE} = 80 V,	V_{BE} = 0						0.2			
	V_{CE} = 100 V,	V_{BE} = 0								0.2	
I_{EBO}	V_{EB} = 5 V,	I_C = 0		1		1		1		1	mA
h_{FE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 1 A,	25		25		25		25		
	V_{CE} = 4 V, See Notes 6 and 7	I_C = 3 A,	10		10		10		10		
V_{BE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 3 A,		1.8		1.8		1.8		1.8	V
$V_{CE(sat)}$	I_B = 600 mA, See Notes 6 and 7	I_C = 3 A,		1.2		1.2		1.2		1.2	V
h_{fe}	V_{CE} = 10 V, f = 1 kHz	I_C = 0.5 A,	20		20		20		20		
$\|h_{fe}\|$	V_{CE} = 10 V, f = 1 MHz	I_C = 0.5 A	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2 %.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

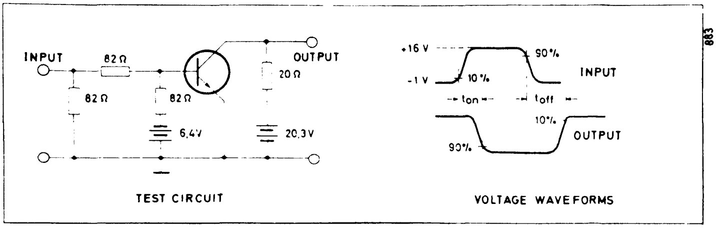
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.125	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

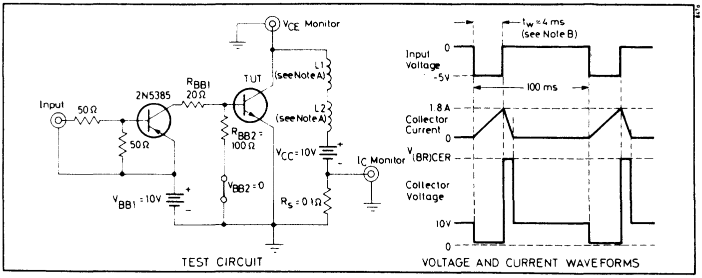
switching characteristics at 25 °C case temperature

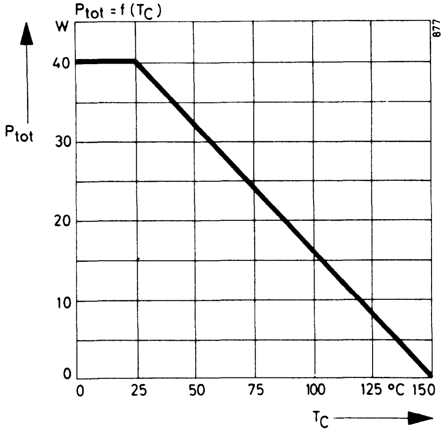
PARAMETER	TEST CONDITIONS$^+$			TYP	UNIT
t_{on}	I_C = 1 A,	$I_{B(1)}$ = 100 mA,	$I_{B(2)}$ = −100 mA,	0.3	μs
t_{off}	$V_{BE(off)}$ = −3.7 V,	R_L = 20 Ω,	See Figure 1	1	

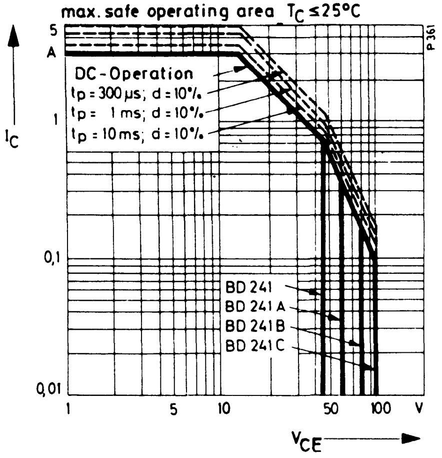
$^+$ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD241, BD241A, BD241B, BD241C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

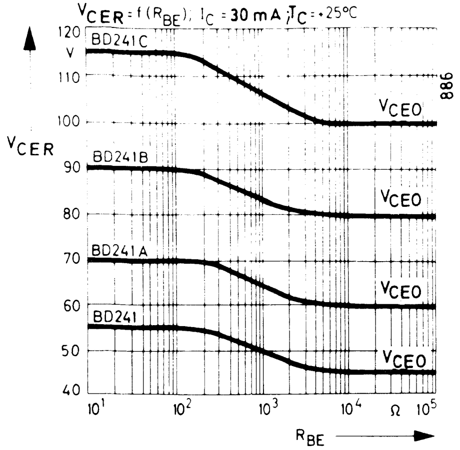


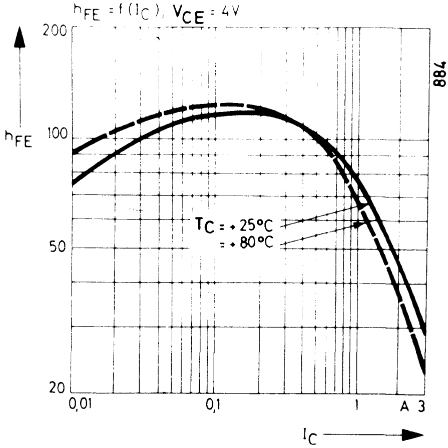


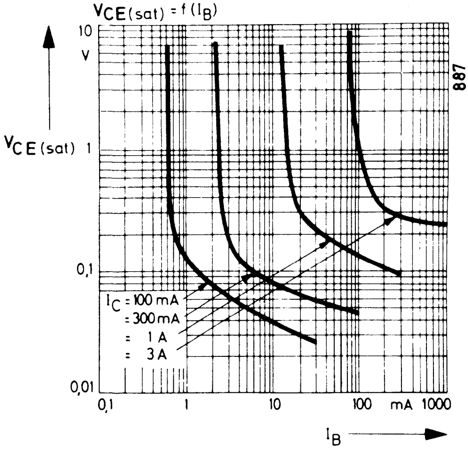


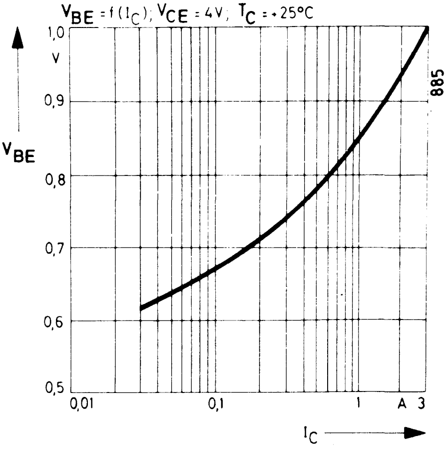


BD241, BD241A, BD241B, BD241C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD242, BD242A, BD242B, BD242C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

REVISED SEPTEMBER 1975

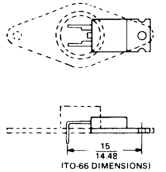
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH BD241A-C

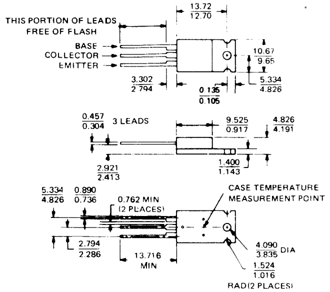
- 40 W at 25 °C Case Temperature
- 3 A Rated Collector Current
- Min f_T of 3 MHz at 10 V, 500 mA

mechanical data

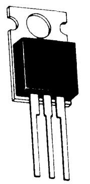
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB

MECHANICAL INTERCHANGEABILITY OF THE PLASTIC PACKAGE WITH TO-66 OUTLINE





ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD242	BD242A	BD242B	BD242C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	−55 V	−70 V	−90 V	−115 V
Collector-Emitter Voltage (See Note 1)	−45 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	←	−5 V		→
Continuous Collector Current	←	−3 A		→
Peak Collector Current (See Note 2)	←	−5 A		→
Continuous Base Current	←	−1 A		→
Safe Operating Region at (or below) 25 °C Case Temperature	←	See Figure 5		→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	←	40 W		→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	←	2 W		→
Unclamped Inductive Load Energy (See Note 5)	←	32 mJ		→
Operating Collector Junction Temperature Range	←	−65 °C to 150 °C		→
Storage Temperature Range	←	−65 °C to 150 °C		→
Lead Temperature 3.2mm from Case for 5 Seconds	←	250 °C		→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.32 W/°C.
4. Derate linearly to 150 °C free-air temperature at the end of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C^2 L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD242, BD242A, BD242B, BD242C
PNP SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD242		BD242A		BD242B		BD242C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	$I_C = -30$ mA, See Note 6	$I_B = 0$,	−45		−60		−80		−100		V
I_{CEO}	$V_{CE} = -30$ V,	$I_B = 0$		−0.3		−0.3					mA
	$V_{CE} = -60$ V,	$I_B = 0$						−0.3		−0.3	
I_{CES}	$V_{CE} = -45$ V,	$V_{BE} = 0$		−0.2							mA
	$V_{CE} = -60$ V,	$V_{BE} = 0$				−0.2					
	$V_{CE} = -80$ V,	$V_{BE} = 0$						−0.2			
	$V_{CE} = -100$ V,	$V_{BE} = 0$								−0.2	
I_{EBO}	$V_{EB} = -5$ V,	$I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -1$ A,	25		25		25		25		
	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -3$ A,	10		10		10		10		
V_{BE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -3$ A,		−1.8		−1.8		−1.8		−1.8	V
$V_{CE(sat)}$	$I_B = -600$ mA, See Notes 6 and 7	$I_C = -3$ A,		−1.2		−1.2		−1.2		−1.2	V
h_{fe}	$V_{CE} = -10$ V, f = 1 kHz	$I_C = -0.5$ A,	20		20		20		20		
$\|h_{fe}\|$	$V_{CE} = -10$ V, f = 1 MHz	$I_C = -0.5$ A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2 %.

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

thermal characteristics

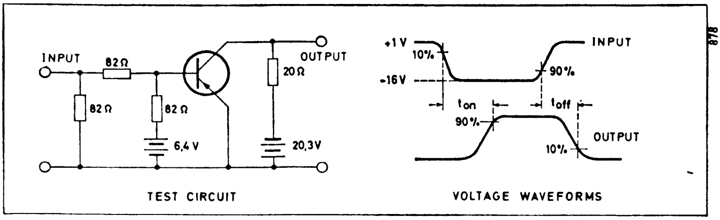
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.125	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDISTIONS +			TYP	UNIT
t_{on}	$I_C = -1$ A,	$I_{B(1)} = -100$ mA,	$I_{B(2)} = 100$ mA,	0.2	μs
t_{off}	$V_{BE(off)} = 3.7$ V,	$R_L = 20\ \Omega$,	See Figure 1	0.3	

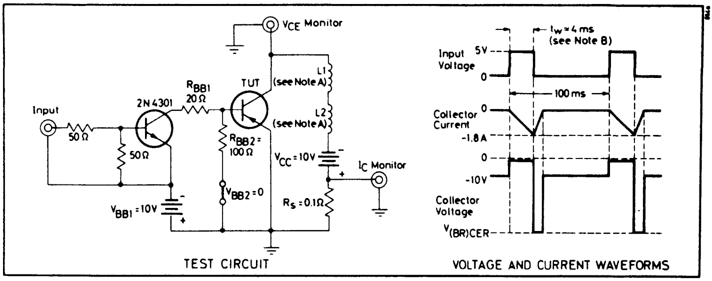
+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD242, BD242A, BD242B, BD242C
PNP SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS



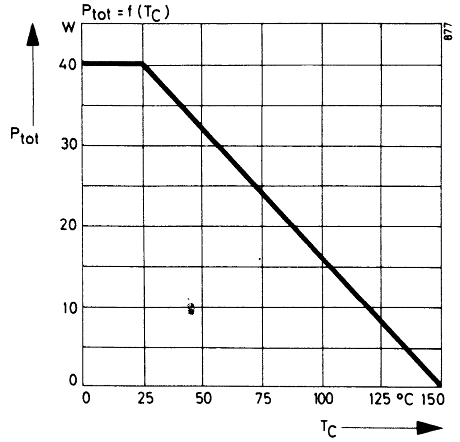
TEST CIRCUIT

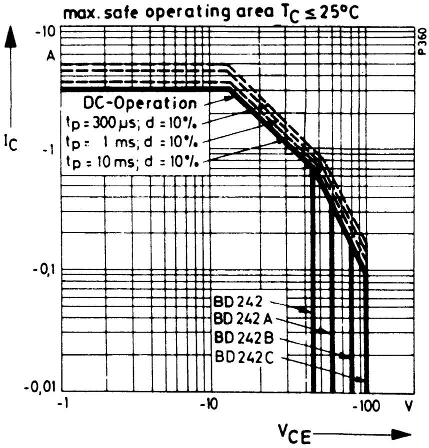
VOLTAGE WAVEFORMS



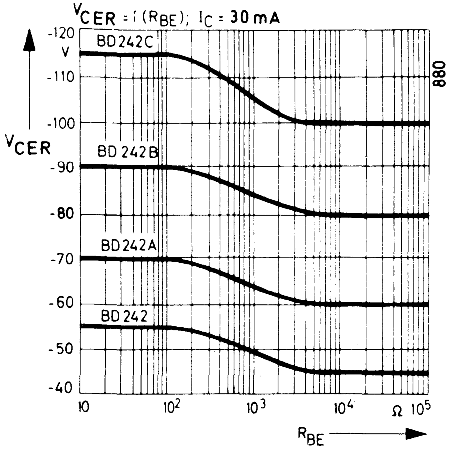
TEST CIRCUIT

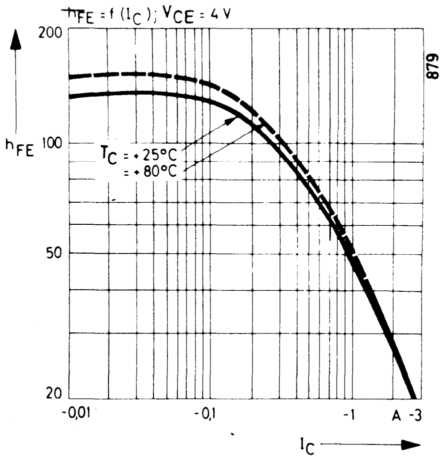
VOLTAGE AND CURRENT WAVEFORMS

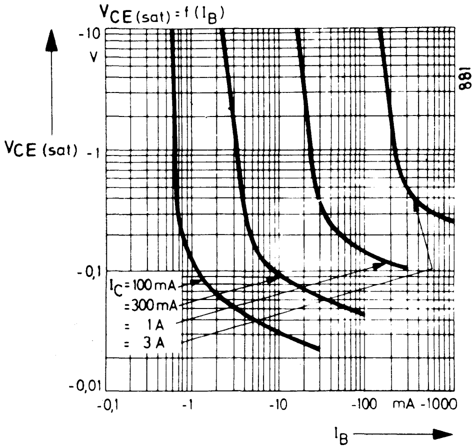


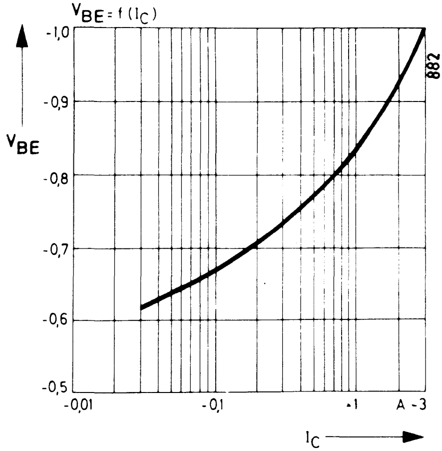


BD242, BD242A, BD242B, BD242C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD243, BD243A, BD243B, BD243C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

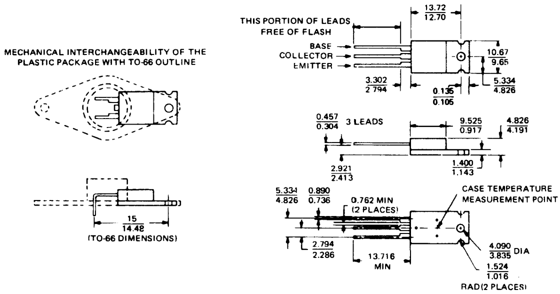
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD244A-C

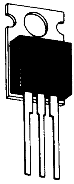
- 65 W at 25 °C Case Temperature
- 6 A Rated Collector Current
- Min f_T of 3 MHz at 10 V, 500 mA

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD243	BD243A	BD243B	BD243C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	55 V	70 V	90 V	115 V
Collector-Emitter Voltage (See Note 1)	45 V	60 V	80 V	100 V
Emitter-Base Voltage	← 5 V →			
Continuous Collector Current	← 6 A →			
Peak Collector Current (See Note 2)	← 10 A →			
Continuous Base Current	← 3 A →			
Safe Operating Region at (or below) 25 °C Case Temperature	← See Figure 5 →			
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	← 65 W →			
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	← 2 W →			
Unclamped Inductive Load Energy (See Note 5)	← 62.5 mJ →			
Operating Collector Junction Temperature Range	← −65 °C to 150 °C →			
Storage Temperature Range	← −65 °C to 150 °C →			
Lead Temperature 3.2mm from Case for 5 Seconds	← 250 °C →			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.52 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 0.52 W/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy ≈ $I_C^2 L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be
published at a later date.

TEXAS INSTRUMENTS

BD243, BD243A, BD243B, BD243C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD243		BD243A		BD243B		BD243C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	I_C = 30 mA, See Note 6	I_B = 0,	45		60		80		100		V
I_{CEO}	V_{CE} = 30 V,	I_B = 0		0.7		0.7					mA
	V_{CE} = 60 V,	I_B = 0						0.7		0.7	
I_{CES}	V_{CE} = 45 V,	V_{BE} = 0		0.4							
	V_{CE} = 60 V,	V_{BE} = 0				0.4					
	V_{CE} = 80 V,	V_{BE} = 0						0.4			
	V_{CE} = 100 V,	V_{BE} = 0								0.4	
I_{EBO}	V_{EB} = 5 V,	I_C = 0		1		1		1		1	mA
h_{FE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 0.3 A,	30		30		30		30		
	V_{CE} = 4 V, See Notes 6 and 7	I_C = 3 A,	15		15		15		15		
V_{BE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 6 A,		2		2		2		2	V
$V_{CE(sat)}$	I_B = 1.0 A, See Notes 6 and 7	I_C = 6 A,		1.5		1.5		1.5		1.5	V
h_{fe}	V_{CE} = 10 V, f = 1 kHz	I_C = 0.5 A,	20		20		20		20		
$\|h_{fe}\|$	V_{CE} = 10 V, f = 1 MHz	I_C = 0.5 A	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2 %.

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

thermal characteristics

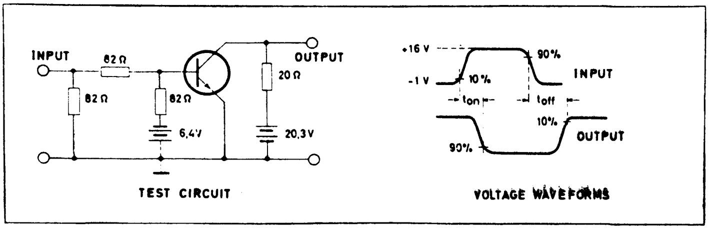
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.92	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS⁺			TYP	UNIT
t_{on}	I_C = 1 A,	$I_{B(1)}$ = 0.1 A,	$I_{B(2)}$ = −0.1 A,	0.3	µs
t_{off}	$V_{BE(off)}$ = −3.7 V, R_L = 20 Ω,		See Figure 1	1	

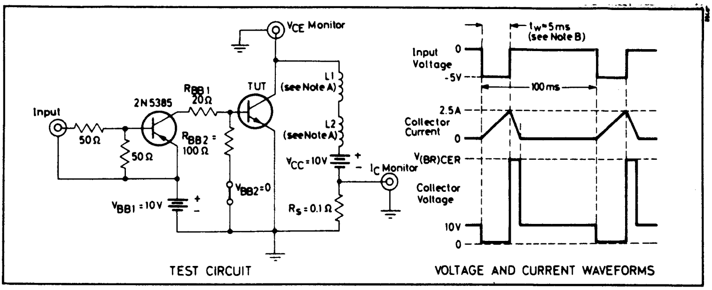
⁺ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD243, BD243A, BD243B, BD243C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS



TEST CIRCUIT

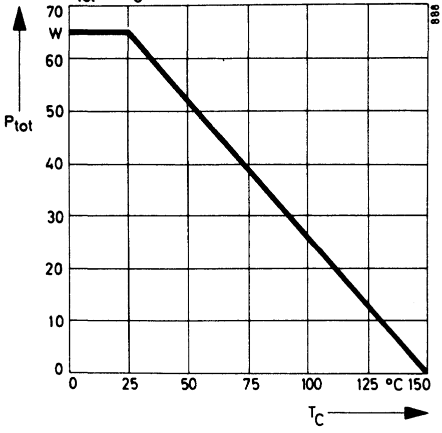
VOLTAGE WAVEFORMS



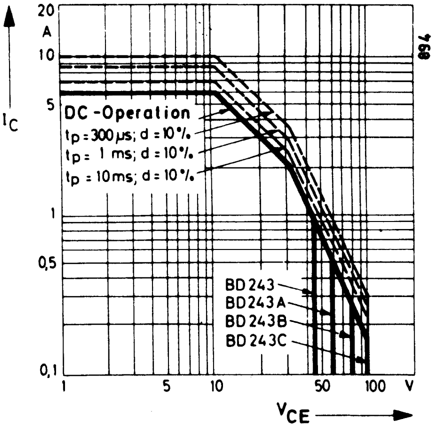
TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

Dissipation derating curve
$P_{tot} = f(T_C)$

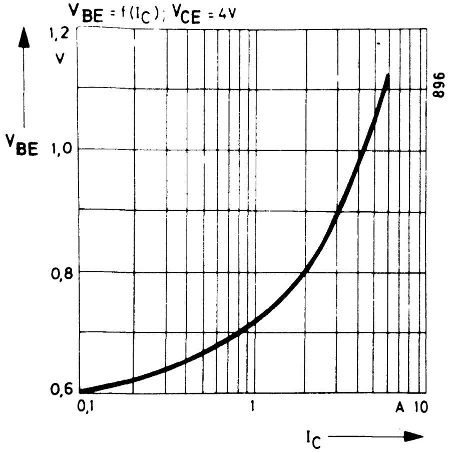


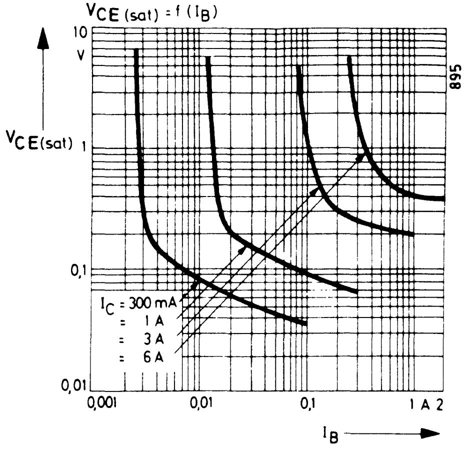
max. safe operating area $T_C \leq 25°C$



TEXAS INSTRUMENTS

BD243, BD243A, BD243B, BD243C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS





BD244, BD244A, BD244B, BD244C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

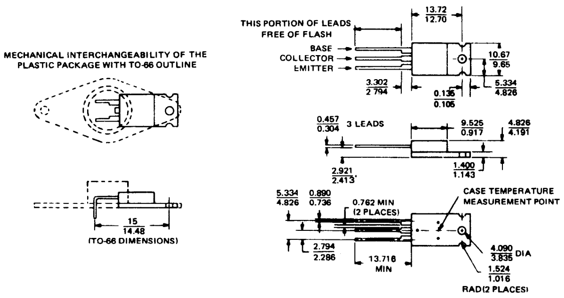
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD243A-C

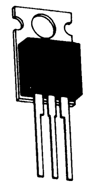
- **65 W at 25 °C Case Temperature**
- **6 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD244	BD244A	BD244B	BD244C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	−55 V	−70 V	−90 V	−115 V
Collector-Emitter Voltage (See Note 1)	−45 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	←	−5 V		→
Continuous Collector Current	←	−6 A		→
Peak Collector Current (See Note 2)	←	−10 A		→
Continuous Base Current	←	−3 A		→
Safe Operating Region at (or below) 25 °C Case Temperature	←	See Figure 5		→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	←	65 W		→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	←	2 W		→
Unclamped Inductive Load Energy (See Note 5)	←	62.5 mJ		→
Operating Collector Junction Temperature Range	←	−65 °C to 150 °C		→
Storage Temperature Range	←	−65 °C to 150 °C		→
Lead Temperature 3.2mm from Case for 5 Seconds	←	250 °C		→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.52 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy $\approx I_C{}^2 L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD249, BD249A, BD249B, BD249C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD244		BD244A		BD244B		BD244C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	$I_C = -30$ mA, See Note 6	$I_B = 0$,	−45		−60		−80		−100		V
I_{CEO}	$V_{CE} = -30$ V,	$I_B = 0$		−0.7		−0.7					mA
	$V_{CE} = -60$ V,	$I_B = 0$						−0.7		−0.7	
I_{CES}	$V_{CE} = -45$ V,	$V_{BE} = 0$		−0.4							mA
	$V_{CE} = -60$ V,	$V_{BE} = 0$				−0.4					
	$V_{CE} = -80$ V,	$V_{BE} = 0$						−0.4			
	$V_{CE} = -100$ V,	$V_{BE} = 0$								−0.4	
I_{EBO}	$V_{EB} = -5$ V,	$I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -0.3$ A,	30		30		30		30		
	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -3$ A,	15		15		15		15		
V_{BE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -6$ A,		−2		−2		−2		−2	V
$V_{CE(sat)}$	$I_B = -1.0$ A, See Notes 6 and 7	$I_C = -6$ A,		−1.5		−1.5		−1.5		−1.5	V
h_{fe}	$V_{CE} = -10$ V, f = 1 kHz	$I_C = -0.5$ A,	20		20		20		20		
$\|h_{fe}\|$	$V_{CE} = -10$ V, f = 1 MHz	$I_C = -0.5$ A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2 %.

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

thermal characteristics

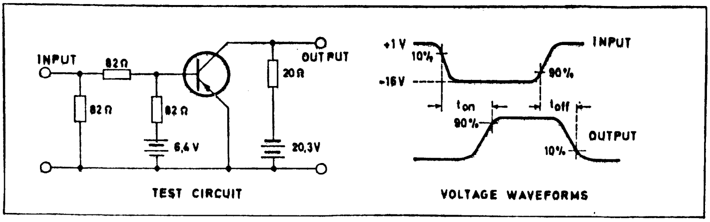
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.92	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS⁺			TYP	UNIT
t_{on}	$I_C = -1$ A,	$I_{B(1)} = -0.1$ A,	$I_{B(2)} = 0.1$ A,	0.2	μs
t_{off}	$V_{BE(off)} = 3.7$ V	$R_L = 20\ \Omega$,	See Figure 1	0.8	

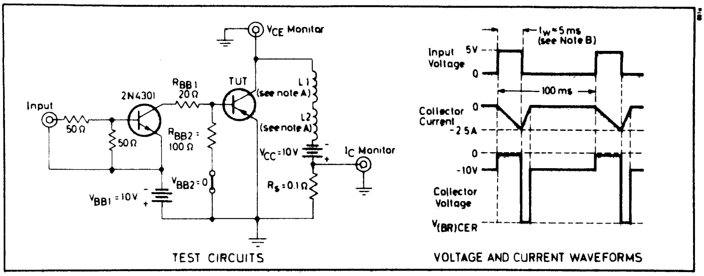
⁺ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD243, BD243A, BD243B, BD243C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS



TEST CIRCUIT

VOLTAGE WAVEFORMS

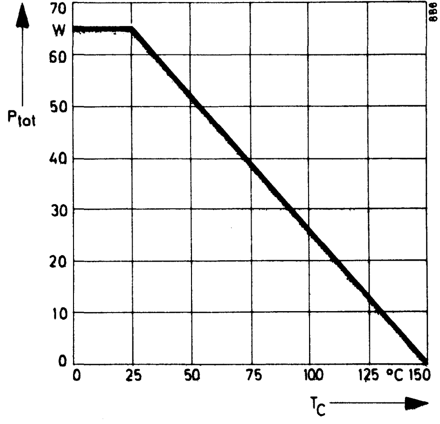


TEST CIRCUITS

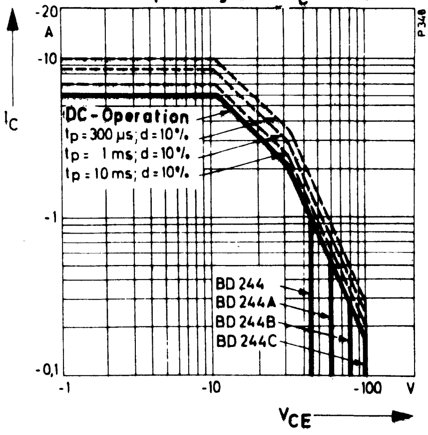
VOLTAGE AND CURRENT WAVEFORMS

Dissipation derating curve

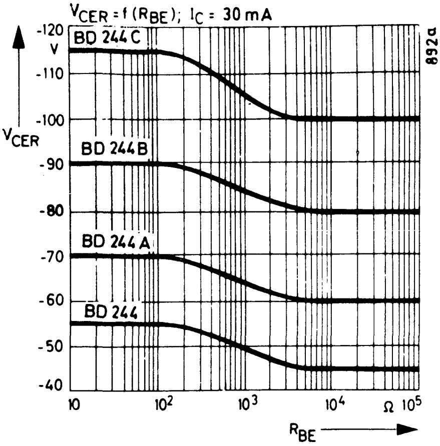
$P_{tot} = f(T_C)$

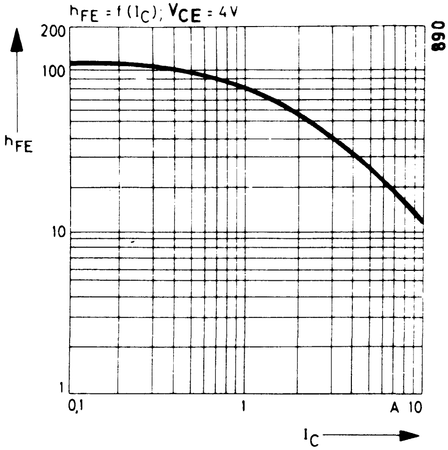


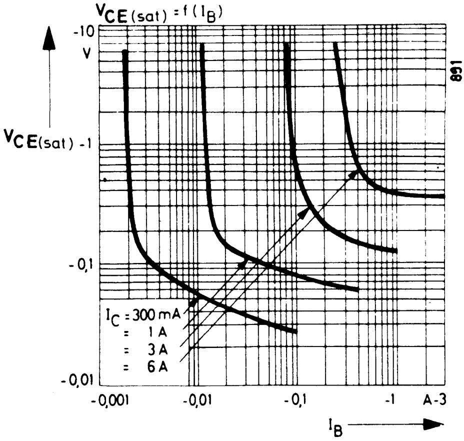
max safe operating area $T_C \le 25$°C

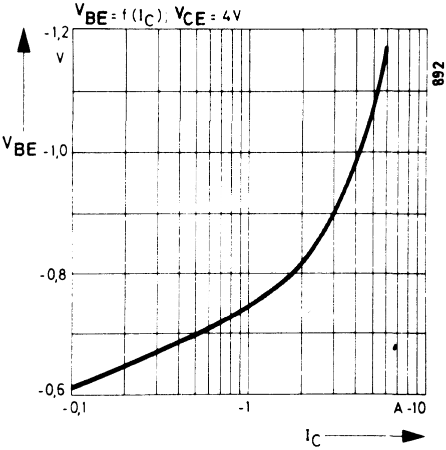


BD244, BD244A, BD244B, BD244C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD245, BD245A, BD245B, BD245C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

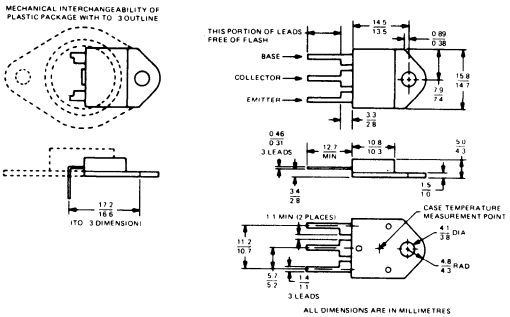
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD246A-C

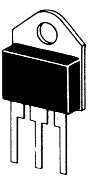
- 80 W at 25 °C Case Temperature
- 10 A Rated Collector Current
- Min f_T of 3 MHz at 10 V, 500 mA

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD245	BD245A	BD245B	BD245C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	55 V	70 V	90 V	115 V
Collector-Emitter Voltage (See Note 1)	45 V	60 V	80 V	100 V
Emitter-Base Voltage	← 5 V →			
Continuous Collector Current	← 10 A →			
Peak Collector Current (See Note 2)	← 15 A →			
Continuous Base Current	← 3 A →			
Safe Operating Region at (or below) 25 °C Case Temperature	← See Figure 5 →			
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	← 80 W →			
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	← 3.0 W →			
Unclamped Inductive Load Energy (See Note 5)	← 62.5 mJ →			
Operating Collector Junction Temperature Range	← −65 °C to 150 °C →			
Storage Temperature Range	← −65 °C to 150 °C →			
Lead Temperature 1/8 Inch from Case for 5 Seconds	← 250 °C →			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.64 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy $\approx I_C{}^2L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD245, BD245A, BD245B, BD245C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER			BD245		BD245A		BD245B		BD245C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	$I_C = 30$ mA, See Note 6	$I_B = 0$,	45		60		80		100		V
I_{CEO}	$V_{CE} = 30$ V,	$I_B = 0$		0.7		0.7					mA
	$V_{CE} = 60$ V,	$I_B = 0$						0.7		0.7	
I_{CES}	$V_{CE} = 45$ V,	$V_{BE} = 0$		0.4							mA
	$V_{CE} = 60$ V,	$V_{BE} = 0$				0.4					
	$V_{CE} = 80$ V,	$V_{BE} = 0$						0.4			
	$V_{CE} = 100$ V,	$V_{BE} = 0$								0.4	
I_{EBO}	$V_{EB} = 5$ V,	$I_C = 0$		1		1		1		1	mA
h_{FE}	$V_{CE} = 4$ V,	$I_C = 1$ A,	40		40		40		40		
	See Notes 6 and 7	$I_C = 3$ A	20		20		20		20		
	$V_{CE} = 4$ V, See Notes 6 and 7	$I_C = 10$ A	4		4		4		4		
V_{BE}	$V_{CE} = 4$ V, See Notes 6 and 7	$I_C = 3$ A,		1.6		1.6		1.6		1.6	V
	$V_{CE} = 4$ V, See Notes 6 and 7	$I_C = 10$ A		3		3		3		3	V
$V_{CE(sat)}$	$I_B = 0.3$ A, See Notes 6 and 7	$I_C = 3$ A,		1		1		1		1	V
	$I_B = 2.5$ A, See Notes 6 and 7	$I_C = 10$ A,		4		4		4		4	V
h_{fe}	$V_{CE} = 10$ V, f = 1 kHz	$I_C = 0.5$ A,	20		20		20		20		
$\|h_{fe}\|$	$V_{CE} = 10$ V, f = 1 MHz	$I_C = 0.5$ A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle $\leqslant 2$ %.

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

thermal characteristics

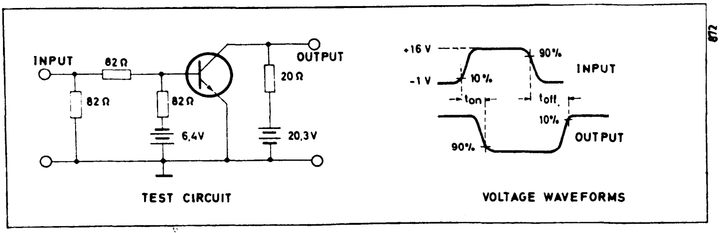
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.56	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	42.0	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS⁺			TYP	UNIT
t_{on}	$I_C = 1$ A,	$I_{B(1)} = 0.1$ A,	$I_{B(2)} = -0.1$ A,	0.3	μs
t_{off}	$V_{BE(off)} = 3.7$ V,	$R_L = 20\ \Omega$,	See Figure 1	1	

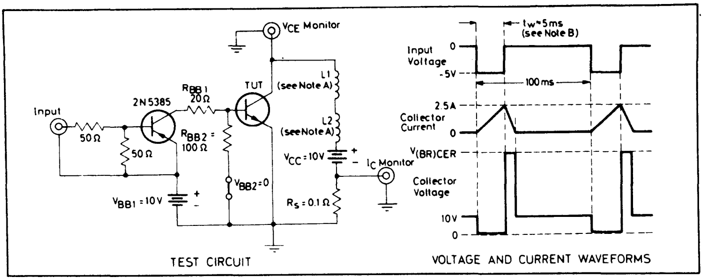
⁺ Voltage and Current values shown are nominal; exact values vary slightly with transistor parameters.

BD245, BD245A, BD245B, BD245C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS



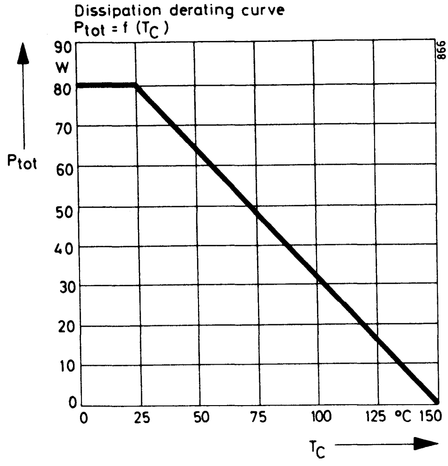
TEST CIRCUIT

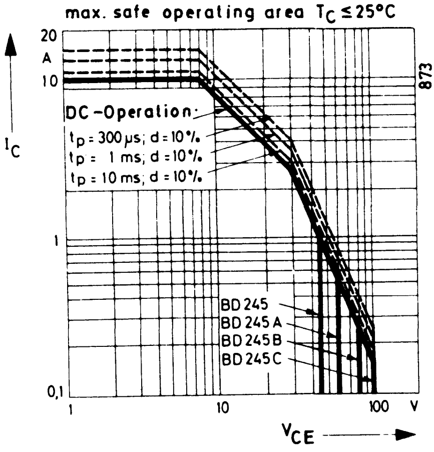
VOLTAGE WAVEFORMS



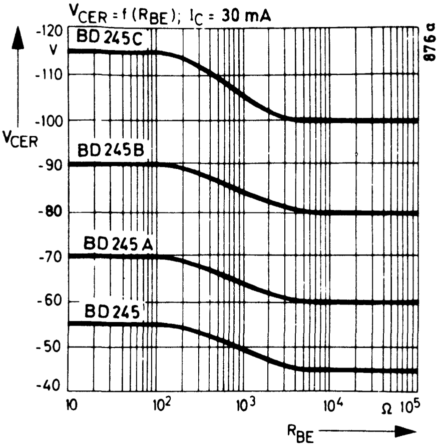
TEST CIRCUIT

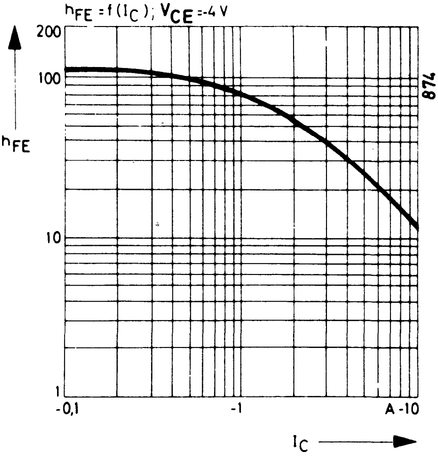
VOLTAGE AND CURRENT WAVEFORMS

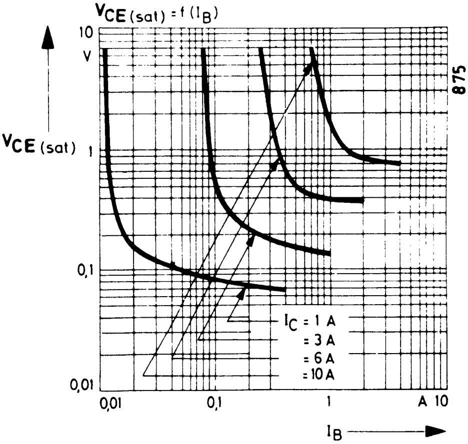

Dissipation derating curve
$P_{tot} = f\ (T_C)$

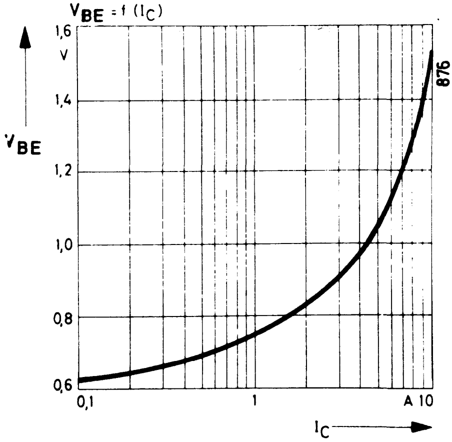

max. safe operating area $T_C \leq 25°C$

BD245, BD245A, BD245B, BD245C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD246, BD246A, BD246B, BD246C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

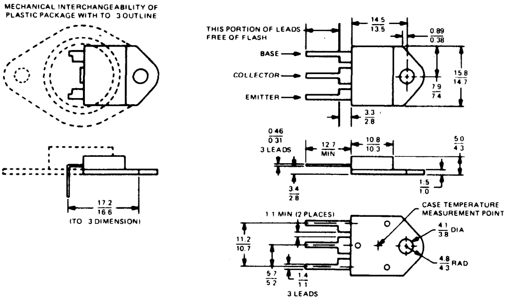
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH BD245A-C

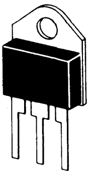
- 80 W at 25 °C Case Temperature
- 10 A Rated Collector Current
- Min f_T of 3 MHz at 10 V, 500 mA

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD246	BD246A	BD246B	BD246C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	−55 V	−70 V	−90 V	−115 V
Collector-Emitter Voltage (See Note 1)	−45 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	←	−5 V		→
Continuous Collector Current	←	−10 A		→
Peak Collector Current (See Note 2)	←	−15 A		→
Continuous Base Current	←	−3 A		→
Safe Operating Region at (or below) 25 °C Case Temperature	←	See Figure 5		→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	←	80 W		→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	←	3 W		→
Unclamped Inductive Load Energy (See Note 5)	←	62.5 mJ		→
Operating Collector Junction Temperature Range	←	−65 °C to 150 °C		→
Storage Temperature Range	←	−65 °C to 150 °C		→
Lead Temperature 1/8 Inch from Case for 5 Seconds	←	250 °C		→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 0.65 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy ≈ 1/2 $I_C{}^2L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD246, BD246A, BD246B, BD246C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD246		BD246A		BD246B		BD246C		
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	UNIT
$V_{(BR)CEO}$	I_C = −30 mA, See Note 6	I_B = 0,	−45		−60		−80		−100		V
I_{CEO}	V_{CE} = −30 V,	I_B = 0		−0.7		−0.7					mA
	V_{CE} = −60 V,	I_B = 0						−0.7		−0.7	
I_{CES}	V_{CE} = −45 V,	V_{BE} = 0		−0.4							mA
	V_{CE} = −60 V,	V_{BE} = 0				−0.4					
	V_{CE} = −80 V,	V_{BE} = 0						−0.4			
	V_{CE} = −100 V,	V_{BE} = 0								−0.4	
I_{EBO}	V_{EB} = −5 V,	I_C = 0		−1		−1		−1		−1	mA
h_{FE}	V_{CE} = −4 V,	I_C = −1 A	40		40		40		40		
	V_{CE} = −4 V,	I_C = −3 A	20		20		20		20		
	V_{CE} = −4 V, See Notes 6 and 7	I_C = −10 A	4		4		4		4		
V_{BE}	V_{CE} = −4 V, See Notes 6 and 7	I_C = −3 A,		−1.6		−1.6		−1.6		−1.6	V
	V_{CE} = −4 V, See Notes 6 and 7	I_C = −10 A,		−3		−3		−3		−3	
$V_{CE(sat)}$	I_B = −0.3 A, See Notes 6 and 7	I_C = −3 A,		−1		−1		−1		−1	V
	I_B = −2.5 A, See Notes 6 and 7	I_C = −10 A,		−4		−4		−4		−4	
h_{fe}	V_{CE} = −10 V, f = 1 kHz	I_C = −0.5 A,	20		20		20		20		
$\|h_{fe}\|$	V_{CE} = −10 V, f = 1 MHz	I_C = −0.5 A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2 %.

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

thermal characteristics

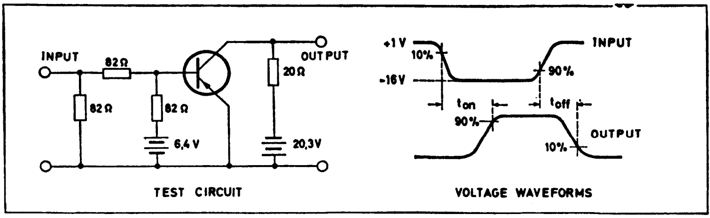
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.56	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	42.0	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS +			TYP	UNIT
t_{on}	I_C = 1 A,	$I_{B(1)}$ = 0.1 A,	$I_{B(2)}$ = 0.1 A,	0.2	μs
t_{off}	$V_{BE(off)}$ = 3.7 V,	R_L = 20 Ω,	See Figure 1	0.8	

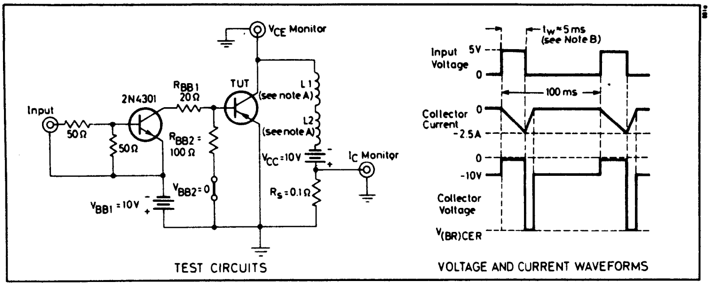
+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD246, BD246A, BD246B, BD246C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS



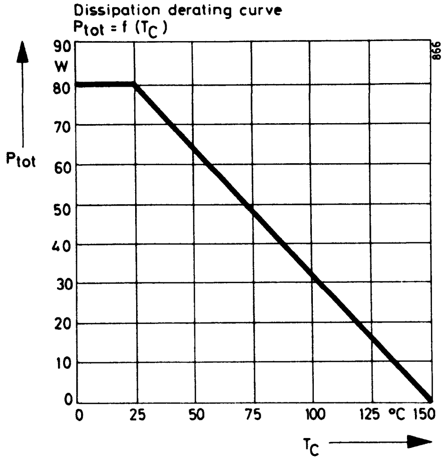
TEST CIRCUIT

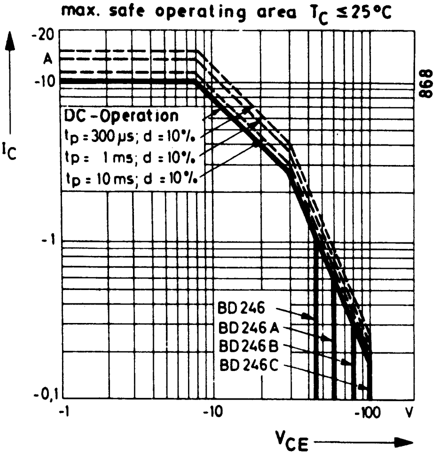
VOLTAGE WAVEFORMS



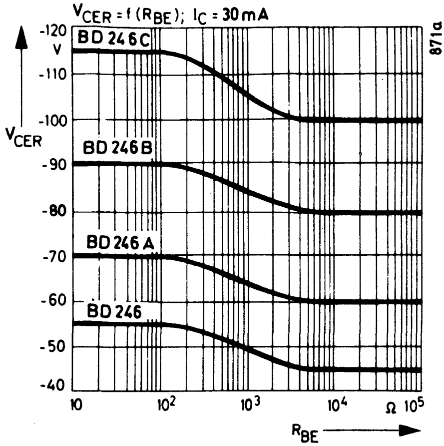
TEST CIRCUITS

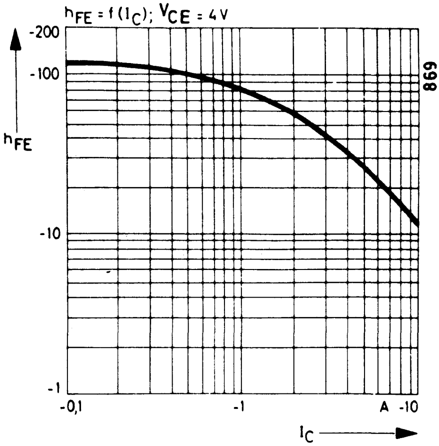
VOLTAGE AND CURRENT WAVEFORMS

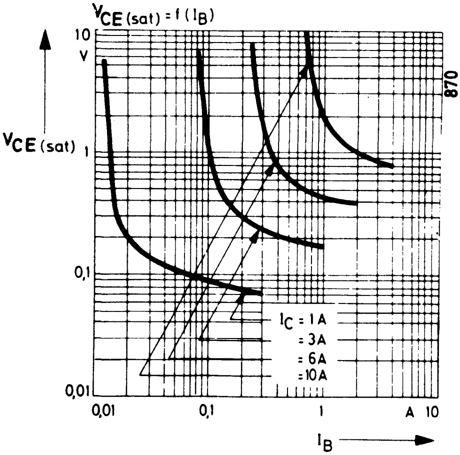


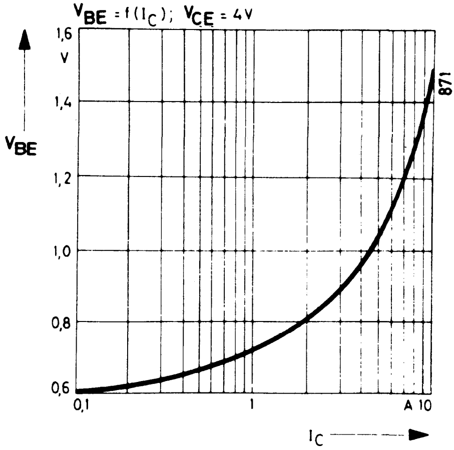


BD246, BD246A, BD246B, BD246C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









TEXAS INSTRUMENTS

BD249, BD249A, BD249B, BD249C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

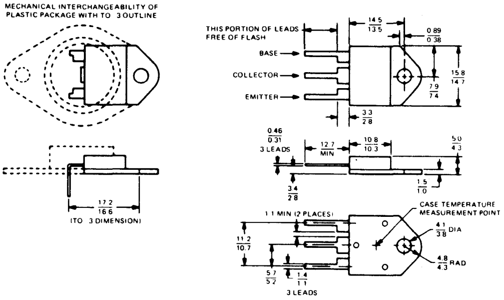
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH BD250A-C

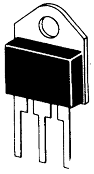
- **125 W at 25 °C Case Temperature**
- **25 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD249	BD149A	BD249B	BD249C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	55 V	70 V	90 V	115 V
Collector-Emitter Voltage (See Note 1)	45 V	60 V	80 V	100 V
Emitter-Base Voltage	←	5 V		→
Continuous Collector Current	←	25 A		→
Peak Collector Current (See Note 2)	←	40 A		→
Continuous Base Current	←	5 A		→
Safe Operating Region at (or below) 25 °C Case Temperature	←	See Figure 5		→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	←	125 W		→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	←	3.0 W		→
Unclamped Inductive Load Energy (See Note 5)	←	90 mJ		→
Operating Collector Junction Temperature Range	←	−65 °C to 150 °C		→
Storage Temperature Range	←	−65 °C to 150 °C		→
Lead Temperature 3.2mm from Case for 5 Seconds	←	250 °C		→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 1 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy $\approx I_C^2 L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

BD249, BD249A, BD249B, BD249C
NPN SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD249 MIN	BD249 MAX	BD249A MIN	BD249A MAX	BD249B MIN	BD249B MAX	BD249C MIN	BD249C MAX	UNIT
$V_{(BR)CEO}$	I_C = 30 mA, See Note 6	I_B = 0,	45		60		80		100		V
I_{CEO}	V_{CE} = 30 V,	I_B = 0		1		1					mA
	V_{CE} = 60 V,	I_B = 0						1		1	
I_{CES}	V_{CE} = 45 V,	V_{BE} = 0		0.7							mA
	V_{CE} = 60 V,	V_{BE} = 0				0.7					
	V_{CE} = 80 V,	V_{BE} = 0						0.7			
	V_{CE} = 100 V,	V_{BE} = 0								0.7	
I_{EBO}	V_{EB} = 5 V,	I_C = 0		1		1		1		1	mA
h_{FE}	V_{CE} = 4 V,	I_C = 1.5 A	25		25		25		25		
	V_{CE} = 4 V,	I_C = 25 A	5		5		5		5		
	V_{CE} = 4 V, See Notes 6 and 7	I_C = 15 A	10		10		10		10		
V_{BE}	V_{CE} = 4 V, See Notes 6 and 7	I_C = 15 A,		2		2		2		2	V
	V_{CE} = 4 V, See Notes 6 and 7	I_C = 25 A,		4		4		4		4	
$V_{CE(sat)}$	I_B = 1.5 A, See Notes 6 and 7	I_C = 15 A,		1.8		1.8		1.8		1.8	V
	I_B = 5 A, See Notes 6 and 7	I_C = 25 A,		4		4		4		4	
h_{fe}	V_{CE} = 10 V, f = 1 kHz	I_C = 1 A,	25		25		25		25		
$\|h_{fe}\|$	V_{CE} = 10 V, f = 1 MHz	I_C = 1 A,	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 µd duty cycle ≤ 2 %.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

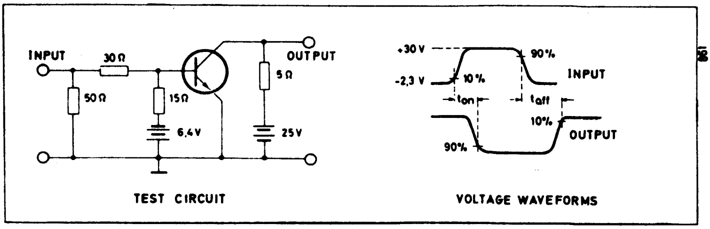
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	42	

switching characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS +			TYP	UNIT
t_{on}	I_C = 5 A,	$I_{B(1)}$ = 5 A,	$I_{B(2)}$ = −5 A,	0.3	µs
t_{off}	$V_{BE(off)}$ = −5 V,	R_L = 5 Ω,	See Figure 1	0.9	

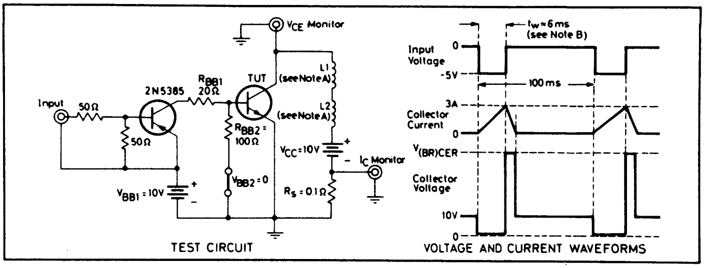
+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD249, BD249A, BD249B, BD249C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS



TEST CIRCUIT

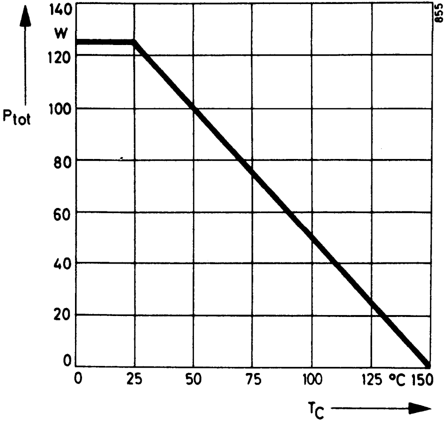
VOLTAGE WAVEFORMS



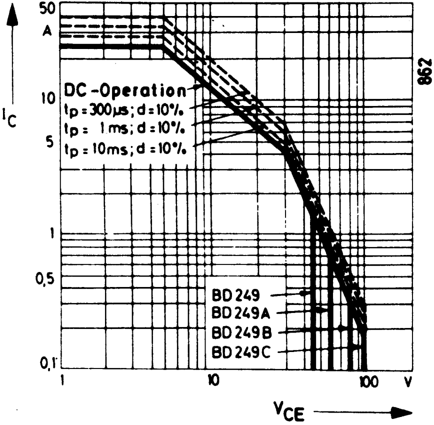
TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

Dissipation derating curve
$P_{tot} = f\ (T_C)$

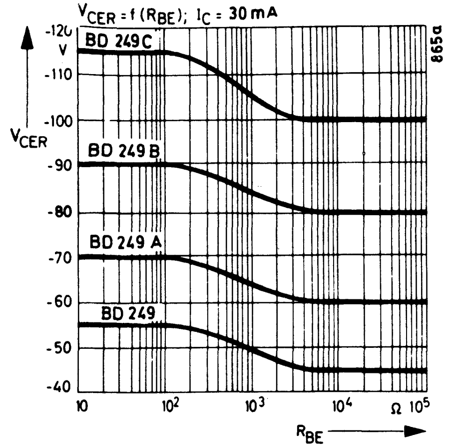


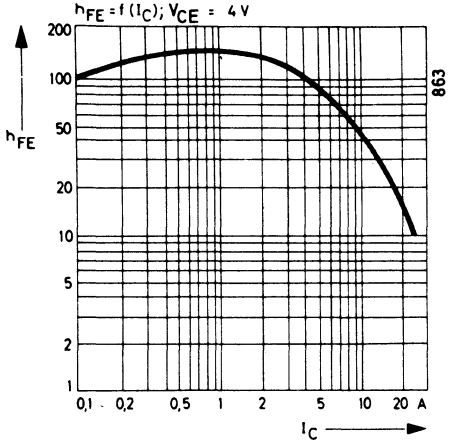
max. safe operating area $T_C \leq 25°C$

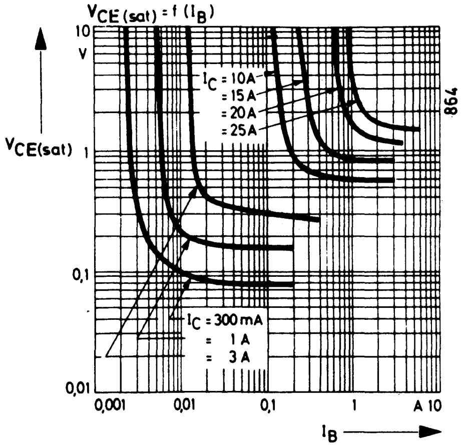


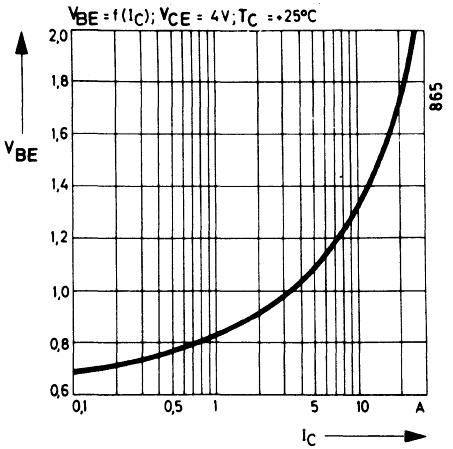
TEXAS INSTRUMENTS

BD249, BD249A, BD249B, BD249C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD250, BD250A, BD250B, BD250C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

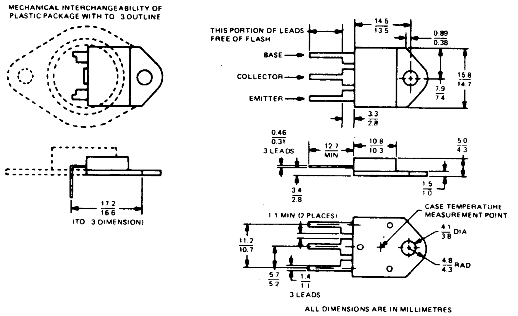
REVISED SEPTEMBER 1975

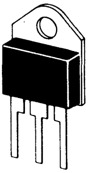
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH BD249A-C

- **125 W at 25 °C Case Temperature**
- **15 A rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	BD250	BD250A	BD250B	BD250C
Collector-Emitter Voltage (R_{BE} = 100 Ω)	−55 V	−70 V	−90 V	−115 V
Collector-Emitter Voltage (See Note 1)	−45 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	←	−5 V		→
Continuous Collector Current	←	−25 A		→
Peak Collector Current (See Note 2)	←	−40 A		→
Continuous Base Current	←	−5 A		→
Safe Operating Region at (or below) 25 °C Case Temperature	←	See figure 5		→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	←	125 W		→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 4)	←	3.0 W		→
Unclamped Inductive Lead Energy (See Note 5)	←	90 mJ		→
Operating Collector Junction Temperature Range	←	−65 °C to 150 °C		→
Storage Temperature Range	←	−65 °C to 150 °C		→
Lead Temperature 3.2mm from Case for 5 Seconds	←	250 °C		→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10$ %.
3. Derate linearly to 150 °C case temperature at the rate of 1 W/°C.
4. Derate linearly to 150 °C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V, Energy $\approx I_C^2 L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be
published at a later date.

TEXAS INSTRUMENTS

BD250, BD250A, BD250B, BD250C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER	TEST CONDITIONS		BD250		BD250A		BD250B		BD250C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	$I_C = -30$ mA, See Note 6	$I_B = 0$	−45		−60		−80		−100		V
I_{CEO}	$V_{CE} = -30$ V,	$I_B = 0$		−1		−1					mA
	$V_{CE} = -60$ V,	$I_B = 0$						−1		−1	
I_{CES}	$V_{CE} = -45$ V,	$V_{BE} = 0$		−0.7							mA
	$V_{CE} = -60$ V,	$V_{BE} = 0$				−0.7					
	$V_{CE} = -80$ V,	$V_{BE} = 0$						−0.7			
	$V_{CE} = -100$ V,	$V_{BE} = 0$								−0.7	
I_{EBO}	$V_{EB} = -5$ V,	$I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	$V_{CE} = -4$ V,	$I_C = -1.5$ A	25		25		25		25		
	$V_{CE} = -4$ V,	$I_C = -15$ A	10		10		10		10		
	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -25$ A	5		5		5		5		
V_{BE}	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -15$ A,		−2		−2		−2		−2	V
	$V_{CE} = -4$ V, See Notes 6 and 7	$I_C = -25$ A,		−4		−4		−4		−4	
$V_{CE(sat)}$	$I_B = -1.5$A, See Notes 6 and 7	$I_C = -15$ A		−1.8		−1.8		−1.8		−1.8	V
	$I_B = -5$ A, See Notes 6 and 7	$I_C = -25$ A		−4		−4		−4		−4	
h_{fe}	$V_{CE} = -10$ V, f = 1 kHz	$I_C = -1$ A	25		25		25		25		
$\|h_{fe}\|$	$V_{CE} = -10$ V, f = 1 MHz	$I_C = -1$ A	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle $\leqslant 2$ %.

7. These parameters are measured with voltagesensing contacts separate from the current-carrying contacts.

thermal characteristics

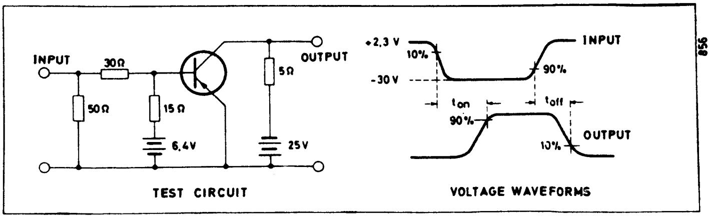
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	42.0	

switching characteristics at 25 °C case temperature

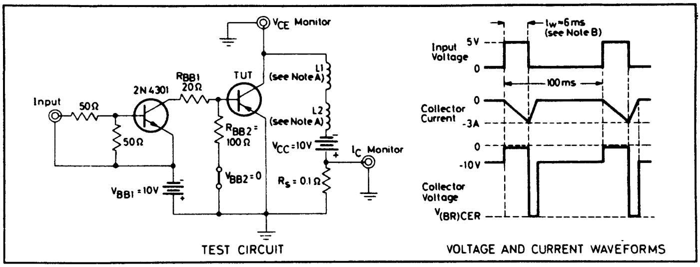
PARAMETER	TEST CONDITIONS +			TYP	UNIT
t_{on}	$I_C = -5$ A,	$I_{B(1)} = -0.5$ A,	$I_{B(2)} = 0.5$ A,	0.2	µs
t_{off}	$V_{BE(off)} = 5$ V,	$R_L = 5\,\Omega$	See Figure 1	0.4	

+ Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD250, BD250A, BD250B, BD250C
PNP SINGLE-DIFFUSED MESA
SILICON POWER TRANSISTORS

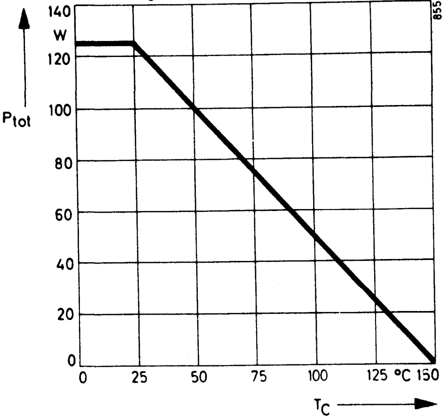


TEST CIRCUIT VOLTAGE WAVEFORMS

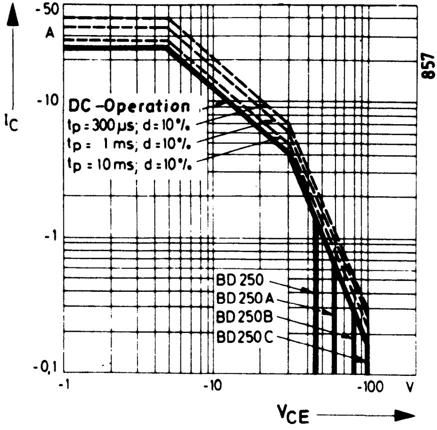


TEST CIRCUIT VOLTAGE AND CURRENT WAVEFORMS

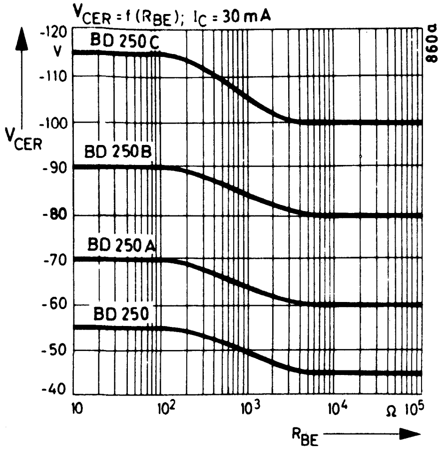
Dissipation derating curve
$P_{tot} = f(T_C)$

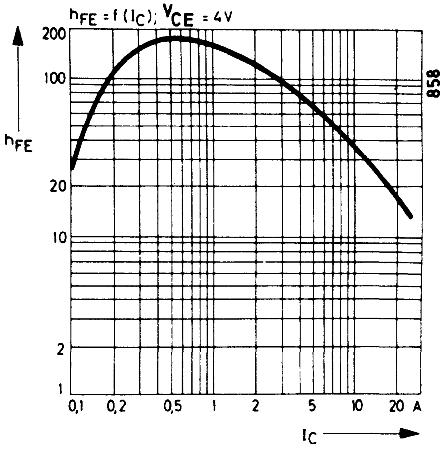


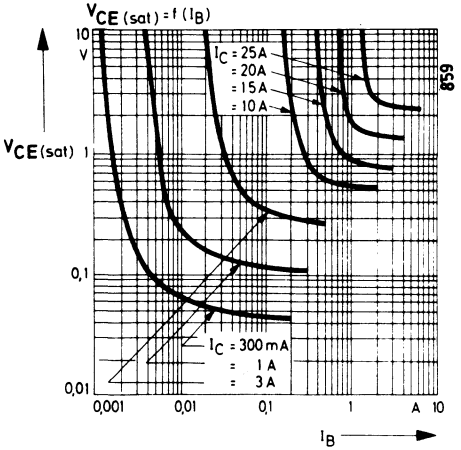
max. safe operating area $T_C \leq 25°C$

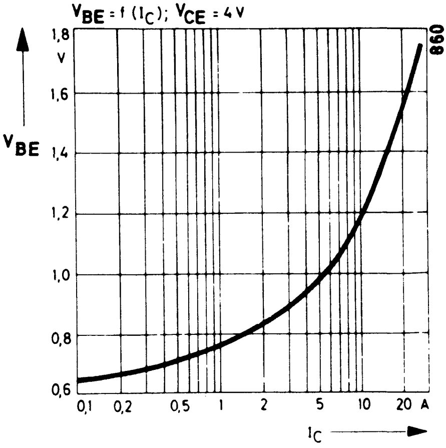


BD250, BD250A, BD250B, BD250C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS









BD253, BD253A, BD253B, BD253C
NPN SILICON POWER TRANSISTORS

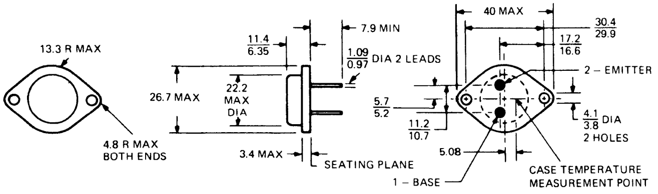
REVISED AUGUST 1975

(Formerly XB33 Series)

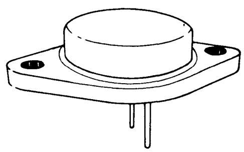
- **High Voltage Rating – V_{CEX} up to 900 Volts**
- **High Current Rating – 6 Amps Peak**
- **Low Saturation Voltage at 3 Amps – 0.6 Volts typ.**
- **Fast Switching t_f at 3 Amps – 300 nano Secs typ.**
- **f_T – 25 MHz typ.**

mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings (T_{case} = 25 °C)

	BD253	BD253A	BD253B	BD253C
Collector-Base Voltage ($I_E = 0$)	350 V	500 V	700 V	900 V
Collector-Emitter Voltage ($-2 \geqslant V_{BE} \geqslant -8$ V)	350 V	500 V	700 V	900 V
Collector-Emitter Voltage ($I_B = 0$)	200 V	250 V	300 V	400 V
Emitter-Base Voltage	← 8 V →			
Collector Current (Peak see Note 1)	← 6 A →			
Collector Current Continuous	← 4 A →			
Base-Current Continuous	← 3 A →			
Total Dissipation ($V_{CE} \leqslant 25$ V) See Note 2	← 50 W →			
Operating Junction Temperature	← −65 °C to +175 °C →			
Storage Temperature	← −65 °C to +175 °C →			

NOTES: 1. Pulse Width ⩽ 1 ms. Duty Cycle ⩽ 25 %.
2. Refer to Figures 1 and 3

BD 253, BD 253A, BD 253B, BD 253C
NPN SILICON POWER TRANSISTORS

electrical characteristics (T_{case} = 25 °C)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
I_{CBO}	Collector-Base Leakage Current	V_{CB} = 350 V, I_E = 0	BD253			2	mA
		V_{CB} = 500 V, I_E = 0	BD253A			2	
		V_{CB} = 700 V, I_E = 0	BD253B			2	
		V_{CB} = 900 V, I_E = 0	BD253C			2	
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 350 V, V_{BE} = −2 V	BD253			2	mA
		V_{CE} = 500 V, V_{BE} = −2 V	BD253A			2	
		V_{CE} = 700 V, V_{BE} = −2 V	BD253B			2	
		V_{CE} = 900 V, V_{BE} = −2 V	BD253C			2	
LV_{CEO}	Collector-Emitter Latching Voltage	I_C = 100 mA, I_B = 0 See Note 3	BD253	200			V
			BD253A	250			
			BD253B	300			
			BD253C	400			
LV_{CER}	Collector-Emitter Latching Voltage	I_E = 100 mA, R_{BE} = 100 Ω See Note 3	BD253	300			V
			BD253A	350			
			BD253B	400			
			BD253C	500			
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 mA, I_C = 0	All	8			V
h_{FE}	DC Gain	I_C = 1 A, V_{CE} = 4 V See Note 3	All	15	50		
h_{FE}	DC Gain	I_C = 3 A, V_{CE} = 4 V See Note 3	All	5	10		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 1 A, I_B = .1 A	All		.5	1,2	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	See Note 3	All		.85	1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 3 A, I_B = 1 A See Note 3	All		.6	2.0	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage		All		1.1	1.6	V
f_T	Transition Frequency	I_C = 0.25 A, V_{CE} = 10 V f = 10 MHz	All	15	25		MHz
$\theta_{j\text{-}c}$	Junction to Case Thermal Resistance		All		2	3	°C/W
t_r	Collector-Current Fall Time	I_C = 3 A, $I_{B(on)}$ = 1 A $I_{B(off)}$ = 1 A, V_{CE} = 60 V	All		0.3	1	μs
t_s	Storage Time		All		1.0	2	μs
t_{on}	Total Turn-on Time		All		0.6	1.5	μs

NOTE 3: Pulsed Test. Pulse Duration ≤ 300 μs. Duty Cycle ≤ 2 %.

BD 253, BD 253A, BD 253B, BD 253C
NPN SILICON POWER TRANSISTORS

FORWARD BIASED SAFE AREA OF OPERATION, D.C.
AND SINGLE NON-REPETITIVE PULSE.
CASE TEMPERATURE 25 °C

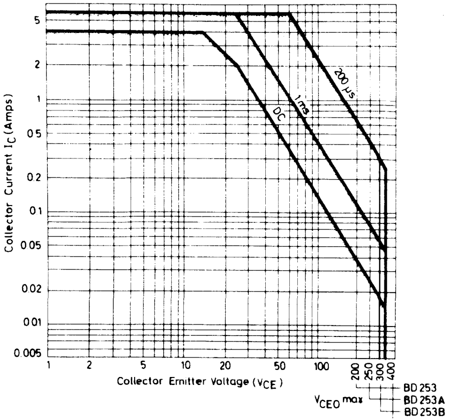


FIGURE 1

TYPICAL VARIATION OF D.C. GAIN WITH COLLECTOR
CURRENT. CASE TEMPERATURE +25 °C

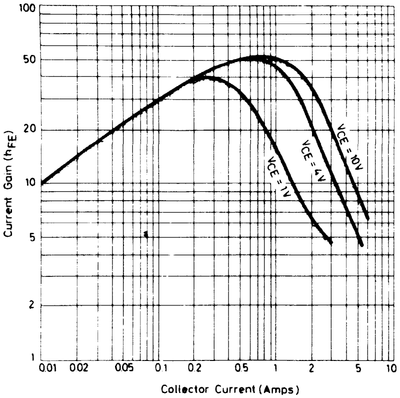


FIGURE 2

DISSIPATION DERATING CURVE

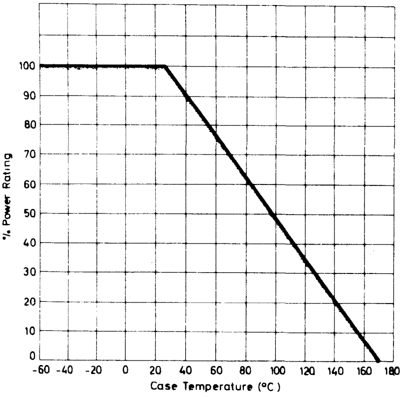


FIGURE 3

The graph on Figure 1 is for single non-repetitive rectangular power pulses, with a case temperature held at 25 C. For operation at case temperatures above 25 C derate the value of current indicated in Figure 1 by the power derating factor, determined from Figure 3.
For repetitive pulse operation the following procedure should be followed. Work out the energy of the power pulse by graphical integration and determine the equivalent rectangular power pulse, using the pulse duration and the peak voltage applied. Ensure that the equivalent power pulse, as determined, is within the safe operating area, applying a derating factor for the case temperature as indicated above. Also calculate the average power dissipation and ensure that it falls within the steady state (DC) condition, having first derated the steady state condition for the effect of case temperature.

BD410

NPN TRIPLE DIFFUSED SILICON TRANSISTOR

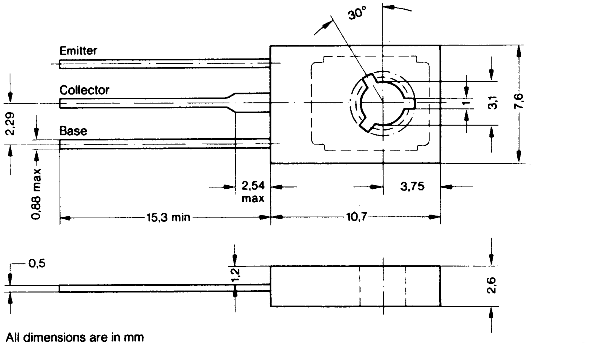
REVISED SEPTEMBER 1975

AF-AMPLIFIER FOR HIGH SUPPLY VOLTAGE

- Control Circuits
- Vertical-Output Stages in TV-Sets
- General Purpose Application
- V_{CER} typ. 450 V at R_{BE} = 1 kΩ
- h_{FE} typ. 60 at I_C = 100 mA
- P_{tot} = 20 W

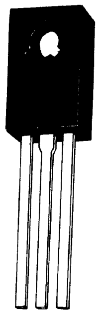
These components are tested according to the appropriate test method of MIL-STD-750. By special agreement, they can also be tested additionally to MIL- or DIN-specifications.

mechanical data



All dimensions are in mm

SOT-32



absolute maximum ratings at 25 °C free-air temeperature (unless otherwise noted)

Collector-Base Voltage	500 V
Collector-Emitter Voltage (See Note 1)	325 V
Emitter-Base Voltage	5 V
Continuous Collector Current	1 A
Peak Collector Current	1.5 A
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (See Note 2)	1.25 W
Continuous Device Dissipation at (or below) 25 °C Case Temperature (See Note 3)	20 W
Storage Temperature Range	–55 °C to 125 °C
Lead Temperature 1.6 mm from Case for 10 Seconds	260 °C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. See power dissipation diagram.
3. See power dissipation diagram.

TEXAS INSTRUMENTS

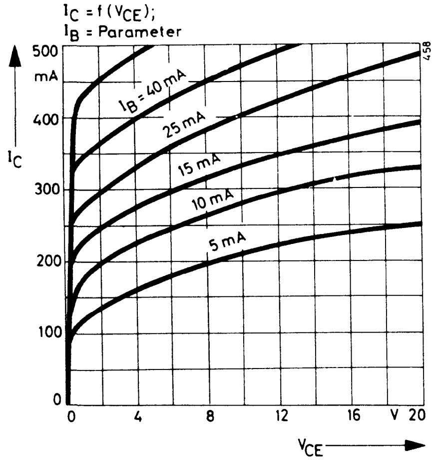
PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

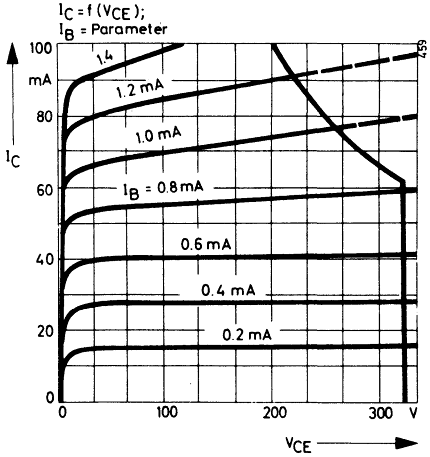
BD410
NPN TRIPLE DIFFUSED SILICON TRANSISTOR

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

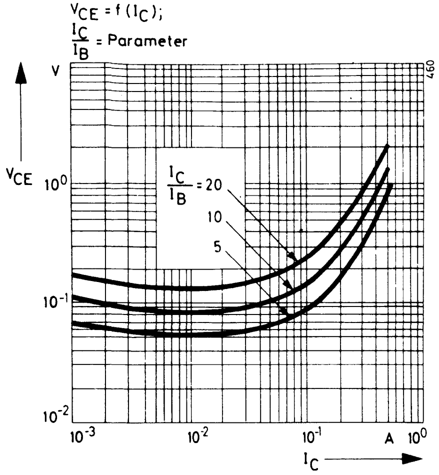
PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 500 μA	I_E = 0		500			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 10 mA,	I_B = 0	See Note 4	325			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 50 μA,	I_C = 0		5			V
I_{CES}	Collector Cutoff Current	V_{CE} = 300 V,	I_B = 0				100	μA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 5 mA		25	55		
		V_{CE} = 10 V,	I_C = 50 mA		30	60	240	
		V_{CE} = 10 V,	I_C = 100 mA		20	60		
V_{BE}	Base-Emitter Voltage	I_B = 10 mA,	I_C = 100 mA				1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 10 mA,	I_C = 100 mA				0.5	V
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V,	I_E = 0,	f = 1 MHz		5.5		pF
C_{ibo}	Common-Base Open-Circuit Input Capacitance	V_{EB} = 0.5 V,	I_E = 0,	f = 1 MHz		90		pF

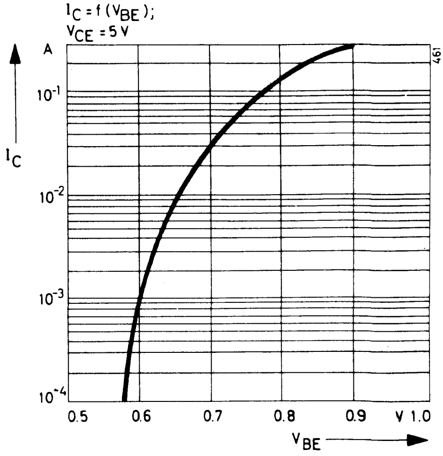
NOTE: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤2 %.

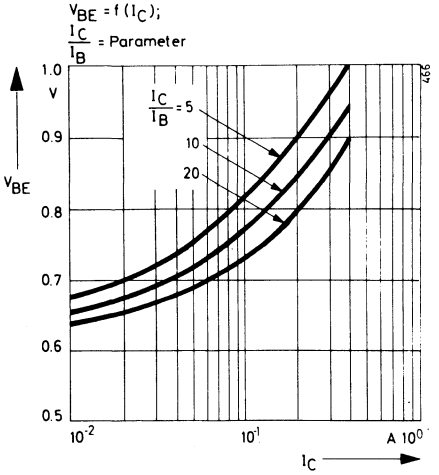


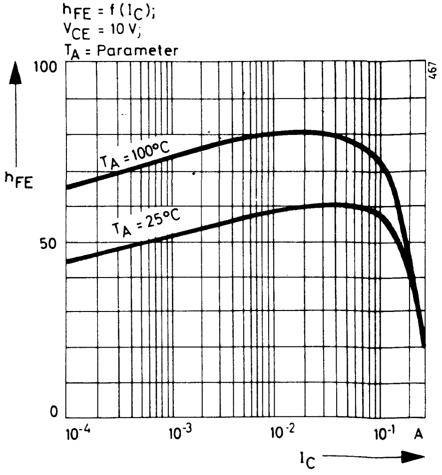


BD410
NPN TRIPLE DIFFUSED SILICON TRANSISTOR



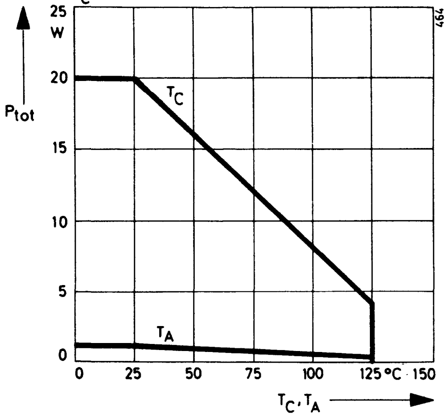




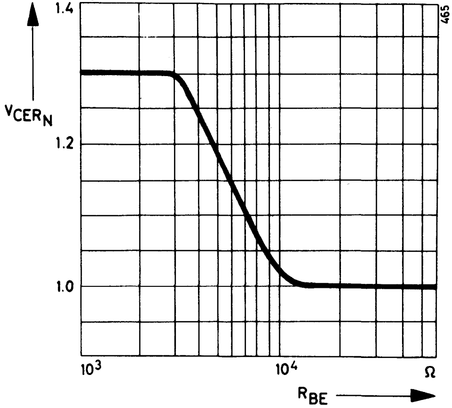


TEXAS INSTRUMENTS

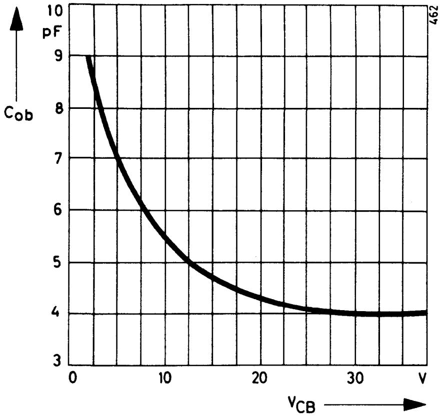
$P_{tot} = f(T_C, T_A)$;
$I_C = 0.5 A$



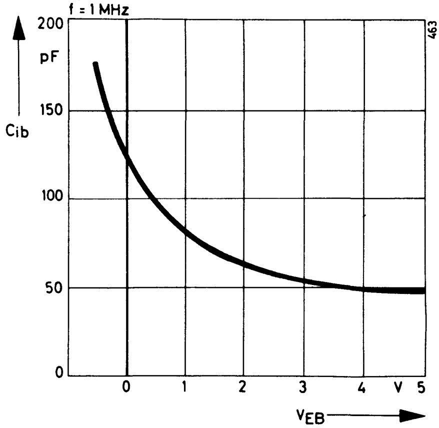
$V_{CER_N} = \frac{V_{CER}}{V_{CEO}} = f(R_{BE})$;
$I_C = 10 mA$



$C_{ob} = f(V_{CB})$;
$I_E = 0$;
f = 1 MHz



$C_{ib} = f(V_{EB})$;
$I_C = 0$;
f = 1 MHz



BD539 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

AUGUST 1975

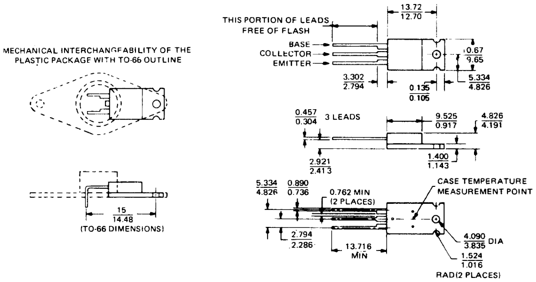
Designed for Medium Power Linear Amplifiers and Switching in Consumer, Automotive and Industrial Applications

features

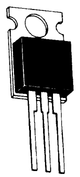
- Low Saturation Voltages $V_{CE(sat)} = 0.8V$ max @ $I_C = 3A$
- Complimentary to PNP Types BD540 Series
- 5A Rated Collector Current
- 45W at 25°C Case Temperature
- Up to 120V V_{CEO} rating

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD539	BD539A	BD539B	BD539C	BD539D
Collector-Base Voltage	40V	60V	80V	100V	120V
Collector-Emitter Voltage (See Note 1)	40V	60V	80V	100V	120V
Emitter-Base Voltage	5V				
Continuous Collector Current	5A				
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	45W				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 3)	2W				
Operating Collector Junction Temperature Range	–65°C to 150°C				
Storage Temperature Range	–65°C to 150°C				
Lead Temperature 3.2mm from Case for 10 Seconds	260°C				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. Derate linearly to 150°C Case Temperature at the rate of 0.36W/°C
3. Derate linearly to 150°C Free-Air Temperature at the rate of 16mW/°C

BD539 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS		BD539		BD539A		BD539B		BD539C		BD539D		UNITS
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=30mA See Note 4	I_B=0	40		60		80		100		120		V
I_{CEO}	V_{CE}=30V	I_B=0		0.3		0.3							mA
	V_{CE}=60V	I_B=0						0.3		0.3			
	V_{CE}=90V	I_B=0										0.3	
I_{CES}	V_{CE}=40V	V_{BE}=0		0.2									mA
	V_{CE}=60V	V_{BE}=0				0.2							
	V_{CE}=80V	V_{BE}=0						0.2					
	V_{CE}=100V	V_{BE}=0								0.2			
	V_{CE}=120V	V_{BE}=0										0.2	
I_{EBO}	V_{EB}=5V	I_C=0		1		1		1		1		1	mA
h_{FE}*	I_C=0.5A	V_{CE}=4V	40		40		40		40		40		
	I_C=1.0A	V_{CE}=4V	30		30		30		30		30		
	I_C=3.0A	V_{CE}=4V	12		12		12		12		12		
$V_{BE(act)}$*	I_C=3.0A	V_{CE}=4V		1.25		1.25		1.25		1.25		1.25	V
$V_{CE(sat)}$*	I_C=1.0A	I_B=125mA		0.25		0.25		0.25		0.25		0.25	V
	I_C=3.0A	I_B=375mA		0.8		0.8		0.8		0.8		0.8	
	I_C=5.0A	I_B=1.0A		1.5		1.5		1.5		1.5		1.5	
h_{fe}	V_{CE}=10V f=1kHz	I_C=0.5A	20		20		20		20		20		
$\lvert h_{fe} \rvert$	V_{CE}=10V f=1MHz	I_C=0.5A	3		3		3		3		3		

*See Notes 4 & 5

NOTES: 4. These parameters must be measured using pulse techniques, t_w = 300μs, duty cycle ⩽2%

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

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.78	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

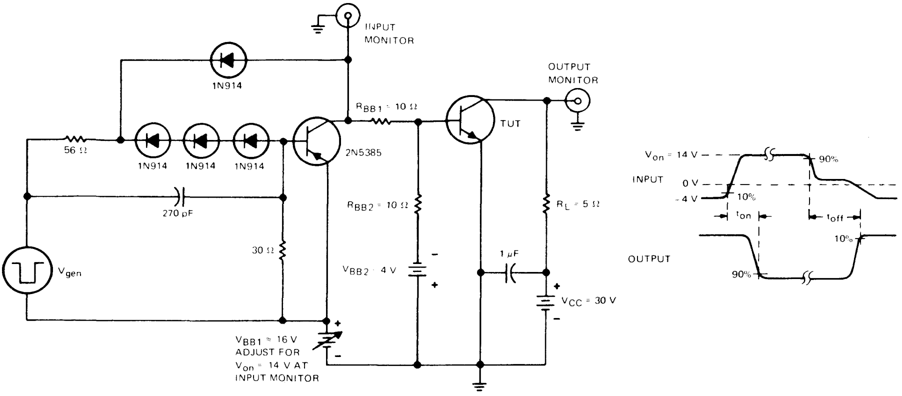
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{ON}	Turn-On Time	I_C = 1A $I_{B(1)}$ = 100mA $I_{B(2)}$ = −100mA	0.5	μsec.
t_{OFF}	Turn-Off Time	$V_{BE(off)}$=−4.3V R_L = 30Ω See Figure 1	2.0	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD 539 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

MAXIMUM SAFE OPERATING REGION

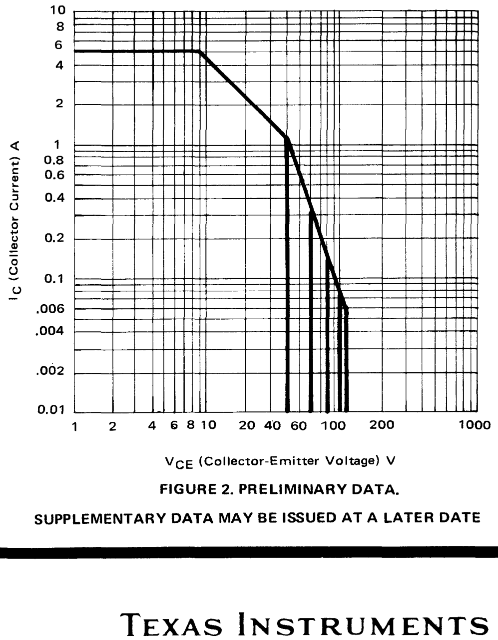


FIGURE 2. PRELIMINARY DATA.

SUPPLEMENTARY DATA MAY BE ISSUED AT A LATER DATE

TEXAS INSTRUMENTS

BD540 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

SEPTEMBER 1975

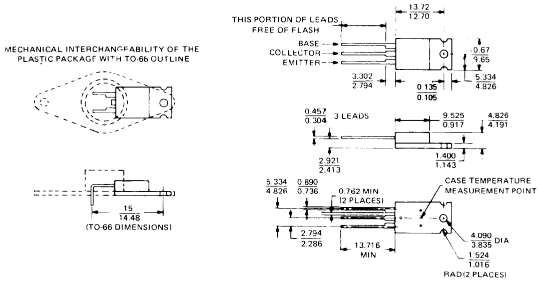
Designed for Medium Power Linear Amplifiers and Switching in Consumer, Automotive and Industrial Applications

features

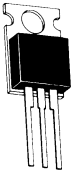
- Low Saturation Voltages $V_{CE(sat)} = 0.8V$ max @ $I_C = 3A$
- Complimentary to NPN Types BD539 Series
- 5A Rated Collector Current
- 45W at 25°C Case Temperature
- Up to 120V V_{CEO} rating

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD540	BD540A	BD540B	BD540C	BD540D
Collector-Base Voltage	–40V	–60V	–80V	–100V	–120V
Collector-Emitter Voltage (See Note 1)	–40V	–60V	–80V	–100V	–120V
Emitter-Base Voltage	–5V				
Continuous Collector Current	–5A				
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	45W				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 3)	2W				
Operating Collector Junction Temperature Range	–65°C to 150°C				
Storage Temperature Range	–65°C to 150°C				
Lead Temperature 3.2mm from Case for 10 Seconds	260°C				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. Derate linearly to 150°C Case Temperature at the rate of 0.36W/°C
3. Derate linearly to 150°C Free-Air Temperature at the rate of 16mW/°C

BD540 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS		BD540		BD540A		BD540B		BD540C		BD540D		UNITS
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=−30mA	I_B=0	−40		−60		−80		−100		−120		V
	See Note 4												
I_{CEO}	V_{CE}=−30V	I_B=0		−0.3		−0.3							
	V_{CE}=−60V	I_B=0						−0.3		−0.3			mA
	V_{CE}=−90V	I_B=0										−0.3	
I_{CES}	V_{CE}=−40V	V_{BE}=0		−0.2									
	V_{CE}=−60V	V_{BE}=0				−0.2							
	V_{CE}=−80V	V_{BE}=0						−0.2					mA
	V_{CE}=−100V	V_{BE}=0								−0.2			
	V_{CE}=−120V	V_{BE}=0										−0.2	
I_{EBO}	V_{EB}=−5V	I_C=0		−1		−1		−1		−1		−1	mA
h_{FE}*	I_C=−0.5A	V_{CE}=−4V	40		40		40		40		40		
	I_C=−1.0A	V_{CE}=−4V	30		30		30		30		30		
	I_C=−3.0A	V_{CE}=−4V	12		12		12		12		12		
$V_{BE(act)}$*	I_C=−3.0A	V_{CE}=−4V		−1.25		−1.25		−1.25		−1.25		−1.25	V
$V_{CE(sat)}$*	I_C=−1.0A	I_B=−125mA		−0.25		−0.25		−0.25		−0.25		−0.25	
	I_C=−3.0A	I_B=−375mA		−0.8		−0.8		−0.8		−0.8		−0.8	V
	I_C=−5.0A	I_B=10A		−1,5		−1.5		−1.5		−1.5		−1.5	
h_{fe}	V_{CE}=−10V	I_C=−0.5A	20		20		20		20		20		
	f=1kHz												
$\|h_{fe}\|$	V_{CE}=−10V	I_C=−0.5A	3		3		3		3		3		
	f=1MHz												
*See Notes 4 & 5													

NOTES: 4. These parameters must be measured using pulse techniques, t_w = 300μs, duty cycle ≤2%

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

thermal characteristics

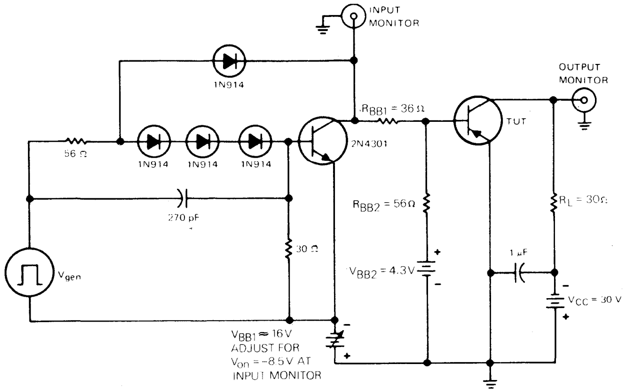
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.78	°C/W
$R_{\theta JR}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

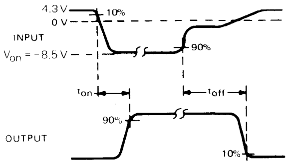
PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{ON}	Turn-On Time	I_C = −1A	$I_{B(1)}$ = −100mA	$I_{B(2)}$ = −100mA	0.3	μsec
t_{OFF}	Turn-Off Time	$V_{BE(off)}$ = 4.3V	R_L = 30Ω	See Figure 1	1.0	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

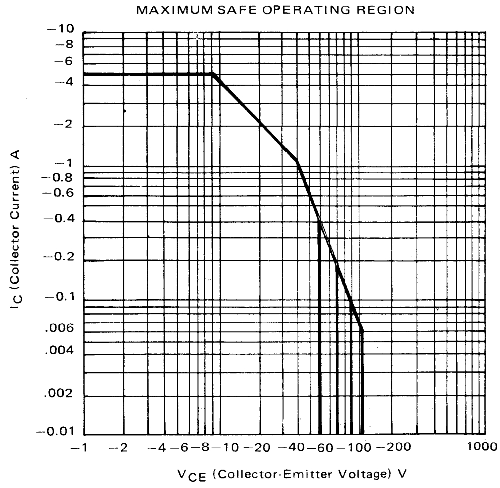


FIGURE 2. PRELIMINARY DATA

BD 543 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

AUGUST 1975

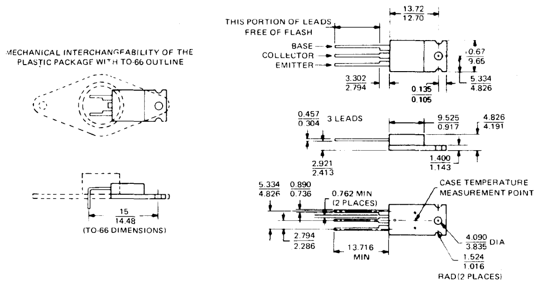
Designed for Medium Power Linear Amplifiers and Switching in Consumer Automotive and Industrial Applications

features

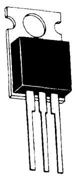
- Low Saturation Voltages $V_{CE(sat)} = 0.5V$ max @ $I_C = 5A$
- Complimentary to PNP Types BD544 Series
- 8A Rated Collector Current
- 70W at 25°C Case Temperature
- Up to 120V V_{CEO} Rating

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD543	BD543A	BD543B	BD543C	BD543D
Collector-Base Voltage	40V	60V	80V	100V	120V
Collector-Emitter Voltage (See Note 1)	40V	60V	80V	100V	120V
Emitter-Base Voltage	← 5V →				
Continuous Collector Current	← 8A →				
Peak Collector Current (See Note 2)	← 10A →				
Safe Operating Region at (or below) 25°C Case Temperature	← See Figure 2 →				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 70W →				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 4)	← 2W →				
Operating Collector Junction Temperature Range	← –65°C to 150°C →				
Storage Temperature Range	← –65°C to 150°C →				
Lead Temperature 3.2mm from Case for 10 Seconds	← 260°C →				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. This value applies for $t_w \leqslant 0.3ms$, duty cycle $\leqslant 10\%$
3. Derate linearly to 150°C Case Temperature at the rate of 0.56W/°C
4. Derate linearly to 150°C Free-Air Temperature at the rate of 16mW/°C

BD 543 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS		BD543		BD543A		BD543B		BD543C		BD543D		UNITS
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=30mA	I_B=0	40		60		80		100		120		V
	See Note 5												
I_{CEO}	V_{CE}=30V	I_B=0		0.7		0.7							
	V_{CE}=60V	I_B=0						0.7		0.7			mA
	V_{CE}=90V	I_B=0										0.7	
I_{CES}	V_{CE}=40V	V_{BE}=0		0.4									
	V_{CE}=60V	V_{BE}=0				0.4							
	V_{CE}=80V	V_{BE}=0						0.4					mA
	V_{CE}=100V	V_{BE}=0								0.4			
	V_{CE}=120V	V_{BE}=0										0.4	
I_{EBO}	V_{EB}=5V	I_C=0		1		1		1		1		1	mA
h_{FE}*	I_C=1A	V_{CE}=4V	60		60		60		60		60		
	I_C=3A	V_{CE}=4V	40		40		40		40		40		
	I_C=5A	V_{CE}=4V	15		15		15		15		15		
$V_{BE(act)}$*	I_C=5A	V_{CE}=4V		1.4		1.4		1.4		1.4		1.4	V
$V_{CE(sat)}$*	I_C=3A	I_B=300mA		0.5		0.5		0.5		0.5		0.5	
	I_C=5A	I_B=1A		0.5		0.5		0.5		0.5		0.5	V
	I_C=8A	I_B=1.6A		1.0		1.0		1.0		1.0		1.0	
h_{fe}	V_{CE}=10V	I_C=0.5A	20		20		20		20		20		
	f=1kHz												
$\lvert h_{fe} \rvert$	V_{CE}=10V	I_C=0.5A	3		3		3		3		3		
	f-1MHz												

*See Notes 5 & 6.

NOTES: 5. These parameters must be measured using pulse techniques, t_w = 300μs, duty cycle ≤2%

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

thermal characteristics

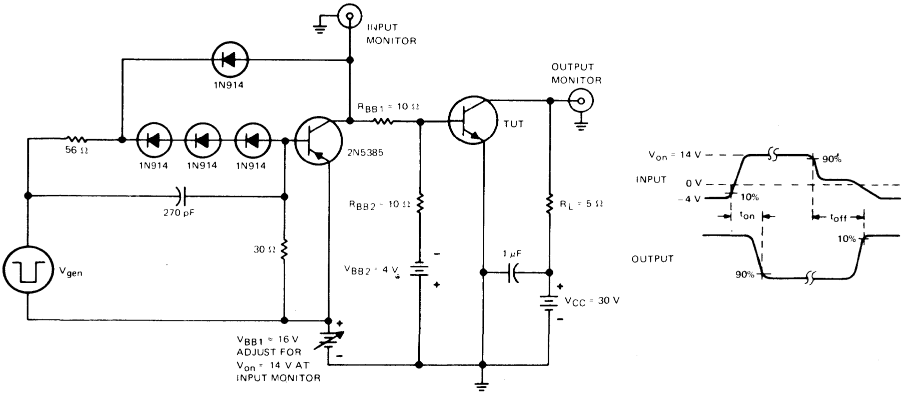
	PARAMETER	MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.79	°C/W
$R_{\theta JR}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

	PARAMETER	TEST CONDITIONS†			TYP	UNIT
t_{ON}	Turn-On Time	I_C = 6A	$I_{B(1)}$ = 0.6A	$I_{B(2)}$ = −0.6A	0.6	μsec
t_{OFF}	Turn-Off Time	$V_{BE(off)}$ = −4V	R_L = 5Ω	See Figure 1	1	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

MAXIMUM SAFE OPERATING REGION

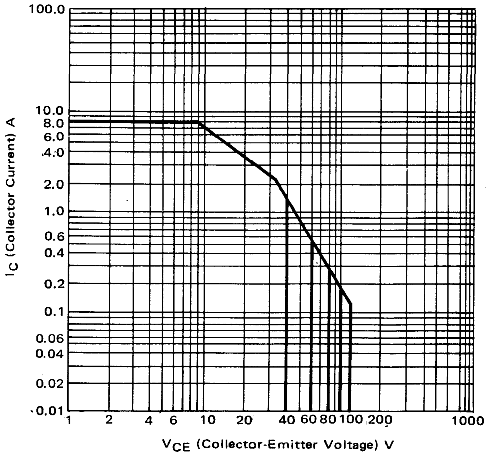


FIGURE 2. PRELIMINARY DATA

BD544 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

AUGUST 1975

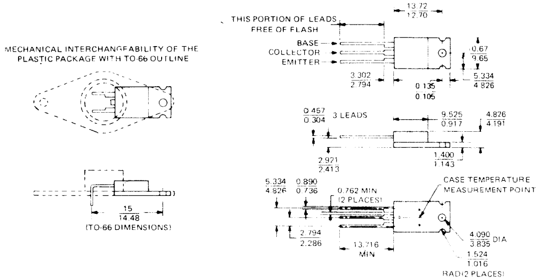
Designed for Medium Power Linear Amplifiers and Switching in Consumer, Automotive and Industrial Applications

features

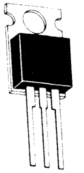
- Low Saturation Voltages $V_{CE(sat)} = 0.5V$ max @ $I_C = 5A$
- Complimentary to NPN Types BD543 Series
- 8A Rated Collector Current
- 70W at 25°C Case Temperature
- Up to 120V V_{CEO} Rating

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD544	BD544A	BD544B	BD544C	BD544D
Collector-Base Voltage	−40V	−60V	−80V	−100V	−120V
Collector-Emitter Voltage (See Note 1)	−40V	−60V	−80V	−100V	−120V
Emitter-Base Voltage	← −5V →				
Continuous Collector Current	← −8A →				
Peak Collector Current (See Note 2)	← −10A →				
Safe Operating Region at (or below) 25°C Case Temperature	← See Figure 2 →				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 70W →				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 4)	← 2W →				
Operating Collector Junction Temperature Range	← −65°C to 150°C →				
Storage Temperature Range	← −65°C to 150°C →				
Lead Temperature 3.2mm from Case for 10 Seconds	← 260°C →				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. This value applies for $t_w \leqslant 0.3ms$, duty cycle $\leqslant 10\%$
3. Derate linearly to 150°C Case Temperature at the rate of 0.56W/°C
4. Derate linearly to 150°C Free-Air Temperature at the rate of 16mW/°C

BD544 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS		BD544		BD544A		BD544B		BD544C		BD544D		UNITS
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=−30mA See Note 5	I_B=0	−40		−60		−80		−100		−120		V
I_{CEO}	V_{CE}=−30V	I_B=0		−0.7		−0.7							
	V_{CE}=−60V	I_B=0						−0.7		−0.7			mA
	V_{CE}=−90V	I_B=0										−0.7	
I_{CES}	V_{CE}=−40V	V_{BE}=0		−0.4									
	V_{CE}=−60V	V_{BE}=0				−0.4							
	V_{CE}=−80V	V_{BE}=0						−0.4					mA
	V_{CE}=−100V	V_{BE}=0								−0.4			
	V_{CE}=−120	V_{BE}=0										−0.4	
I_{EBO}	V_{EB}=−5V	I_C=0		−1		−1		−1		−1		−1	mA
h_{FE}*	I_C=−1A	V_{CE}=−4V	60		60		60		60		60		
	I_C=−3A	V_{CE}=−4V	40		40		40		40		40		
	I_C=−5A	V_{CE}=−4V	15		15		15		15		15		
$V_{BE(act)}$*	I_C=−5A	V_{CE}=−4V		−1.4		−1.4		−1.4		−1.4		−1.4	V
$V_{CE(sat)}$*	I_C=−3A	I_B=−300mA		−0.5		−0.5		−0.5		−0.5		−0.5	
	I_C=−5A	I_B=−1A		−0.5		−0.5		−0.5		−0.5		−0.5	V
	I_C=−8A	I_B=−1.6A		−1.0		−1.0		−1.0		−1.0		−1.0	
h_{fe}	V_{CE}=−10V f=1kHz	I_C=−0.5A	20		20		20		20		20		
$\|h_{fe}\|$	V_{CE}=−10V f=1MHz	I_C=−0.5A	3		3		3		3		3		

*See Notes 5 & 6

NOTES: 5. *These parameters must be measured using pulse techniques, t_w = 300µs, duty cycle ⩽2%*
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts

thermal characteristics

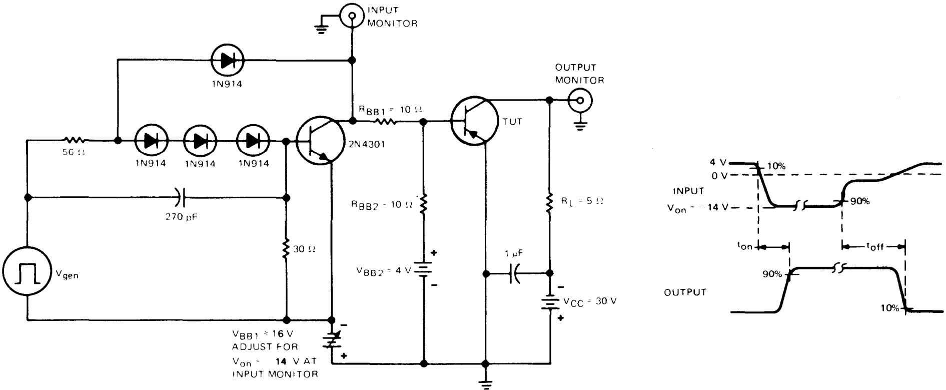
	PARAMETER	MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.79	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

	PARAMETER	TEST CONDITIONS†			TYP	UNIT
t_{ON}	Turn-On Time	I_C = −6A	$I_{B(1)}$ = −0.6A	$I_{B(2)}$ = +0.6A	0.4	µsec
t_{OFF}	Turn-Off Time	$V_{BE(off)}$ = 4V	R_L = 5Ω	See Figure 1	0.7	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

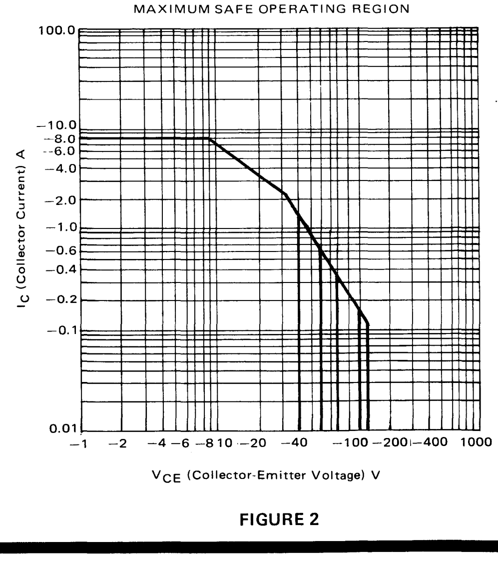


FIGURE 2

BD545 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

AUGUST 1975

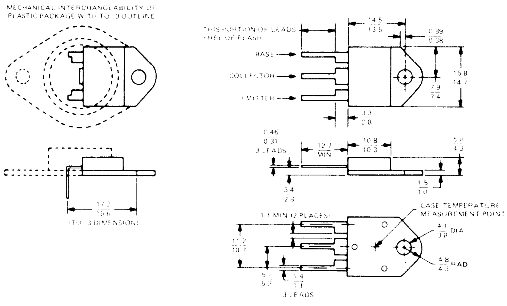
Designed for Power Linear Amplifiers and Switching in Consumer, Automotive and Industrial Applications

features

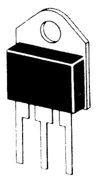
- Low Saturation Voltages $V_{CE(sat)} = 1V$ max @ $I_C = 10A$
- Complimentary to BD546 Series
- 15A Rated Collector Current
- 85W at 25°C Case Temperature
- Up to 120V V_{CEO}

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD545	BD545A	BD545B	BD545C	BD545D
Collector-Base Voltage	40V	60V	80V	100V	120V
Collector-Emitter Voltage (See Note 1)	40V	60V	80V	100V	120V
Emitter-Base Voltage	5V				
Continuous Collector Current	15A				
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	85W				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 3)	3.5W				
Operating Collector Junction Temperature Range	−65°C to 150°C				
Storage Temperature Range	−65°C to 150°C				
Lead Temperature 3.2mm from Case for 10 Seconds	260°C				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. Derate linearly to 150°C Case Temperature at the rate of 0.68W/°C
3. Derate linearly to 150°C Free-Air Temperature at the rate of 28mW/°C

BD545 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	BD545		BD545A		BD545B		BD545C		BD545D		UNITS
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=30mA I_B=0 See Note 4	40		60		80		100		120		V
I_{CEO}	V_{CE}=30V I_B=0		0.7		0.7							mA
	V_{CE}=60V						0.7		0.7			
	V_{CE}=90V										0.7	
I_{CES}	V_{CE}=40V V_{BE}=0		0.4									mA
	V_{CE}=60V V_{BE}=0				0.4							
	V_{CE}=80V V_{BE}=0						0.4					
	V_{CE}=100V V_{BE}=0								0.4			
	V_{CE}=120V V_{BE}=0										0.4	
I_{EBO}	V_{EB}=5V I_C=0		1		1		1		1		1	mA
h_{FE}*	I_C=1A V_{CE}=4V	60		60		60		60		60		
	I_C=5A V_{CE}=4V	25		25		25		25		25		
	I_C=10A V_{CE}=4V	10		10		10		10		10		
$V_{BE(act)}$*	I_C=10A V_{CE}=4V		1.8		1.8		1.8		1.8		1.8	V
$V_{CE(sat)}$*	I_C=5A I_B=625mA		0.8		0.8		0.8		0.8		0.8	V
	I_C=10A I_B=2A		1		1		1		1		1	
h_{fe}	V_{CE}=10V I_C=0.5A f=1kHz	20		20		20		20		20		
$\|h_{fe}\|$	V_{CE}=10V I_C=0.5A f-1MHz	3		3		3		3		3		

*See Notes 4 & 5

NOTES: 4. These parameters must be measured using pulse techniques, t_w = 300μs, duty cycle $\leqslant$2%

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

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.47	°C/W
$R_{\theta JR}$	Junction-to-Free-Air Thermal Resistance	35.7	

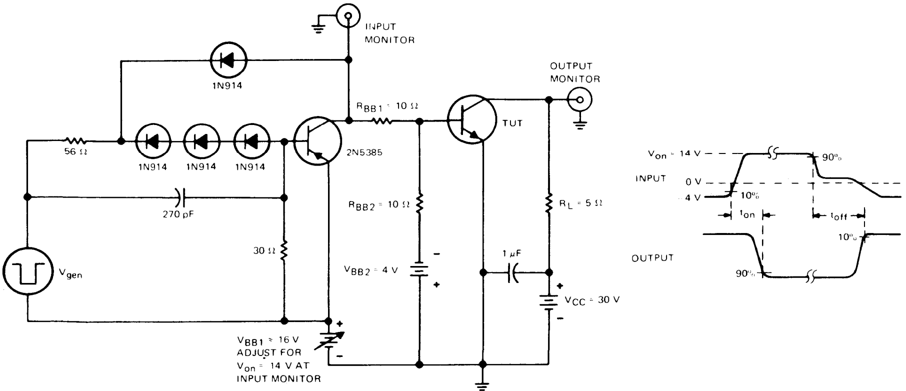
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{ON}	Turn-On Time	I_C = 6A	$I_{B(1)}$ = 0.6A	$I_{B(2)}$ = −0.6A	0.6	μsec
t_{OFF}	Turn-Off Time	$V_{BE(off)}$ = −4V	R_L - 5Ω	See Figure 1	1	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

BD545 SERIES
NPN SINGLE DIFFUSED SILICON POWER TRANSISTORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

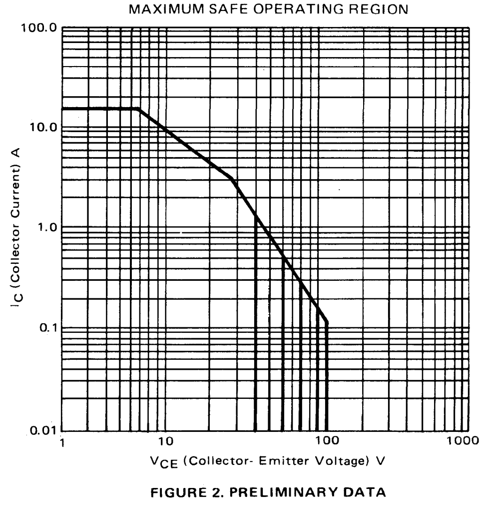


FIGURE 2. PRELIMINARY DATA

BD 546 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

AUGUST 1975

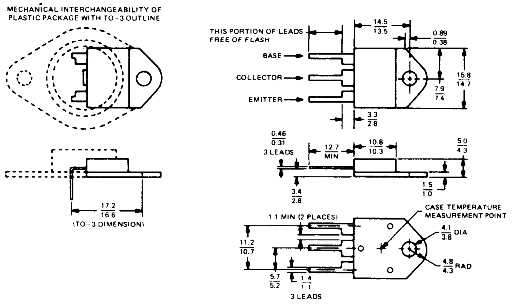
Designed for Power Linear Amplifiers and Switching in Consumer, Automotive and Industrial Applications

Features

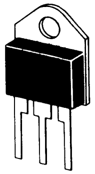
- **Low Saturation Voltages $V_{CE(sat)}$ = 1V max @ 10A**
- **Complimentary to BD545 Series**
- **15A Rated Collector Current**
- **85W at 25°C Case Temperature**
- **Up to 120V V_{CEO}**

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	BD546	BD546A	BD546B	BD546C	BD546D
Collector-Base Voltage	−40V	−60V	−80V	−100V	−120V
Collector-Emitter Voltage (See Note 1)	−40V	−60V	−80V	−100V	−120V
Emitter-Base Voltage	← −5V →				
Continuous Collector Current	← 15A →				
Safe Operating Region at (or below) 25°C Case Temperature	← See Figure 2 →				
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 85W →				
Continuous Device Dissipation at (or below) 25°C Free Air Temperature (See Note 3)	← 3.5W →				
Operating Collector Junction Temperature Range	← −65°C to 150°C →				
Storage Temperature Range	← −65°C to 150°C →				
Lead Temperature 3.2mm from Case for 10 Seconds	← 260°C →				

NOTES:
1. This value applies when the base-emitter diode is open-circuited
2. Derate linearly to 150°C Case Temperature at the rate of 0.68W/°C
3. Derate linearly to 150°C Free-Air Temperature at the rate of 28mW/°C

BD 546 SERIES
PNP SINGLE DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	BD546		BD546A		BD546B		BD546C		BD546D		UNITS
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
$V_{(BR)CEO}$	I_C=−30mA I_B=0 (See Note 4)	−40		−60		−80		−100		−120		V
I_{CEO}	V_{CE}=−30V I_B=0		−0.7		−0.7							
	V_{CE}=−60V I_B=0						−0.7		−0.7			mA
	V_{CE}=−90V I_B=0										−0.7	
I_{CES}	V_{CE}=−40V V_{BE}=0		−0.4									
	V_{CE}=−60V V_{BE}=0				−0.4							
	V_{CE}=−80V V_{BE}=0						−0.4					mA
	V_{CE}=−100V V_{BE}=0								−0.4			
	V_{CE}=−120V V_{BE}=0										−0.4	
I_{EBO}	V_{EB}=−5V I_C=0		−1		−1		−1		−1		−1	mA
h_{FE}*	I_C=−1A V_{CE}=−4V	60		60		60		60		60		
	I_C=−5V V_{CE}=−4V	25		25		25		25		15		
	I_C=−10A V_{CE}=−4V	10		10		10		10		8		
$V_{BE(act)}$*	I_C=−10A V_{CE}=−4V		−1.8		−1.8		−1.8		−1.8		−1.8	V
$V_{CE(sat)}$*	I_C=−5A I_B=−625mA		−0.8		−0.8		−0.8		−0.8		−0.8	V
	I_C=−10A I_B=−2A		−1		−1		−1		−1			
h_{fe}	V_{CE}=−10V I_C=−0.5A L=1kHz	20		20		20		20		20		
$\|h_{fe}\|$	V_{CE}=−10V I_C=−0.5A f=1MHz	3		3		3		3		3		
*See Notes 4 & 5												

NOTES: 4. These parameters must be measured using pulse techniques, t_w=300μs, duty cycle ≤2%

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

thermal characteristics

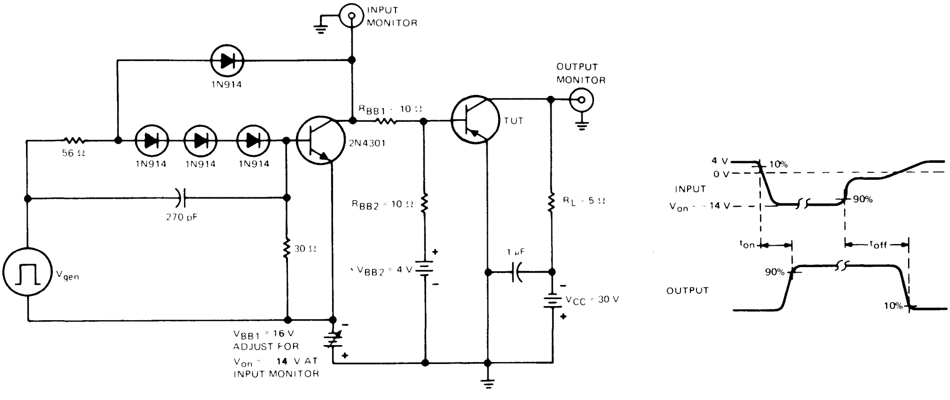
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.47	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{ON}	Turn-On Time	I_C = −6A	$I_{B(1)}$ = −0.6A	$I_{B(2)}$ = 0.6A	0.4	μsec
t_{OFF}	Turn-Off Time	$V_{BE(off)}$ = 4V	R_L = 5Ω	See Figure 1	0.7	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters..

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

MAXIMUM SAFE OPERATING REGION

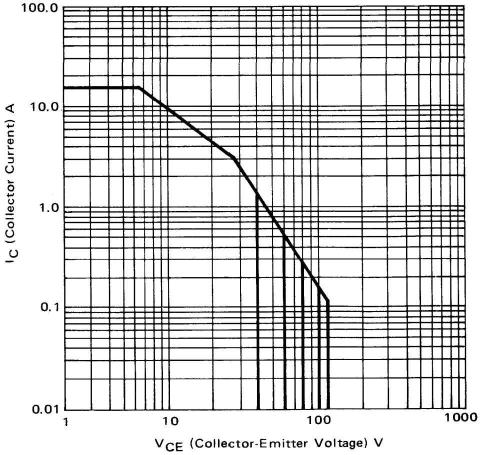


FIGURE 2. PRELIMINARY DATA

PRELIMINARY

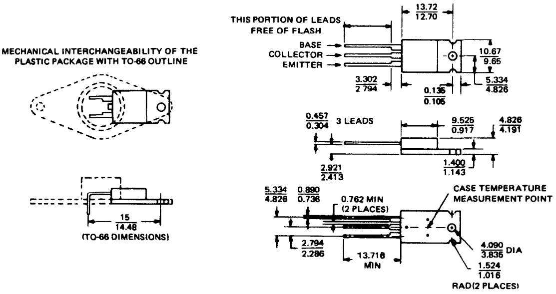
BD633,BD635,BD637
NPN EPIBASE POWER TRANSISTORS

REVISED AUGUST 1975

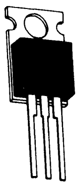
- Amplifier
- Switch
- Complementary Output Stages
- Complementary with BD634, BD636, BD638

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings

	BD633	BD635	BD637
Collector-Emitter Voltage	45 V	60 V	80 V
Collector-Base Voltage	45 V	60 V	100 V
Emitter-Base Voltage	←	5 V	→
Continuous Collector Current	←	2 A	→
Peak Collector Current	←	5 A	→
Continuous Base Current	←	0.3 A	→
Junction Temperature	←	150 °C	→
Storage Temperature Range	←	−55 °C to +150 °C	→
Device Dissipation ($T_C < 25$ °C) (See Note 1)	←	30 W	→
Collector Junction to Case Thermal Resistance	←	<4.17 K/W	→
Continuous Device Dissipation at 25 °C Free Air Temperature (See Note 2)	←	2 W	→

NOTES: 1. Derate linearly to 150 °C case temperature at a rate of 0.24 W/°C.
2. Derate linearly to 150 °C free air temperature at a rate of 16 mW/°C.

BD633,BD635,BD637
NPN EPIBASE POWER TRANSISTORS

electrical characteristics at 25 °C free-air temperature

	PARAMETER	TEST CONDITIONS		BD633	BD635	BD637	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA		>45	>60	>80	V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\,\mu$A		>45	>60	>100	V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 1$ mA		>5	>5	>5	V
I_{CES}	Collector Cutoff Current	$V_{CE} = 45$ V		<200			μA
		$V_{CE} = 60$ V			<200		μA
		$V_{CE} = 100$ V				<200	μA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 1$ A,	$I_B = 0.1$ A	<0.6	<0.6	<0.6	V
V_{BE}	Base-Emitter Voltage	$I_C = 1$ A,	$V_{CE} = 2$ V	<1.3	<1.3	<1.3	V
h_{FE}	Small Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 2$ V,	$I_C = 25$ mA	>40	>40	>40	
		$V_{CE} = 1$ A,	$I_C = 1$ A	>25	>25	>25	

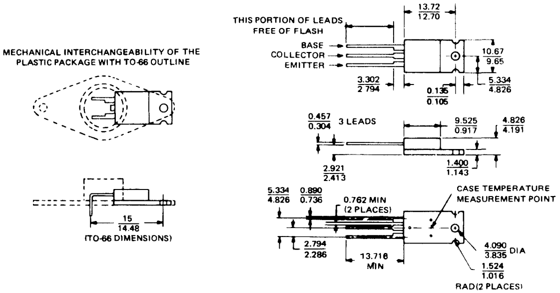
BD 634, BD 636, BD 638
PNP EPIBASE POWER TRANSISTORS

REVISED AUGUST 1975

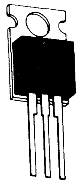
- Amplifier
- Switch
- Complementary Output Stages
- Complementary with BD633, BD635, BD637

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings

	BD634	BD636	BD638
Collector-Emitter Voltage	−45 V	−60 V	−80 V
Collector-Base Voltage	−45 V	−60 V	−100 V
Emitter-Base Voltage	←	−5 V	→
Continuous Collector Current	←	−2 A	→
Peak Collector Current	←	−5 A	→
Continuous Base Current	←	−0.3 A	→
Junction Temperature	←	150 °C	→
Storage Temperature Range	←	−55 °C to 150 °C	→
Device Dissipation ($T_C < 25$ °C) (See Note 1)	←	30 W	→
Collector Junction to Case Thermal Resistance	←	< 4.17 K/W	→
Continuous Device Dissipation at 25 °C Free Air Temperature (See Note 2)	←	2 W	→

NOTES: 1. Derate linearly to 150 °C case temperature at a rate of 0.24 W/°C.
2. Derate linearly to 150 °C free air temperature at a rate of 16 mW/°C.

BD 634, BD 636, BD 638
PNP EPIBASE POWER TRANSISTORS

electrical characteristics at 25 °C free-air temperature

PARAMETER		TEST CONDITIONS	BD634	BD636	BD638	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA	>-45	>-60	>-80	V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100$ µA	>-45	>-60	>-100	V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -1$ mA	>-5	>-5	>-5	V
I_{CES}	Collector Cutoff Current	$V_{CE} = -45$ V	<-200			µA
		$V_{CE} = -60$ V		<-200		µA
		$V_{CE} = -100$ V			<-200	µA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = -1$ A, $I_B = -0.1$ A	<-0.6	<-0.6	<-0.6	V
V_{BE}	Base-Emitter Voltage	$I_C = -1$ A, $V_{CE} = -2$ V	<-1.3	<-1.3	<-1.3	V
h_{FE}	Small Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -2$ V, $I_C = -25$ mA	>40	>40	>40	
		$V_{CE} = -2$ V, $I_C = -1$ A	>25	>25	>25	

BD 733, BD 735, BD 737
NPN EPIBASE POWER TRANSISTORS

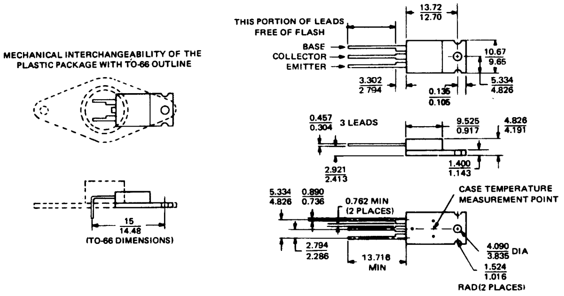
REVISED SEPTEMBER 1975

HIGH GAIN GERMANIUM REPLACEMENT

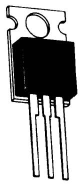
- Car and Portable Radio
- Complementary Output Stages
- Complementary with BD734, BD736, BD738

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings

	BD733	BD735	BD737
Collector-Emitter-Voltage	25 V	35 V	45 V
Collector-Base-Voltage	25 V	35 V	45 V
Emitter-Base Voltage	←	5 V	→
Continuous Collector Current	←	4 A	→
Peak Collector Current	←	7 A	→
Continuous Base Current	←	1 A	→
Junction Temperature	←	150 °C	→
Storage Temperature Range	←	−55 °C to +150 °C	→
Device Dissipation ($T_C < 25$ °C/V_{CE} = 10 V, See Note 1)	←	40 W	→
Collector Junction to Case Thermal Resistance	←	< 3.12 K/W	→
Continuous Device Dissipation at 25 °C Free Air Temperature (See Note 2)	←	2 W	→

NOTES: 1. Derate linearly to 150 °C case temperature at a rate of 0.32 W/°C.
2. Derate linearly to 150 °C free air temperature at a rate of 16 mW/°C.

BD 733, BD 735, BD 737
NPN EPIBASE POWER TRANSISTORS

electrical characteristics at 25 °C free-air temperature

PARAMETER		TEST CONDITIONS		BD733	BD735	BD737	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA		25	35	45	V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\,\mu$A		25	35	45	V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 1$ mA		5	5	5	V
I_{CES}	Collector Cutoff Current	$V_{CE} = 25$ V		<200			μA
		$V_{CE} = 35$ V			<200		μA
		$V_{CE} = 45$ V				<200	μA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 2$ A,	$I_B = 0.2$ A	<0.6	<0.6	<0.8	V
V_{BE}	Base-Emitter Voltage	$I_C = 2$ A,	$V_{CE} = 1$ V	<1.1	<1.1.	<1.1.	V
h_{FE}	Small Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 20$ mA	>40	>40	>40	
		$V_{CE} = 1$ V,	$I_C = 2$ A	>50	>40	>40	

PRELIMINARY

BD734, BD736, BD738
NPN EPIBASE POWER TRANSISTORS

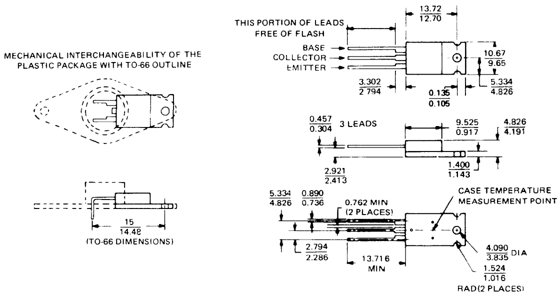
REVISED AUGUST 1975

HIGH GAIN GERMANIUM REPLACEMENT

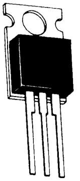
- Car and Portable Radio
- Complementary Output Stages
- Complementary with BD733, BD735, BD737

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings

	BD734	BD736	BD738
Collector-Emitter Voltage	–25 V	–35 V	–45 V
Collector-Base Voltage	–25 V	–35 V	–45 V
Emitter-Base Voltage	←	–5 V	→
Continuous Collector Current	←	–4 A	→
Peak Collector Current	←	–7 A	→
Continuous Base Current	←	–1 A	→
Junction Temperature	←	150 °C	→
Storage Temperature Range	←	–55 °C to +150 °C	→
Device Dissipation ($T_C < 25$ °C) $V_{CE} = 10$ V (See Note 1)	←	40 W	→
Collector Junction to Case Thermal Resistance	←	< 3.12 K/W	→
Continuous Device Dissipation at 25 °C Free Air Temperature	←	2 W	→

NOTES: 1. Derate linearly to 150 °C case temperature at a rate of 0.32 W/°C.
2. Derate linearly to 150 °C free air temperature at a rate of 16 mW/°C.

BD734, BD736, BD738
NPN EPIBASE POWER TRANSISTORS

electrical characteristics at 25 °C free-air temperature

	PARAMETER	TEST CONDITIONS		BD734	BD736	BD738	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA		−25	−35	−45	V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = -100\ \mu A$		−25	−35	−45	V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = -1$ mA)		−5	−5	−5	V
I_{CES}	Collector Cutoff Current	$V_{CE} = -25$ V		<−200			μA
		$V_{CE} = -35$ V			<−200		μA
		$V_{CE} = -45$ V				<−200	μA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = -2$ A,	$I_B = -0.2$ A	<0.6	<0.6	<0.8	V
V_{BE}	Base-Emitter Voltage	$I_C = -2$ A,	$V_{CE} = -1$ V	<−1.1	<−1.1	<−1.1	V
h_{FE}	Small Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -20$ mA	>40	>40	>40	
		$V_{CE} = -1$ V,	$I_C = -2$ A	>50	>40	>40	

BDX 32
NPN SILICON POWER TRANSISTORS

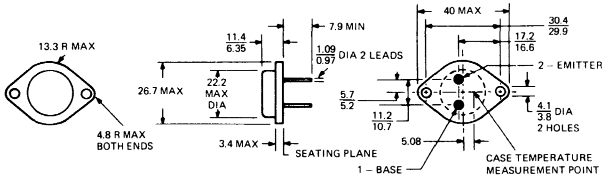
REVISED AUGUST 1975

DESIGNED FOR HIGH VOLTAGE C.R.T. SCANNING

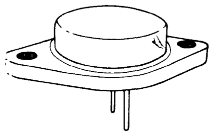
- **V_{CEX} rating 1700 V**
- **Current Rating – 4 Amps Continuous – 5 Amps Peak**
- **Fast Switching – t_f at 3.5 Amps 0.7 Microsecond Typical**

mechanical specification

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C ambient temperature

Collector-Base Voltage (Peak see Note 1)	1700 V
Collector-Emitter Voltage (Peak see Note 1) $V_{EB} = 2$ V	1700 V
Collector Current Continuous	4.0 A
Base Current Continuous	4.0 A
Total Dissipation ($V_{CE} \leqslant 100$ V, $T_{case} \leqslant 80$ °C) See Figure 1	12.5 W
Total Dissipation at 25 °C Case See Figure 1	40 W
Operating Junction Temperature	–65 °C to 100 °C
Storage Temperature	–65 °C to 100 °C

NOTES: 1. Pulse Width $\leqslant 20\ \mu s$. Duty Cycle $\leqslant 25$ %

TEXAS INSTRUMENTS

BDX 32
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25 °C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1700 V,	V_{BE} = −2 V	See Note 1			1.0	mA
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 100 mA,	I_C = 0		5			V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 3.5 A,	I_B = 1.8 A	See Note 2			5	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 3.5 A,	I_B = 1.8 A	See Note 2			1.5	V
t_f	Collector Current Fall Time	I_C = 3.5 A,	$I_{B(on)}$ = 1.8 A,	$I_{B(off)}$ = 1.1 A		0.7		μs

NOTES: 1. Pulse width $\leqslant$20 μs. Duty Cycle $\leqslant$25 %.
2. Pulse Test. Pulse Duration $\leqslant$300 μs. Duty Cycle $\leqslant$2 %. This test must be measured with voltage sensing contacts separate from carrying contacts.

DISSIPATION DERATING CURVE

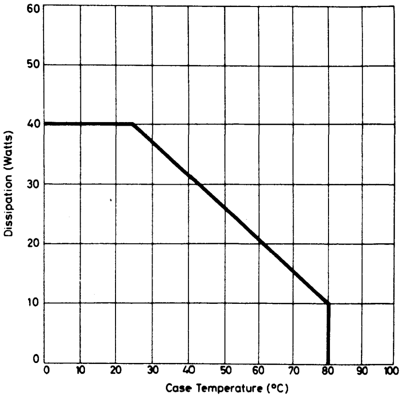


FIGURE 1

BF457, BF458, BF459
NPN EPITAXIAL PLANAR SILICON TRANSISTORS

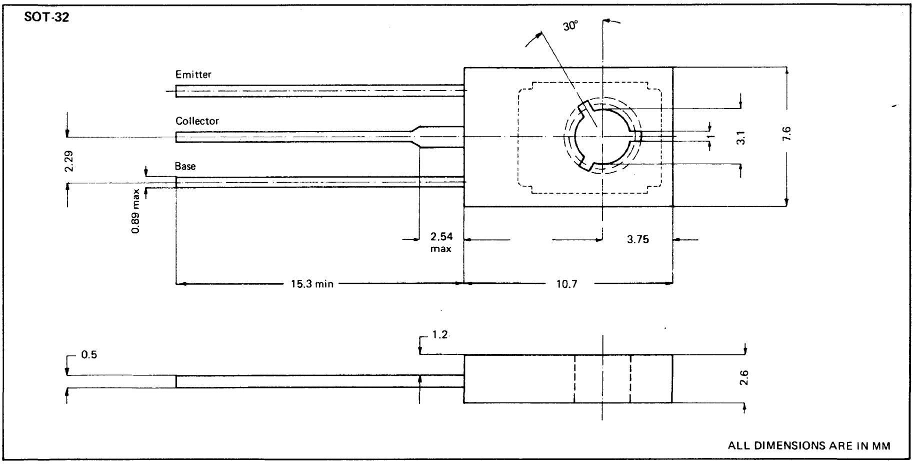
- **For Video and RGB outputs**

mechanical data

These transistors are plastic encapsulated. The encapsulation process[†], especially developed for this application, has been completely mechanised by TI.

Encapsulation withstands full load temperature without distortion. Even under high humidity conditions the device shows stable behaviour and it satisfies the requirements of MIL-STD-202C method 106B.

The transistor is not light sensitive.



BF457, BF458, BF459
NPN EPITAXIAL PLANAR SILICON TRANSISTORS

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

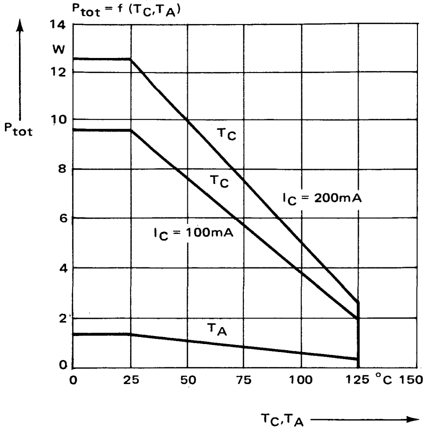
	BF457	BF458	BF459
Collector-Base Voltage	160V	250V	300V
Collector-Emitter Voltage (Note 1)	160V	250V	300V
Emitter-Base Voltage	←	5V	→
Continuous Collector Current	←	200mA	→
Peak Collector Current	←	300mA	→
Continuous Device Dissipation at (or below) T_A = 25°C (Note 2)	←	1.25W	→
Continuous Device Dissipation at (or below) T_C = 25°C (Note 2)	←	12.5W	→
Storage Temperature Range	←	−55°C to 125°C	→
Lead Temperature 1/16 Inch from Case for 10 Seconds	←	260°C	→

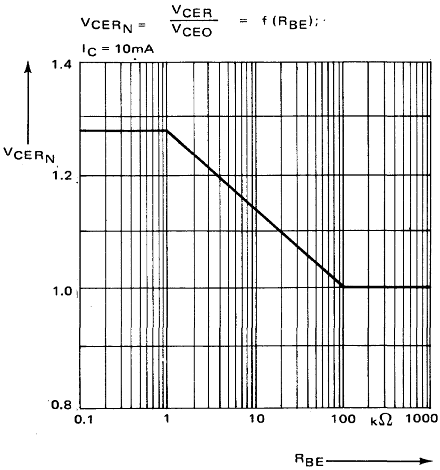
NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. See Dissipation Diagram.

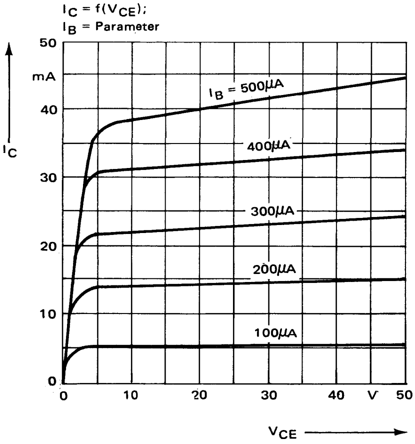
electrical characteristics at 25°C free-air temperature (unless otherwise noted)

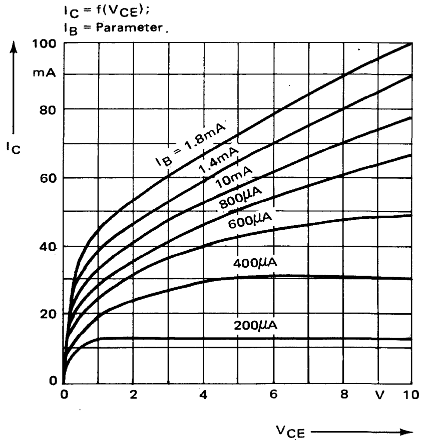
		BF457			BF458			BF459			
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	I_C = 100μA, I_E = 0	160			250			300			V
$V_{(BR)CEO}$	I_C = 10mA, I_B = 0 (Note 3)	160			250			300			V
$V_{(BR)EBO}$	I_E = 100μA, I_C = 0	5			5			5			V
I_{CBO}	V_{CB} = 100V, I_E = 0			50							nA
	V_{CB} = 200V, I_E = 0						50				nA
	V_{CB} = 250V, I_E = 0									50	nA
I_{EBO}	V_{EB} = 3V, I_C = 0			50			50			50	nA
h_{FE}	V_{CE} = 10V, I_C = 30mA	25			25			25			
$V_{CE(sat)}$	I_B = 6mA, I_C = 30mA			1.0			1.0			1.0	V
C_{12e}	V_{CB} = 30V, I_E = 0 f = 1MHz		4.2			4.2			4.2		pF
C_{22e}	V_{CB} = 30V, I_E = 0 f = 1MHz		5.5			5.5			5.5		pF
f_t	V_{CE} = 10V, I_C = 15mA f = 20MHz		90			90			90		MHz

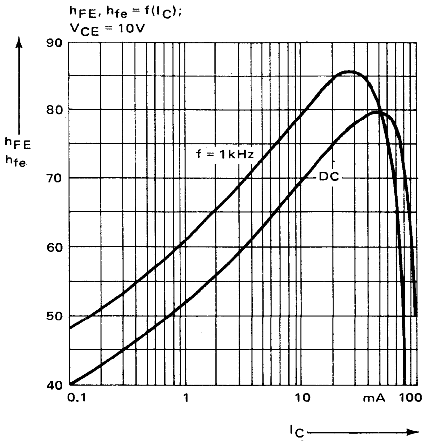
NOTE 3. These parameters must be measured using pulse techniques t_p = 300 μs, duty cycle ⩽2%

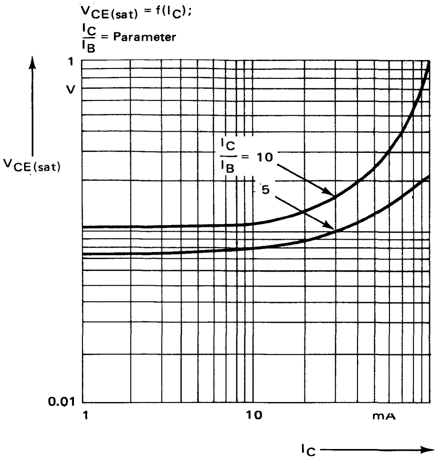

$P_{tot} = f (T_C, T_A)$
14
W
12
10
8
6
4
2
0
P_{tot}
T_C
T_C
I_C = 200mA
I_C = 100mA
T_A
0
25
50
75
100
125 °C 150
T_C, T_A

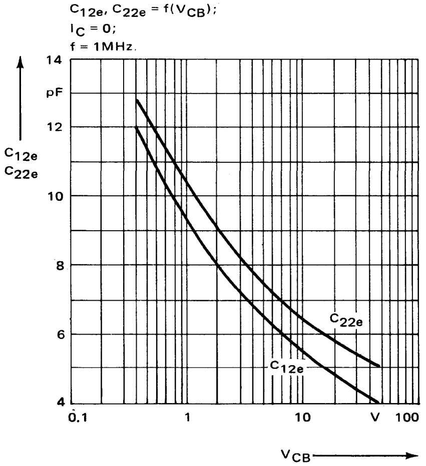

$V_{CER_N} = \frac{V_{CER}}{V_{CEO}} = f(R_{BE})$;
I_C = 10mA
1.4
1.2
1.0
0.8
V_{CER_N}
0.1
1
10
100
kΩ
1000
R_{BE}

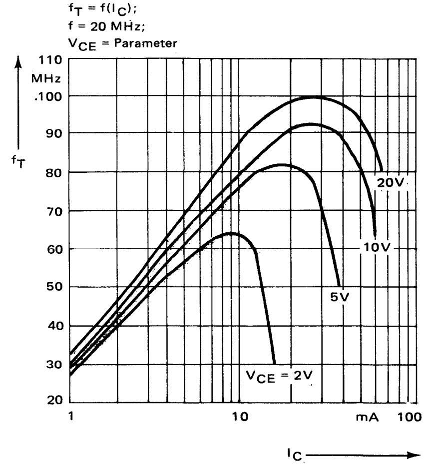

$I_C = f(V_{CE})$;
I_B = Parameter
50
mA
40
30
20
10
0
I_C
I_B = 500μA
400μA
300μA
200μA
100μA
0
10
20
30
40
V
50
V_{CE}


$I_C = f(V_{CE})$;
I_B = Parameter
100
mA
80
60
40
20
0
I_C
I_B = 1.8mA
1.4mA
10mA
800μA
600μA
400μA
200μA
0
2
4
6
8
V
10
V_{CE}


h_{FE}, h_{fe} = f(I_C);
V_{CE} = 10V
h_{FE}
h_{fe}
90
80
70
60
50
40
f = 1kHz
DC
0.1
1
10
mA 100
I_C


$V_{CE(sat)}$ = f(I_C);
$\frac{I_C}{I_B}$ = Parameter
$V_{CE(sat)}$
1
V
0.01
$\frac{I_C}{I_B}$ = 10
5
1
10
mA
I_C


C_{12e}, C_{22e} = f(V_{CB});
I_C = 0;
f = 1MHz.
C_{12e}
C_{22e}
14
pF
12
10
8
6
4
C_{22e}
C_{12e}
0.1
1
10
V 100
V_{CB}


f_T = f(I_C);
f = 20 MHz;
V_{CE} = Parameter
f_T
110
MHz
100
90
80
70
60
50
40
30
20
20V
10V
5V
V_{CE} = 2V
1
10
mA 100
I_C

TEXAS INSTRUMENTS LIMITED

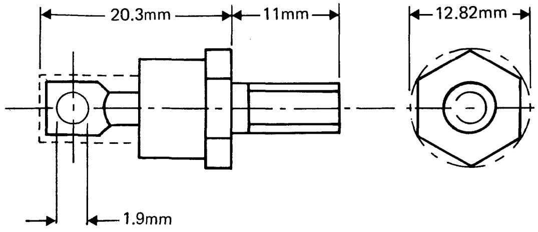
MANTON LANE, BEDFORD
Telephone Bedford 67466 Telex 82178

BS 9331 F027

ISSUE 1 JULY 1973

ELECTRONIC COMPONENTS OF ASSESSED QUALITY; DETAIL SPECIFICATION

Outline and dimensions



Terminal Identification:
Normal polarity types – stud = Cathode
Reverse polarity types – stud = Anode

For detail dimensions see BS 3934 SO–10A

MEDIUM CURRENT
FAST RECOVERY
RECTIFIER DIODES

GENERAL APPLICATION
CATEGORY Q

MANUFACTURER'S TYPE NUMBERS 1N3879 TO 1N3883 AND 1N3879R TO 1N3883R

SILICON, GLASS METAL SEALED

1. **Limiting conditions of use** (not for inspection purposes)
Absolute maximum values over the operating temperature range.

		1N3879 1N3879R	1N3880 1N3880R	1N3881 1N3881R	1N3882 1N3882R	1N3883 1N3883R
Voltage ratings						
V_{RWM}	Crest working reverse voltage	50 V	100 V	200 V	300 V	400 V
V_{RRM}	Repetitive peak reverse voltage	50 V	100 V	200 V	300 V	400 V
V_{RSM}	Non-repetitive peak reverse voltage	50 V	100 V	200 V	300 V	400 V
V_R	Continuous reverse voltage	50 V	100 V	200 V	300 V	400 V

			ALL TYPES
Current ratings			
$I_{F(AV)}$	Mean forward current. See derating curve Fig. 1		10 A
I_{FRM}	Repetitive peak forward current at $T_{case} = 60^oC$		60 A
I_{FSM}	Non-repetitive forward surge current (single half-cycle of 50 Hz)		75 A
I_F	Continuous forward current. See derating curve Fig. 1		15 A
Thermal ratings			
T_{case}	Case operating temperatures	−55 to +175	^oC
T_{stg}	Storage temperatures	−55 to +175	^oC
Mechanical ratings			
Torque between nut and stud			1.7 Nm

2. Characteristics (not for inspection purposes)

At 25°C case temperature unless otherwise stated.

V_{FM}	Peak forward voltage at $I_{FM} = 30A$	1.65 V max.
I_{R1}	Reverse current at $V_R = 50$ V (1N3879, 1N3879R) $V_R = 100$ V (1N3880, 1N3880R) $V_R = 200$ V (1N3881, 1N3881R) $V_R = 300$ V (1N3882, 1N3882R) $V_R = 400$ V (1N3883, 1N3883R)	15 μA max.
I_{R3}	Reverse current at $T_{case} = 100^oC$ $V_R = 50$ V (1N3879, 1N3879R) $V_R = 100$ V (1N3880, 1N3880R) $V_R = 200$ V (1N3881, 1N3881R) $V_R = 300$ V (1N3882, 1N3882R) $V_R = 400$ V (1N3883, 1N3883R)	1.0 mA max.
t_{rr}	Reverse recovery time at $di/_{dt} \equiv 25$ A/μs, $I_F = 1$ A	200 ns max.
I_{rr}	Reverse recovery current at $di/_{dt} = 25$ A/μs, $I_F = 1$ A $V_R = 30$ V	2.0 A max.

3. Marking

(1) Each rectifier shall bear the following markings:-
  a. Cathode terminal shall be identified.
  b. The type designation, e.g., 1N3879.
  c. The factory identification code.
  d. The date code.

(2) Each package containing one or more of these rectifiers shall bear markings b, c, and d, above, and in addition, the number of this detail specification, i.e., BS9331 FO27, Issue 1.

4. Related Documents.

BS 3934. 'Dimensions of semiconductor devices'.
BS 6001. 'Sampling procedures and tables for inspection by attributes,' (or BS 9001 which has the same technical content).
BS 9000. 'General requirements for electronic components of assessed quality', and
BS 9002. 'Qualified products list for electronic components of assessed quality'.
BS 9300. 'Semiconductor devices of assessed quality. Generic data and methods of test'.
BS 9331. 'Rules for the preparation of detail specifications for medium current rectifier diodes'.

5. Ordering Information. Orders for these rectifiers shall contain the following minimum information:-

----- (Qty) Fast Recovery Rectifier Type----------------
Conforming to BS9331 FO27, Issue 1, Dated July 1973

INSPECTION REQUIREMENTS

At 25 ± 2°C case temperature unless otherwise stated (see 1.2.4.1.5 of BS 9300:1969)

Inspection	BS 9300 (1969) reference and conditions of test		Symbol	Limits		Unit
				min	max	
GROUP A	*Subgroups A3, A4, and A5 not applicable*					
Subgroup A1		*Insp. level I, AQL 1.5%*				
Visual inspection	1.2.2					
Subgroup A2		*Insp. level II, AQL 1.0%*				
Peak forward voltage	1502	I_{FM} = 30A, f = 50 Hz	V_{FM}		1.65	V
Reverse current	1503	V_R = 50 V 1N3879, 1N3879R V_R = 100 V 1N3880, 1N3880R V_R = 200 V 1N3881, 1N3881R V_R = 300 V 1N3882, 1N3882R V_R = 400 V 1N3883, 1N3883R	I_{R1}		15	μA
Reverse recovery time		di/dt = 25 A/μs I_F = 1 A, V_R = 30 V (see Annex 1)	t_{rr}		200	ns
Reverse recovery current		di/dt = 25 A/μs I_F = 1 A, V_R = 30 V (see Annex 1)	I_{rr}		2.0	A
GROUP B	*Subgroups B4, B5 and B6 not applicable*					
Subgroup B1		*Insp. level S-2, AQL 6.5%*				
Dimensions	1.2.3	Ref. BS 3934 SO-10A	ΦD		12.82	mm
Subgroup B2						
(a) Solderability	1.2.6.10.1	*Insp. level S-4, AQL 4.0%*	J		20.32	mm
Subgroup B2 (b)		*Insp. level S-4, AQL 4.0%*				
Rapid change of temperature and	1.2.6.7	T_{amb} = −55°C to 150°C				
damp heat, cyclic	1.2.6.3	Six cycles				
Subgroup B3		*Insp. level S-3, AQL 6.5%*				
Stud torque	1.2.6.11.2	1.7 Nm				
Subgroup B7		*Insp. level S-4, AQL 1.5%*				
Electrical endurance	1.2.7.4.2	Duration = 160 h min.				
Post-test end-points for subgroups B2(b), B3 and B7						
Peak forward voltage	1502	I_{FM} = 30A, f = 50 Hz	V_{FM}		1.82	V
Reverse current	1503	V_R = 50 V 1N3879, 1N3879R V_R = 100 V 1N3880, 1N3880R V_R = 200 V 1N3881, 1N3881R V_R = 300 V 1N3882, 1N3882R V_R = 400 V 1N3883, 1N3883R	I_{R1}		30	μA
Subgroup B8						
CTR information	1.1.11	Attributes information for subgroups B2(b), B3 and B7				

INSPECTION REQUIREMENTS *(continued)*

Inspection	BS 9300 (1969) reference and conditions of test		Symbol	Limits		Unit
				min	max	
GROUP C	*Subgroup C4 not applicable*					
Subgroup C1		*Insp. level S-2, AQL 6.5%*				
Dimensions	**1.2.3**	Ref. BS 3934 SO-10A	ΦT	1.53	2.28	mm
			N	10.72	11.5	mm
Subgroup C2(a)		*Insp. level S-4, AQL 4.0%*				
Non-repetitive forward surge current	1505	I_{FSM} = 75 A, Z_S = 2 kohms,	I_{FSM}			
		f = 50 Hz, half cycle,				
		V_{RRM} = 50 V 1N3879,1N3879R				
		V_{RRM} = 100 V 1N3880,1N3880R				
		V_{RRM} = 200 V 1N3881,1N3881R				
		V_{RRM} = 300 V 1N3882,1N3882R				
		V_{RRM} = 400 V 1N3883,1N3883R				
		No. of cycles = 1				
Non-repetitive peak reverse voltage	1507	f = 50 Hz, Z_S = 2 kohms	V_{RSM}			
		V_{RSM} = 50 V 1N3879,1N3879R				
		V_{RSM} = 100 V 1N3880,1N3880R				
		V_{RSM} = 200 V 1N3881,1N3881R				
		V_{RSM} = 300 V 1N3882,1N3882R				
		V_{RSM} = 400 V 1N3883,1N3883R				
Subgroup C2(b)		*Insp. level I, AQL 2.5%*				
Reverse current	1503	T_{case} = 100°C	I_{R3}		1.0	mA
		V_R = 50 V 1N3879, 1N3879R				
		V_R = 100 V 1N3880, 1N3880R				
		V_R = 200 V 1N3881, 1N3881R				
		V_R = 300 V 1N3882, 1N3882R				
		V_R = 400 V 1N3883, 1N3883R				
Subgroup C3		*Insp. level S-2, AQL 6.5%*				
Vibration, swept frequency	**1.2.6.5**	f = 150 Hz to 2000 Hz				
		Acceleration = 196 m/s^2				
followed by						
Acceleration, steady state	**1.2.6.6**	Acceleration = 196 000 m/s^2				
		Mounted: Stud inwards				
		Direction of acceleration: radially				
Subgroup C5		*Insp. level S-3, AQL 4.0%*				
Electrical endurance	**1.2.7.4.2**	Duration = 2000 h min.				
Post-test end-points for subgroups C2(a), C3 and C5						
Peak forward voltage	1502	I_{FM} = 30A, f = 50 Hz	V_{FM}		1.82	V
Reverse current	1503	V_R = 50 V 1N3879, 1N3879R	I_{R1}		30	μA
		V_R = 100 V 1N3880, 1N3880R				
		V_R = 200 V 1N3881, 1N3881R				
		V_R = 300 V 1N3882, 1N3882R				
		V_R = 400 V 1N3883, 1N3883R				
Subgroup C6						
CTR information	**1.1.11**	Attributes information for subgroups C2(a) and C3 Measurements information for V_{FM} and I_{R1} before and after the test in subgroup C5				

INSPECTION REQUIREMENTS *(continued)*

Inspection	BS 9300 (1969) reference and conditions of test		Symbol	Limits		Unit
				min	max	
GROUP D	*Subgroups D2 and D3 not applicable*					
Subgroup D1		*Insp. level S-2, AQL 6.5%* *(Note 1)*				
Dimensions	1.2.3	Ref. BS 3934 SO-10A	A		10.28	mm
			ΦD_1		10.76	mm
			ΦD_2		6.35	mm
			F	2.0	4.4	mm
			ΦM	3.69	4.82	mm
			N_1		2.03	mm
			Z	1.53		
Subgroup D4		*Insp. level S-3, AQL 4.0%* *(Note 1)*				
Electrical endurance	1.2.7.4.2	Duration = 8000 h min.				
Post-test end-points for subgroups D4						
Peak forward voltage	1502	I_{FM} = 30A, f = 50 Hz	V_{FM}		1.82	V
Reverse current	1503	V_R = 50 V 1N3879, 1N3879R V_R = 100 V 1N3880, 1N3880R V_R = 200 V 1N3881,·1N3881R V_R = 300 V 1N3882, 1N3882R V_R = 400 V 1N3883, 1N3883R	I_{R1}		30	μA
Subgroup D5						
CTR information	1.1.11	Measurements information for V_{FM} and I_{R1} before and after the test in subgroup D4				

NOTE 1: AQL values are for Qualification Approval purposes only (see 1.1.10 of BS 9300: 1969).

6. Supplementary Information

(1) Forward current derating curves are given in Fig. 1.

(2) A graph of average forward power loss against forward current is given in Fig. 2.

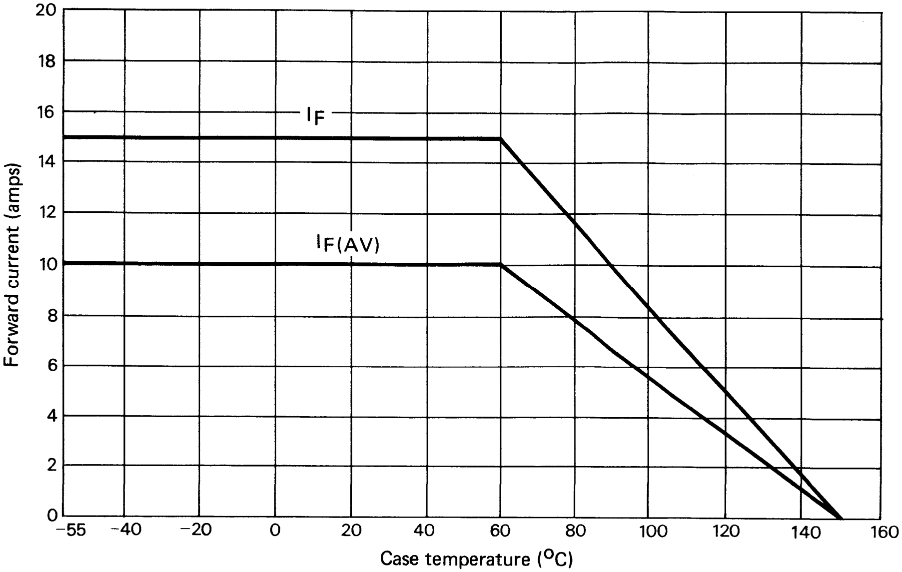


FIG. 1. Forward current derating curves.

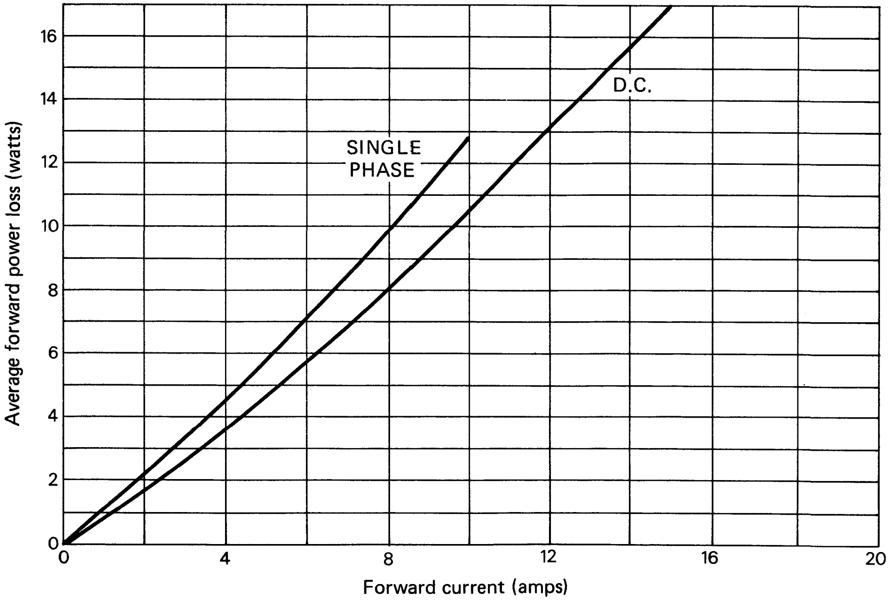


FIG. 2. Average forward power loss against forward current.

ANNEX 1

REVERSE RECOVERY TIME T_{rr} AND REVERSE RECOVERY CURRENT I_{rr}

PURPOSE

To measure the reverse recovery time and reverse recovery current of a rectifier diode under specified conditions

CIRCUIT

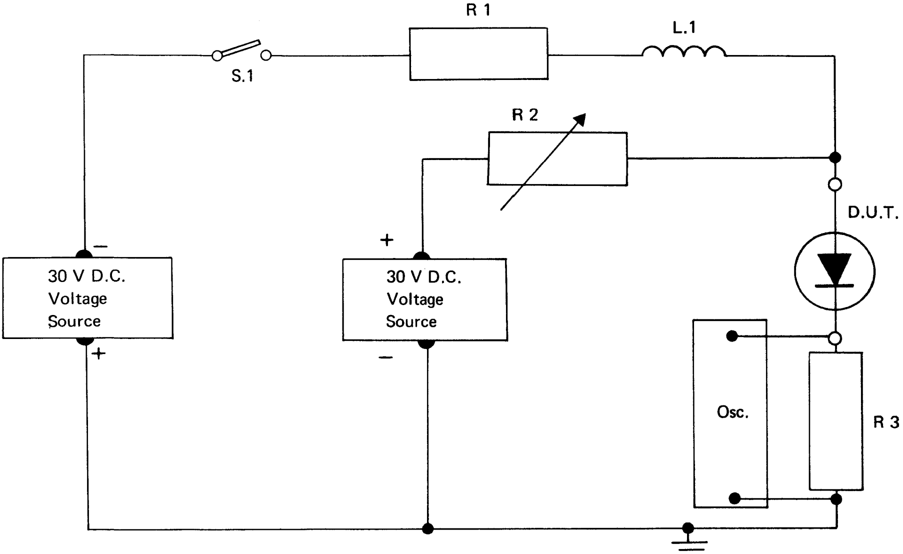


Fig. a.

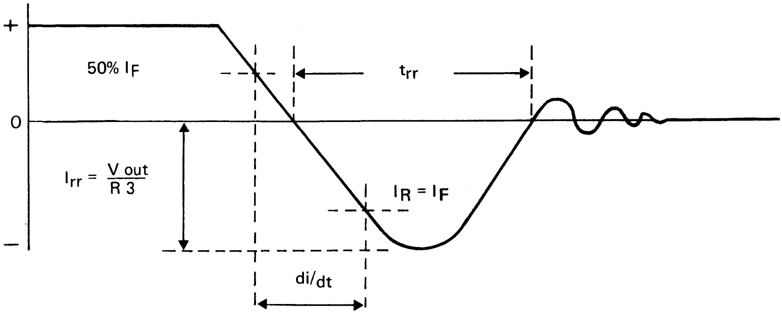


Fig. b.

DESCRIPTION

S.1 is an electro-mechanical switch which conducts for at least 20 times the t_{rr} being measured, when this switch is closed the reverse recovery is initiated.

The time constant L.1/R.1 is such that the specified rate of rise of reverse recovery current (di/dt) is obtained.

di/dt is measured from 50% I_F to $I_R = I_F$ (see Fig. b. of Annex 1)

R_2 is a forward current limiting resistor.

R_3 is a current shunt and should have low residual inductance.

The oscilloscope monitors the current waveform and should have the following characteristics:-

Tr $\leqslant$ 5% ot the t_{rr} being measured, Input resistance $\geqslant$ 10 megohms,

Input Capacitance $\leqslant$ 12 pF, Series Input Inductance $\leqslant$ 0.5 μH.

PROCEDURE

The voltage sources are set to zero.

Switch S1 is set to operate at a duty cycle of $\leqslant$ 2%.

The rectifier diode is inserted into the test socket and the temperature set to the specified value.

The forward current and reverse voltage are set to the specified values.

The rate of rise of reverse recovery current (di/dt) is set to the specified value.

The voltage waveform across the current shunt is examined and if within the limits specified, as defined in Fig. b, the device is passed.

The voltage sources are reduced to zero and the rectifier diode removed from the test socket.

SPECIFIED CONDITIONS

The values of the following test conditions will be obtained from the detail specification.

1. D.C. forward current.
2. Reverse voltage.
3. Rate of rise of reverse recovery current (di/dt).
4. Case temperature.

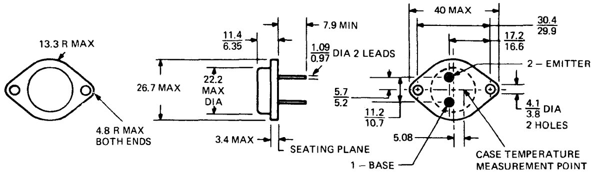
BU 105
NPN SILICON POWER TRANSISTOR

REVISED JUNE 1975

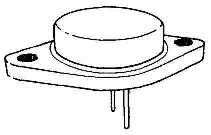
- ✻ **Designed for High Voltage C.R.T. Scanning**
- ✻ **V_{CES} Rating 1500V**
- ✻ **Current Rating – 2.5 Amps Peak**
- ✻ **Fast Switching – t_F at 2 Amps 0.6 Microsecond Typical**

Mechanical

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute Maximum Ratings (T_{case} = 25°C)

Collector Emitter Voltage (Peak See Note 1, $R_{BE} \leqslant 100\ \Omega$)	1500V
Collector Base Voltage (Peak See Note 1.)	1500V
Collector Current Continuous	2.5A
Base Current Continuous	1.5A
Total Dissipation ($V_{CE} \leqslant 100V$, $T_{case} \leqslant 90°C$) See Note 2.	10W
Operating Junction Temperature	−65°C to +115°C
Storage Temperature	−65°C to 15°C

NOTES: 1. Pulse Width $\leqslant$ 20 μs Duty cycle $\leqslant$ 25%
2. Refer to Figs 3, 4.

TEXAS INSTRUMENTS

BU 105
NPN SILICON POWER TRANSISTOR

Electrical Characteristics (T_{case} = 25°C)

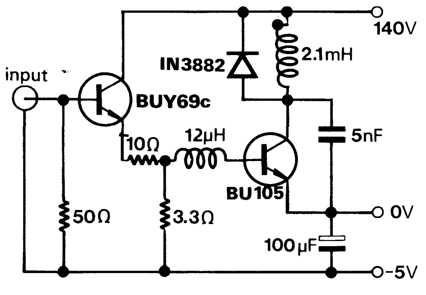
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CES}	Collector Emitter Leakage Current	V_{CE}=1500V, V_{BE}=0 (See Note 1)			1.0	mA
$V_{(BR)EBO}$	Emitter Base Breakdown Voltage	I_E=100mA, I_C=0	5	7.0		V
$V_{CE(SAT)}$	Collector Emitter Saturation Voltage	I_C=2.5A, I_B=1.5A (See Note 3)			5	V
$V_{BE(SAT)}$	Base Emitter Saturation Voltage	I_C=2.5A, I_B=1.5A (See Note 3)			1.5	V
f_T	Transition Frequency	V_{CE}=5V, I_C=0.1A, f=5MHz		7.0		MHz
C_{OBO}	Common Base Open Circuit Output Capacitance	V_{CB}=10V, I_E=I_C=0, f=1MHz		55		pF
t_f	Collector Current Fall Time	I_C=2A, $I_{B(on)}$=1.5A $I_{B(off)}$=1.0A, (See Figs 1, 2)		0.6	1.1	µs
θ_{JC}	Junction to Case Thermal Resistance				2.5	°C/W

NOTES: 1. Pulse width ⩽ 20 µs. Duty Cycle ⩽ 25%.

3. Pulsed Test. Pulse duration ⩽ 300 µs. Duty Cycle ⩽ 2%.

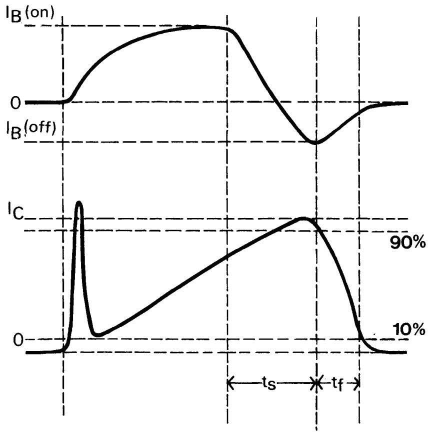
This test must be measured with voltage sensing contacts seperate from carrying contacts.

Details for measurement of switching parameters



Pulse Width = 30us
Pulse Repetition Rate = 200 p.p.s.
Resistors are Non-inductive types
Recommended Pulse Generator Mewlett Packard 214A
Current measured using Current Probe such as
TEKTRONIX type P6019, P6020, P6042
Oscilloscope to have rise better than 20ns

Fig.1



Current Waveforms of I_C and I_B

Fig.2

BU 105
NPN SILICON POWER TRANSISTOR

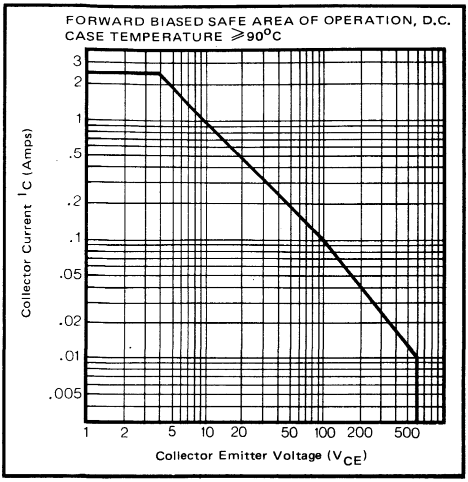


Fig.3

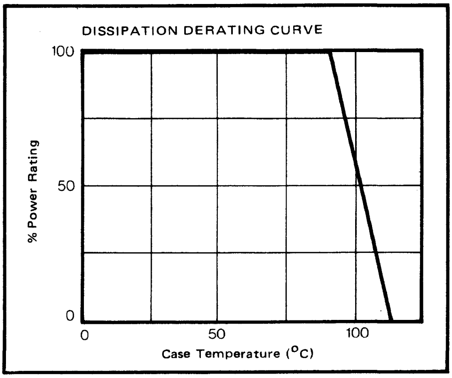


Fig.4

The graph on figure 3 is with a case temperature held at 90°C. For operation at case temperatures above 90°C derate the value of current indicated in figure 3 by the power derating factor, determined from figure 4.

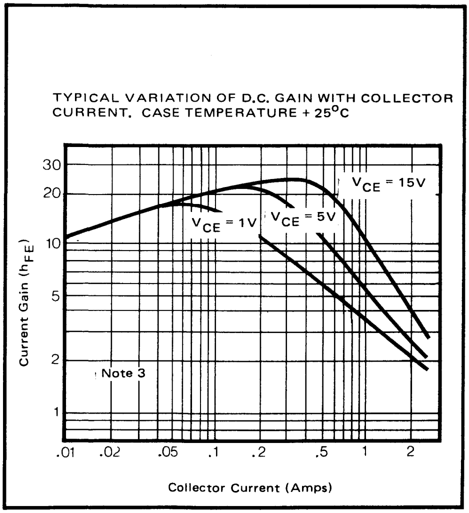


Fig.5

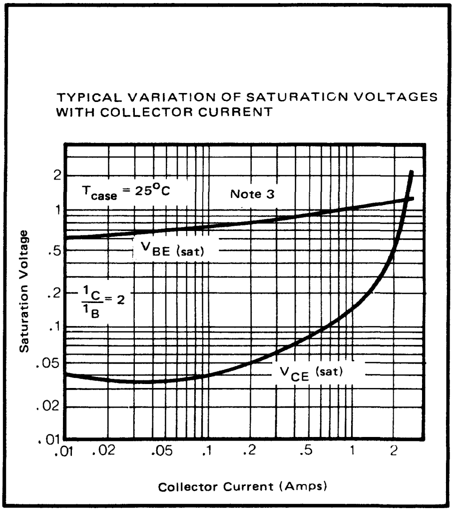


Fig.6

TEXAS INSTRUMENTS

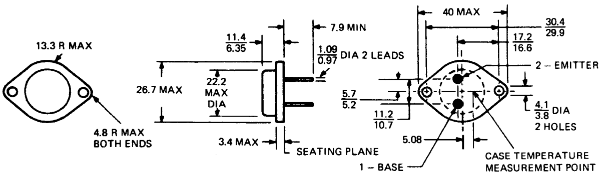
BU108
NPN SILICON POWER TRANSISTOR

REVISED JUNE 1975

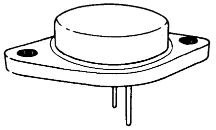
- ✱ **Designed for High Voltage C.R.T. Scanning**
- ✱ **V_{CEX} Rating – 1500V Peak**
- ✱ **Collector Current Rating – 5 Amps**
- ✱ **Fast Switching – t_f at 4.5 Amps 0.7 Microsecond Typical**

Mechanical

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute Maximum Ratings ($T_{case} = 25°C$)

Collector-Emitter Voltage (Peak see Note 1), $-2V \geqslant V_{BE} \geqslant -5V$	1500V
Collector-Base Voltage (Peak see Note 1)	1500V
Emitter-Base Voltage	5V
Continuous-Collector Current	5A
Continuous-Base Current	3.5A
Continuous-Emitter Current	8.5A
Total Dissipation ($V_{CE} \leqslant 100V$, $T_{case} \leqslant 95°C$) (See Note 2)	12.5W
Operating Junction Temperature	−65°C to +115°C
Storage Temperature	−65°C to +115°C

NOTES: 1. Pulse width $\leqslant 20\mu s$ Duty cycle $\leqslant 25\%$

2. Refer to Figs. 3, 4.

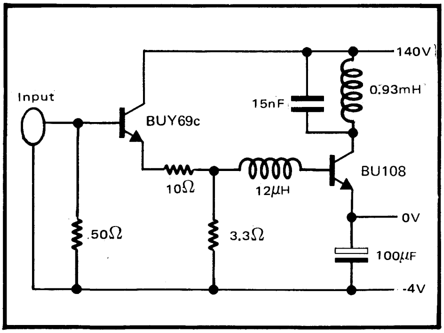
BU108
NPN SILICON POWER TRANSISTOR

Electrical Characteristics (T_{case} = 25°C)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1500V V_{BE} = −2V (Note 3)			1	mA
I_{CBO}	Collector-Base Leakage Current	V_{CB} = 1500V I_C = 0 (Note 3)			1	mA
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_C = 100mA I_C = 0	5	7		V
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage	I_C = 4.5A I_B = 2A (Note 4)		.4	5	V
$V_{BE(SAT)}$	Base-Emitter Saturation Voltage			1.1	1.3	V
t_f	Collector-Current Fall Time	I_C = 4.5A $I_{B(ON)}$ = 1.5A (Note 5)		7	1.2	μs
θ_{jc}	Junction to Case				1.6	°C/W

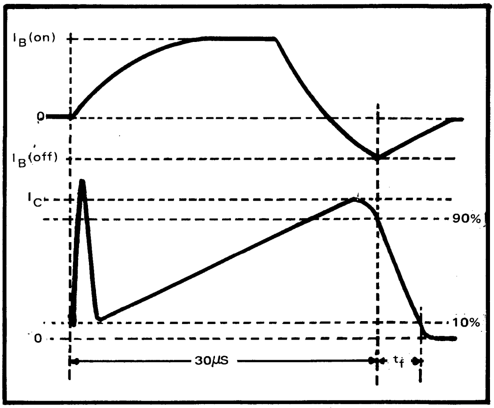
NOTES:
3. Pulsed Test. Pulse duration ⩽20 μS. Duty cycle ⩽25%.
4. Pulsed Test Pulse duration ⩽300 μS. Duty cycle ⩽2%.
5. Refer to Fig. 1, 2.

Details for the measurement of switching parameters



Pulse Width = 30μS
Pulse Repetition Rate = 200 p.p.s.
Resistors are Non-inductive types.
Recommended Pulse Generator Hewlett Packard 214A.
Current measured using Current Probe such as TEKTRONIX type P6019, P6020, P6042.
Oscilloscope to have rise better than 20nS.

FIG. 1.



Current Waveforms of I_C and I_B

FIG. 2.

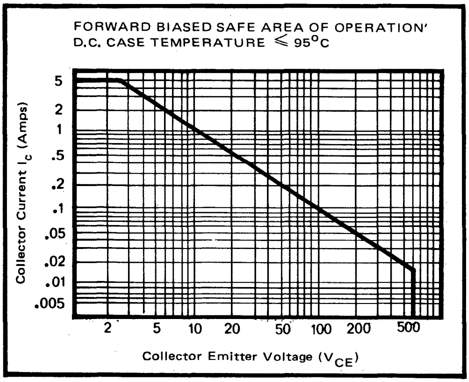


FIG. 3.

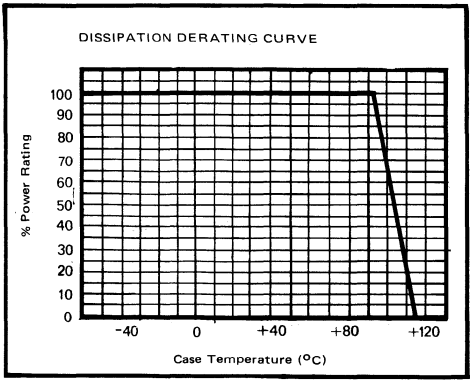


FIG. 4.

The graph on figure 3 is for a case temperature held at 95°C.
For operation at case temperatures above 95°C derate the value of current indicated in figure 3 by the power derating factor, determined from figure 4.

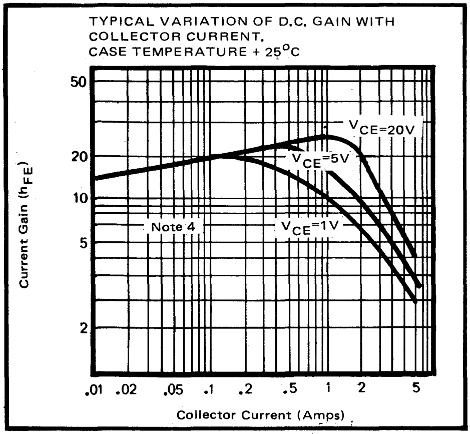


FIG. 5.

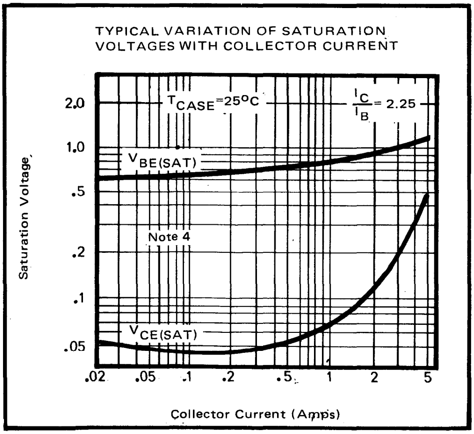


FIG. 6.

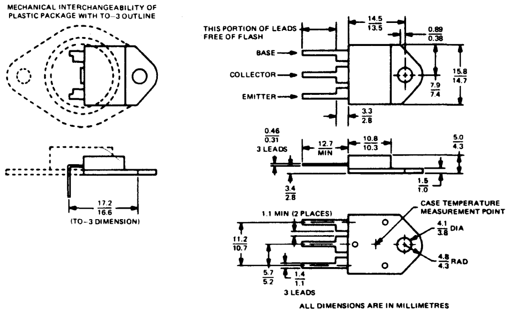
BU124
NPN SILICON POWER TRANSISTOR

AUGUST 1975

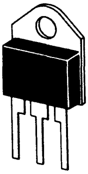
- Transistor Type BU124 has been designed specifically for portable TV linescan applications.
- The plastic package makes it suitable for direct substitution for metal can (TO-3) devices.

mechanical specification

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings (at 25°C ambient temperature)

Collector Base Voltage (IE = 0)	350V
Emitter Base Voltage	8V
Continuous Collector Current (See Note)	10A (Peak: 15A)
Continuous Dissipation ($T_{case} \leqslant 25^{o}C$)	50W
Operating Temperature Range	−65°C to +150°C

NOTE 1: Pulse width ⩽1mS Duty cycle 25%.

TEXAS INSTRUMENTS

BU124
NPN SILICON POWER TRANSISTOR

electrical characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CBO}	$V_{CB} = 350V$			1	mA
BV_{EBO}	$I_B = 10mA$	8			V
$V_{CE(sat)}$	$I_C = 4A, \quad I_B = 0.5A$			0.5	V
$V_{BE(sat)}$	$I_C = 4A, \quad I_B = 0.5A$			1.5	V
t_f	$I_C = 4A, \quad I_B = 0.5A$		0.5		µS
$\theta_{J\text{-}C}$	Junction to Case Thermal Resistance			2.5	°C/W

DISSIPATION DERATING CURVE

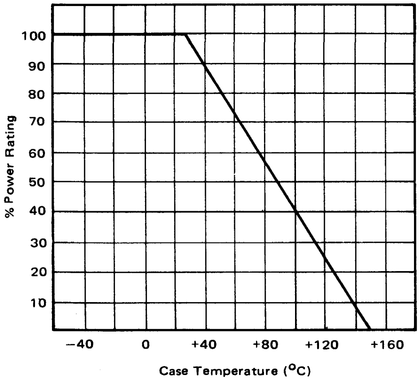


FIGURE 1.

TYPICAL VARIATION OF DC GAIN WITH COLLECTOR CURRENT.
CASE TEMPERATURE +25°C

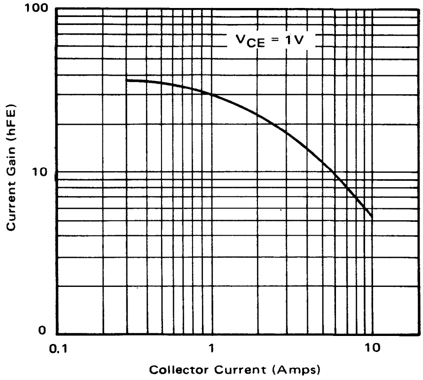


FIGURE 2.

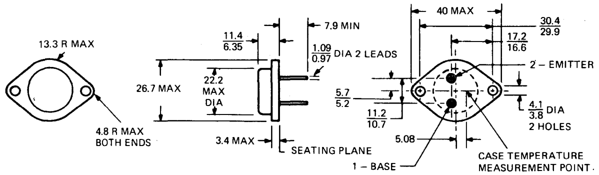
BU126
NPN SILICON POWER TRANSISTOR

REVISED JULY 1975

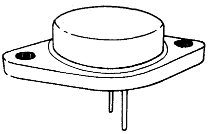
- **BU126 is a high voltage NPN silicon power transistor designed for general industrial and consumer applications primarily intended for use in switching mode power supplies.**

mechanical specification

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings (at 25°C ambient temperature)

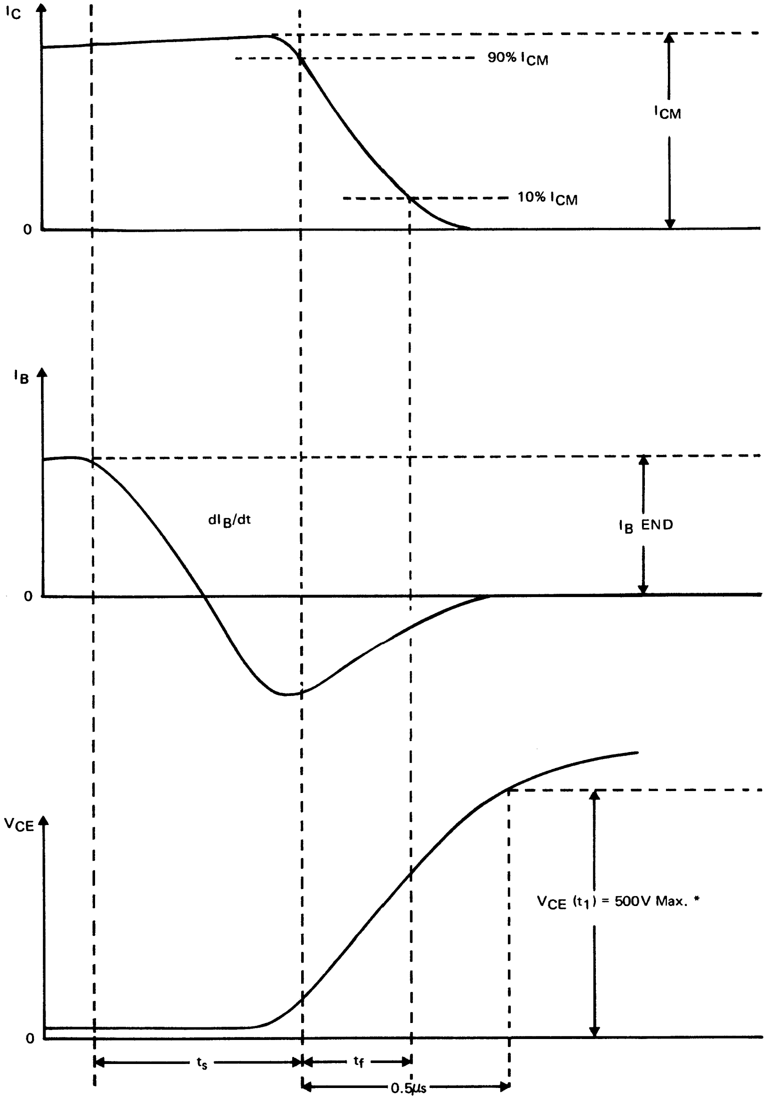
Collector-Base Voltage	750V
Collector-Emitter Voltage ($V_{BE} = -1.5V$)	750V
Continuous-Collector Current	4A
Continuous-Dissipation ($T_{amb} \leqslant 25^oC$) $V_{CE} \leqslant 25V$	50W
Operating Temperature Range	–65°C to +175°C

electrical characteristics at T_{case} = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector Emitter Cut off Current	V_{CE} = 750V, V_{EB} = 1.5V			0.5	mA
I_{EBO}	Emitter Base Cut off Current	V_{EB} = 6V			5	mA
h_{FE}	Static Forward Current Transfer Ratio (Note 1)	I_C = 1A, V_{CE} = 5V I_C = 4A, V_{CE} = 15V	15 5		60	– –
$V_{CE(SAT)}$	Collector Emitter Saturation Voltage (Note 1)	I_C = 2.5A, I_B = 0.25A I_C = 4A, I_B = 1A			10 5	V V
$V_{BE(SAT)}$	Base Emitter Saturation Voltage	I_C = 2.5A, I_B = 0.25A			1.5	V
$V_{CEO(SUST)}$	Collector Emitter Sustaining Voltage (Note 2)	I_B = 0, I_C = 100mA L = 25mH	300			V
t_s	Collector Current Storage Time	I_{CM} = 2.5A, I_B END = 0.25A dI_B/dt = 1.5A/µS. (Fig. 1)		1.0		µS
t_f	Collector Current Fall Time			0.1		µS

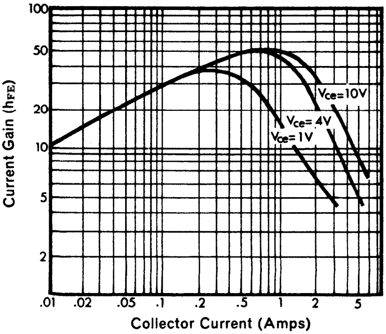
NOTES: 1. Pulsed Test, Pulse duration ⩽300µs. Duty cycle ⩽2%.
2. Inductive loop switching.

FIG. 1. TURN-OFF WAVEFORMS

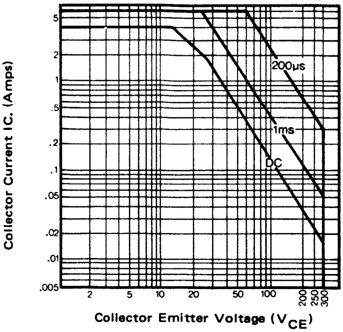


N.B. After turn off V_{CE} may rise to 750V provided that a reverse bias (greater than 1.5 Volts) is maintained between the base emitter terminals. However the rate of rise of voltage should be limited so that 0.5µs after the commencement of fall time $V_{CE(t1)}$ should be $\leqslant$500V.

TYPICAL VARIATION OF D.C. GAIN WITH COLLECTOR CURRENT. CASE TEMPERATURE + 25°C



FORWARD BIASED SAFE AREA OF OPERATION, D.C. AND SINGLE NON-REPETITIVE PULSE.
CASE TEMPERATURE 25°C



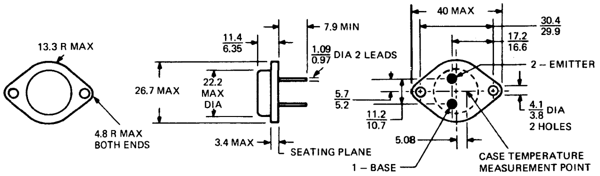
BU137
NPN SILICON POWER TRANSISTOR

JULY 1975

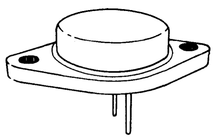
- **Designed for High Voltage C.R.T. Scanning and Switching Mode Power Supplies**

mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings ($T_{case} = 25^oC$)

Collector Emitter Voltage (Peak see Note 1) $-2V \geqslant V_{BE} \geqslant -5V$	1000V
Collector Base Voltage (Peak see Note 1)	1000V
Emitter Base Voltage	7V
Continuous Collector Current	12A
Total Dissipation ($T_{case} \leqslant 25^oC$)	70W
Operating Junction Temperature	-65^oC to 150^oC
Storage Temperature	-65^oC to 150^oC

NOTES: Pulse Width $\leqslant 20\mu s$. Duty Cycle $\leqslant 25\%$.

electrical characteristics (T_{case} = 25°C)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector Emitter Leakage Current	V_{CE} = 1000V, V_{BE} = −2V (Note 3)			1	mA
I_{CBO}	Collector Base Leakage Current	V_{CB} = 1000V, I_C = 0 (Note 3)			1	mA
$V_{(BR)EBO}$	Emitter Base Breakdown Voltage	I_E = 10mA, I_C = 0	7			V
$V_{CE(sat)}$	Collector Emitter Saturation Voltage	I_C = 5.5A, I_B = 1.2A (Note 4)			2.2	V
$V_{BE(sat)}$	Base Emitter Saturation Voltage				1.5	V
$V_{CE(sat)}$	Collector Emitter Saturation Voltage	I_C = 7.5A, I_B = 2A (Note 4)			5	V
t_f	Collector Current Fall Time	I_C = 7.5A, I_B =2A			1.0	μS

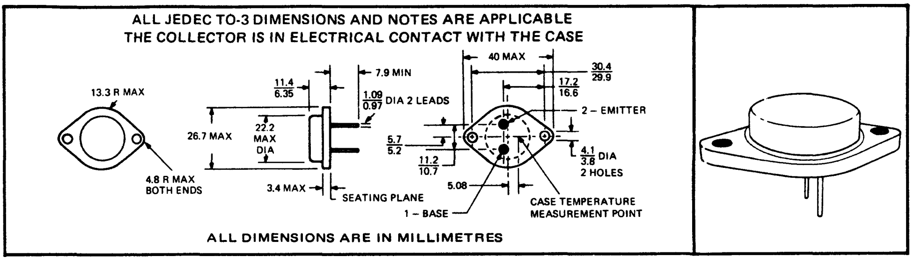
NOTE: 3. Pulsed Test. Pulse duration ≤ 20μs. Duty Cycle ≤25%.
4. Pulsed Test. Pulse duration ≤ 300μs. Duty Cycle ≤2%.

BU157
NPN SILICON POWER TRANSISTORS

SEPTEMBER 1975

- Designed for High Voltage C.R.T. Scanning

mechanical



ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings (T_{Case} = 25°C)

Collector Emitter Voltage (Peak see Note 1.) $-2V \geqslant V_{BE} \geqslant -5V$	1500V
Collector Base Voltage (Peak see Note 1)	1500V
Emitter Base Voltage	7V
Continuous Collector Current	12A
Total Dissipation ($T_{Case} \leqslant 25°C$)	70W
Operating Junction Temperature	−65°C to 150°C
Storage Temperature	−65°C to 150°C

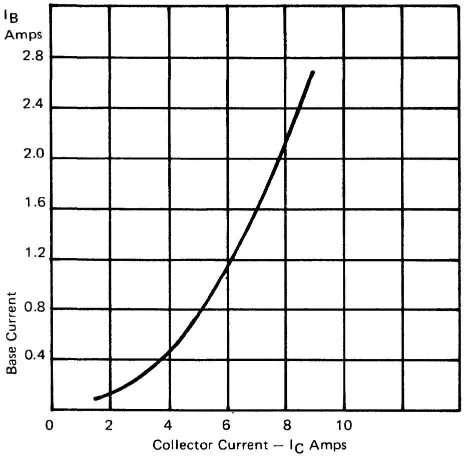
Note 1. Pulse Width $\leqslant 20\mu s$ Duty Cycle $\leqslant 25\%$

electrical characteristics (T_{Case} = 25°C)

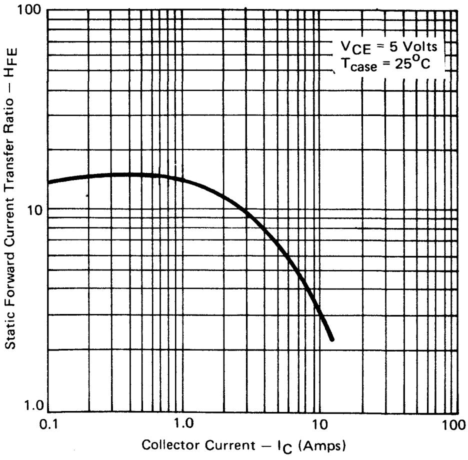
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector Emitter Leakage Current	V_{CE} = 1500V, V_{BE} = −2V (Note 1)			1	mA
I_{CBO}	Collector Base Leakage Current	V_{CB} = 1500V, I_E = 0 (Note 1)			1	mA
$V_{(BR)EBO}$	Emitter Base Breakdown Voltage	I_E = 10mA, I_C = 0	7			V
$V_{CE(SAT)}$	Collector Emitter Saturation Voltage	I_C = 6A, I_B = 1.2A (Note 2)			5	V
$V_{BE(SAT)}$	Base Emitter Saturation Voltage				1.6	V
LV_{CEO}	Collector Emitter Voltage	I_C = 0.5A; L = 10mH I_B = 0	650			V
tf	Collector Current Fall Time	I_C = 6A, I_B = 1.2A			1.0	μS

NOTES: 1. Pulsed Test Pulse duration ≤20μS. Duty Cycle ≤25%
2. Pulsed Test Pulse duration ≤300μS. Duty Cycle ≤2%

RECOMMENDED BASE CURRENT V COLLECTOR CURRENT



TYPICAL VARIATION OF STATIC FORWARD CURRENT TRANSFER RATIO, WITH COLLECTOR CURRENT



BU208
NPN SILICON POWER TRANSISTOR

AUGUST 1975

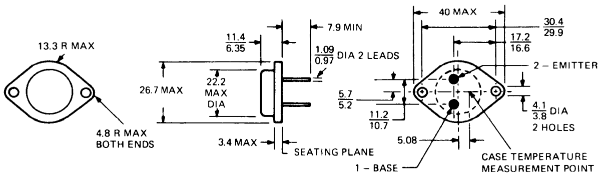
- **Designed for High Voltage C.R.T. Scanning**
- **V_{CEX} Rating – 1500V Peak**
- **Collector Current Rating – 7.5 Amps Peak**
- **Fast Switching – t_f at 4.5 Amps 0.7 Microsecond Typical**

Development Type

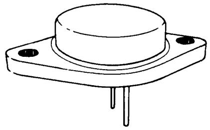
The data presented here is of a device under development, and may be subject to change without notice. No responsibility is assumed for future manufacture of this device.

Mechanical

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute Maximum Ratings (T_{case} = 25°C)

Collector-Emitter Voltage (Peak see Note 1), $-2V \geqslant V_{BE} \geqslant -5V$	1500V
Collector-Base Voltage (Peak see Note 1)	1500V
Emitter-Base Voltage	5V
Continuous-Collector Current	5A
Continuous-Base Current	3.5A
Continuous-Emitter Current	8.5A
Total Dissipation ($V_{CE} \leqslant 100V$, $T_{case} \leqslant 95°C$) (See Note 2)	12.5W
Operating Junction Temperature	–65°C to +115°C
Storage Temperature	–65°C to +115°C

NOTES:
1. Pulse width $\leqslant 20\mu s$ Duty cycle $\leqslant 25\%$
2. Refer to Figs. 3, 4.

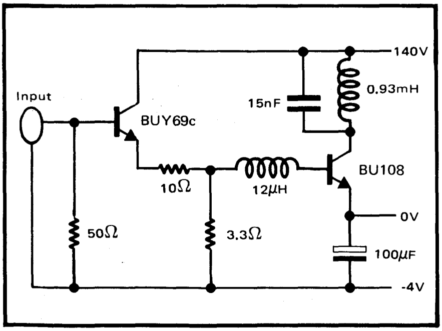
BU208
NPN SILICON POWER TRANSISTOR

Electrical Characteristics (T_{case} = 25°C)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1500V V_{BE} = −2V (Note 3)			1	mA
I_{CBO}	Collector-Base Leakage Current	V_{CB} = 1500V I_E = 0 (Note 3)			1	mA
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_C = 100mA I_C = 0	5	7		V
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage	I_C = 4.5A I_B = 2A (Note 4)		.4	5	V
$V_{BE(SAT)}$	Base-Emitter Saturation Voltage			1.1	1.3	V
t_f	Collector-Current Fall Time	I_C = 4.5A $I_{B(ON)}$ = 1.8A (Note 5)		.7	1.2	µs
θ_{jc}	Junction to Case				1.6	°C/W
LV_{CEO}	Collector-Emitter Latching Voltage	I_C = 100mA I_B = 0 (Note 4) L = 25mH	700			V

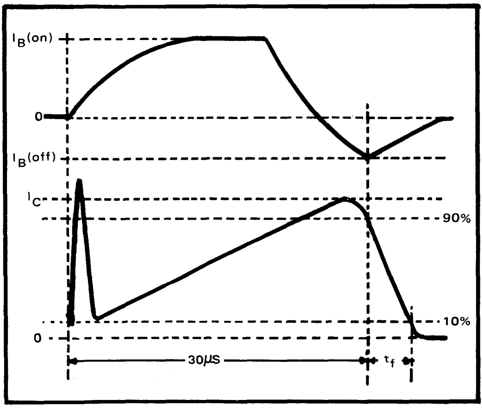
NOTES: 3. Pulsed Test. Pulse duration ⩽20 µS. Duty cycle ⩽25%.
4. Pulsed Test Pulse duration ⩽300 µS. Duty cycle ⩽2%.
5. Refer to Fig. 1, 2.

Details for the measurement of switching parameters



Pulse Width = 30µS
Pulse Repetition Rate = 200 p.p.s.
Resistors are Non-inductive types.
Recommended Pulse Generator Hewlett Packard 214A.
Current measured using Current Probe such as TEKTRONIX type P6019, P6020, P6042.
Oscilloscope to have rise better than 20nS.

FIG. 1.



Current Waveforms of I_C and I_B

FIG. 2.

TEXAS INSTRUMENTS

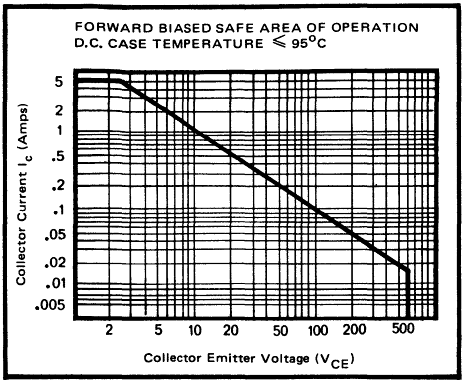

FORWARD BIASED SAFE AREA OF OPERATION
D.C. CASE TEMPERATURE ≤ 95°C

FIG. 3.

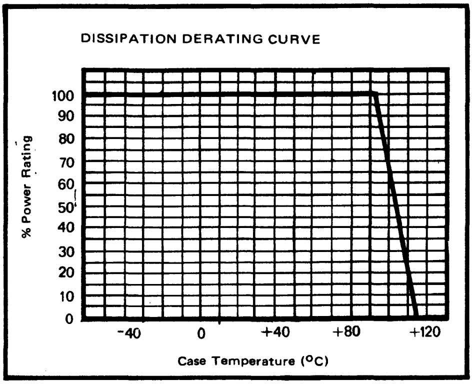

DISSIPATION DERATING CURVE

FIG. 4.

The graph on figure 3 is for a case temperature held at 95°C.
For operation at case temperatures above 95°C derate the value of current indicated in figure 3 by the power derating factor, determined from figure 4.

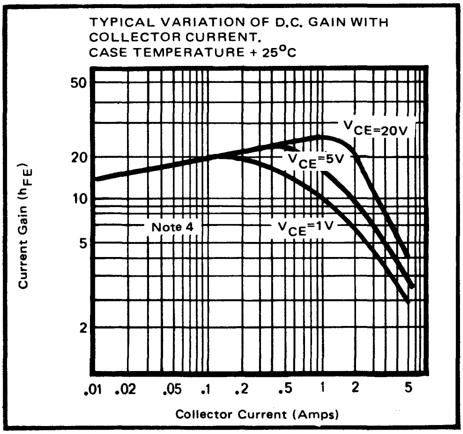

TYPICAL VARIATION OF D.C. GAIN WITH COLLECTOR CURRENT.
CASE TEMPERATURE + 25°C

FIG. 5.

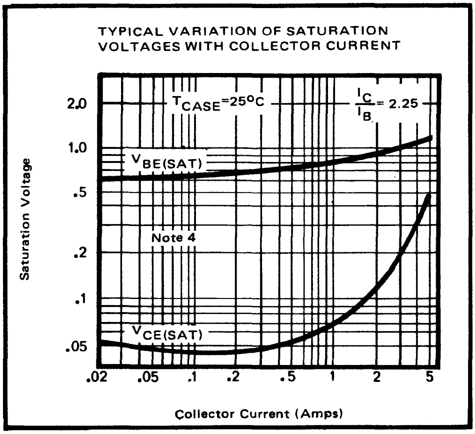

TYPICAL VARIATION OF SATURATION VOLTAGES WITH COLLECTOR CURRENT

FIG. 6.

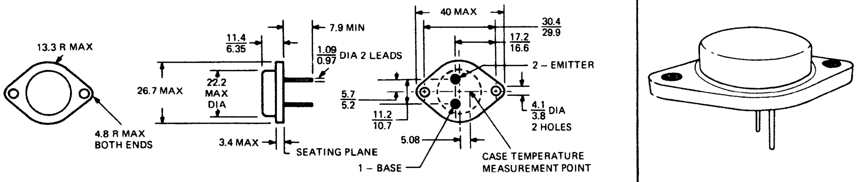
BU308
NPN SILICON POWER TRANSISTOR

AUGUST 1975

- **Designed for High Voltage C.R.T. Scanning**
- **V_{CEX} Rating – 1500V Peak**
- **Collector Current Rating – 5 Amps**
- **Fast Switching – t_f at 4.5 Amps 0.7 Microsecond Typical**

mechanical

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings (T_{case} = 25°C)

Collector-Emitter Voltage (Peak see Note 1), $-2V \geqslant V_{BE} \geqslant -5V$	1500V
Collector-Base Voltage (Peak see Note 1)	1500V
Emitter-Base Voltage	5V
Continuous-Collector Current	5A
Continuous-Base Current	3.5A
Continuous-Emitter Current	8.5A
Total Dissipation ($V_{CE} \leqslant 100V$, $T_{case} \leqslant 95°C$) (See Note 2)	12.5W
Operating Junction Temperature	−65°C to +115°C
Storage Temperature	−65°C to +115°C

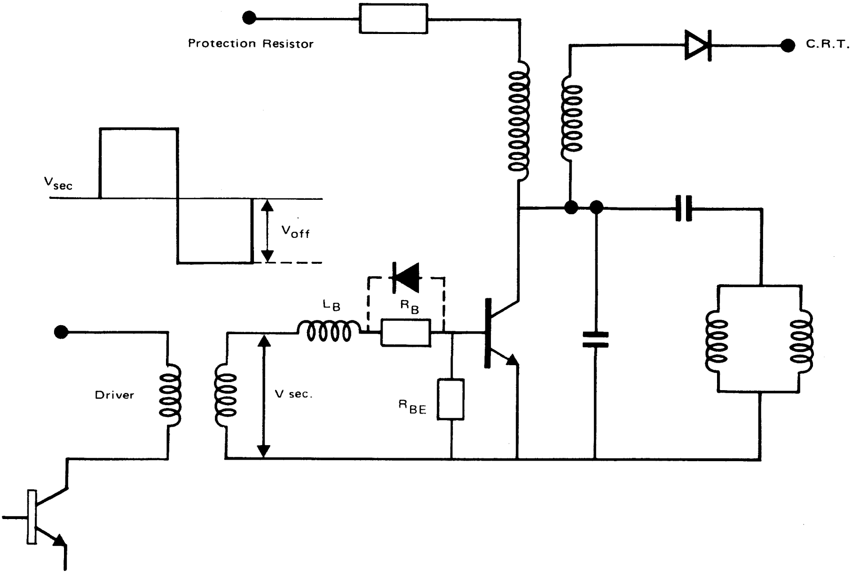
NOTES: 1. Pulse width $\leqslant 20\mu s$ Duty cycle $\leqslant 25\%$

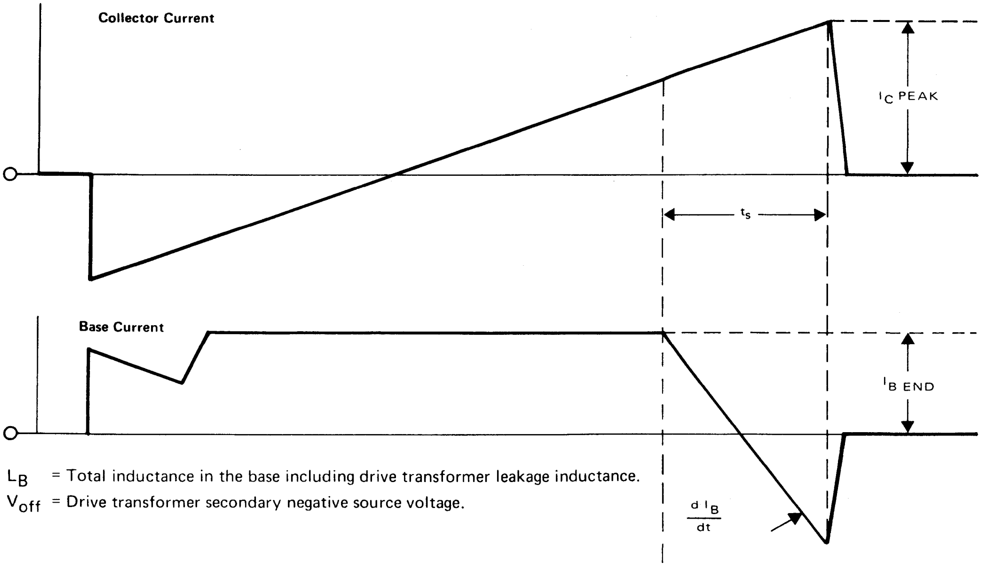
BU308
NPN SILICON POWER TRANSISTOR

electrical characteristics (T_{case} = 25°C)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1500V V_{BE} = −2V (Note 3)			1	mA
I_{CBO}	Collector-Base Leakage Current	V_{CB} = 1500V I_E = 0 (Note 3)			1	mA
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 100mA I_C = 0	5	7		V
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage	I_C = 4.5A I_B = 2A (Note 4)		4	5	V
$V_{BE(SAT)}$	Base-Emitter Saturation Voltage			1.1	1.3	V
t_f	Collector-Current	I_C = 4.5A		0.7	1.2	µs
θ_{jc}	Junction to Case				1.6	°C/W

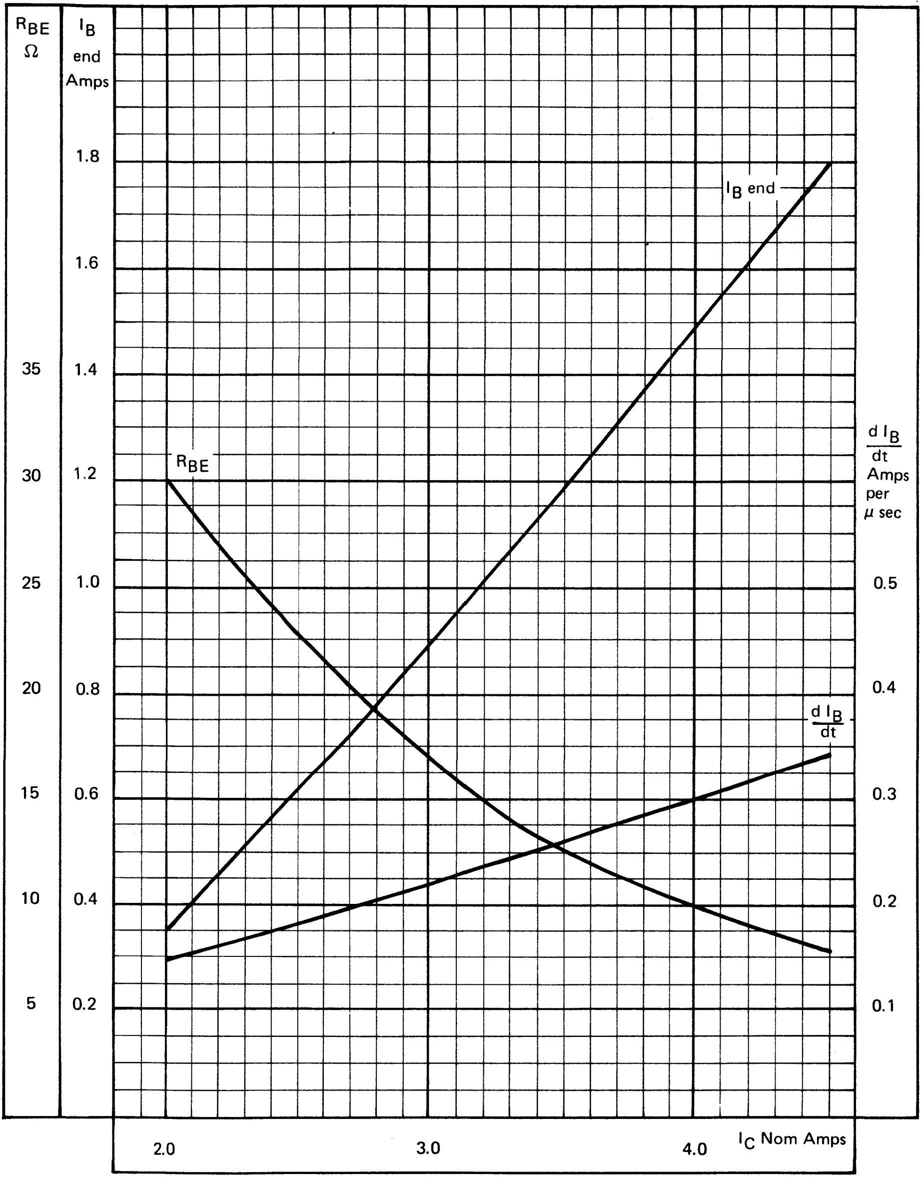
NOTES: 3. Pulsed Test. Pulse duration ⩽20µs. Duty cycle ⩽25%.
4. Pulsed Test. Pulse duration ⩽300µs. Duty cycle ⩽2%.





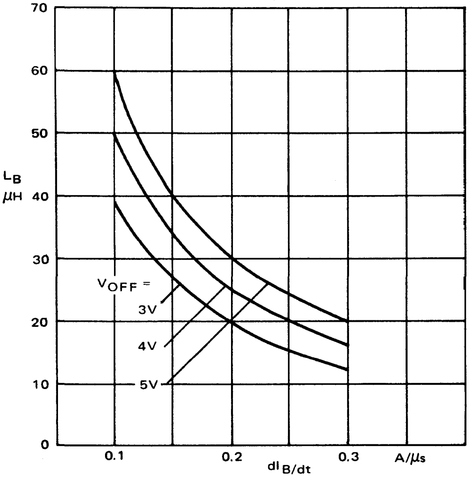
L_B = Total inductance in the base including drive transformer leakage inductance.
V_{off} = Drive transformer secondary negative source voltage.

BU308
NPN SILICON POWER TRANSISTOR

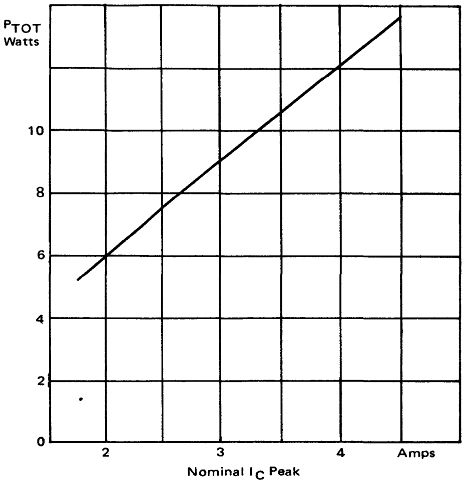


TEXAS INSTRUMENTS

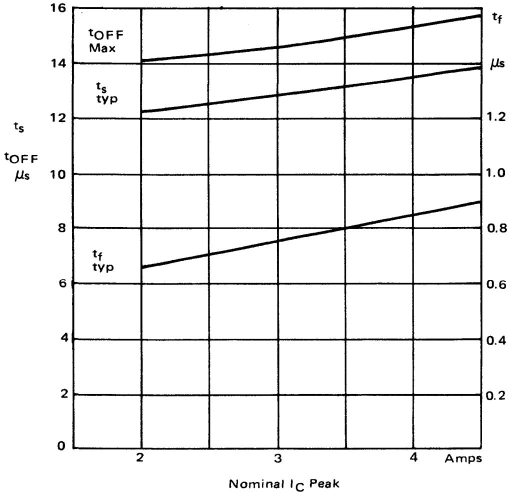
DETERMINATION OF L_B
TO OBTAIN CORRECT dI_B/dt
FOR VARIOUS VALVES OF V_{OFF}



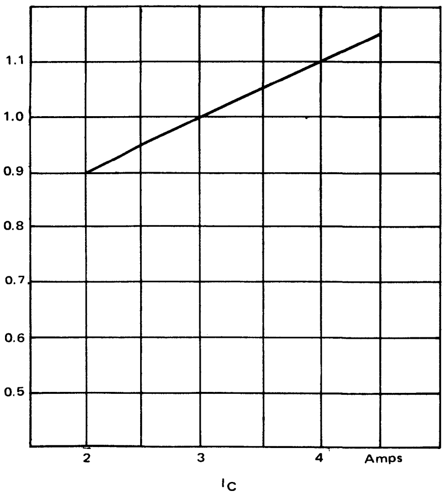
MAXIMUM DEVICE DISSIPATION
VERSES I_C PEAK (NOMINAL)
OPERATING WITH T_{CASE} = 90°C



SWITCHING TIMES WHEN
OPERATING IN A LINE OUTPUT
STAGE AT T_{CASE} = 90°C



TYPICAL BASE-EMITTER
VOLTAGE UNDER RECOMMENDED
DRIVE CONDITIONS



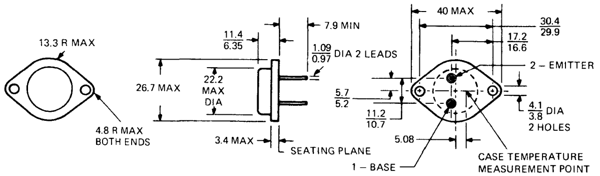
BU 361
NPN SILICON POWER TRANSISTOR

APRIL 1975

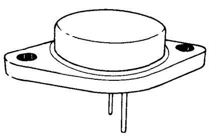
- Designed for Horizontal Deflection of 110° PI Colour Tubes with Toroidal Yoke

mechanical

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



Dimensions in mm



absolute maximum ratings ($T_{case} = 25°C$)

Collector Emitter Voltage	$-2V \geqslant V_{BE} \geqslant -5V$	800V
Collector Base Voltage		800V
Emitter Base Voltage		7V
Continuous Collector Current		12A
Total Dissipation ($T_{case} \geqslant 25°C$)		70W
Operating Junction Temperature		–65°C to 150°C
Storage Temperature		–65°C to 150°C

electrical characteristics ($T_{case} = 25°C$)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CEX}	Collector Emitter Leakage Current	$V_{CE} = 800V$ $V_{BE} = -2V$			1	mA
I_{CBO}	Collector Base Leakage Current	$V_{CB} = 800V$ $I_C = 0$			1	mA
$V_{(BR)EBO}$	Emitter Base Breakdown Voltage	$I_E = 10mA$ $I_C = 0$	7			V
$V_{CE(sat)}$	Collector Emitter Saturation Voltage	$I_C = 8A$ $I_B = 2A$ (Note 1)			3.5	V
$V_{BE(sat)}$	Base Emitter Saturation Voltage				2.0	V
t_f	Collector Current Fall Time	$I_C = 8A$ $I_B = 2A$			1.0	μS

Note 1: Pulsed Test Pulse duration ⩾300μS. Duty Cycle ⩾2%.

DEVELOPMENT TYPE
The data presented here is of a device under development and may be subject to change without notice. No responsibility is assumed for future manufacture of this device.

BUY69 SERIES
NPN SILICON POWER TRANSISTORS

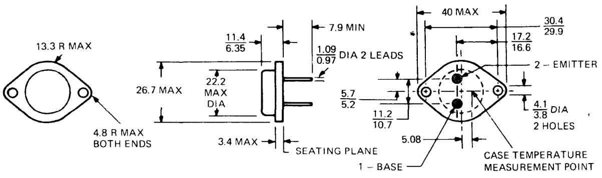
REVISED JULY 1975

BUY69 Series Transistors are designed for use in;

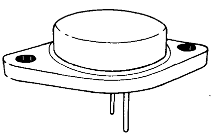
- **Switching Mode Power Supplies, Inverters and C.R.T. Scanning Systems.**
- **They feature High Voltage and Peak Current Capability together with fast Switching and a High Degree of Robustness.**

Mechanical Specification

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute Maximum Ratings (at 25°C case temperature)	**BUY69A**	**BUY69B**	**BUY69C**	
Collector-Base Voltage ($I_E = 0$)	1000	800	500	V
Collector-Emitter Voltage ($I_B = 0$)	400	325	200	V
Emitter-Base Voltage	8	8	8	V
Collector Current Peak (See Note 1)	15	15	15	A
Collector Current Continuous	10	10	10	A
Continuous-Dissipation ($V_{CE} \leqslant 17V$) (See Note 2)	100	100	100	W
Continuous Base Current	3	3	3	A
Operating Temperature Range				−65°C to +200°C

NOTES:
1. Pulse Width $\leqslant$ 500μSec. Duty Cycle $\leqslant$ 25%
2. Refer to Safe Operating and Dissipation Derating Curves
3. Pulsed Test. Pulse Width $\leqslant$ 300μSec. Duty Cycle $\leqslant$ 2%

BUY69 SERIES
NPN SILICON POWER TRANSISTORS

Electrical Characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 1mA, I_E = 0 Note 1	BUY69A BUY69B BUY69C	1000 800 500			V
LV_{CEO}	Collector-Emitter Latching Voltage	I_C = 50mA, I_B = 0	BUY69A BUY69B BUY69C	400 325 200			V
BV_{EBO}	Emitter-Base Breakdown Voltage	I_B = 10mA	ALL	8			V
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1000V V_{CE} = 800V V_{CE} = 500V V_{BE} = −2V	BUY69A BUY69B BUY69C			1.0	mA
h_{FE}	D.C. Current Gain	I_C = 2.5A V_{CE} = 10V Note 3	ALL	15			
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 8.0A I_B = 2.5A	ALL			2.2	V
$V_{CE(sat)}$	Collector Emitter Saturation Voltage	I_C = 8.0A I_B = 2.5A	ALL			3.3	V
t_f	Collector Current Fall Time	I_C = 8.0A V_{CE} = 40V $I_{B(on)}$ = 2.5A $I_{B(off)}$ = 2.5A	ALL			1.0	μS
f_t	Transition Frequency	V_{CE} = 10V I_C = 0.5A	ALL		6		MHz
C_{OBO}	Output Capacitance	V_{CB} = 20V I_C = 0	ALL			150	f_p

TYPICAL VARIATION OF COLLECTOR-EMITTER SATURATION VOLTAGE WITH COLLECTOR CURRENT

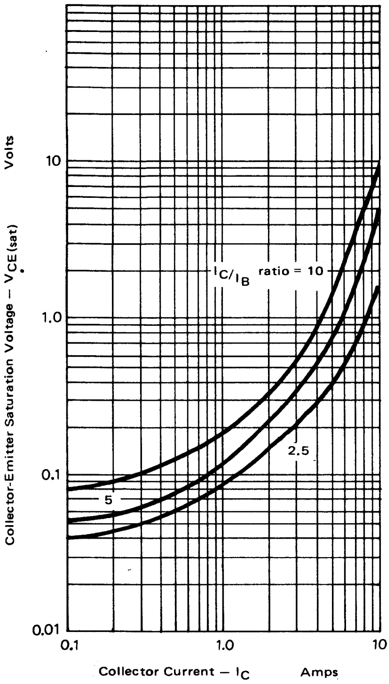


FIG 5

TYPICAL VARIATION OF STORAGE AND FALL TIMES WITH COLLECTOR CURRENT

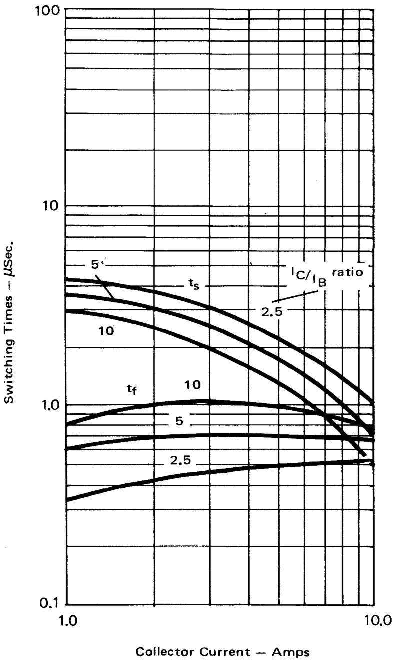


FIG 6

TYPICAL AND MAXIMUM* VARIATION OF I_{CBO} WITH TEMPERATURE

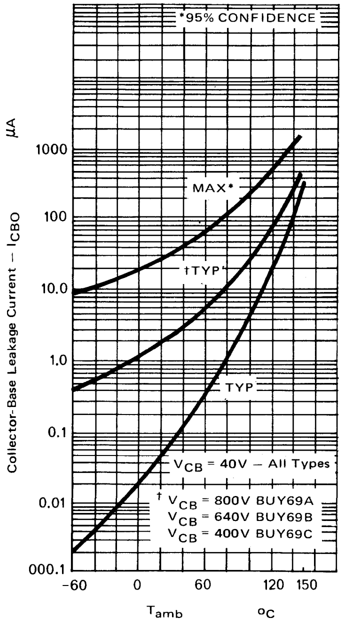


FIG 7

TYPICAL VARIATIONS OF BASE-EMITTER SATURATION VOLTAGE WITH COLLECTOR CURRENT

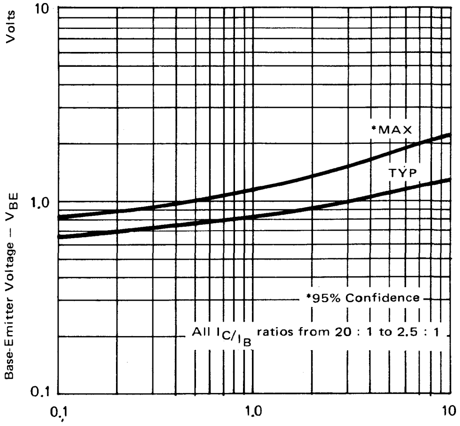


FIG 8

TYPICAL VARIATION OF TRANSITION FREQUENCY WITH COLLECTOR CURRENT

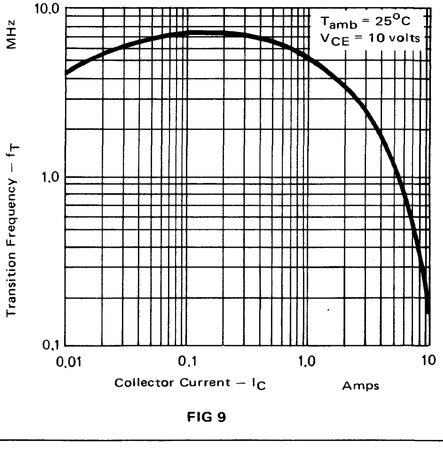


FIG 9

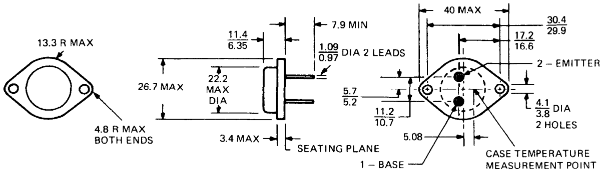
BUY70 SERIES
NPN SILICON POWER TRANSISTORS

REVISED JULY 1975

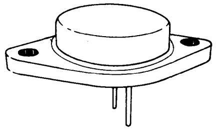
- **BUY70 Series Transistors are designed for use in;**
- **Switching Mode Power Supplies, Inverters and C.R.T. Scanning Systems.**
- **They feature High Voltage and Peak Current Capability together with Fast Switching and a High Degree of Robustness.**

Mechanical Specification

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute Maximum Ratings (at 25°C case temperature)

	BUY70A	BUY70B	BUY70C	
Collector-Base Voltage ($I_E = 0$)	1000	800	500	V
Collector-Emitter Voltage ($I_B = 0$)	400	325	200	V
Emitter-Base Voltage	8	8	8	V
Collector Current Peak (See Note 1)	15	15	15	A
Collector Current Continuous	10	10	10	A
Continuous-Dissipation ($V_{CE} \leqslant 17V$) (See Note 2)	75	75	75	W
Continuous Base Current	3	3	3	
Operating Temperature Range				−65°C to +200°C

NOTES:
1. Pulse Width $\leqslant$ 500 μSec. Duty Cycle $\leqslant$ 25%
2. Refer to Safe Operating and Dissipation Derating Curves
3. Pulsed Test. Pulse Width $\leqslant$ 300 μSec. Duty Cycle $\leqslant$ 2%

Electrical Characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 1mA I_E = 0 Note 2	BUY70A BUY70B BUY70C	1000 800 500			V
LV_{CEO}	Collector-Emitter Latching Voltage	I_C = 50mA I_B = 0	BUY70A BUY70B BUY70C	400 325 200			V
BV_{EBO}	Emitter-Base Breakdown Voltage	I_B = 10mA	ALL	8			V
I_{CEX}	Collector-Emitter Leakage Current	V_{CE} = 1000V V_{CE} = 500V V_{CE} = 500V V_{BE} = −2V	BUY70A BUY70B BUY70C			1.0 1.0 1.0	mA
H_{FE}	DC Current Gain	I_C = 1.0A V_{CE} = 10V Note 2	ALL	15			
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 4.0A I_B = 0.8A Note 2	ALL			1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 4.0A I_B = 0.8A Note 2	ALL			5.0	V
t_f	Collector-Current Fall Time	I_C = 4.0A V_{CE} = 40V $I_{B(on)}$ = 0.8A $I_{B(off)}$ = 0.8A	ALL			1.0	µs
f_T	Transition Frequency	V_{CE} = 10V I_C = 0.5A	ALL		6		MHz
C_{obo}	Output Capacitance	V_{CB} = 20V I_C = 0	ALL			150	pF

TYPICAL VARIATION OF COLLECTOR EMITTER SATURATION VOLTAGE WITH COLLECTOR CURRENT

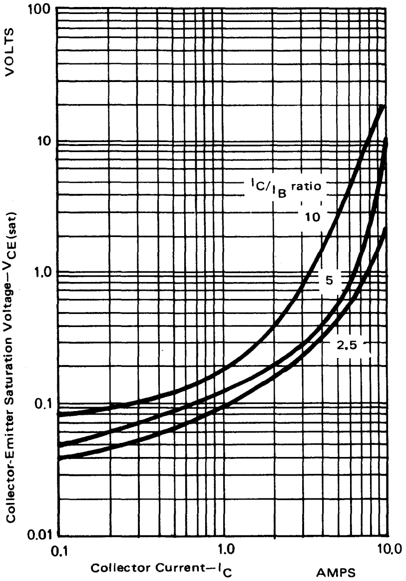


FIG 5

TYPICAL VARIATION OF STORAGE AND FALL TIMES WITH COLLECTOR CURRENT

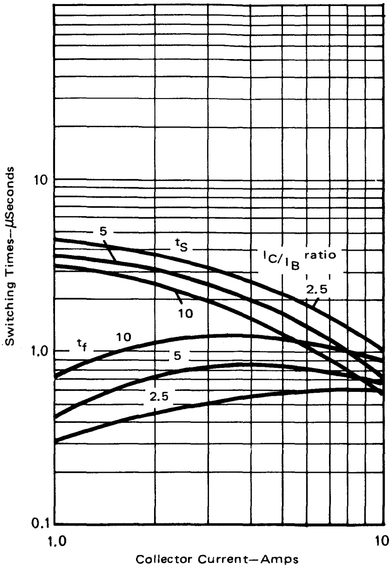


FIG 6

TYPICAL AND MAXIMUM*VARIATION OF I_{CBO} WITH TEMPERATURE

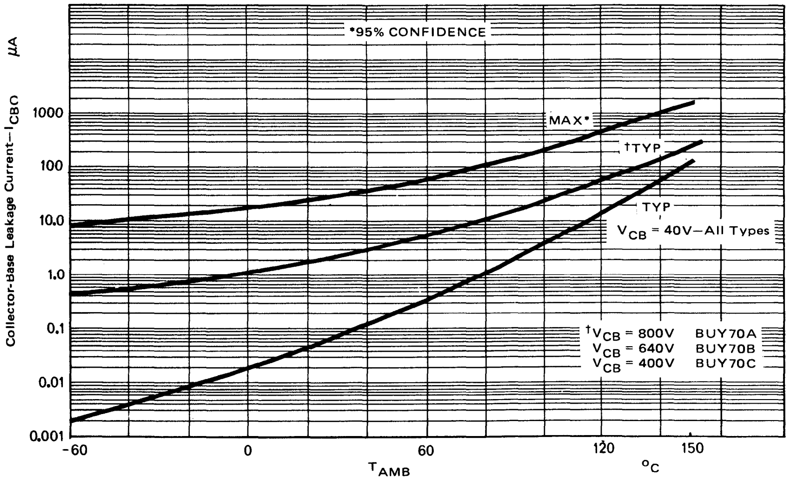


FIG 7

TYPICAL VARIATION OF BASE EMITTER SATURATION VOLTAGE WITH COLLECTOR CURRENT

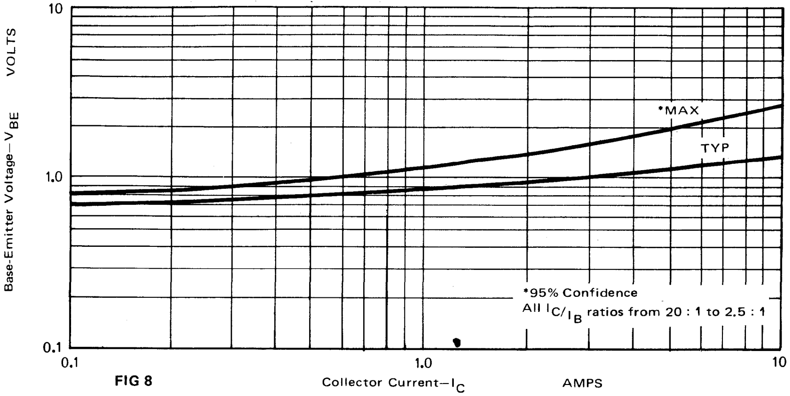


FIG 8

TYPICAL VARIATION OF TRANSITION FREQUENCY WITH COLLECTOR CURRENT

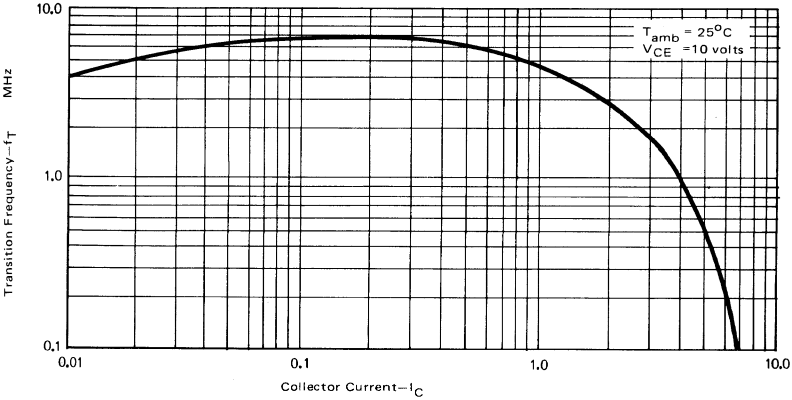


FIG 9

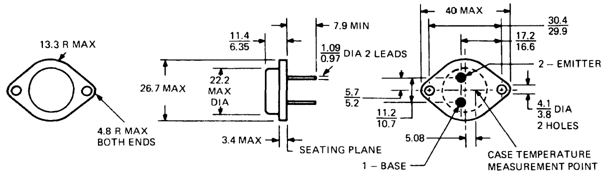
BUY71
NPN SILICON POWER TRANSISTOR

REVISED JULY 1975

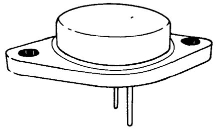
- **Designed for high voltage C.R.T. scanning**
- **V_{CEX} rating 2200 V**
- **Current rating – 2 Amps continuous**
- **Fast switching – t_f at 1.5 Amps 0.7 microsecond typical @ 25°C case temperature**

Mechanical specification

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute maximum ratings (at 25°C ambient temperature)

Collector-Base Voltage (Peak see Note 1)	2200	V
Collector-Emitter Voltage (Peak see Note 1) V_{EB} = 2V	2200	V
Collector Current Continuous	2.0	A
Base Current Continuous	2.0	A
Total Dissipation ($V_{CE} \leqslant$ 100V, $T_{case} \leqslant$ 80°C) See Figure 1.	10	W
Total Dissipation @ 25°C Case See Figure 1	40	W
Operating Junction Temperature	–65°C to 100°C	
Storage Temperature	–65°C to 100°C	

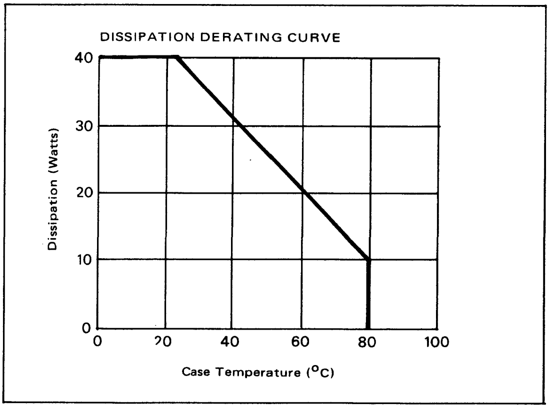
NOTES: Pulse Width $\leqslant 20\mu s$ Duty Cycle $\leqslant$25%.

BUY71
NPN SILICON POWER TRANSISTOR

Electrical Characteristics at 25°C Case Temperature (unless otherwise noted)

Parameter		Test Conditions	Min	Typ	Max	Unit
I_{CEX}	Collector Emitter Leakage Current	V_{CE} = 2200V, V_{BE} = −2V (See Note 1)			1.0	mA
$V_{(BR)EBO}$	Emitter Base Breakdown Voltage	I_E = 100mA, I_C = 0	5			V
$V_{CE(sat)}$	Collector Emitter Saturation Voltage	I_C = 1.5A, I_B = 1.5A (See Note 2)			10	V
$V_{BE(sat)}$	Base Emitter Saturation Voltage	I_C = 1.5A, I_B = 1.5A (See Note 2)			1.5	V
t_f	Collector Current Fall Time	I_C = 1.2A Under recommended drive conditions. T_{case} = 80°C		0.7		µs

NOTES: 1.Pulse width ⩽20µs. Duty cycle ⩽25%
2.Pulse test. Pulse duration ⩽300µs. Duty cycle ⩽2%.
This test must be measured with voltage sensing contacts separate from current carrying contacts.



TEXAS INSTRUMENTS

Application notes

The operating efficiency and overall reliability of line scan transistors are very much functions of the transient dissipation during device 'turn-off', which is controlled largely by the applied base drive.

Texas Instruments have determined the critical factors in the drive waveform for high voltage transistors and recognise that optimisation of these must comprehend device distributions, the total conditions of operation and the circuit tolerances experienced during equipment manufacture.

The values given in Figure (1) are for the drive parameters as defined in Figure (2) for a BUY71, operating in a line output stage, without an efficiency diode, and comprehend operation at case temperatures up to 80°C and variations of ± 20% on nominal values due to supply and frequency variations and circuit component tolerances.

Example

A BUY71 operating in a line output stage with nominal I_C peak 1.2 amps and with output and driver acting in a non-simultaneous mode.

Reference to Figure (1) yields values for:-

I_B end = 0.55 amps
d I_B/dt = 0.24 amps/μ sec
R_{BE} = 33 Ω

The purpose of R_{BE} is to prevent ringing during the 'off'period of the transistor. Its value is not critical and can be subjected to the normal preferred value tolerances.

V_{off} – the secondary negative source voltage – can be established by the circuit designer.

From Figure (3) with V_{off} = 4 volts, d I_B/dt = 0.24 A/μs is obtained by using L_B = 21 μH.

Taking a mark-space ratio on : off = 36 : 28 as derived from SN76544 the secondary positive source voltage V_{on} = 28 x V_{off}/36 = 3.1 volts.

Drive current supplied during the 'on' period

I Drive = V_{BE} typ/R_{BE} + I_B end
= (V_{on} – V_{BE} typ) /R_B
∴ R_B = 3.8 Ω nearest preferred value = 3.9 Ω

At this stage $L_B/R_B \gg t_{off}$ max. must be applied. If this criteria is not satisfied then deviation from the recommended d I_B/dt will be observed causing large variations in t_s and t_f and increasing device dissipation. Placing a diode across R_B as shown in Figure (1) will make the effects of R_B negligible during 'turn off'.

Finally the effects of the diode and resistance in the driver secondary circuit may necessitate fine adjustment of L_B in order to realise the recommended value of d I_B/dt.

Average power calculations for a transistor in a line output stage are very complex and application of the forward safe area curves to determine the effect junction to case thermal resistance is not strictly correct since a condition of negative base current exists during the period of maximum dissipation.

However, operation of the BUY71, under the recommended drive conditions, is guaranteed at $T_{CASE} \leqslant 80^oC$. This provides a convenient reference point which is easily accessible for measurement by the design engineer.

Hence:-

$T_{AMB} + P_{TOT}$ (θc – amb) $\leqslant T_{CASE}$ max.
where θc – amb = θc – hs + θhs – amb.
i.e. thermal resistance case to ambient
equals thermal resistance case to heat sink
plus thermal resistance heat sink to ambient.

Example. A BUY71 operating in a line output stage with a nominal I_C peak = 1.2 amps and maximum internal equipment ambient = 50°C.

Figure (4) shows that the maximum power dissipation by the BUY71 will be 7.5 watts allowing for all tolerances on the nominal conditions.

∴ θc – amb $\leqslant$ (80°C – 50°C) / 7.5 Watts = 4°C/Watt.

Allowing 1°C/watt for θc – hs means a minimum heat sink design would be for 3°C/watt maximum.

RECOMMENDED DRIVE CONDITIONS VERSUS NOMINAL PEAK COLLECTOR CURRENT FOR MINIMUM DEVICE DISSIPATION

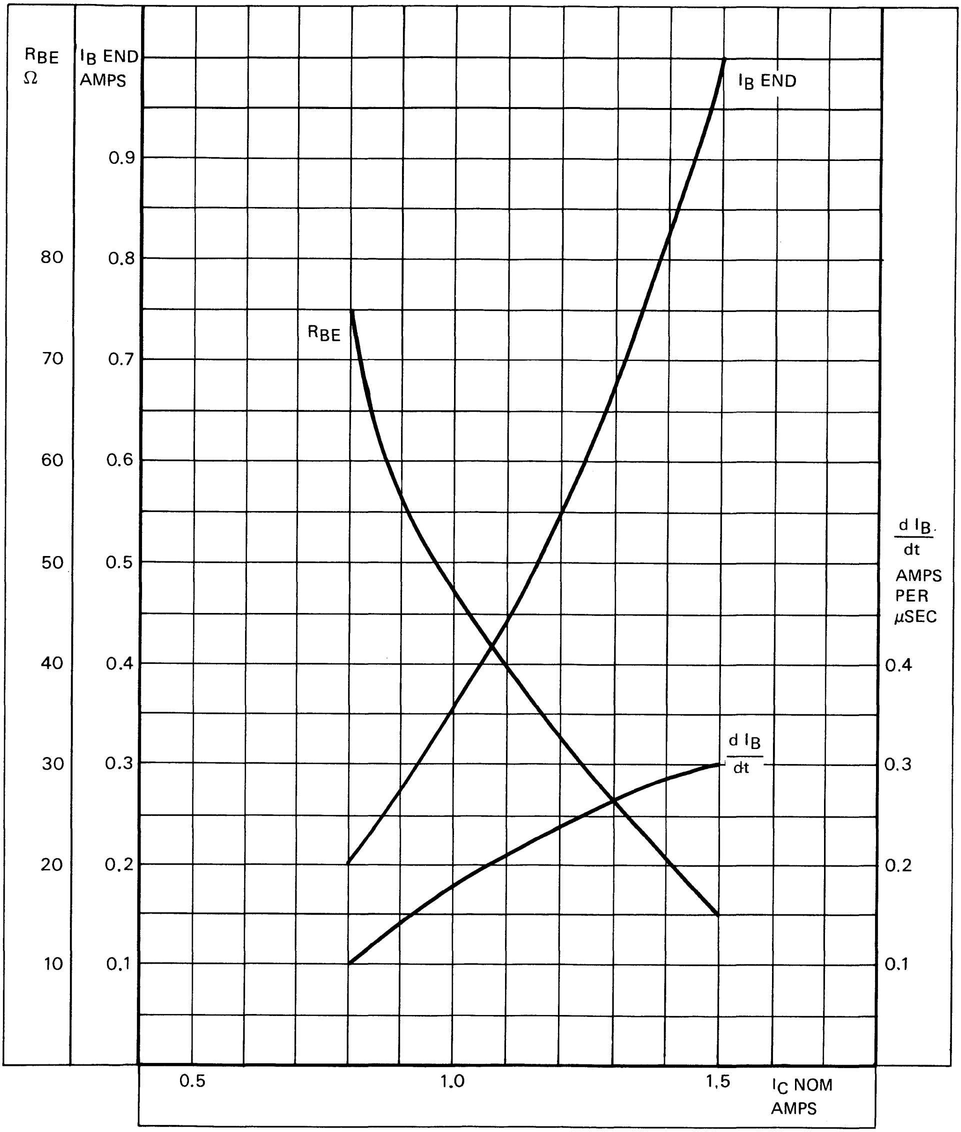
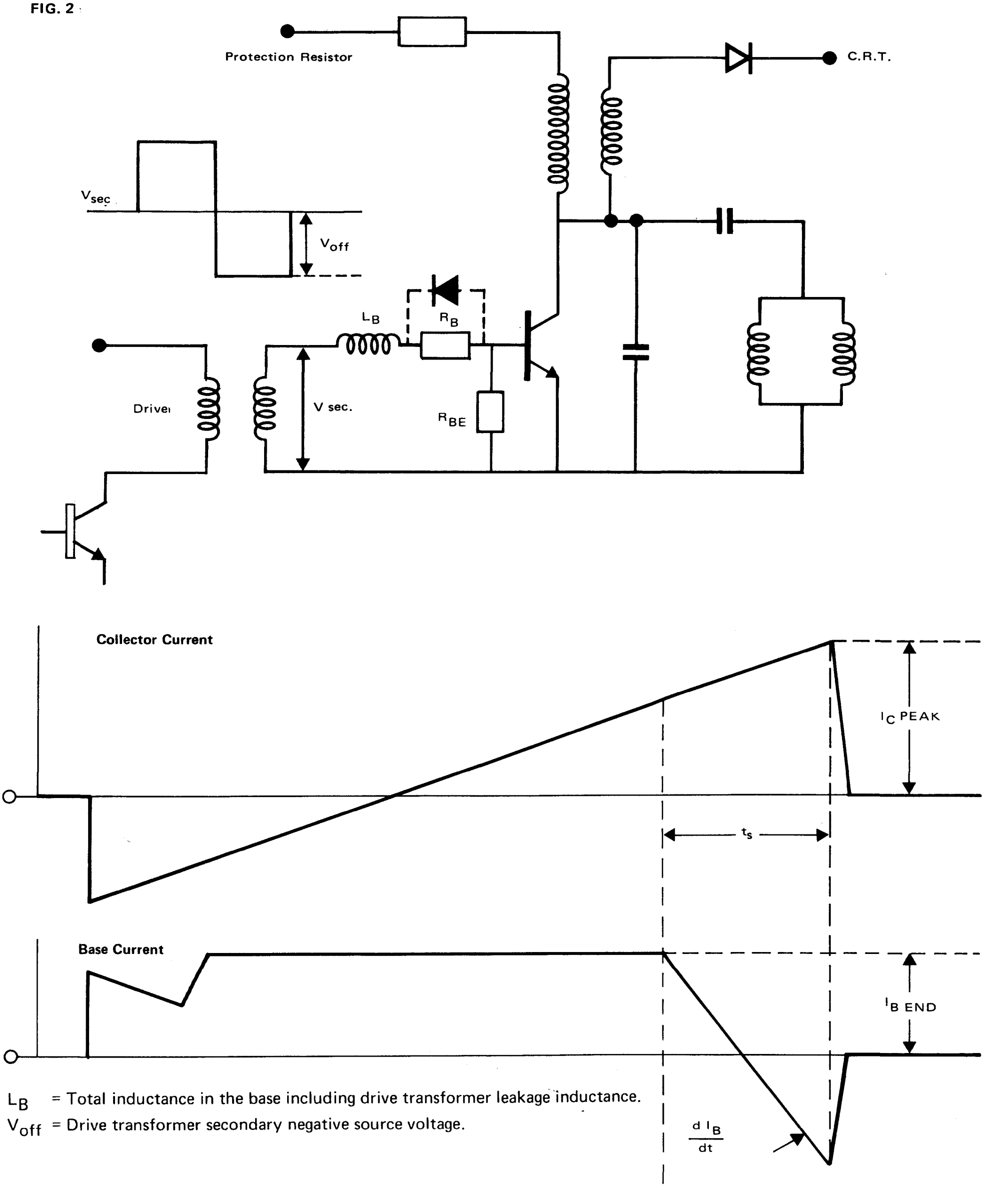


FIG. 1

FIG. 2



L_B = Total inductance in the base including drive transformer leakage inductance.
V_{off} = Drive transformer secondary negative source voltage.

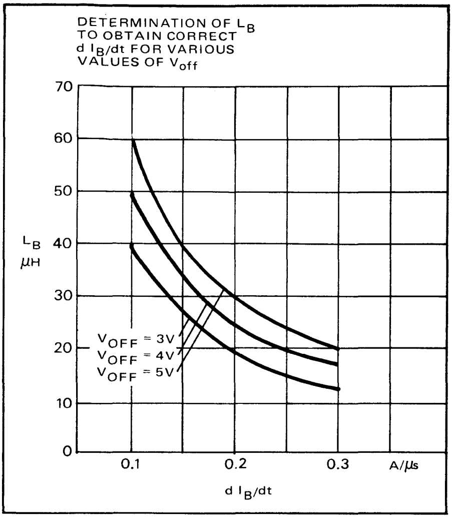


FIG. 3

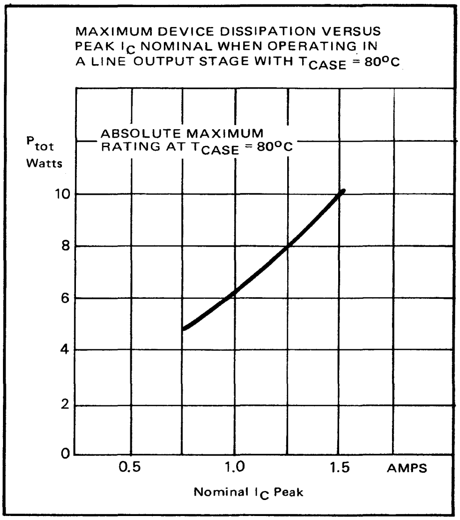


FIG. 4

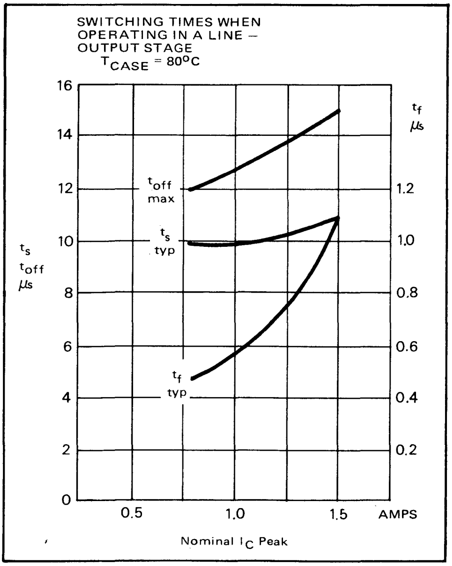


FIG. 5

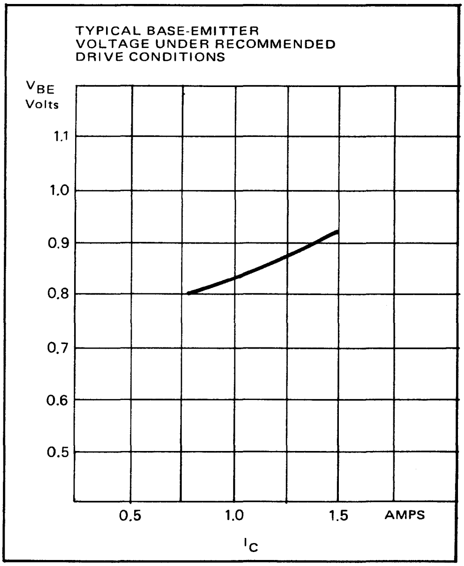


FIG. 6

BY205-100 TO BY205-1000
DIFFUSED SILICON,FAST,SOFT RECOVERY RECTIFIERS

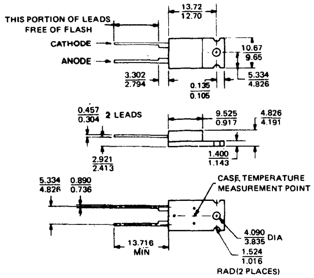
AUGUST 1975

Designed for high frequency switching applications. Avoids transients generated by conventional fast rectifiers.

Especially suitable for T.V. Line-scan, switching mode power supplies inverters, converters. Utilises glass passivated wafers.

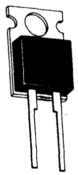
mechanical data

THE CATHODE IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES

(Mounting Hardware as for TO-66 Plastic)



absolute maximum ratings

	BY205–	100	200	400	600	800	1000	
V_{RRM}	Repetitive peak reverse voltage	100	200	400	600	800	1000	Volts
$I_{F(AV)}$	Average rectified forward current up to 125°C Case Temp.	← 3 →						Amps
I_{FRM}	Repetitive peak forward current up to 125°C Case Temp.	← 15 →						Amps
I_{FSM}	Non-repetitive forward surge current 1 cycle at 50Hz and up to 125°C Case Temp.	← 35 →						Amps
P_D	Continuous device dissipation up to 90°C Case Temp. (Note 1 and Note 4)	← 20 →						Watts
P_D	Continuous device dissipation up to 25°C ambient temp. in free air (Note 2 and Note 4)	← 2 →						Watts
T_c	Operating case temperature	← −55 to +150 →						°C
T_{stg}	Storage temperature	← −55 to +150 →						°C

electrical characteristics

	BY205–	100	200	400	600	800	1000	UNITS
I_R	Reverse leakage current at $V_R = V_{RRM}$ and 25°C Case Temp.	← 100 →						µA
V_F	Forward Voltage drop at I_F = 5A and 25°C Case Temp. (Note 3)	← 1.5 →						Volts

BY205-100 TO BY205-1000
DIFFUSED SILICON,FAST,SOFT RECOVERY RECTIFIERS

switching characteristics

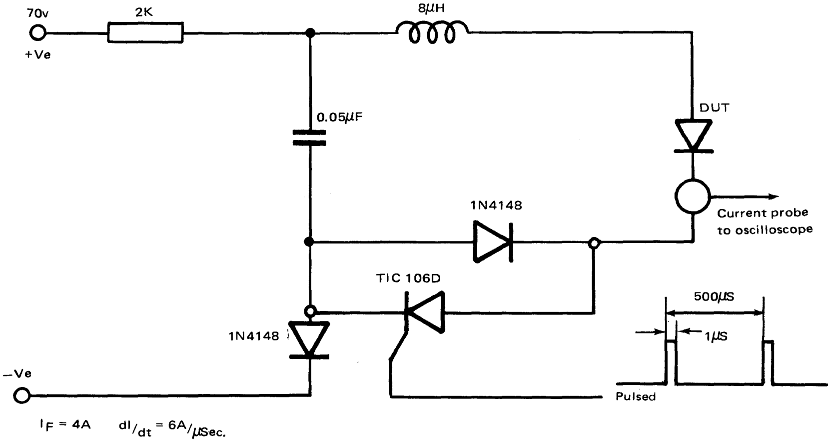
t_{rr}	Maximum reverse recovery time (For circuit and conditions see Fig. 1.	ALL TYPES – 850n. Secs.

thermal characteristics

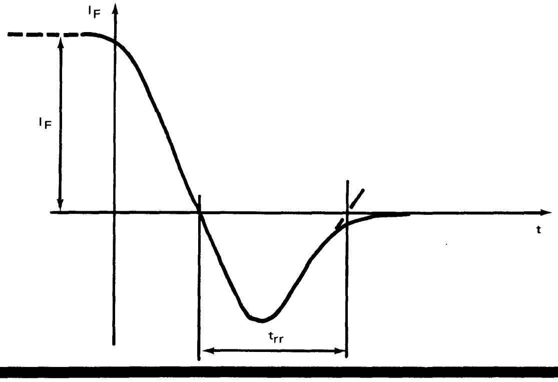
		MAX	UNIT
θ_{j-c}	Junction-to-case thermal resistance	3	°C/W
θ_{j-a}	Junction-to-free air thermal resistance	62.5	°C/W

NOTES:
1. Derate linearly to 150°C case temperature at the rate of 0.33W/°C.
2. Derate linearly to 150°C free-air temperature at the rate of 16mW/°C.
3. This parameter is a pulse measurement such that there is only negligible heating of the junction.
4. Device dissipation includes forward, reverse and switching losses.

TEST CONDITIONS OF t_{rr} MEASUREMENT



TYPICAL RECOVERY WAVE-FORM



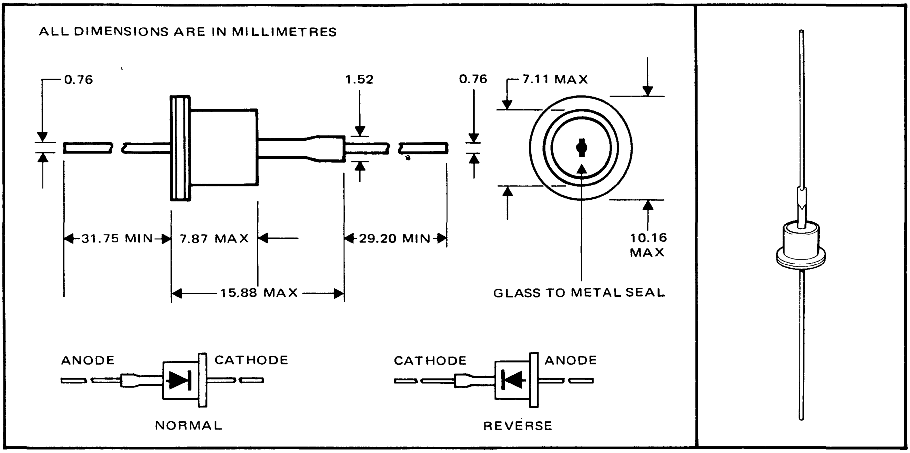
TEXAS INSTRUMENTS

BYW10-50, BYW10-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

JULY 1975

- Designed for switching applications to eliminate interference caused by ringing.
- Suitable for switching mode power supplies, TV linescan, converters, inverters and all professional applications.

mechanical data



absolute maximum ratings (at specified case temperature)

	BYW10-50 –50R	100 100R	200 200R	300 300R	400 400R	600 600R	800 800R	1000 1000R	Units
V_{RRM} max. repetitive peak reverse voltage.	50	100	200	300	400	600	800	1000	Volts
V_{RWM} max. crest working reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_R max. continuous reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_{RSM} max. non-repetitive peak reverse voltage	55	110	220	330	440	660	880	1100	Volts
$I_{F(AV)}$ max. mean forward current	← 1.5 →								Amps
I_{FRM} max. repetitive peak forward current	← 15 →								Amps
I_{FSM} max. non-repetitive forward surge current at $T_a = 25^{\circ}C$	← 35 →								Amps
T_{case} operating case temperature	← –55 to +175 →								$^{\circ}C$
T_{stg} storage temperature	← –55 to +175 →								$^{\circ}C$

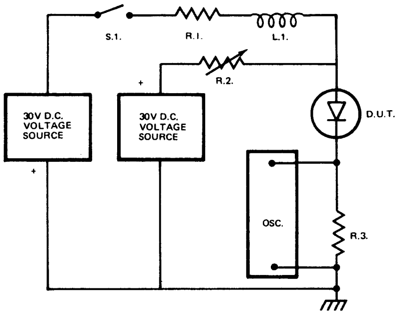
BYW10-50, BYW10-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

electrical characteristics (case temperature = 25°C unless otherwise stated).

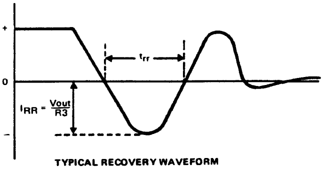
PARAMETER	CONDITIONS	MAX	UNITS
V_F max. forward voltage	I_F = 4A (Note 1)	1.4	Volts
I_R max. reverse current	V_R = rated V_R	15	µA
I_R max. reverse current	V_R = rated V_R, T_{case} = 100°C	500	µA
t_{rr} max. reverse recovery time	I_F = 1A, V_R = 30V, di/dt = 25A/µSec. (Note 2)	400	nSec
	I_F = 4A, di/dt = 4A/µS (Note 3)	850	nSec
θj-c Thermal resistance junction to case		48	°C/W

NOTE 1. The forward voltage drop is a pulse measurement such that there is negligible heating of the device.

NOTE 2.

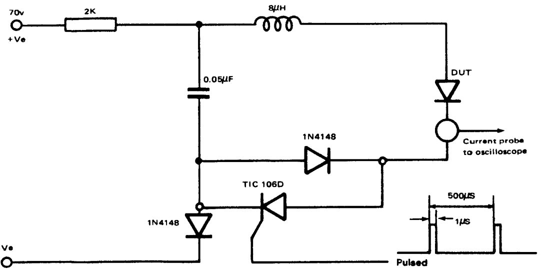


JEDEC TEST CIRCUIT USED.



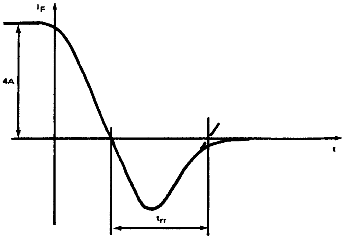
TYPICAL RECOVERY WAVEFORM

NOTE 3.



I_F = 4A $dI/_{dt}$ = $6A/_{\mu Sec.}$

TEST CONDITIONS OF t_{rr} MEASUREMENT



TYPICAL RECOVERY WAVEFORM

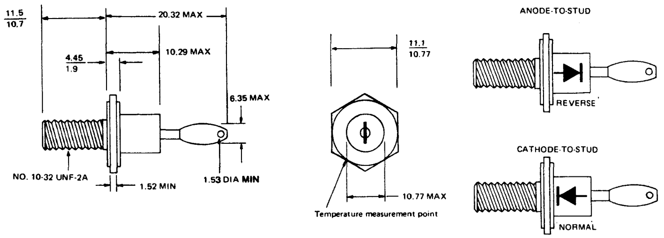
BYW11-50, BYW11-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

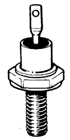
REVISED AUGUST 1975

- **Designed for switching applications to eliminate interference caused by ringing.**
- **Suitable for switching mode power supplies, TV linescan, converters, inverters and all professional applications.**

mechanical data

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings (at specified case temperature)

	BYW11-50 –50R	100 100R	200 200R	300 300R	400 400R	600 600R	800 800R	1000 1000R	UNITS
V_{RRM} max. repetitive peak reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_{RWM} max. crest working reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_R max. continuous reverse voltage –65°C to +150°C (Note 2)	50	100	200	300	400	600	800	1000	Volts
V_{RSM} max. non-repetitive peak reverse voltage	55	110	220	330	440	660	880	1100	Volts
$I_{F(AV)}$ average rectified forward current	← 6 →								Amps
I_{FRM} max. repetitive peak forward current	← 50 →								Amps
I_{FSM} max. non-repetitive forward surge current at $T_a = 25°C$	← 75 →								Amps
T_{amb} operating temperature	← –55 to +175 →								°C
T_{stg} storage temperature	← –55 to +175 →								°C

TEXAS INSTRUMENTS

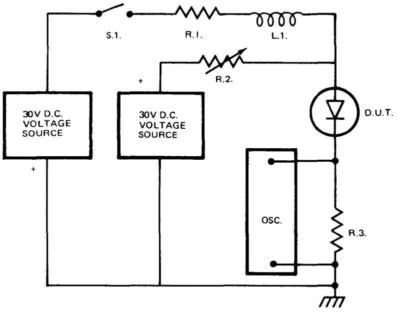
BYW11-50, BYW11-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

electrical characteristics (case temperature = 25°C unless otherwise stated)

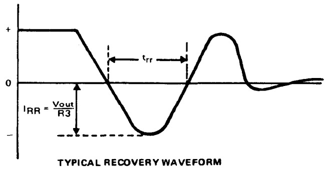
PARAMETER	CONDITIONS	MAX	UNIT
V_F max. forward voltage	I_F = 6A (Note 1)	1.4	Volts
I_R max. reverse current	V_R = rated V_R	15	µA
I_R max. reverse current	V_R = rated V_R, T_{case} = 100°C	500	µA
t_{rr} max. reverse recovery time	I_F = 1A, V_R = 30V, di/dt = 25A/µSec (Note 2)	400	nSec
	I_F = 4A, di/dt = 6A/µSec	850	nSec
θj-c Thermal resistance junction to case		7	°C/W

NOTE 1. The forward voltage drop is a pulse measurement such that there is negligible heating of the device.

NOTE 2.

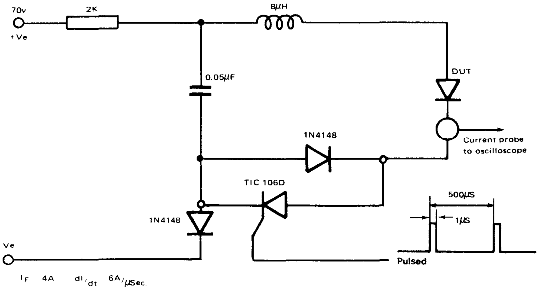


JEDEC TEST CIRCUIT USED.

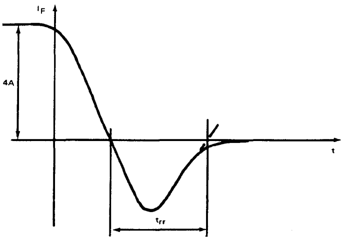


TYPICAL RECOVERY WAVEFORM

NOTE 3.



TEST CONDITIONS OF t_{rr} MEASUREMENT



TYPICAL RECOVERY WAVEFORM

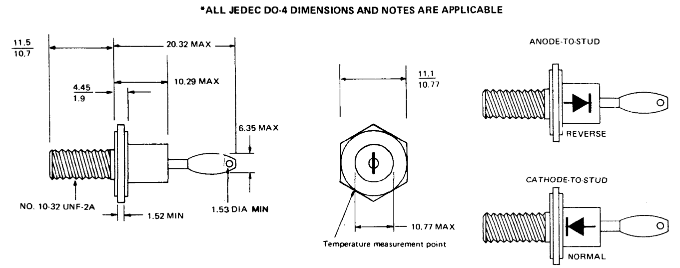
TEXAS INSTRUMENTS

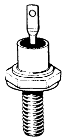
BYW12-50, BYW12-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

AUGUST 1975

- **Designed for switching applications to eliminate interference caused by ringing.**
- **Suitable for switching mode power supplies, TV linescan, converters, inverters and all professional applications.**

mechanical data





NOTES*: A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings (at specified case temperature)

	BYW12-50 -50R	100 100R	200 200R	300 300R	400 400R	600 600R	800 800R	1000 1000R	UNITS
V_{RRM} max. repetitive peak reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_{RWM} max. crest working reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_R max. continuous reverse voltage	50	100	200	300	400	600	800	1000	Volts
V_{RSM} max. non-repetitive peak reverse voltage	55	110	220	330	440	660	880	1100	Volts
$I_{F(AV)}$ max. mean forward current at Tc = 75°C	← 15 →								Amps
I_{FRM} max. repetitive peak forward current	← 70 →								Amps
I_{FSM} max. non-repetitive forward surge current at T_a = 25°C	← 150 →								Amps
I_F max. continuous forward current at Tc = 80°C	← 18 →								Amps
T_{case} operating case temperature	← −55 to +175 →								°C
T_{STG} storage temperature	← −55 to +175 →								°C

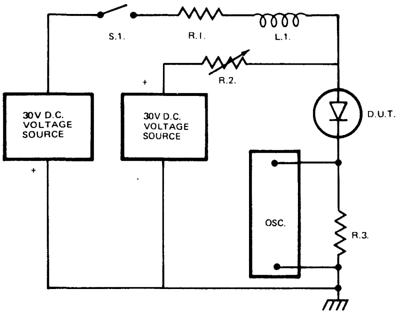
TEXAS INSTRUMENTS

BYW12-50, BYW12-1000
DIFFUSED SILICON FAST, SOFT RECOVERY RECTIFIER

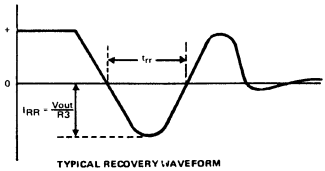
electrical characteristics (case temperature = 25°C unless otherwise stated)

PARAMETER	CONDITIONS	MAX	UNIT
V_F max. forward voltage	I_F = 18A (Note 1)	1.4	Volts
I_R max. reverse current	V_R = rated V_R	15	µA
I_R max. reverse current	V_R = rated V_R, T_{case} = 100°C	500	µA
C max. capacitance	V_R = 20V, f = 1MHz	80	pF
t_{rr} max. reverse recovery time	I_F = 1A, V_R = 30V, di/dt = 25A/µSec. (Note 2)	400	nSec
	I_F = 4A, di/dt = 6A/µSec	850	nSec
θj-c Thermal resistance junction to case		4.5	°C/W

NOTE 1. The forward voltage drop is a pulse measurement such that there is negligible heating of the device.
NOTE 2.



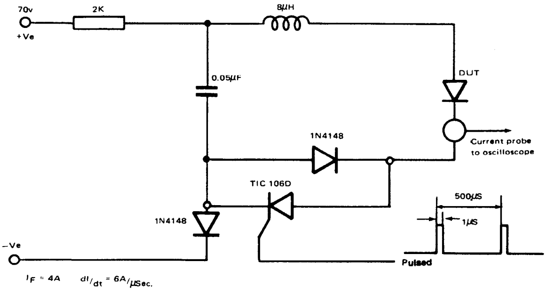
JEDEC TEST CIRCUIT USED.



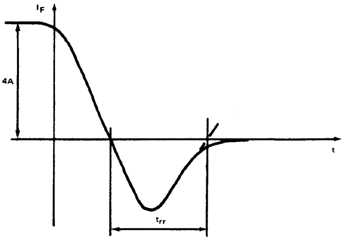
TYPICAL RECOVERY WAVEFORM

NOTE 3.

TEST CONDITIONS OF t_{rr} MEASUREMENT



TYPICAL RECOVERY WAVE-FORM



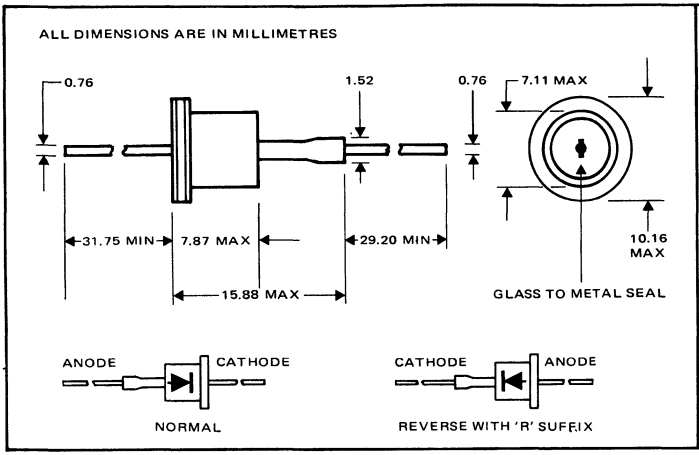
BYX 45 SERIES
SILICON AVALANCHE RECTIFIERS

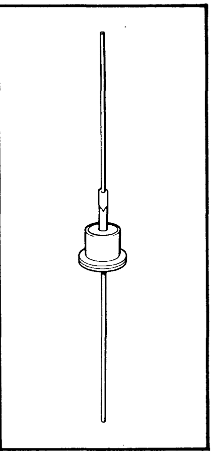
AUGUST 1975

- 1.5 Amperes
- 600, 800 & 1000V V_{RWM}

Silicon rectifiers with controlled avalanche characteristics.
They are designed for medium power applications and are capable to absorb transient energy without damage to the rectifiers

Mechanical Data : Conforms to BS3934 SO-16





absolute maximum ratings (temperatures are ambient unless otherwise stated)

	BYX45–	600 600R	800 800R	1000 1000R	UNIT
V_{RWM}	Maximum crest working reverse voltage	600	800	1000	V
I_F	Maximum continuous forward current 30°C	2.0	2.0	2.0	A
$I_{F(AV)}$	Maximum mean forward current 55°C (Note 1)	1.5	1.5	1.5	A
$I_{F(RMS)}$	Maximum RMS forward current	2.4	2.4	2.4	A
I_{FRM}	Maximum repetitive peak forward current	15	15	15	A
I_{FSM}	Maximum surge forward current (Note 2)	40	40	40	A
P_{RSM}	Maximum non-repetitive peak reverse power (Note 3)	2.5	2.5	2.5	kW
P_{RRM}	Maximum 50Hz repetitive peak reverse transient power (Note 4)	800	800	800	W
T_{stg}	Storage temperature range	−55 to +150			°C
T_j	Junction operating temperature range	−55 to +150			°C

NOTES
1. Averaged over any 20msec period.
2. Peak value of 10msec half sine-wave
3. 10μsec square wave, T_j = 25°C.
4. 10μsec square wave, T_j = 25°C.

BYX 45 SERIES
SILICON AVALANCHE RECTIFIERS

electrical characteristics (absolute limits at T_j = 25°C unless otherwise stated.)

	BYX 45 –	600	800	1000	UNIT
V_F	Maximum forward voltage at I_F = 5A	1.45	1.45	1.45	V
I_R	Maximum reverse current at $V_R = V_{RWM}$, T_j = 125°C	100	100	100	μA
$V_{(BR)Rmin}$	Minimum breakdown voltage (Avalanche) at I_R = 1.0mA	750	1000	1250	V
$V_{(BR)Rmax}$	Maximum breakdown voltage (Avalanche) at I_R = 1.0mA	2000	2000	2000	V

thermal characteristics

$R_{th(j\text{-}amb)}$	Thermal resistance, Junction to ambient with 10mm leads, mounted on solder lugs.	60°C/W
$R_{th(j\text{-}amb)}$	Thermal resistance, Junction to ambient with 10mm leads, mounted on printed circuit board.	90°C/W

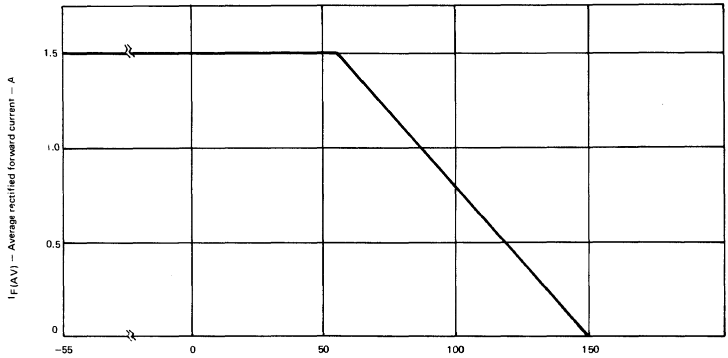


FIG.1. AVERAGE RECTIFIED FORWARD CURRENT vs AMBIENT TEMPERATURE

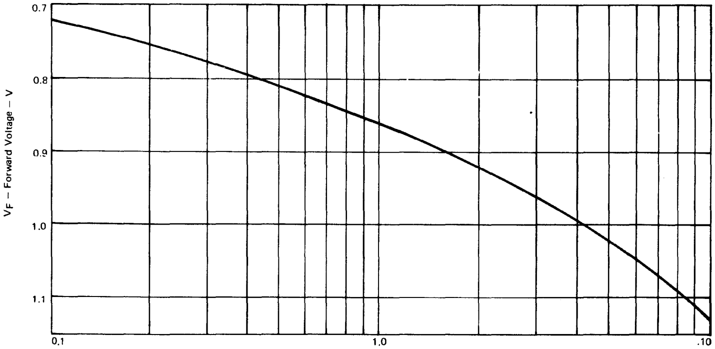


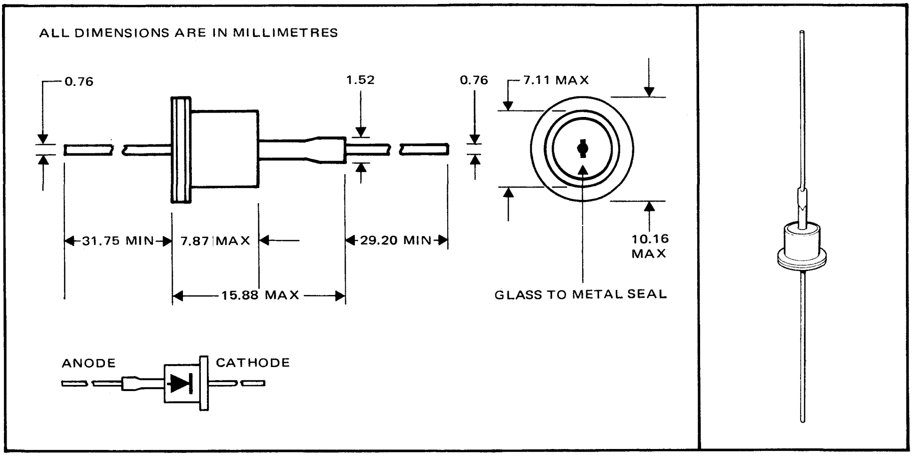
FIG.2. TYPICAL FORWARD VOLTAGE vs FORWARD CURRENT

ED1
SILICON RECTIFIER

AUGUST 1975

- **General purpose rectifier for low voltage medium current rectifying application.**

mechanical specifications



absolute maximum ratings (at 25°C ambient temperature)

V_R	Continuous reverse voltage	50V
V_{RWM}	Crest working reverse voltage	50V
V_{RRM}	Repetitive peak reverse voltage	100V
$I_{F(AV)}$	Mean forward current	1.0A
I_{FSM}	Non-repetitive peak forward current (peak value of 10mS half-sine wave)	25.0A
T_{amb}	Operating temperature range	−55°C to +175°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_F Maximum forward voltage drop	I_F = 1.0A			1.5	V
I_R Maximum reverse current	V_R = 50V			20	µA

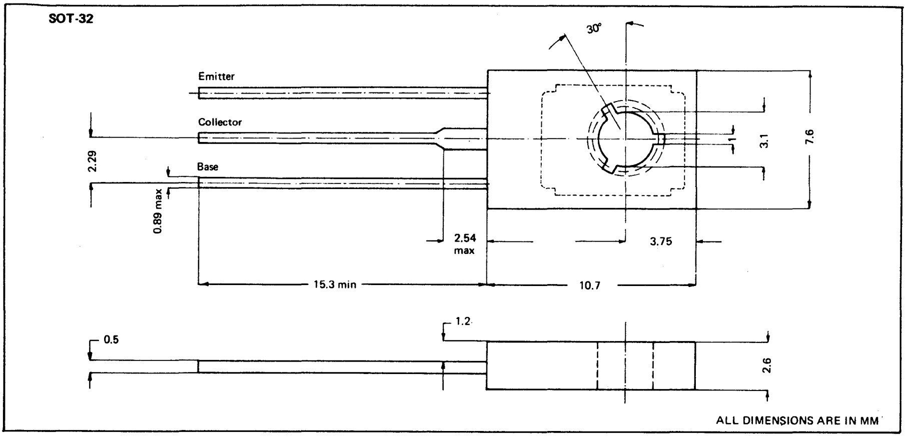
P7029
NPN TRIPLE DIFFUSED SILICON TRANSISTOR

JANUARY 1975

- Audio amplifier with high supply voltage
- Vertical deflection in B + W sets
- General industrial applications

- $V_{CEO} \geqslant 300$ V
- $I_C = 1$ A
- $P_{TOT} = 20$ W

mechanical data



ALL DIMENSIONS ARE IN MM

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter-Voltage (see note 1)	300 V
Emitter-Base-Voltage	5 V
Continuous Collector-Current	1 A
Peak Collector-Current	1.5 A
Power Dissipation at $T_A \leqslant 25^oC$	1.25 W
Power Dissipation at $T_C = 25^oC$	20 W
Storage Temperature Range	–55°C to 125°C
Lead Temperature 1/16 Inch from case for 10 seconds	260°C

NOTE 1. This value applies when the Base-Emitter Diode is open-circuited

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1mA, I_B = 0$ Note 2	300			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 50\mu A, I_C = 0$	5			V
I_{CBO}	Collector Cutoff Current	$V_{CB} = 300V, I_E = 0$			100	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 10V, I_C = 50mA$	30	60	240	
C_{ob}	Common-Base Open-Circuit Capacitance	$V_{CB} = 10V, I_E = 0$ f = 1MHz		5.5		pF
C_{ib}	Common-Base Open-Circuit Input Capacitance	$V_{EB} = 0.5V, I_E = 0$ f = 1MHz		90		pF

NOTE 2. These parameters must be measured using pulse techniques $t_p = 300\mu s$, duty cycle $\leqslant 2\%$.

TG1/8,TM1/8,TM1/4
sensistor® SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

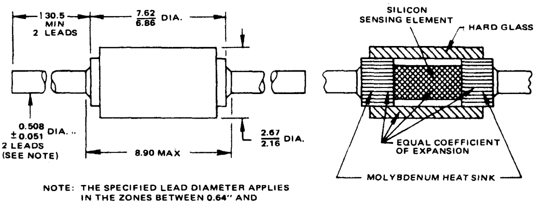
POSITIVE-TEMPERATURE-COEFFICIENT, TEMPERATURE-SENSING, TEMPERATURE-COMPENSATING THERMISTORS

- **Designed to meet or exceed all electrical requirements of MIL-T-23648 for positive-TC thermistors**
- **TG 1/8 electrically equivalent to RTH42**
- **TM 1/8 electrically equivalent to RTH22**
- **Large positive temperature coefficient of resistance (approx. 0.7%/deg)**

mechanical data

The TG 1/8 resistor is encapsulated in a hard-glass, hermetically sealed package with welded unborated solder-coated dumet leads.

The TM 1/8 and TM 1/4 resistors are encapsulated in molded packages with solder-coated copper leads. A-nickel leads, or gold-plated A-nickel leads, are also available upon request.

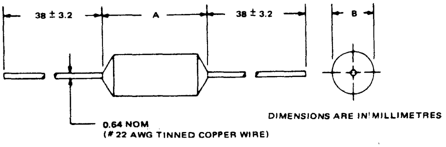


NOTE: THE SPECIFIED LEAD DIAMETER APPLIES IN THE ZONES BETWEEN 0.64" AND 30.5" FROM THE END PLUGS.

DIMENSIONS ARE IN MILLIMETRES

TG 1/8

COLOR: GREEN



DIMENSIONS ARE IN MILLIMETRES

A = 10.3 ± 0.40
B = 3.55 ± 0.38

TM 1/8, TM 1/4

maximum ratings

Power Dissipation at (or below) 25°C Ambient Temperature (See Figure 1)	TG 1/8	250 mW
Power Dissipation at 100°C Ambient Temperature (See Figure 1)	TG 1/8	125 mW
Power Dissipation at (or below) 100°C Ambient Temperature (See Figures 2 and 3)	TM 1/8 TM 1/4	125 mW 250 mW
Operating Ambient Temperature Range		–65°C to 150°C
Storage Temperature Range		–65°C to 150°C

electrical and thermal characteristics

PARAMETER		TG 1/8	TM 1/8	TM 1/4	UNIT
$R_{25°C}/R_{125°C}$	Zero-Power Resistance Ratio	0.55 ± 15%	0.55 ± 15%	0.55 ± 15%	
τ	Thermal Time Constant	35 typ 60 max	35 typ 40 max	54 typ 60 max	s

TG1/8,TM1/8,TM1/4
SOLID-STATE TEMPERATURE-SENSING SILICON RESISTORS

standard zero-power resistance values (ohms) at 25°C ambient temperature

10	12	15	18	22	27	33	39	47	50	56	68	82
100	120	150	180	220	270	330	390	470	500	560	680	820
1000	1200	1500	1800	2200	2700	3300*	3900*	4700*	5000*	5600*	6800*	8200*
10000*												

*These values apply to types TM 1/8 and TM 1/4 only.

Standard stock tolerances are ±5% and ±10%

performance characteristics

TEST PER APPLICABLE MIL-T-23648 PROCEDURE	MAXIMUM RESISTANCE CHANGE, $T_A = 25°C$
Short-Time Overload	±1%
Dielectric Withstanding Voltage	±1%
Low-Temperature Storage	±1%
High-Temperature Storage	±2%
Terminal Strength	±1%
Thermal Shock	±2%
Resistance to Soldering Heat	±1%
Moisture Resistance	±2%
1000-Hour Load Life, T_A = 100°C	±2%
Vibration, High-Frequency	±1%
Shock	±1%
Immersion	±1%

military applications

The *sensistor* silicon resistor has been designed to operate under military test conditions as stated above. Production lots are regularly tested to these criteria as part of TI's continuing process-control testing program.

Special methods have been developed for load-life and temperature-coefficient testing. Test details, recommended test parameters, and test results are available upon request.

dissipation derating curve

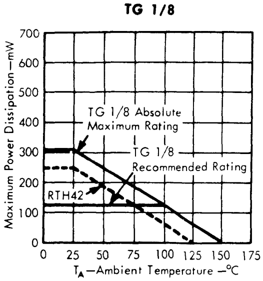


FIGURE 1

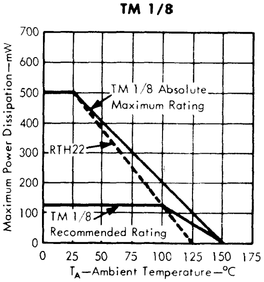


FIGURE 2

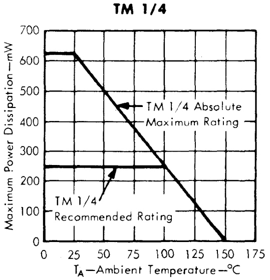


FIGURE 3

TYPICAL CHARACTERISTICS

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 4, 5, or 6, multiply this by the nominal zero-power resistance. This product is then corrected for the actual ambient temperature by use of a multiplying factor from Figure 7.

TG 1/8
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION

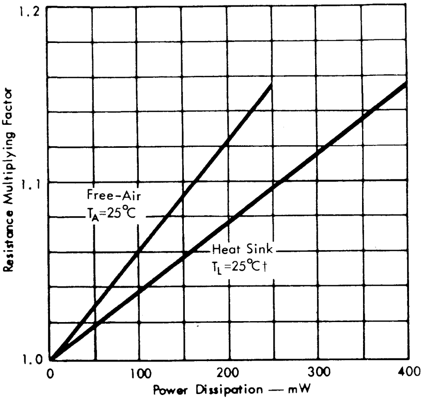


FIGURE 4

TM 1/8
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION

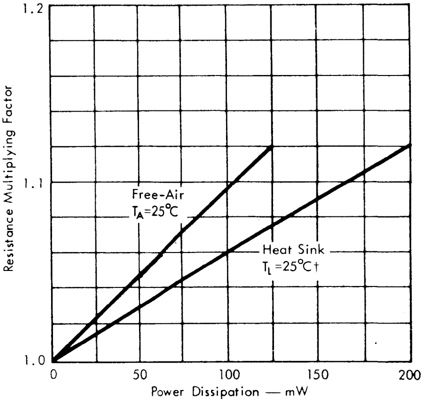


FIGURE 5

TM 1/4
PERCENT RESISTANCE CHANGE
vs
POWER DISSIPATION

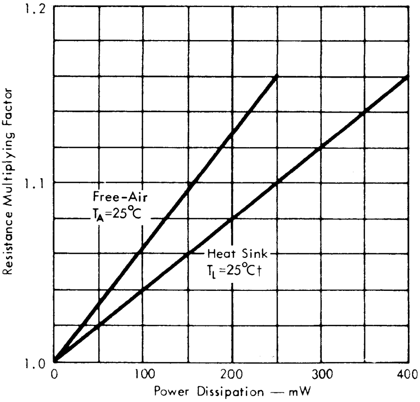
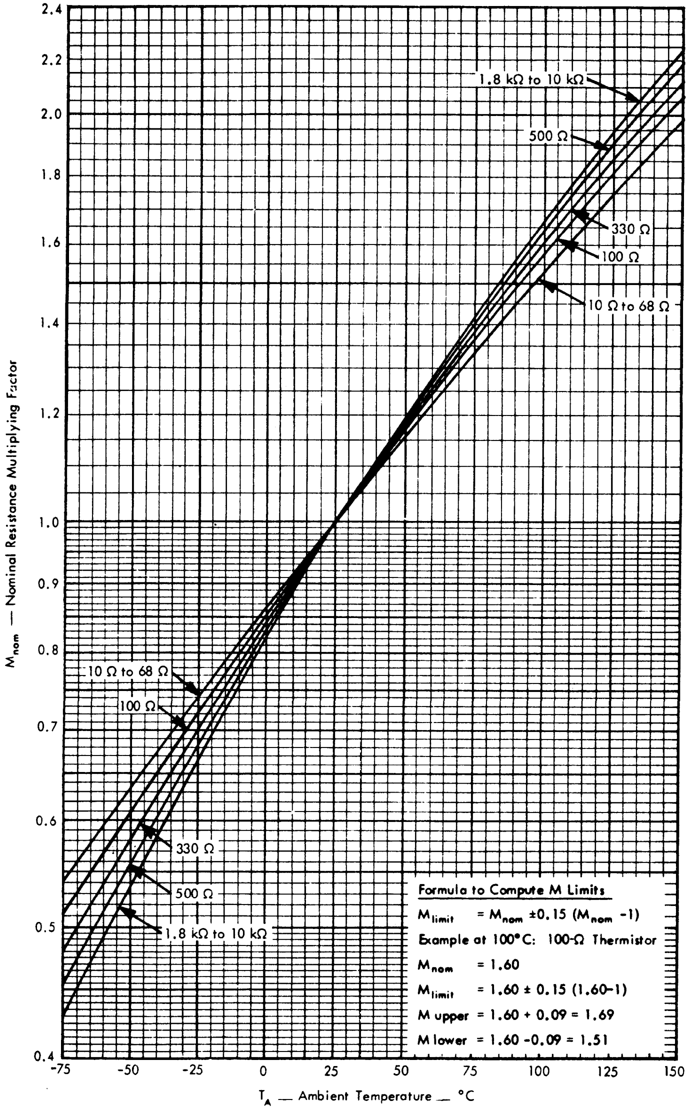


FIGURE 6

† T_L is lead temperature measured 1/16 inch from the body.

TYPICAL CHARACTERISTICS

NOMINAL RESISTANCE MULTIPLYING FACTOR vs AMBIENT TEMPERATURE



Formula to Compute M Limits

M_{limit} = M_{nom} ±0.15 (M_{nom} -1)

Example at 100°C: 100-Ω Thermistor

M_{nom} = 1.60

M_{limit} = 1.60 ± 0.15 (1.60-1)

M upper = 1.60 + 0.09 = 1.69

M lower = 1.60 -0.09 = 1.51

FIGURE 7

TYPES TI1131, TI1132, TI1133, TI1134, TI1135, TI1136
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

REVISED JULY 1975

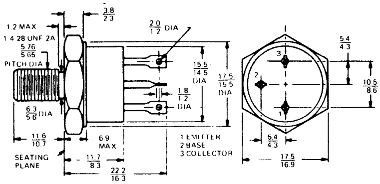
HIGH-VOLTAGE, HIGH-FREQUENCY POWER TRANSISTORS FOR INDUSTRIAL APPLICATIONS

- 80 Watts at 55°C Case Temperature
- Maximum r_{CS} of 0.5 Ohm at 2 Amperes I_C
- Maximum V_{BE} of 2 Volts at 2 Amperes I_C
- Minimum f_T of 7.5 Megacycles

mechanical data

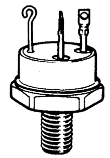
The transistors are in hermetically-sealed welded packages.

ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.



ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TI1131 TI1132	TI1133 TI1134	TI1135 TI1136
Collector-Base Voltage	200 v	150 v	100 v
Collector-Emitter Voltage (See Note 1)	100 v	75 v	50 v
Emitter-Base Voltage	←	8 v	→
Collector Current, Continuous	←	7.5 a	→
Emitter Current, Continuous	←	7.5 a	→
Safe Continuous Operating Region at (or below) 55°C Case Temperature	See Figure 1		
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	←	3 w	→
Total Device Dissipation at (or below) 55°C Case Temperature (See Note 3)	←	80 w	→
Operating Collector Junction Temperature	←	175°C	→
Storage Temperature Range	−65°C to +200°C		

NOTES: 1. This value applies when base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 20 mw/C°.
3. Derate linearly to 175°C case temperature at the rate of 0.67 w/C°.

TYPES TI1131, TI1132, TI1133, TI1134, TI1135, TI1136
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10$ ma, $I_E = 0$	TI1131, TI1132	200		v
			TI1133, TI1134	150		v
			TI1135, TI1136	100		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 0.2$ a, $I_B = 0$, (See Note 4)	TI1131, TI1132	100		v
			TI1133, TI1134	75		v
			TI1135, TI1136	50		v
I_{CES}	Collector Cutoff Current	$V_{CE} = 30$ v, $V_{BE} = 0$	All		100	μa
		$V_{CE} = 100$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1131, TI1132		10	ma
		$V_{CE} = 75$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1133, TI1134		10	ma
		$V_{CE} = 50$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1135, TI1136		10	ma
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 8$ v, $I_C = 0$	All		1.0	ma
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ v, $I_C = 2.0$ a, (See Note 4)	TI1131, TI1133 TI1135	30	120	
			TI1132, TI1134 TI1136	15	60	
V_{BE}	Base-Emitter Voltage	$I_B = 0.20$ a, $I_C = 2.0$ a, (See Note 4)	All		2.0	v
$r_{CE(sat)}$	Static Collector-Emitter Saturation Resistance	$I_B = 0.20$ a, $I_C = 2.0$ a, (See Note 4)	All		0.5	ohm
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 15$ v, $I_C = 0.5$ a, f = 7.5 mc, (See Note 5)	All	1.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 15$ v, $I_E = 0$ f = 1.0 mc	All		550	pf

NOTES: 4. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle $\leq 2\%$.

5. If tested without a heat sink, DC collector current must not be applied longer than 5 seconds.

thermal characteristics

PARAMETER		TYPE	MIN	MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	All		1.5	C°/w
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	All		50	C°/w

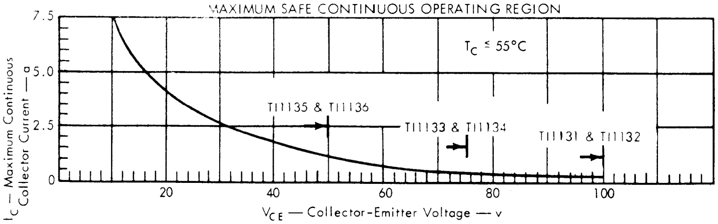


Figure 1

TYPES TI1151, TI1152, TI1153, TI1154, TI1155, TI1156
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

REVISED JULY 1975

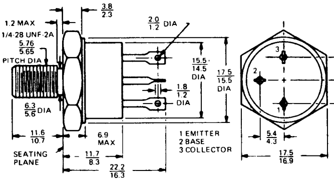
HIGH-VOLTAGE, HIGH-FREQUENCY POWER TRANSISTORS FOR INDUSTRIAL APPLICATIONS

- **80 Watts at 55°C Case Temperature**
- **Maximum r_{CS} of 0.5 Ohm at 5 Amperes I_C**
- **Maximum V_{BE} of 2 Volts at 5 Amperes I_C**
- **Minimum f_T of 7.5 Megacycles**

mechanical data

The transistors are in hermetically-sealed welded packages.

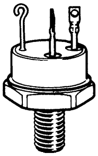
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TI1151 TI1152	TI1153 TI1154	TI1155 TI1156
Collector-Base Voltage	200 v	150 v	100 v
Collector-Emitter Voltage (See Note 1)	100 v	75 v	50 v
Emitter-Base Voltage	← 8 v →		
Collector Current, Continuous	← 7.5 a →		
Emitter Current, Continuous	← 7.5 a →		
Safe Continuous Operating Region at (or below) 55°C Case Temperature	See Figure 1		
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	← 3 w →		
Total Device Dissipation at (or below) 55°C Case Temperature (See Note 3)	← 80 w →		
Operating Collector Junction Temperature	← 175°C →		
Storage Temperature Range	−65°C to +200°C		

NOTES: 1. This value applies when base-emitter diode is open-circuited.
2. Derate linearly to 175°C free-air temperature at the rate of 20 mw/C°.
3. Derate linearly to 175°C case tempeiuture at the rate of 0.67 w/C°.

TYPES TI1151, TI1152, TI1153, TI1154, TI1155, TI1156
N-P-N TRIPLE-DIFFUSED MESA SILICON TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	MAX	UNIT
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10$ ma, $I_E = 0$	TI1151, TI1152	200		v
			TI1153, TI1154	150		v
			TI1155, TI1156	100		v
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 0.2$ a, $I_B = 0$, (See Note 4)	TI1151, TI1152	100		v
			TI1153, TI1154	75		v
			TI1155, TI1156	50		v
I_{CES}	Collector Cutoff Current	$V_{CE} = 30$ v, $V_{BE} = 0$	All		100	μa
		$V_{CE} = 100$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1151, TI1152		10	ma
		$V_{CE} = 75$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1153, TI1154		10	ma
		$V_{CE} = 50$ v, $V_{BE} = 0$, $T_C = 150°C$	TI1155, TI1156		10	ma
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 8$ v, $I_C = 0$	All		1.0	ma
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ v, $I_C = 5.0$ a, (See Note 4)	TI1151, TI1153 TI1155	20	80	
			TI1152, TI1154 TI1156	10	40	
V_{BE}	Base-Emitter Voltage	$I_B = 0.50$ a, $I_C = 5.0$ a, (See Note 4)	All		2.0	v
$r_{CE(sat)}$	Static Collector-Emitter Saturation Resistance	$I_B = 0.50$ a, $I_C = 5.0$ a, (See Note 4)	All		0.5	ohm
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 15$ v, $I_C = 0.5$ a, f = 7.5 mc, (See Note 5)	All	1.0		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 15$ v, $I_E = 0$, f = 1.0 mc	All		550	pf

NOTES: 4. These parameters must be measured using pulse techniques. PW = 300μsec, Duty Cycle ≤2%.
5. If tested without a heat sink, DC collector current must not be applied longer than 5 seconds.

thermal characteristics

PARAMETER		TYPE	MIN	MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	All		1.5	C°/w
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	All		50	C°/w

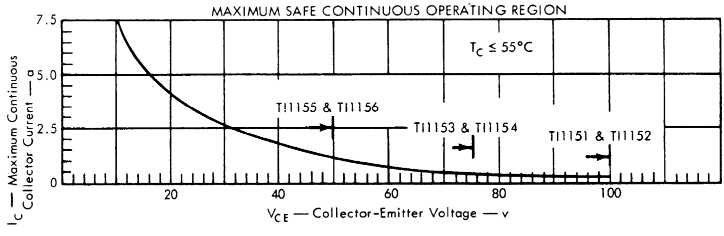


Figure 1

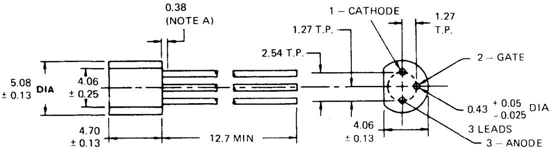
TIC44, TIC45, TIC46, TIC47
PNPN PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

SILECT† THYRISTORS‡
600 mA DC • 30 thru 200 VOLTS

Rugged, One-Piece Construction with Standard TO-18 100-mil Pin-Circle Configuration

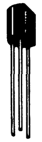
mechanical data

These thyristors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The thyristors are insensitive to light.



NOTES: A. Lead diameter is not controlled in this area.
B. Leads having maximum diameter (0.48) shall be within 0.18 of their true positions measured in the gaging plane 1.37 below the seating plane of the device relative to a maximum-diameter package.
C. All dimensions are in millimetres.

THE GATE IS CONNECTED TO A P REGION



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

	TIC44	TIC45	TIC46	TIC47	UNIT
Static Off-State Voltage, V_D (See Note 1)	30	60	100	200	V
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	30	60	100	200	V
Static Reverse Voltage, V_R (See Note 1)	30	60	100	200	V
Repetitive Peak Reverse Voltage, V_{RRM} (See Note 1)	30	60	100	200	V
Continuous or RMS On-State Current at (or below) 55°C Case Temperature (See Note 2)	600				mA
Continuous or RMS On-State Current at (or below) 25°C Free-Air Temperature (See Note 3)	300				mA
Average On-State Current (180° Conduction Angle) at (or below) 55°C Case Temperature (See Note 4)	430				mA
Surge On-State Current (See Note 5)	6				A
Peak Negative Gate Voltage	8				V
Peak Positive Gate Current (Pulse Width ≤ 300 μs)	1				A
Peak Gate Power Dissipation (Pulse Width ≤ 300 μs)	4				W
Operating Free-Air Temperature Range	−55 to 125				°C
Storage Temperature Range	−55 to 150				°C
Lead Temperature 1.588mm from Case for 10 Seconds	260				°C

NOTES: 1. These values apply when the gate-cathode resistance $R_{GK} \leq 1\ k\Omega$.
2. These values apply for continuous d-c operation with resistive load. Above 55°C derate according to Figure 5.
3. These values apply for continuous d-c operation with resistive load. Above 25°C derate according to Figure 6.
4. This value may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 55°C derate according to Figure 5.
5. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

†Trademark of Texas Instruments
‡U. S. Patent No. 3,439,238

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
I_D	Static Off-State Current	V_D = Rated V_D, R_{GK} = 1 kΩ, T_A = 125°C		50	μA
I_R	Static Reverse Current	V_R = Rated V_R, R_{GK} = 1 kΩ, T_A = 125°C		50	μA
I_{GT}	Gate Trigger Current (See Note 6)	V_{AA} = 6 V, R_L = 100 Ω, $t_{p(g)} \geq 20$ μs		200	μA
V_{GT}	Gate Trigger Voltage (See Note 6)	V_{AA} = 6 V, R_L = 100 Ω, $t_{p(g)} \geq 20$ μs		0.8	V
		V_{AA} = 6 V, R_L = 100 Ω, $t_{p(g)} \geq 20$ μs, T_A = 125°C	0.2		
I_H	Holding Current	R_L = 100 Ω, R_{GK} = 1 kΩ		5	mA
V_T	On-State Voltage	I_T = 300 mA, $R_{GK} \geq 1$ kΩ, See Note 7		1.4	V

NOTES: 6. When measuring these parameters, a 1-kΩ resistor should be used between gate and cathode to prevent triggering by random noise.

7. This parameter is measured using pulse techniques. t_w = 1 ms, duty cycle ≤ 1%.

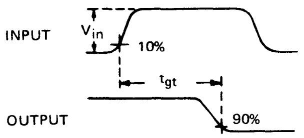
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_{gt}	Gate-Controlled Turn-On Time	V_{AA} = 30 V, R_L = 50 Ω, R_G = 20 kΩ, V_{in} = 20 V, See Figure 1	3.5	μs
t_q	Circuit-Commutated Turn-Off Time	V_{AA} = 30 V, R_L = 50 Ω, I_{RM} = 1 A, See Figure 2	6.8	μs

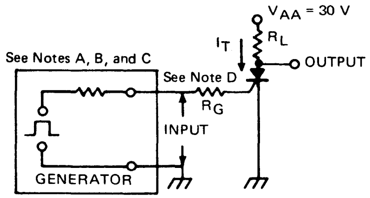
thermal characteristics

PARAMETER			MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance		75	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance		275	

PARAMETER MEASUREMENT INFORMATION

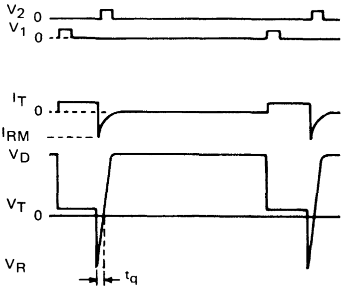


VOLTAGE WAVEFORMS

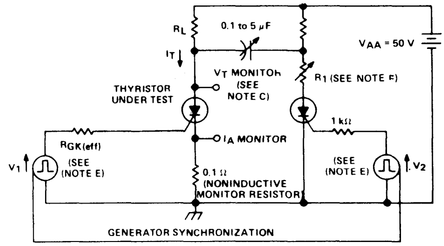


TEST CIRCUIT

FIGURE 1—TURN-ON TIME



WAVEFORMS



TEST CIRCUIT

FIGURE 2—COMMUTATING TURN-OFF TIME

NOTES:
- A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.
- B. The input waveform of Figure 1 has the following characteristics: $t_r \leqslant 40$ ns, $t_w \geqslant 20$ μs.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 12$ pF.
- D. R_G includes the total resistance of the generator and the external resistor.

NOTES:
- E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: $t_w = 50$ to 300 μs, duty cycle = 1%. The pulse widths of V_1 and V_2 are $\geqslant 10$ μs.
- F. Resistor R_1 is adjusted for $I_{RM} = 1$ A.

TIC44, TIC45, TIC46, TIC47

PNPN PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

THERMAL INFORMATION

The minimum heat-sink requirements may be calculated for any on-state current, heat-sink combination by the following procedure:

1. Determine worst-case power dissipation from Figure 3.
2. Calculate maximum allowable case-to-free-air thermal resistance by use of the equation.

$$R_{\theta CA} = \frac{T_J - T_A}{P_{A(av)}} - R_{\theta JC}$$

where: T_J = Junction temperature

T_A = Free-air temperature

$P_{A(av)}$ = Average anode power dissipation (see Figure 3 for worst-case values)

$R_{\theta JC}$ = Junction-to-case thermal resistance = 75°C/W maximum.

3. Determine area of heat sink from Figure 4.

EXAMPLE

Determine: Minimum size of 1/16″-thick aluminum heat sink for safe operation of thyristor at an average current of 0.4 A with a conduction angle of 180°

Given: Maximum T_J = 125°C

T_A = 35°C

$R_{\theta JC}$ = 75°C

Solution: From Figure 3, $P_{A(av)}$ = 0.84 W for 0.4 A with 180° conduction angle. Using the equation of step 2 above:

$$R_{\theta CA} = \frac{125^\circ C - 35^\circ C}{0.84\ W} - 75^\circ C/W = 32^\circ C/W$$

Figure 4 shows that for $R_{\theta CA}$ of 32°C/W, the area is 18 sq. in. The minimum dimensions of the sides should be:

$$\sqrt{\frac{area}{2}} \times \sqrt{\frac{area}{2}} = \sqrt{\frac{18}{2}} \times \sqrt{\frac{18}{2}} = 3'' \times 3''$$

MAXIMUM AVERAGE ANODE POWER DISSIPATED
vs
AVERAGE ON-STATE CURRENT

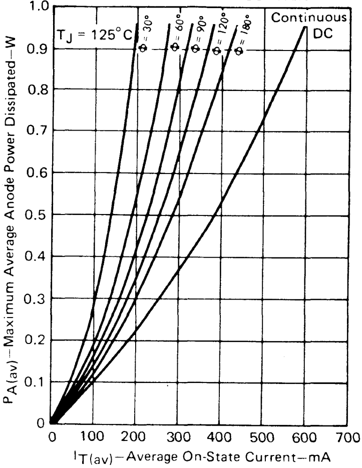


FIGURE 3

TYPICAL HEAT-SINK AREA
vs
CASE-TO-FREE-AIR THERMAL RESISTANCE
1/16″-THICK ALUMINUM HEAT SINK

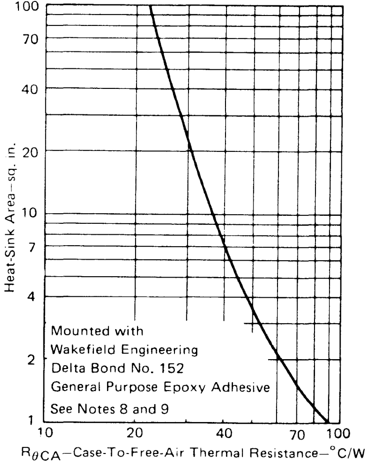


FIGURE 4

NOTES: 8. The thyristor is mounted in the center of a square heat sink vertically positioned in still free air with both sides exposed. The heat-sink area is twice the area of one side.

9. $R_{\theta CA}$ includes the case-to-heat sink thermal resistance, $R_{\theta CHS}$, in addition to the heat-sink-to-free-air thermal resistance, $R_{\theta HSA}$ and is defined by the equation, $R_{\theta CA} = R_{\theta CHS} + R_{\theta HSA}$.

THERMAL INFORMATION

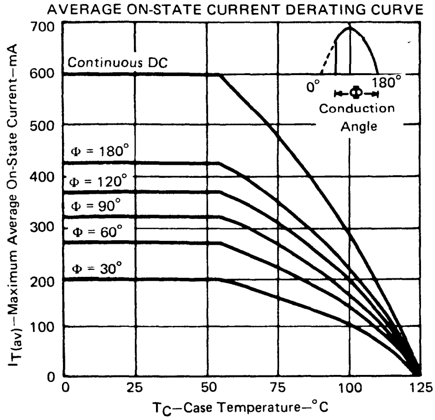


FIGURE 5

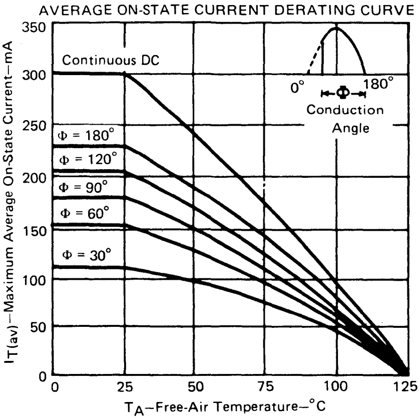


FIGURE 6

TYPICAL CHARACTERISTICS

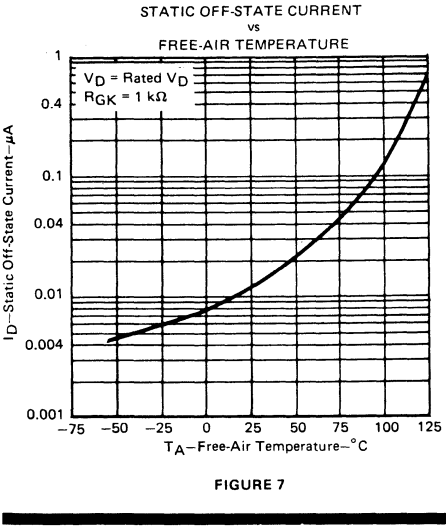


FIGURE 7

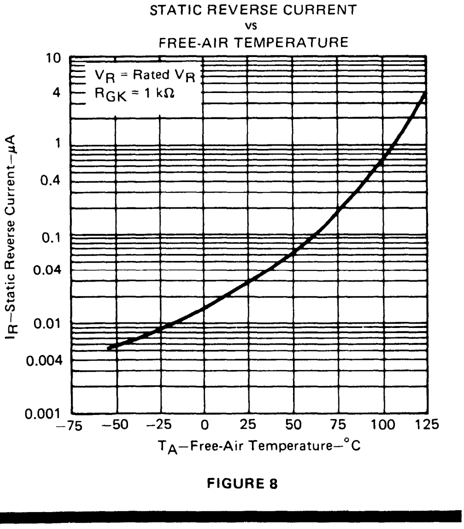


FIGURE 8

TYPICAL CHARACTERISTICS

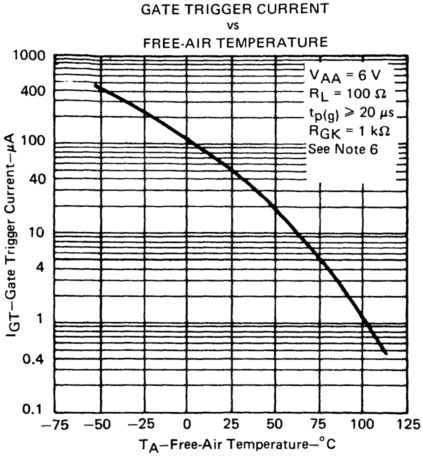


FIGURE 9

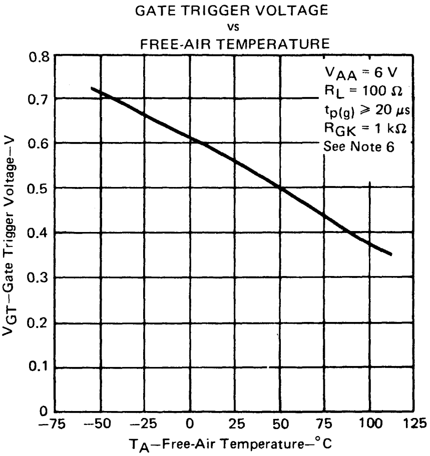


FIGURE 10

NOTE 6: When measuring these parameters, a 1-kΩ resistor should be used between gate and cathode to prevent triggering by random noise.

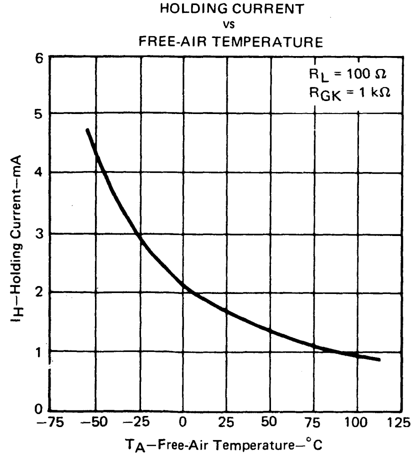


FIGURE 11

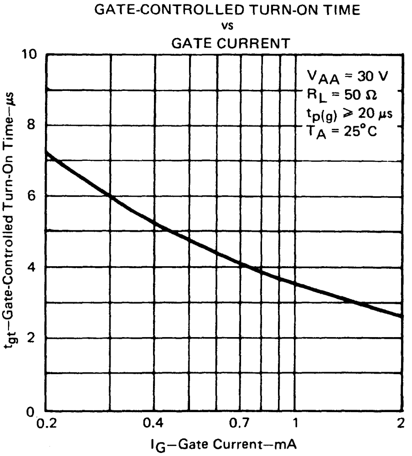


FIGURE 12

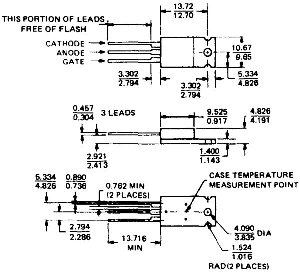
SERIES TIC106
PNPN SILICON REVERSE-BLOCKING TRIODE THYRISTORS

REVISED JULY 1975

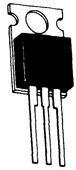
- 5 A DC
- 30 V to 400 V
- 30 A Surge-Current
- Max I_{GT} of 200 μA

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



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

	TIC106Y	TIC106F	TIC106A	TIC106B	TIC106C	TIC106D	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	30	50	100	200	300	400	V
Repetitive Peak Reverse Voltage, V_{RRM}	30	50	100	200	300	400	V
Continuous On-State Current at (or below) 80°C Case Temperature (See Note 2)	5						A
Average On-State Current (180° Conduction Angle) at (or below) 80°C Case Temperature (See Note 3)	3.2						A
Surge On-State Current (See Note 4)	30						A
Peak Positive Gate Current (Pulse Width ⩽ 300 μs)	0.2						A
Peak Gate Power Dissipation (Pulse Width ⩽ 300 μs)	1.3						W
Average Gate Power Dissipation (See Note 5)	0.3						W
Operating Case Temperature Range	−40 to 110						°C
Storage Temperature Range	−40 to 125						°C
Lead Temperature 1.588mm from Case for 10 Seconds	230						°C

NOTES:
1. These values apply when the gate-cathode resistance R_{GK} = 1 kΩ.
2. These values apply for continuous d-c operation with resistive load. Above 80°C derate according to Figure 3.
3. This value may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load. Above 80°C derate according to Figure 3.
4. This value applies for one 60-Hz half-sine-wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.
5. This value applies for a maximum averaging time of 16.6 ms.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{DRM}	Repetitive Peak Off-State Current	V_D = Rated V_{DRM}, R_{GK} = 1 kΩ, T_C = 110°C			400	μA
I_{RRM}	Repetitive Peak Reverse Current	V_R = Rated V_{RRM}, I_G = 0, T_C = 110°C			1	mA
I_{GT}	Gate Trigger Current	V_{AA} = 6 V, R_L = 100 Ω, $t_{p(g)} \geqslant$ 20 μs		60	200	μA
V_{GT}	Gate Trigger Voltage	V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 μs, T_C = −40°C			1.2	V
		V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 μs	0.4	0.6	1	
		V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 μs, T_C = 110°C	0.2			
I_H	Holding Current	V_{AA} = 6 V, R_{GK} = 1 kΩ, Initiating I_T = 10 mA, T_C = −40°C			8	mA
		V_{AA} = 6 V, R_{GK} = 1 kΩ, Initiating I_T = 10 mA			5	
V_{TM}	Peak On-State Voltage	I_{TM} = 5 A, See Note 6			1.7	V
dv/dt	Critical Rate of Rise of Off-State Voltage	V_D = Rated V_D, R_{GK} = 1 kΩ, T_C = 110°C		10		V/μs

thermal characteristics

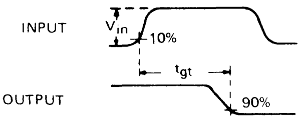
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

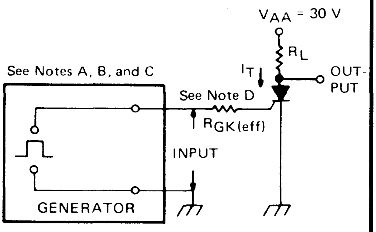
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_{gt}	Gate-Controlled Turn-On-Time	$V_{AA} = 30$ V, $R_L = 6\ \Omega$, $R_{GK(eff)} = 5\ k\Omega$, $V_{in} = 50$ V, See Figure 1	1.75	μs
t_q	Circuit-Commutated Turn-Off Time	$V_{AA} = 30$ V, $R_L = 6\ \Omega$, $I_{RM} \approx 8$ A, See Figure 2	7.7	μs

PARAMETER MEASUREMENT INFORMATION

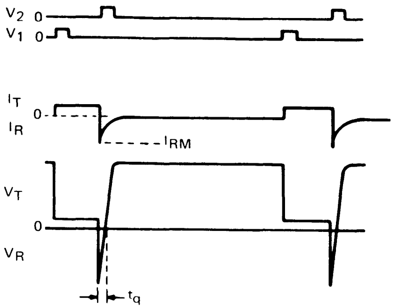


VOLTAGE WAVEFORMS

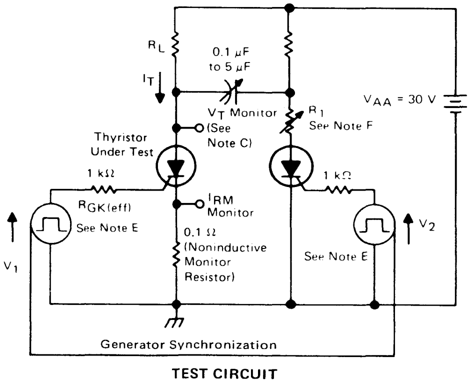


TEST CIRCUIT

FIGURE 1 – GATE-CONTROLLED TURN-ON TIME



WAVEFORMS



TEST CIRCUIT

FIGURE 2–CIRCUIT-COMMUTATED TURN-OFF TIME

NOTES:
- A. V_{in} is measured with gate and cathode terminals open.
- B. The input waveform of Figure 1 has the following characteristics: $t_r \leqslant 40$ ns, $t_w \geqslant 20$ μs.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 12$ pF.
- D. $R_{GK(eff)}$ includes the total resistance of the generator and the external resistor.
- E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: $t_w = 50$ to 300 μs, duty cycle = 1%. The pulse widths of V_1 and V_2 are $\geqslant 10$ μs.
- F. Resistor R_1 is adjusted for $I_{RM} \approx 8$ A.

THERMAL INFORMATION

AVERAGE ANODE
FORWARD CURRENT DERATING CURVE

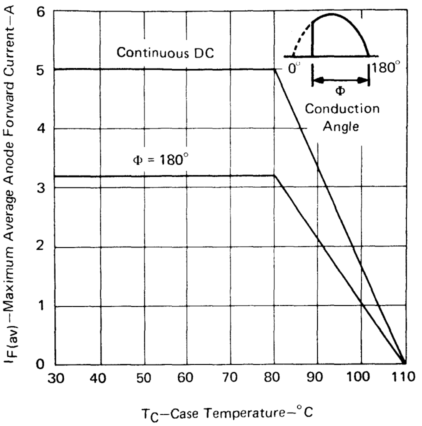


FIGURE 3

MAXIMUM CONTINUOUS ANODE POWER DISSIPATED
vs
CONTINUOUS ANODE FORWARD CURRENT

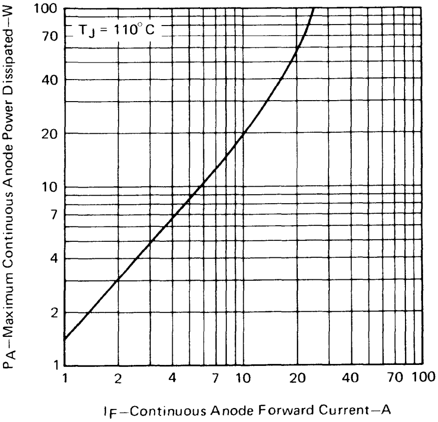


FIGURE 4

SURGE ON-STATE CURRENT
vs
CYCLES OF CURRENT DURATION

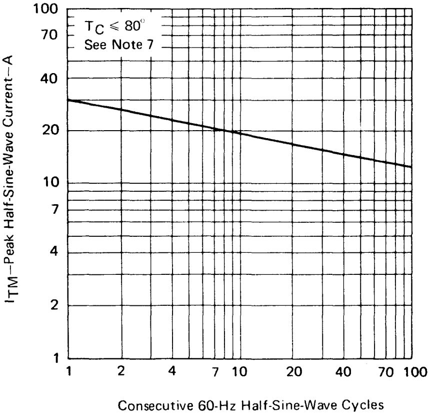


FIGURE 5

TRANSIENT THERMAL RESISTANCE
vs
CYCLES OF CURRENT DURATION

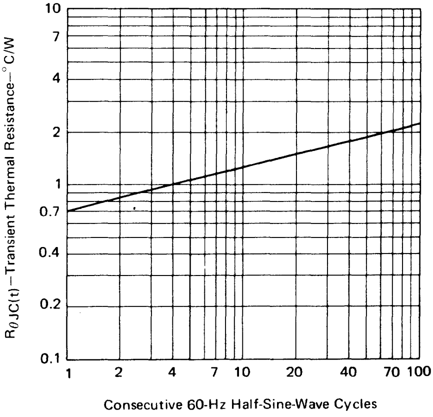


FIGURE 6

NOTE 7: This curve shows the maximum number of cycles of surge current for which gate control is guaranteed provided the device is initially at nonoperating thermal equilibrium.

TYPICAL CHARACTERISTICS

GATE TRIGGER CURRENT
vs
CASE TEMPERATURE

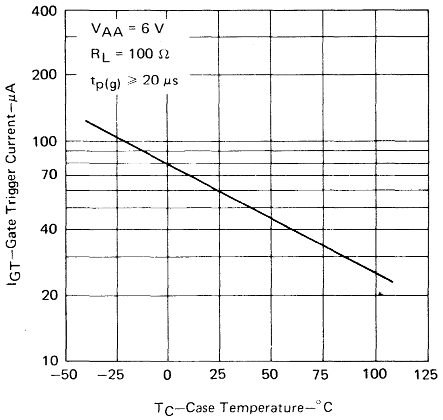


FIGURE 7

GATE TRIGGER VOLTAGE
vs
CASE TEMPERATURE

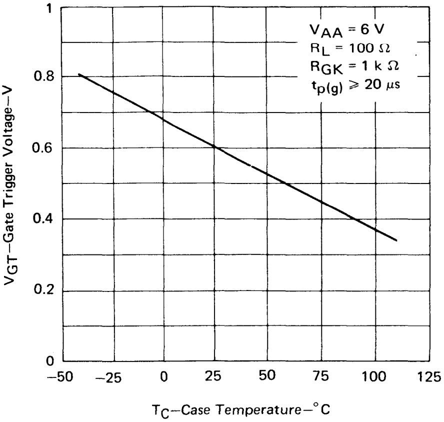


FIGURE 8

GATE FORWARD VOLTAGE
vs
GATE FORWARD CURRENT

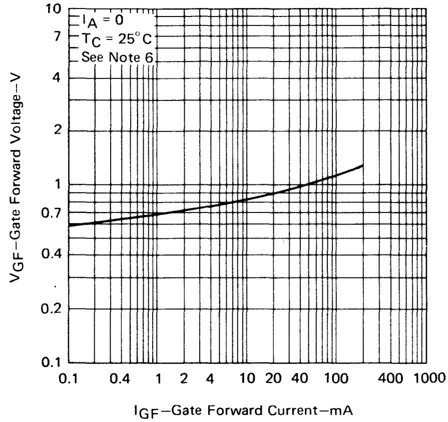


FIGURE 9

HOLDING CURRENT
vs
CASE TEMPERATURE

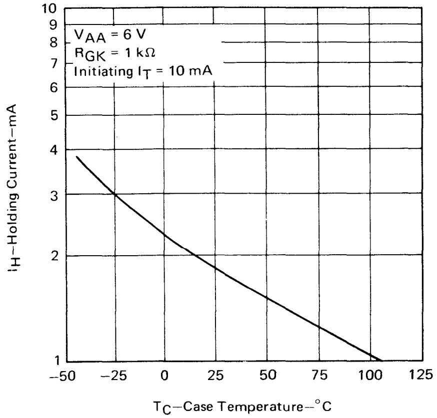


FIGURE 10

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 µs, duty cycle ≤ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

TYPICAL CHARACTERISTICS

PEAK ON-STATE VOLTAGE
vs
PEAK-ON-STATE CURRENT

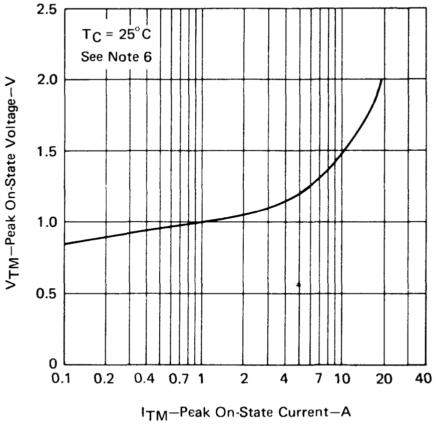


FIGURE 11

GATE-CONTROLLED TURN-ON TIME
vs
GATE CURRENT

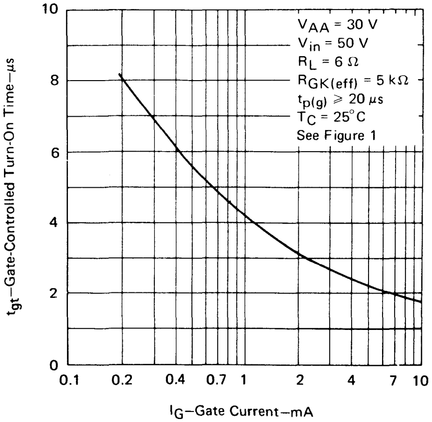


FIGURE 12

CIRCUIT-COMMUTATED TURN-OFF TIME
vs
CASE TEMPERATURE

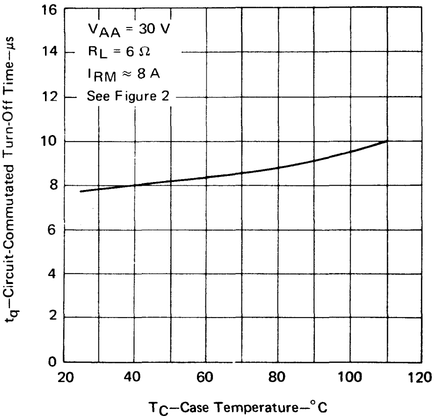


FIGURE 13

NOTE 6: This parameter must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leq 2\%$. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 0.125 inch from the device body.

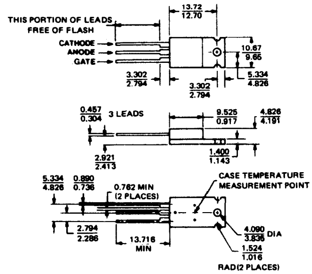
TIC116, TIC126
PNPN SILICON REVERSE-BLOCKING TRIODE THYRISTORS

REVISED JUNE 1975

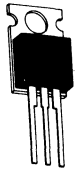
- 8 A and 12 A DC
- 80 A and 100 A Surge Current
- 50 V to 600 V
- MAX I_{GT} of 20 mA

mechanical data

THE MAIN TERMINAL 2 IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB
THE GATE TERMINAL IS CONNECTED TO A P REGION



ALL DIMENSIONS ARE IN MILLIMETRES



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

		SERIES TIC116	SERIES TIC126	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	F Suffix	50	50	V
	A Suffix	100	100	
	B Suffix	200	200	
	C Suffix	300	300	
	D Suffix	400	400	
	E Suffix	500	500	
	M Suffix	600	600	
Repetitive Peak Reverse Voltage, V_{RRM}	F Suffix	50	50	V
	A Suffix	100	100	
	B Suffix	200	200	
	C Suffix	300	300	
	D Suffix	400	400	
	E Suffix	500	500	
	M Suffix	600	600	
Continuous On-State Current at (or below) 70°C Case Temperature (See Note 2)		8	12	A
Average On-State Current (180° Conduction Angle) at (or below) 70°C Case Temperature (See Note 3)		5	7.5	A
Surge On-State Current (See Note 4)		80	100	A
Peak Positive Gate Current (Pulse Width ⩽ 300 μs)		3		A
Peak Gate Power Dissipation (Pulse Width ⩽ 300 μs)		5		W
Average Gate Power Dissipation (See Note 5)		1		W
Operating Case Temperature Range		−40 to 110		°C
Storage Temperature Range		−40 to 125		°C
Lead Temperature 1.588mm from Case for 10 Seconds		230		°C

NOTES:
1. These values apply when the gate-cathode resistance $R_{GK} = 1\ k\Omega$.
2. These values apply for continuous d-c operation with resistive load. Above 70°C derate according to Figure 3.
3. This value may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 70°C derate according to Figure 3.
4. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.
5. This value applies for a maximum averaging time of 16.6 ms.

TIC116, TIC126
PNPN SILICON REVERSE-BLOCKING TRIODE THYRISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	SERIES	MIN	TYP	MAX	UNIT
I_{DRM}	Repetitive Peak Off-State Current	V_D = Rated V_{DRM}, R_{GK} = 1 kΩ, T_C = 110°C	All			2	mA
I_{RRM}	Repetitive Peak Reverse Current	V_R = Rated V_{RRM}, I_G = 0, T_C = 110°C	All			2	mA
I_{GT}	Gate Trigger Current	V_{AA} = 6 V, R_L = 100 Ω, $t_{p(g)} \geqslant$ 20 µs	All		5	20	mA
V_{GT}	Gate Trigger Voltage	V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 µs, T_C = −40°C	All			2.5	V
		V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 µs	All		0.8	1.5	
		V_{AA} = 6 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geqslant$ 20 µs, T_C = 110°C	All	0.2			
I_H	Holding Current	V_{AA} = 6 V, R_{GK} = 1 kΩ, Initiating I_T = 100 mA, T_C = −40°C	All			70	mA
		V_{AA} = 6 V, R_{GK} = 1 kΩ, Initiating I_T = 100 mA	All			40	
V_{TM}	Peak On-State Voltage	I_{TM} = 8 A, See Note 6	TIC116			1.7	V
		I_{TM} = 12 A, See Note 6	TIC126			1.4	
dv/dt	Critical Rate of Rise of Off-State Voltage	V_D = Rated V_D, I_G = 0, T_C = 110°C	All		100		V/µs

thermal characteristics

PARAMETER		SERIES TIC116	SERIES TIC126	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3	2.4	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	62.5	

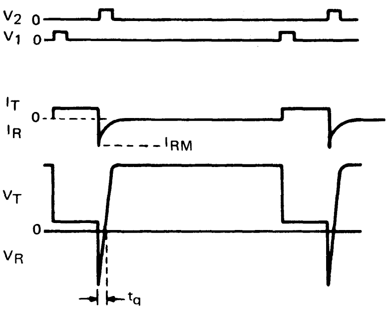
NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

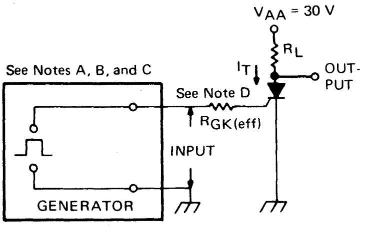
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_{gt}	Gate-Controlled Turn-On Time	V_{AA} = 30 V, R_L = 6 Ω, $R_{GK(eff)}$ = 100 Ω, V_{in} = 20 V, See Figure 1	0.8	μs
t_q	Circuit-Commutated Turn-Off Time	V_{AA} = 30 V, R_L = 6 Ω, I_{RM} = 10 A, See Figure 2	11	μs

PARAMETER MEASUREMENT INFORMATION

WAVEFORMS

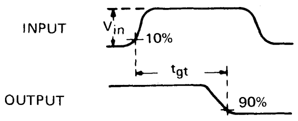


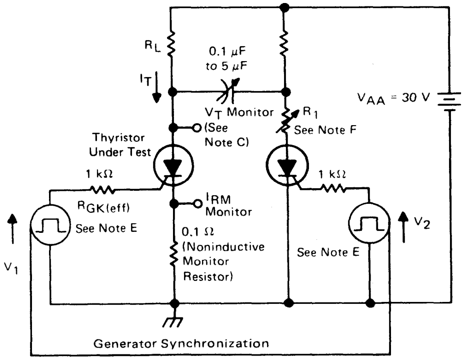


TEST CIRCUIT

FIGURE 1 – GATE-CONTROLLED TURN-ON TIME

VOLTAGE WAVEFORMS





TEST CIRCUIT

FIGURE 2–CIRCUIT-COMMUTATED TURN-OFF TIME

NOTES:
- A. V_{in} is measured with gate and cathode terminals open.
- B. The input waveform of Figure 1 has the following characteristics: $t_r \leqslant 40$ ns, $t_w \geqslant 20$ μs.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 12$ pF.
- D. $R_{GK(eff)}$ includes the total resistance of the generator and the external resistor.
- E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: t_w = 50 to 300 μs, duty cycle = 1%. The pulse widths of V_1 and V_2 are $\geqslant$ 10 μs.
- F. Resistor R_1 is adjusted for $I_{RM} \approx 10$ A.

THERMAL INFORMATION

AVERAGE ON-STATE CURRENT DERATING CURVE

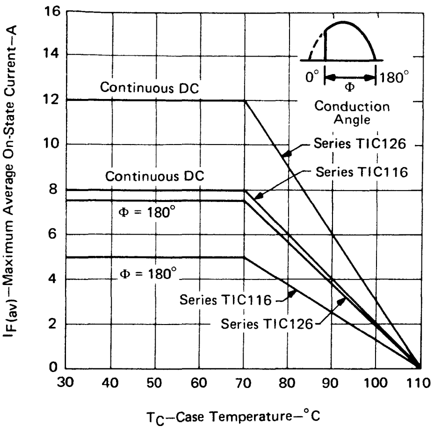


FIGURE 3

MAXIMUM CONTINUOUS ANODE POWER DISSIPATED
vs
CONTINUOUS ON-STATE CURRENT

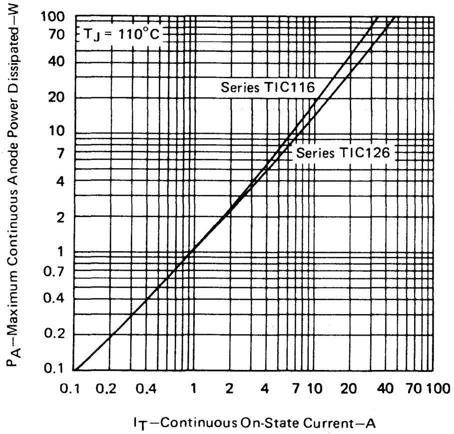


FIGURE 4

SURGE ON-STATE CURRENT
vs
CYCLES OF CURRENT DURATION

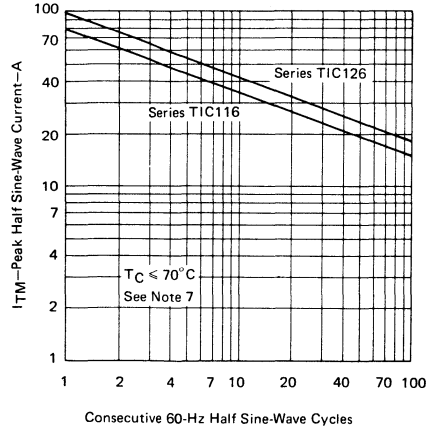


FIGURE 5

TRANSIENT THERMAL RESISTANCE
vs
CYCLES OF CURRENT DURATION

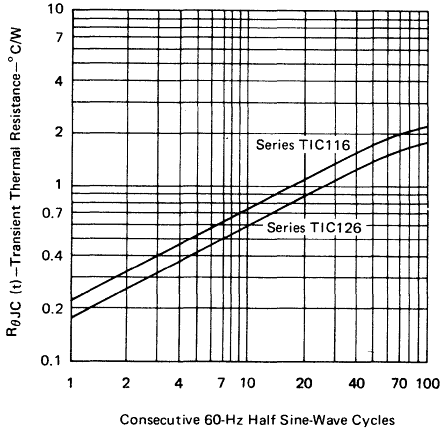


FIGURE 6

NOTE 7: This curve shows the maximum number of cycles of surge current for which gate control is guaranteed provided the device is initailly at nonoperating thermal equilibrium.

TYPICAL CHARACTERISTICS

GATE TRIGGER CURRENT
vs
CASE TEMPERATURE

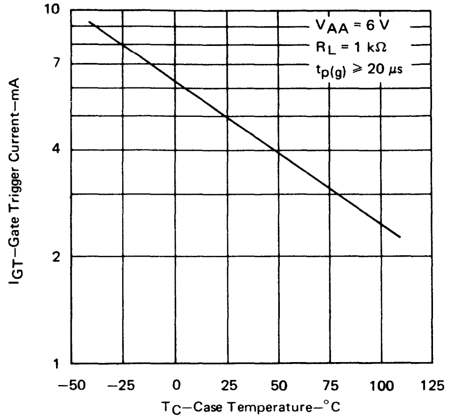


FIGURE 7

GATE TRIGGER VOLTAGE
vs
CASE TEMPERATURE

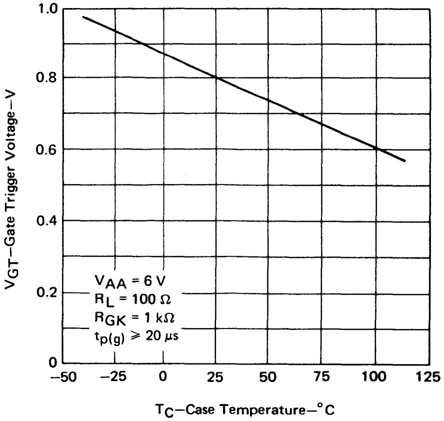


FIGURE 8

GATE FORWARD VOLTAGE
vs
GATE FORWARD CURRENT

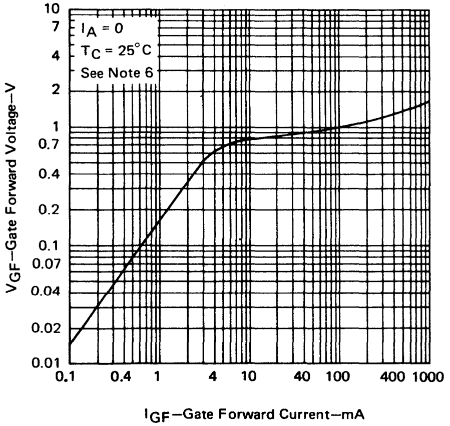


FIGURE 9

HOLDING CURRENT
vs
CASE TEMPERATURE

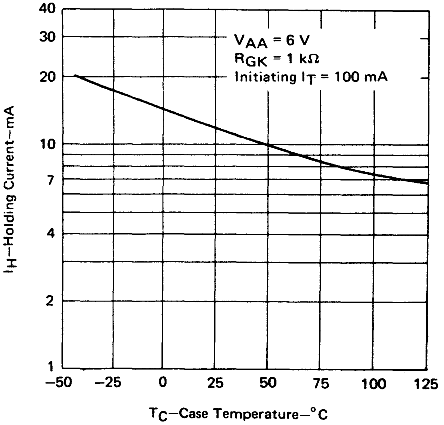


FIGURE 10

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

TYPICAL CHARACTERISTICS

PEAK ON-STATE VOLTAGE
vs
PEAK ON-STATE CURRENT

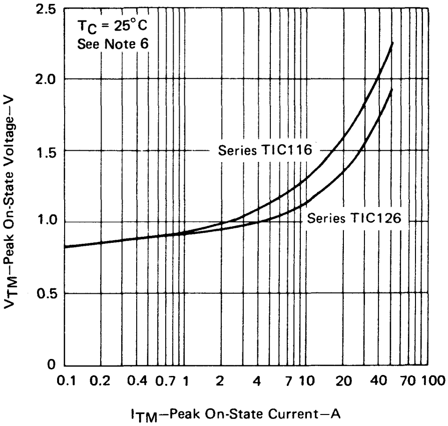


FIGURE 11

GATE-CONTROLLED TURN-ON TIME
vs
GATE CURRENT

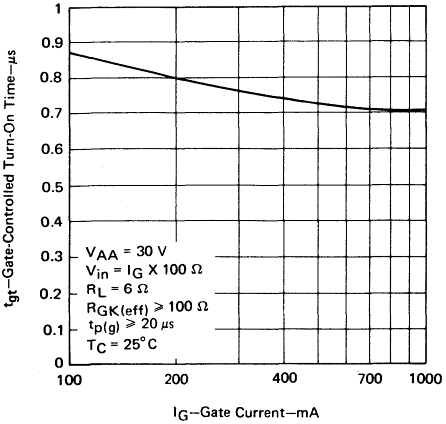


FIGURE 12

CIRCUIT-COMMUTATED TURN-OFF TIME
vs
CASE TEMPERATURE

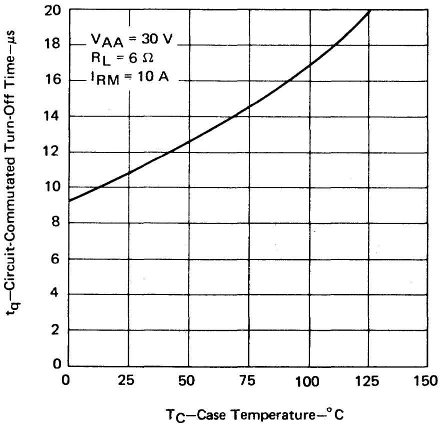


FIGURE 13

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 µs, duty cycle ≤ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

SERIES TIC206
SILICON BIDIRECTIONAL TRIODE THYRISTOR
REVISED APRIL 1975

SENSITIVE-GATE TRIAC

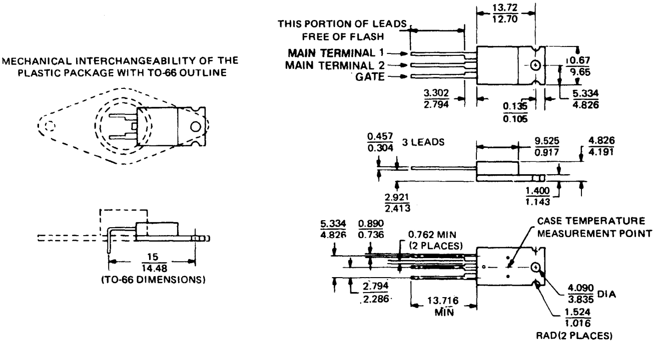
- 3 A RMS
- 100 V, 200 V, and 400 V V_{DRM}

description

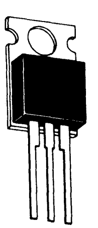
This device is a bidirectional triode thyristor (triac) which may be triggered from the off-state to the on-state by either polarity of gate signal with Main Terminal 2 at either polarity.

mechanical data

THE MAIN TERMINAL 2 IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



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

		SERIES TIC206	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	A Suffix	100	V
	B Suffix	200	
	D Suffix	400	
Full-Cycle RMS On-State Current at (or below) 70°C Case Temperature, $I_{T(RMS)}$ (See Note 2)		3	A
Peak On-State Surge Current, Full-Sine-Wave, I_{TSM} (See Note 3)		20	A
Peak Gate Current, I_{GM}		±1	A
Operating Case Temperature Range		−40 to 110	°C
Storage Temperature Range		−40 to 125	°C
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds		230	°C

NOTES: 1. These values apply bidirectionally for any value of resistance between the gate and Main Terminal 1.

2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 70°C derate linearly to 110°C case temperature at the rate of 50 mA/°C.

3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

†All voltage values are with respect to Main Terminal 1.

electrical characteristics at 25°C case temperature (unless otherwise noted)†

PARAMETER		TEST CONDITIONS			SERIES TIC206		UNIT
					MIN	MAX	
I_{DRM}	Repetitive Peak Off-State Current	V_{DRM} = Rated V_{DRM},	$I_G = 0$,	$T_C = 110°C$		±1	mA
I_{GTM}	Peak Gate Trigger Current	$V_{supply} = +12\ V^{\dagger}$	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		5	mA
		$V_{supply} = +12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		−5	
		$V_{supply} = -12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		−5	
		$V_{supply} = -12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		10	
V_{GTM}	Peak Gate Trigger Voltage	$V_{supply} = +12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		2	V
		$V_{supply} = +12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		−2	
		$V_{supply} = -12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		−2	
		$V_{supply} = -12\ V^{\dagger}$,	$R_L = 10\ \Omega$,	$t_{p(g)} \geq 20\ \mu s$		2	
V_{TM}	Peak On-State Voltage	$I_{TM} = ±2.8\ A$,	$I_G = 50\ mA$,	See Note 4			V
		$I_{TM} = ±4.2\ A$,	$I_G = 50\ mA$,	See Note 4		±2.2	
I_H	Holding Current	$V_{supply} = +12\ V^{\dagger}$,	$I_G = 0$,	Initiating $I_{TM} = 100\ mA$		30	mA
		$V_{supply} = -12\ V^{\dagger}$,	$I_G = 0$,	Initiating $I_{TM} = -100\ mA$		−30	

†All voltage values are with respect to Main Terminal 1.

NOTES: 4. This parameter must be measured using pulse techniques. $t_w \leq 1$ ms, duty cycle $\leq 2\%$. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2 mm from the device body.

thermal characteristics

PARAMETER		SERIES TIC206	UNIT
		MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	7.8	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

SERIES TIC216
SILICON BIDIRECTIONAL TRIODE THYRISTOR

REVISED APRIL 1975

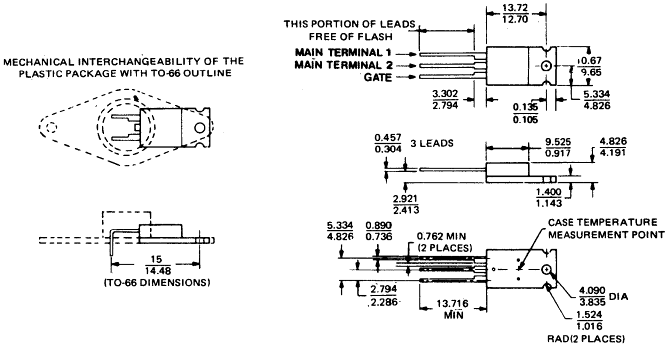
SENSITIVE-GATE TRIAC
6 A RMS • 100 V, 200 V, and 400 V

description

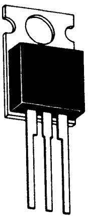
This device is a bidirectional triode thyristor (triac) which may be triggered from the off-state to the on-state by either polarity of gate signal with Main Terminal 2 at either polarity.

mechanical data

THE MAIN TERMINAL 2 IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



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

		SERIES TIC216	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	A Suffix	100	V
	B Suffix	200	
	D Suffix	400	
Full-Cycle RMS On-State Current at (or below) 70°C Case Temperature, $I_{T(RMS)}$ (See Note 2)		6	A
Peak On-State Surge Current, Full-Sine-Wave, I_{TSM} (See Note 3)		60	A
Peak Gate Current, I_{GM}		±1	A
Operating Case Temperature Range		–40 to 110	°C
Storage Temperature Range		–40 to 125	°C
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds		230	°C

NOTES:
1. These values apply bidirectionally for any value of resistance between the gate and Main Terminal 1.
2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 70°C derate linearly to 110°C case temperature at the rate of 75 mA/°C.
3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

†All voltage values are with respect to Main Terminal 1.

electrical characteristics at 25°C case temperature (unless otherwise noted)†

PARAMETER		TEST CONDITIONS	SERIES TIC216			UNIT
			MIN	TYP	MAX	
I_{DRM}	Repetitive Peak Off-State Current	V_{DRM} = Rated V_{DRM}, I_G = 0, T_C = 110°C			±2	mA
I_{GTM}	Peak Gate Trigger Current	V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			5	mA
		V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−5	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−5	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			10	
V_{GTM}	Peak Gate Trigger Voltage	V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			2.2	V
		V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−2.2	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−2.2	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			3	
V_{TM}	Peak On-State Voltage	I_{TM} = ±4.2 A, I_G = 100 mA, See Note 4				V
		I_{TM} = ±8.4 A, I_G = 100 mA, See Note 4			±1.7	
I_H	Holding Current	V_{supply} = +12 V†, I_G = 0, Initiating I_{TM} = 100 mA			30	mA
		V_{supply} = −12 V†, I_G = 0, Initiating I_{TM} = −100 mA			−30	
I_L	Latching Current	V_{supply} = +12 V†, See Note 5		50		mA
		V_{supply} = −12 V†, See Note 5		−20		

†All voltage values are with respect to Main Terminal 1.

NOTES: 4. This parameter must be measured using pulse techniques. $t_w \leqslant 1$ ms, duty cycle $\leqslant 2\%$. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

5. The triacs are triggered by a 15-V (open-circuit amplitude) pulse supplied by a generator with the following characteristics: R_G = 100 Ω, t_w = 20 μs, $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, f = 1 kHz.

thermal characteristics

PARAMETER		SERIES TIC216	UNIT
		MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5.1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

TIC226B, TIC226D
SILICON BIDIRECTIONAL TRIODE THYRISTORS

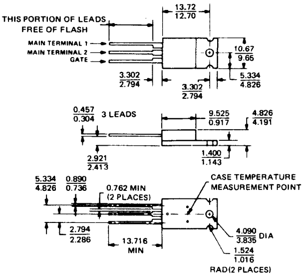
REVISED JULY 1975

8 A RMS • 200 V and 400 V
TRIACS
for
HIGH-TEMPERATURE, HIGH-CURRENT, and HIGH-VOLTAGE APPLICATIONS
• Typ dv/dt of 500 V/μs at 25°C

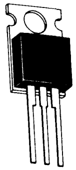
description

These devices are bidirectional triode thyristors (triacs) which may be triggered from the off-state to the on-state by either polarity of gate signal with Main Terminal 2 at either polarity.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



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

			UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	TIC226B	200	V
	TIC226D	400	
Full-Cycle RMS On-State Current at (or below) 85°C Case Temperature, $I_{T(RMS)}$ (See Note 2)		8	A
Peak On-State Surge Current, Full-Sine-Wave, I_{TSM} (See Note 3)		70	A
Peak On-State Surge Current, Half-Sine-Wave, I_{TSM} (See Note 4)		80	A
Peak Gate Current, I_{GM}		1	A
Peak Gate Power Dissipation, P_{GM}, at (or below) 85°C Case Temperature (Pulse Width $\leqslant$ 200 μs)		2.2	W
Average Gate Power Dissipation, $P_{G(av)}$, at (or below) 85°C Case Temperature (See Note 5)		0.9	W
Operating Case Temperature Range		–40 to 110	°C
Storage Temperature Range		–40 to 125	°C
Lead Temperature 1.588mm from Case for 10 Seconds		230	°C

NOTES: 1. These values apply bidirectionally for any value of resistance between the gate and Main Terminal 1.
2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 85°C derate according to Figure 2.
3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) the rated value of on-state current. Surge may be repeated after the device has returned to original thermal equilibrium. During the surge, gate control may be lost.
4. This value applies for one 60-Hz half sine wave when the device is operating at (or below) the rated value of on-state current. Surge may be repeated after the device has returned to original thermal equilibrium. During the surge, gate control may be lost.
5. This value applies for a maximum averaging time of 16.6 ms.

† All voltage values are with respect to Main Terminal 1.

TIC226B, TIC226D
SILICON BIDIRECTIONAL TRIODE THYRISTORS

electrical characteristics at 25° C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{DRM}	Repetitive Peak Off-State Current	V_{DRM} = Rated V_{DRM}, $I_G = 0$, $T_C = 110°C$			±2	mA
I_{GTM}	Peak Gate Trigger Current	$V_{supply} = +12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		15	50	mA
		$V_{supply} = +12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		−25	−50	
		$V_{supply} = -12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		−30	−50	
		$V_{supply} = -12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		75		
V_{GTM}	Peak Gate Trigger Voltage	$V_{supply} = +12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		0.9	2.5	V
		$V_{supply} = +12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		−1.2	−2.5	
		$V_{supply} = -12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		−1.2	−2.5	
		$V_{supply} = -12$ V†, $R_L = 10\ \Omega$, $t_{p(g)} \geqslant 20\ \mu s$		1.2		
V_{TM}	Peak On-State Voltage	$I_{TM} = \pm 12$ A, $I_G = 100$ mA, See Note 6			±2.1	V
I_H	Holding Current	$V_{supply} = +12$ V†, $I_G = 0$, Initiating $I_{TM} = 500$ mA		20	60	mA
		$V_{supply} = -12$ V†, $I_G = 0$, Initiating $I_{TM} = -500$ mA		−30	−60	
I_L	Latching Current	$V_{supply} = +12$ V†, See Note 7		30	70	mA
		$V_{supply} = -12$ V†, See Note 7		−40	−70	
dv/dt	Critical Rate of Rise of Off-State Voltage	V_{DRM} = Rated V_{DRM}, $I_G = 0$, $T_C = 110°C$		500		V/µs
dv/dt	Critical Rate of Rise of Commutation Voltage	V_{DRM} = Rated V_{DRM}, $I_{TRM} = \pm 12$ A, $T_C = 85°C$, See Figure 3	5			V/µs

†The supply voltage is called positive when it causes Main Terminal 2 to be positive with respect to Main Terminal 1.

NOTES: 6. This parameter must be measured using pulse techniques. $t_w \leqslant 1$ ms, duty cycle $\leqslant 2\%$. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

7. The triacs are triggered by a 15-V (open-circuit amplitude) pulse supplied by a generator with the following characteristics: $R_G = 100\ \Omega$, $t_w = 20\ \mu s$, $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $f = 1$ kHz.

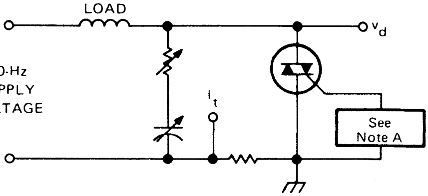
thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

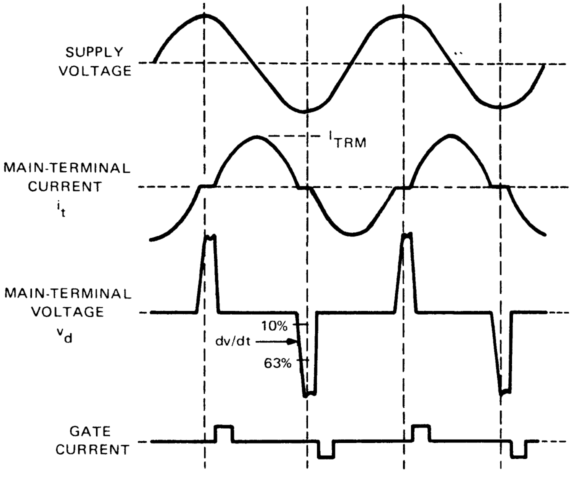
PARAMETER MEASUREMENT INFORMATION

The rate of rise of commutation voltage is defined as the slope of the line connecting the 10% and 63% test voltage points.

The critical rate of rise of commutation voltage is the rate above which the device will not sustain the off-state following conduction but will conduct current in the opposite direction in the absence of a gate-trigger signal. While this failure to switch to the off-state is not detrimental to the thyristor, it does result in loss of control of power to the load.



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1—COMMUTATING dv/dt

NOTE A: The gate-current pulse is furnished by a trigger circuit which presents essentially an open circuit between pulses. The pulse is timed so that the off-state-voltage duration is approximately 800 μs.

TIC226B, TIC226D
SILICON BIDIRECTIONAL TRIODE THYRISTORS

THERMAL INFORMATION

MAXIMUM RMS ON-STATE CURRENT
vs
CASE TEMPERATURE

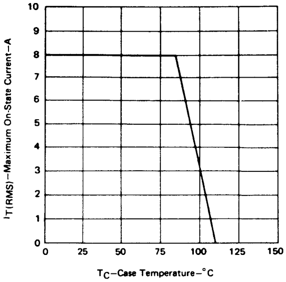


FIGURE 2

MAXIMUM AVERAGE POWER DISSIPATED
vs
RMS ON-STATE CURRENT

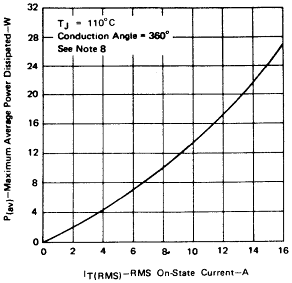


FIGURE 3

SURGE ON-STATE CURRENT
vs
CYCLES OF CURRENT DURATION

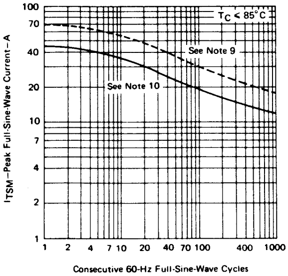


FIGURE 4

NOTES:
8. For operation at current greater than 8 amps rms, see Figure 4.
9. The dashed curve shows the maximum number of cycles of surge current recommended for safe operation provided the device is initially operating at, or below, the rated value of on-state current; however, during the surge period gate control of the device may be lost.
10. The solid curve shows the maximum number of cycles of surge current for which gate control is guaranteed provided the device is initially at nonoperating thermal equilibrium.

TYPICAL CHARACTERISTICS

PEAK GATE TRIGGER CURRENT
vs
CASE TEMPERATURE

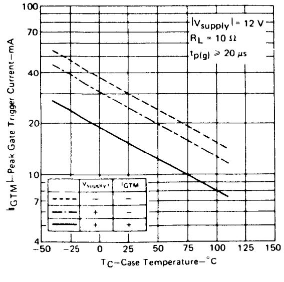


FIGURE 5

PEAK GATE TRIGGER VOLTAGE
vs
CASE TEMPERATURE

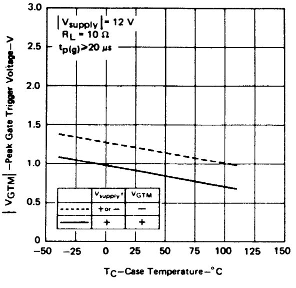


FIGURE 6

† The supply voltage is called positive when it causes Main Terminal 2 to be positive with respect to Main Terminal 1.

SERIES TIC236,TIC246
SILICON BIDIRECTIONAL TRIODE THYRISTORS

REVISED JUNE 1975

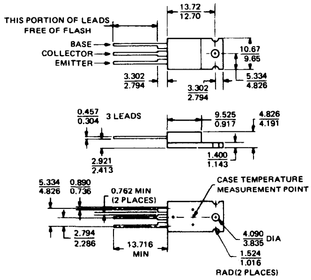
TRIACS
12 A and 16 A RMS • 200 V and 400 V

description

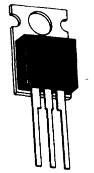
These devices are bidirectional triode thyristors (triacs) which may be triggered from the off-state by either polarity of gate signal with Main Terminal 2 at either polarity. This triac is available in the isolated tab package as a special device. For information contact a TI field sales office or Power Product Marketing, MS 51, P.O. Box 5012, Dallas, Texas 75222.

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



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

		SERIES TIC236	SERIES TIC246	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	B Suffix	200	200	V
	D Suffix	400	400	
Full-Cycle RMS On-State Current at (or below) 70°C Case Temperature, $I_{T(RMS)}$ (See Note 2)		12	16	A
Peak On-State Surge Current, Full-Sine-Wave, I_{TSM} (See Note 2)		100	125	A
Peak Gate Current, I_{GM}		±1	±1	A
Operating Case Temperature Range		−40 to 110		°C
Storage Temperature Range		−40 to 125		°C
Terminal Temperature **1.588**mm from Case for 10 Seconds		230		°C

NOTES:
1. These values apply bidirectionally for any value of resistance between the gate and Main Terminal 1.
2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 70°C derate linearly to 110°C case temperature at the rate of 300 mA/°C for Series TIC236 and 400 mA/°C for Series TIC246.
3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

†All voltage values are with respect to Main Terminal 1.

electrical characteristics at 25°C case temperature (unless otherwise noted)†

PARAMETER		TEST CONDITIONS			SERIES TIC236			SERIES TIC246			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
I_{DRM}	Repetitive Peak Off-State Current	V_{DRM} = Rated V_{DRM}, I_G = 0		T_C = 110°C			±2			±2	mA
I_{GTM}	Peak Gate Trigger Current	V_{supply} = +12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		15	50		15	50	mA
		V_{supply} = +12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		−25	−50		−25	−50	
		V_{supply} = −12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		−30	−50		−30	−50	
		V_{supply} = −12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		75			75		
V_{GTM}	Peak Gate Trigger Voltage	V_{supply} = +12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		1.2	2.5		1.2	2.5	V
		V_{supply} = +12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		−1.2	−2.5		−1.2	−2.5	
		V_{supply} = −12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		−1.2	−2.5		−1.2	−2.5	
		V_{supply} = −12 V†,	R_L = 10 Ω,	$t_{p(g)} \geq 20\ \mu s$		1.2			1.2		
V_{TM}	Peak On-State Voltage	I_{TM} = ±17 A,	I_G = 100 mA,	See Note 4			±2.1				V
		I_{TM} = ±22.5 A,	I_G = 100 mA,	See Note 4						±1.7	
I_H	Holding Current	V_{supply} = +12 V†,	I_G = 0,	Initiating I_{TM} = 150 mA			50			50	mA
		V_{supply} = −12 V†,	I_G = 0,	Initiating I_{TM} = −150 mA			−50			−50	
I_L	Latching Current	V_{supply} = +12 V†,	See Note 5			20			20		mA
		V_{supply} = −12 V†,	See Note 5			−20			−20		

†All voltage values are with respect to Main Terminal 1.

NOTES: 4. This parameter must be measured using pulse techniques. $t_w \leq 1$ ms, duty cycle $\leq 2\%$. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2 mm from the device body.

5. The triacs are triggered by a 15-V (open-circuit amplitude) pulse supplied by a generator with the following characteristics: $R_G = 100\ \Omega$, $t_w = 20\ \mu s$, $t_r \leq 15$ ns, $t_f \leq 15$ ns, f = 1 kHz.

thermal characteristics

PARAMETER		SERIES TIC236	SERIES TIC246	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2	1.9	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	62.5	

SERIES TIC253, TIC263
SILICON BIDIRECTIONAL TRIODE THYRISTORS

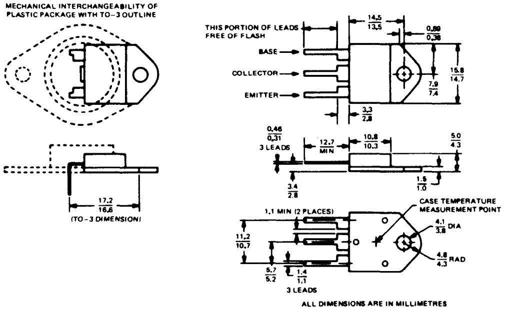
TRIACS
20 A and 25 A RMS • 200 V, 400 V, 500 V, and 600 V

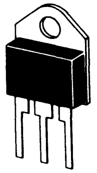
description

These devices are bidirectional triode thyristors (triacs) which may be triggered from the off-state by either polarity of gate signal with Main Terminal 2 at either polarity.

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





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

		SERIES TIC253	SERIES TIC263	UNIT
Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	B Suffix	200	200	V
	D Suffix	400	400	
	E Suffix	500	500	
	M Suffix	600	600	
Full-Cycle RMS On-State Current at (or below) 70°C Case Temperature, $I_{T(RMS)}$ (See Note 2)		20	25	A
Peak On-State Surge Current, Full-Sine-Wave, I_{TSM} (See Note 3)		150	175	A
Peak Gate Current, I_{GM}		±1	±1	A
Operating Case Temperature Range		−40 to 110		°C
Storage Temperature Range		−40 to 125		°C
Terminal Temperature 1.588mm from Case for 10 Seconds		230		°C

NOTES:
1. These values apply bidirectionally for any value of resistance between the gate and Main Terminal 1.
2. This value applies for 50-Hz to 60-Hz full-sine-wave operation with resistive load. Above 70°C derate linearly to 110°C case temperature at the rate of 500 mA/°C for Series TIC253 and 625 mA/°C for Series TIC263.
3. This value applies for one 60-Hz full sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

†All voltage values are with respect to Main Terminal 1.

electrical characteristics at 25°C case temperature (unless otherwise noted)†

PARAMETER		TEST CONDITIONS	SERIES TIC253			SERIES TIC263			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
I_{DRM}	Repetitive Peak Off-State Current	V_{DRM} = Rated V_{DRM}, $I_G = 0$ T_C = 110°C			±2			±2	mA
I_{GTM}	Peak Gate Trigger Current	V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			50			50	mA
		V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−50			−50	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−50			−50	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$		50			50		
V_{GTM}	Peak Gate Trigger Voltage	V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			2.5			2.5	V
		V_{supply} = +12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−2.5			−2.5	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$			−2.5			−2.5	
		V_{supply} = −12 V†, R_L = 10 Ω, $t_{p(g)} \geqslant 20\ \mu s$		1.2			1.2		
V_{TM}	Peak On-State Voltage	I_{TM} = ±28.2 A, I_G = 100 mA, See Note 4			±1.7				V
		I_{TM} = 35.2 A, I_G = 100 mA, See Note 4						±1.7	
I_H	Holding Current	V_{supply} = +12 V†, $I_G = 0$, Initiating I_{TM} = 100 mA			50			50	mA
		V_{supply} = −12 V†, $I_G = 0$, Initiating I_{RM} = −100 mA			−50			−50	
I_L	Latching Current	V_{supply} = +12 V†, See Note 5		20			20		mA
		V_{supply} = −12 V†, See Note 5		−20			−20		

†All voltage values are with respect to Main Terminal 1.

NOTES: 4. This parameter must be measured using pulse techniques. $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.175 mm from the device body.

5. The triacs are triggered by a 15-V (open-circuit amplitude) pulse supplied by a generator with the following characteristics: R_G = 100 Ω, t_w = 20 μs, $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, f = 1 kHz.

thermal characteristics

PARAMETER		SERIES TIC253	SERIES TIC263	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.52	1.22	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	36	36	

TIP29,TIP29A,TIP29B,TIP29C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

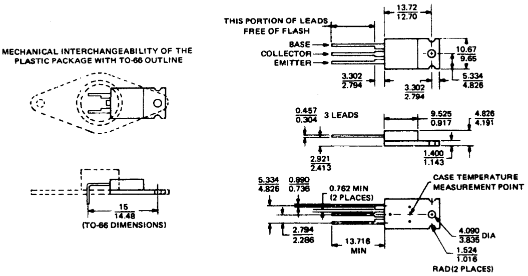
REVISED APRIL 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP30, TIP30A, TIP30B, TIP30C

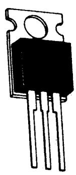
- **30 W at 25° C Case Temperature**
- **1 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 200 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP29	TIP29A	TIP29B	TIP29C
Collector-Base Voltage	40 V	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V	100 V
Emitter-Base Voltage	5 V			
Continuous Collector Current	1 A			
Peak Collector Current (See Note 2)	3 A			
Continuous Base Current	0.4 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	30 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	32 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.24 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP29,TIP29A,TIP29B,TIP29C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP29		TIP29A		TIP29B		TIP29C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	40		60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		0.3		0.3					mA
		V_{CE} = 60 V, I_B = 0						0.3		0.3	
I_{CES}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = 0		0.2							mA
		V_{CE} = 60 V, V_{BE} = 0				0.2					
		V_{CE} = 80 V, V_{BE} = 0						0.2			
		V_{CE} = 100 V, V_{BE} = 0								0.2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 0.2 A, See Notes 6 and 7	40		40		40		40		
		V_{CE} = 4 V, I_C = 1 A, See Notes 6 and 7	15	75	15	75	15	75	15	75	
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 1 A, See Notes 6 and 7		1.3		1.3		1.3		1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 125 mA, I_C = 1 A, See Notes 6 and 7		0.7		0.7		0.7		0.7	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

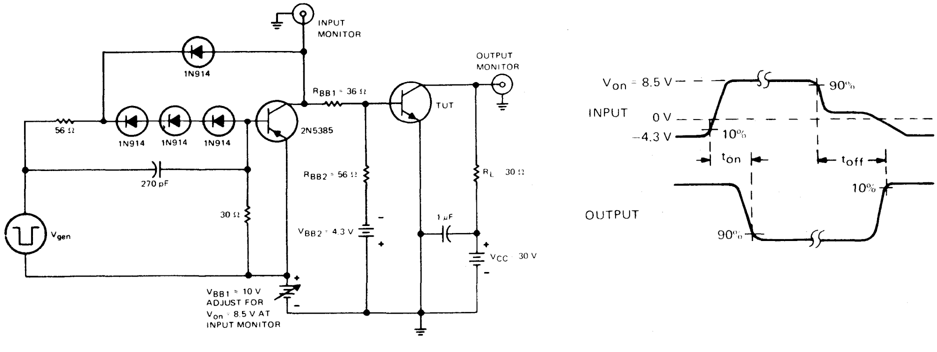
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	4.17	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA,	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.3 V, R_L = 30 Ω, See Figure 1	2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.

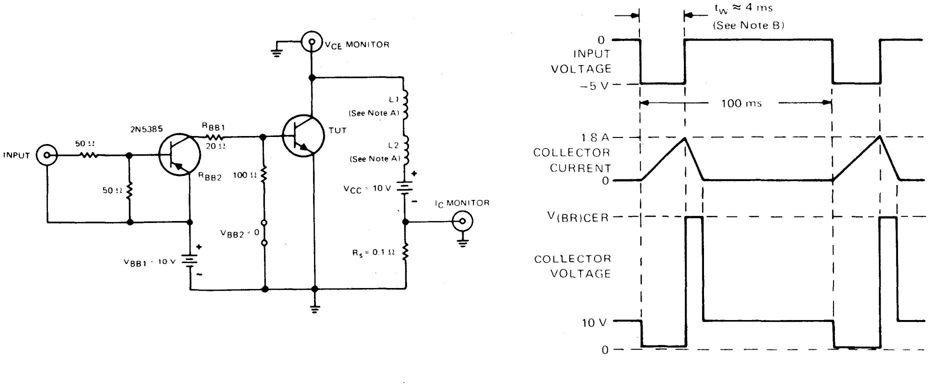
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES: A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.

B. Input pulse width is increased until $I_{CM} = 1.8$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

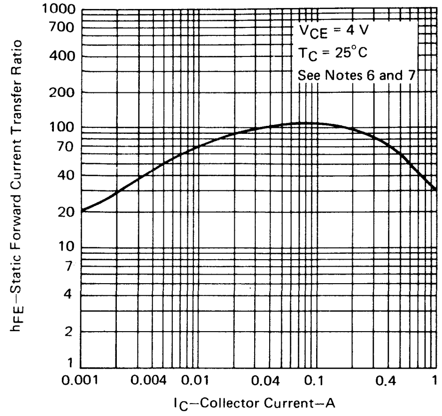


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

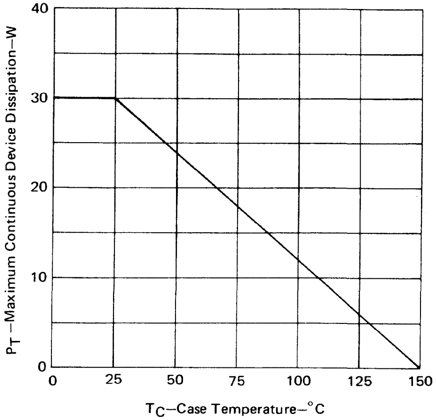


FIGURE 4

MAXIMUM SAFE OPERATING REGION

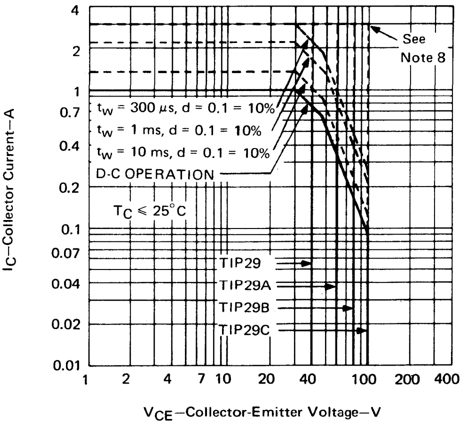


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP30,TIP30A,TIP30B,TIP30C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

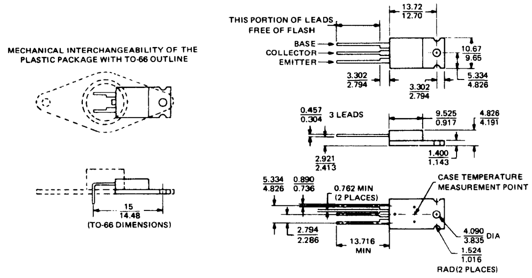
REVISED APRIL 1975

For Power-Amplifier and High-Speed-Switching Applications
Designed for Complementary use with TIP29, TIP29A, TIP29B, TIP29C

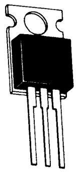
- **30W at 25°C Case Temperature**
- **1A Rated Collector Current**
- **Min f_T of 3MHz at 10V, 200mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP30	TIP30A	TIP30B	TIP30C
Collector-Base Voltage	−40 V	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V			
Continuous Collector Current	−1 A			
Peak Collector Current (See Note 2)	−3 A			
Continuous Base Current	−0.4 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	30 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	32 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.24 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP30,TIP30A,TIP30B,TIP30C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP30		TIP30A		TIP30B		TIP30C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−40		−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.3		−0.3					mA
		$V_{CE} = -60$ V, $I_B = 0$						−0.3		−0.3	
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.2							mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.2					
		$V_{CE} = -80$ V, $V_{BE} = 0$						−0.2			
		$V_{CE} = -100$ V, $V_{BE} = 0$								−0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -0.2$ A, See Notes 6 and 7	40		40		40		40		
		$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 6 and 7	15	75	15	75	15	75	15	75	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 6 and 7		−1.3		−1.3		−1.3		−1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -125$ mA, $I_C = -1$ A, See Notes 6 and 7		−0.7		−0.7		−0.7		−0.7	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.2$ A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.2$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.

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

thermal characteristics

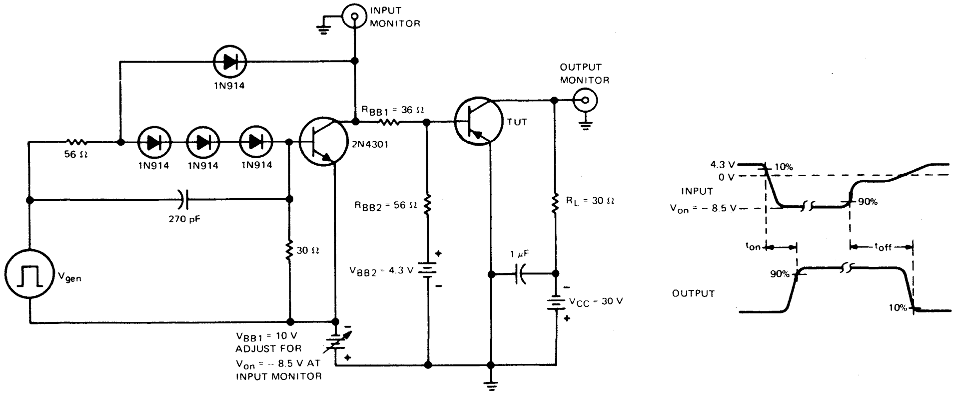
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	4.17	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -100$ mA, $I_{B(2)} = 100$ mA,	0.3	µs
t_{off}	Turn-Off Time	$V_{BE(off)} = 4.3$ V, $R_L = 30\ \Omega$, See Figure 1	1.0	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

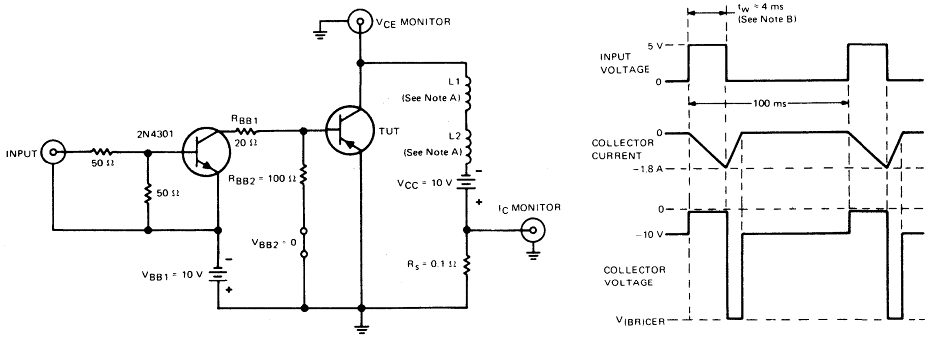


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ≤ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
- A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
- B. Input pulse width is increased until $I_{CM} = -1.8$ A.

FIGURE 2

TIP30,TIP30A,TIP30B,TIP30C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

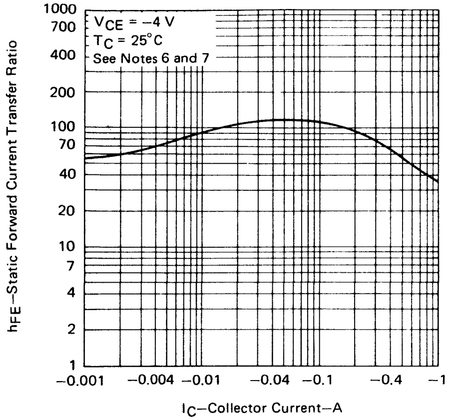


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

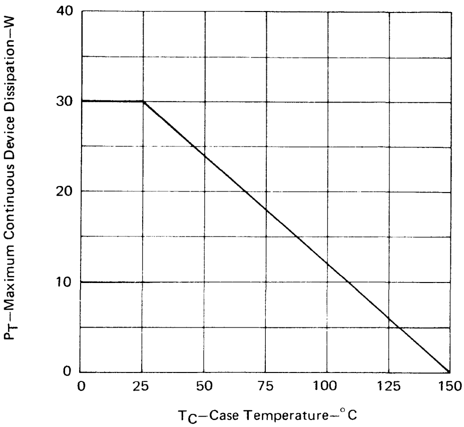


FIGURE 4

MAXIMUM SAFE OPERATING REGION

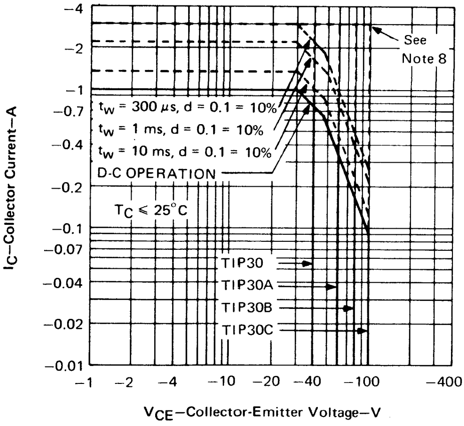


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

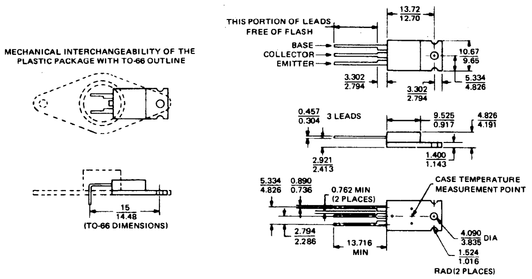
TIP31,TIP31A,TIP31B,TIP31C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

REVISED APRIL 1975

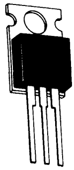
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP32, TIP32A, TIP32B, TIP32C

- **40 W at 25°C Case Temperature**
- **3 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP31	TIP31A	TIP31B	TIP31C
Collector-Base Voltage	40 V	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V	100 V
Emitter-Base Voltage	5 V			
Continuous Collector Current	3 A			
Peak Collector Current (See Note 2)	5 A			
Continuous Base Current	1 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	40 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	32 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.32W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP31,TIP31A,TIP31B,TIP31C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP31		TIP31A		TIP31B		TIP31C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	40		60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		0.3		0.3					mA
		V_{CE} = 60 V, I_B = 0						0.3		0.3	
I_{CES}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = 0		0.2							mA
		V_{CE} = 60 V, V_{BE} = 0				0.2					
		V_{CE} = 80 V, V_{BE} = 0						0.2			
		V_{CE} = 100 V, V_{BE} = 0								0.2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 1 A, See Notes 6 and 7	25		25		25		25		
		V_{CE} = 4 V, I_C = 3 A, See Notes 6 and 7	10	50	10	50	10	50	10	50	
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 3 A, See Notes 6 and 7		1.8		1.8		1.8		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 375 mA, I_C = 3 A, See Notes 6 and 7		1.2		1.2		1.2		1.2	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

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

thermal characteristics

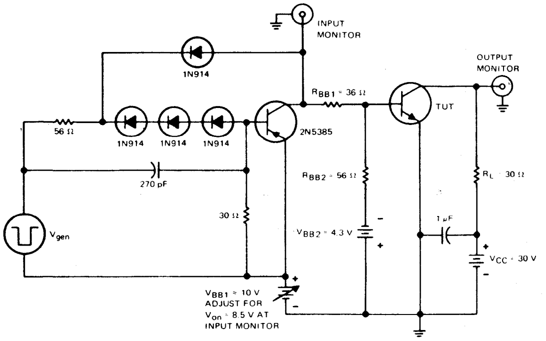
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.125	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

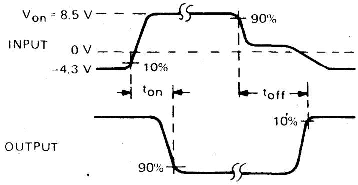
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA,	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.3 V, R_L = 30 Ω, See Figure 1	2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



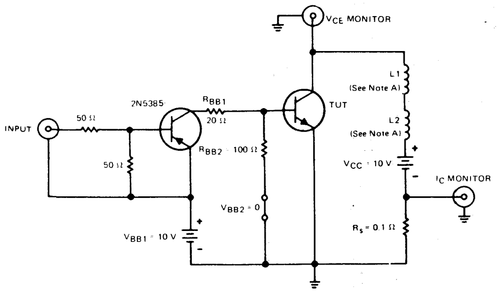


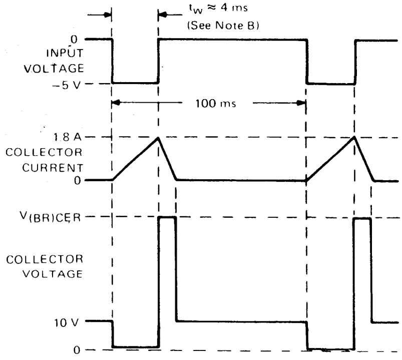
TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50$ Ω, $t_w = 20$ μs, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING





TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES: A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
B. Input pulse width is increased until $I_{CM} = 1.8$ A.

FIGURE 2

TIP31,TIP31A,TIP31B,TIP31C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

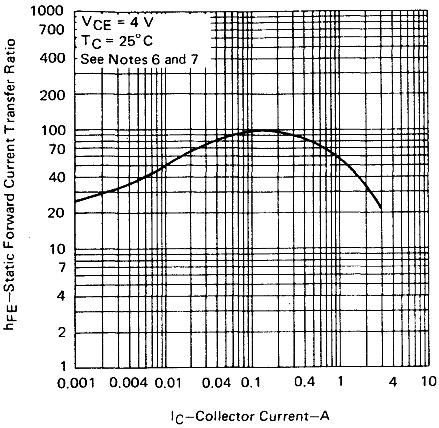


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

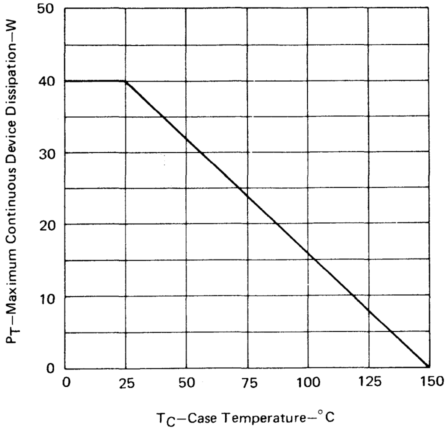


FIGURE 4

MAXIMUM SAFE OPERATING REGION

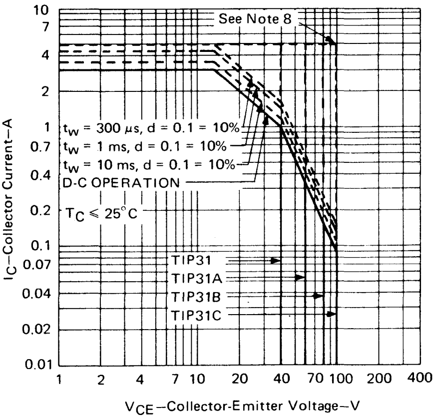


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP32,TIP32A,TIP32B,TIP32C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

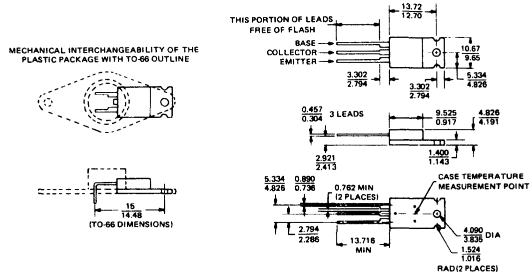
REVISED APRIL 1975

For Power-Amplifier and High-Speed-Switching Applications
Designed for Complementary use with TIP31, TIP31A, TIP31B, TIP31C

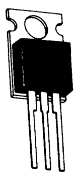
- **40W at 25°C Case Temperature**
- **3A Rated Collector Current**
- **Min f_T of 3 MHz at 10V, 500mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP32	TIP32A	TIP32B	TIP32C
Collector-Base Voltage	−40 V	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V			
Continuous Collector Current	−3 A			
Peak Collector Current (See Note 2)	−5 A			
Continuous Base Current	−1 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	40 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	32 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.32 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB1} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 10 V. Energy ≈ $I_C^2L/2$.

TIP32,TIP32A,TIP32B,TIP32C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP32		TIP32A		TIP32B		TIP32C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−40		−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.3		−0.3					mA
		$V_{CE} = -60$ V, $I_B = 0$						−0.3		−0.3	
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.2							mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.2					
		$V_{CE} = -80$ V, $V_{BE} = 0$						−0.2			
		$V_{CE} = -100$ V, $V_{BE} = 0$								−0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 6 and 7	25		25		25		25		
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 6 and 7	10		10		10		10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 6 and 7		−1.8		−1.8		−1.8		−1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -375$ mA, $I_C = -3$ A, See Notes 6 and 7		−1.2		−1.2		−1.2		−1.2	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leq 2\%$.

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

thermal characteristics

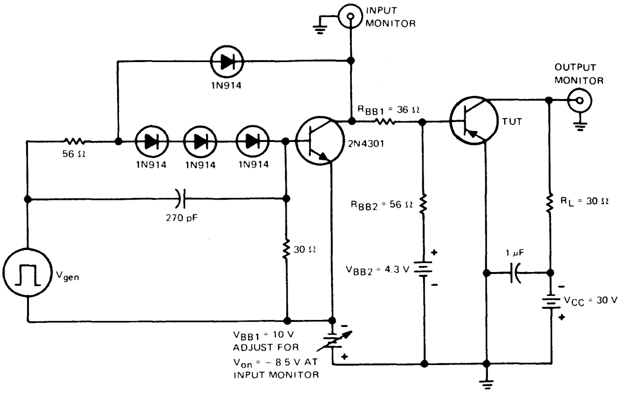
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.125	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

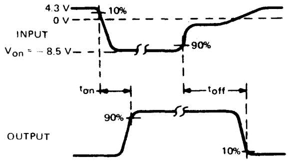
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -100$ mA, $I_{B(2)} = 100$ mA, $V_{BE(off)} = 4.3$ V, $R_L = 30\ \Omega$, See Figure 1	0.3	μs
t_{off}	Turn-Off Time		1.0	

†Voltages and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

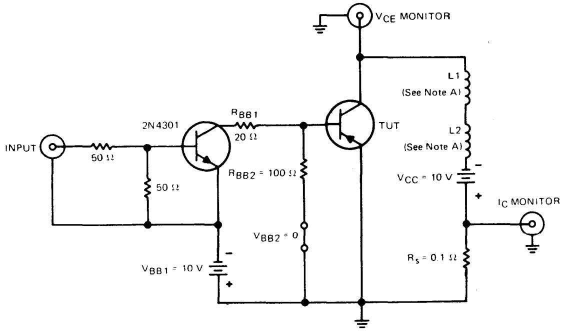


VOLTAGE WAVEFORMS

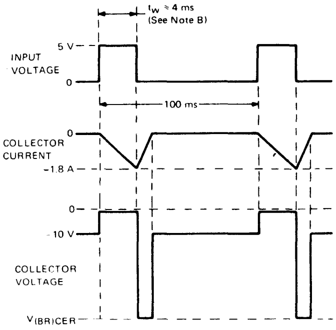
NOTES:
- A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTES:
- A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
- B. Input pulse width is increased until $I_{CM} = -1.8$ A.

FIGURE 2

TIP32,TIP32A,TIP32B,TIP32C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

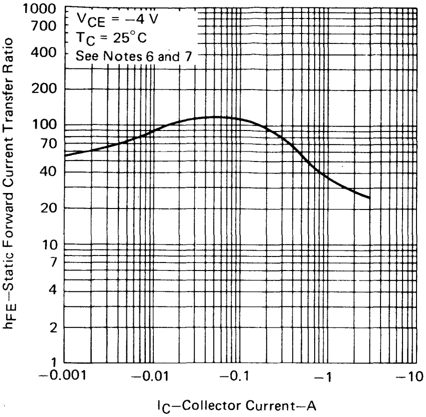


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

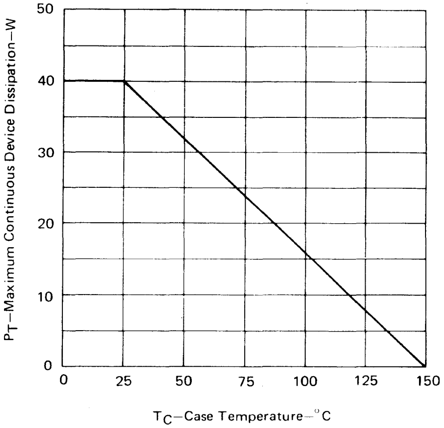


FIGURE 4

MAXIMUM SAFE OPERATING REGION

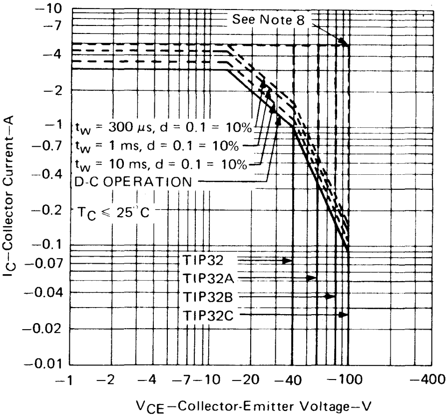


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP33,TIP33A,TIP33B,TIP33C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

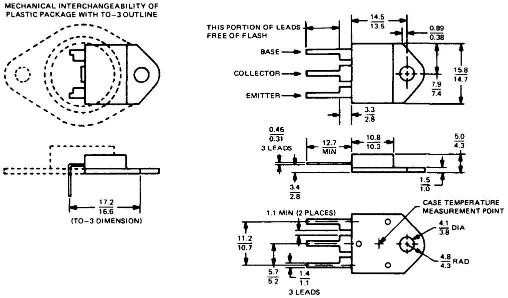
REVISED APRIL 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP34, TIP34A, TIP34B, TIP34C

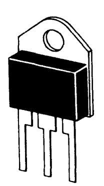
- **80 W at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP33	TIP33A	TIP33B	TIP33C
Collector-Base Voltage	40 V	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V	100 V
Emitter-Base Voltage	5 V			
Continuous Collector Current	10 A			
Peak Collector Current (See Note 2)	15 A			
Continuous Base Current	3 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	80 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W			
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.64 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP33,TIP33A,TIP33B,TIP33C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP33		TIP33A		TIP33B		TIP33C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 6	40		60		80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7		0.7					mA
		$V_{CE} = 60$ V, $I_B = 0$						0.7		0.7	
I_{CES}	Collector Cutoff Current	$V_{CE} = 40$ V, $V_{BE} = 0$		0.4							mA
		$V_{CE} = 60$ V, $V_{BE} = 0$				0.4					
		$V_{CE} = 80$ V, $V_{BE} = 0$						0.4			
		$V_{CE} = 100$ V, $V_{BE} = 0$								0.4	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, See Notes 6 and 7	40		40		40		40		
		$V_{CE} = 4$ V, $I_C = 3$ A, See Notes 6 and 7	20	100	20	100	20	100	20	100	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 3$ A, See Notes 6 and 7		1.6		1.6		1.6		1.6	V
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 6 and 7		3		3		3		3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.3$ A, $I_C = 3$ A, See Notes 6 and 7		1		1		1		1	V
		$I_B = 2.5$ A, $I_C = 10$ A, See Notes 6 and 7		4		4		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle $\leq 2\%$.

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

thermal characteristics

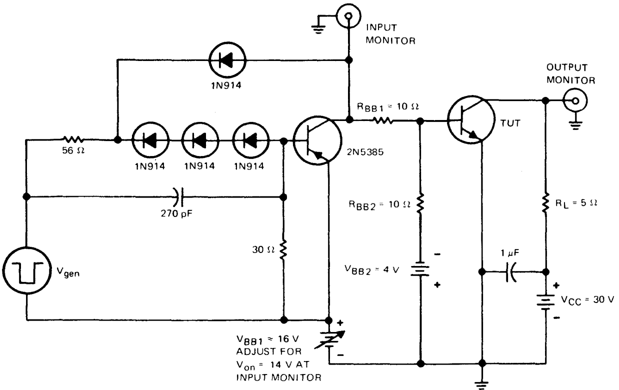
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.56	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

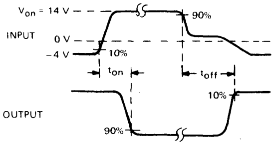
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 6$ A, $I_{B(1)} = 0.6$ A, $I_{B(2)} = -0.6$ A,	0.6	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4$ V, $R_L = 5\ \Omega$, See Figure 1	1	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.

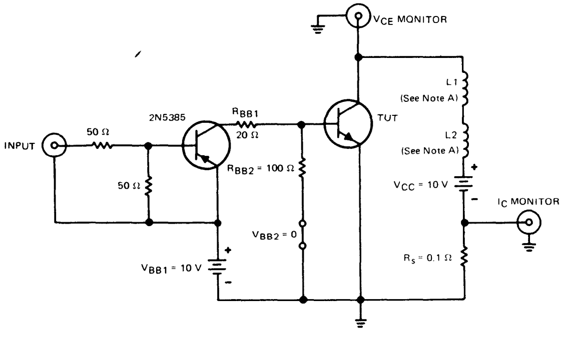
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

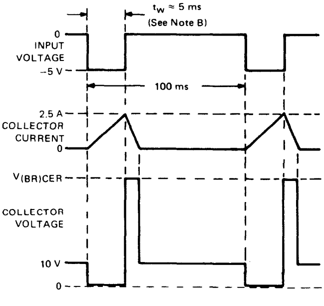
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTES: A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.

B. Input pulse width is increased until I_{CM} = 2.5 A.

FIGURE 2

TIP33,TIP33A,TIP33B,TIP33C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

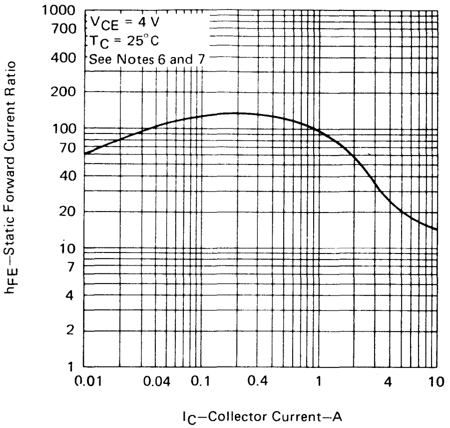


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

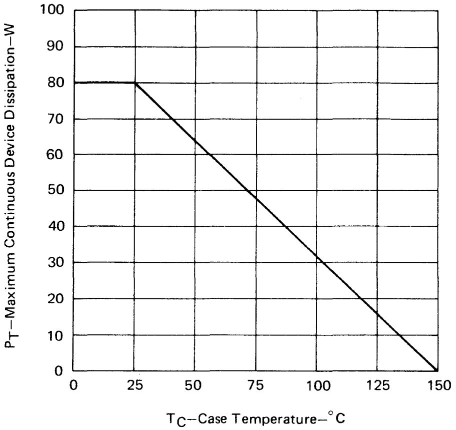


FIGURE 4

MAXIMUM SAFE OPERATING REGION

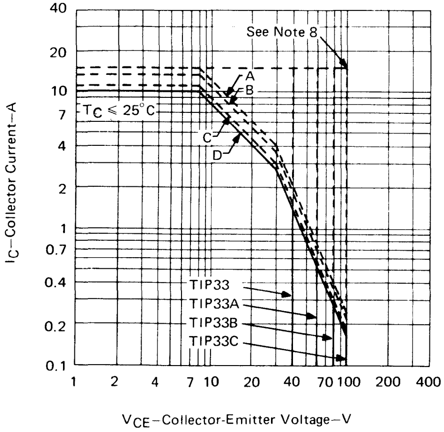


FIGURE 5

KEY FOR FIGURE 5

CURVE	CONDITIONS
A	t_w = 300 μs, d = 0.1 = 10%
B	t_w = 1 ms, d = 0.1 = 10%
C	t_w = 10 ms, d = 0.1 = 10%
D	D-C OPERATION

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP34,TIP34A,TIP34B,TIP34C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

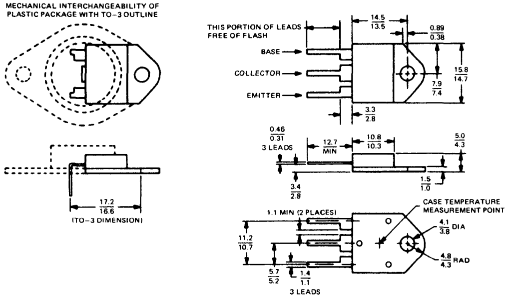
REVISED APRIL 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP33, TIP33A, TIP33B, TIP33C

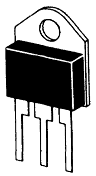
- **80 W at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP34	TIP34A	TIP34B	TIP34C
Collector-Base Voltage	−40 V	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V			
Continuous Collector Current	−10 A			
Peak Collector Current (See Note 2)	−15 A			
Continuous Base Current	−3 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	80 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W			
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:

1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.64 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\Omega$ $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx 1/2\ I_C{}^2 L/2$.

TIP34,TIP34A,TIP34B,TIP34C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP34		TIP34A		TIP34B		TIP34C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−40		−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.7		−0.7					mA
		$V_{CE} = -60$ V, $I_B = 0$						−0.7		−0.7	
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.4							mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.4					
		$V_{CE} = -80$ V, $V_{BE} = 0$						−0.4			
		$V_{CE} = -100$ V, $V_{BE} = 0$								−0.4	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 6 and 7	40		40		40		40		
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 6 and 7	20	100	20	100	20	100	20	100	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 6 and 7		−1.6		−1.6		−1.6		−1.6	V
		$V_{CE} = -4$ V, I_C −10 A, See Notes 6 and 7		−3		−3		−3		−3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.3$ A, $I_C = -3$ A, See Notes 6 and 7		−1		−1		−1		−1	V
		$I_B = -2.5$ A, $I_C = -10$ A, See Notes 6 and 7		−4		−4		−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.

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

thermal characteristics

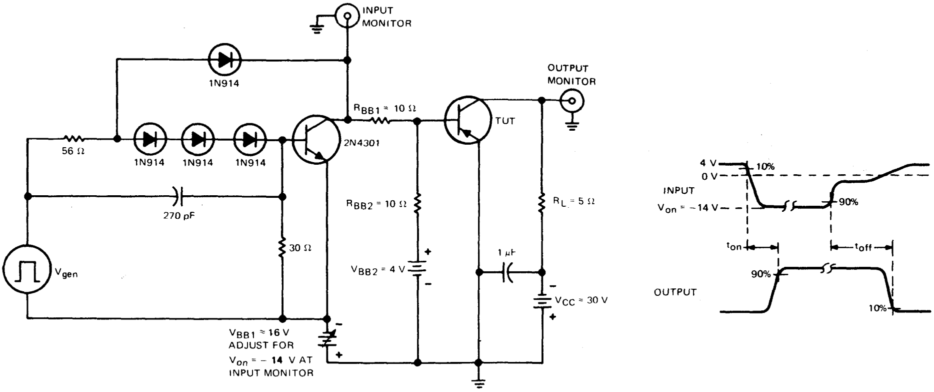
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.56	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = -6$ A,	$I_{B(1)} = -0.6$ A,	$I_{B(2)} = 0.6$ A,	0.4	µs
t_{off}	Turn-Off Time	$V_{BE(off)} = 4$ V,	$R_L = 5\ \Omega$,	See Figure 1	0.7	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant$ 15 ns, $t_f \leqslant$ 15 ns, Z_{out} = 50 Ω, t_w = 20 µs, duty cycle ⩽ 2%.

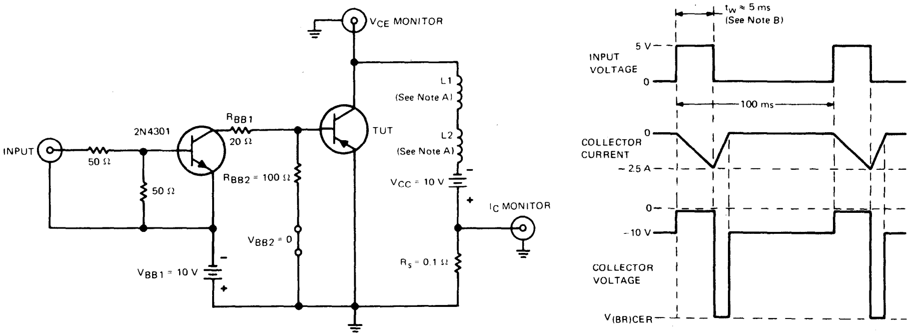
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant$ 15 ns, $R_{in} \geqslant$ 10 MΩ, $C_{in} \leqslant$ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTES: A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.

B. Input pulse width is increased until I_{CM} = −2.5 A.

FIGURE 2

TIP34,TIP34A,TIP34B,TIP34C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

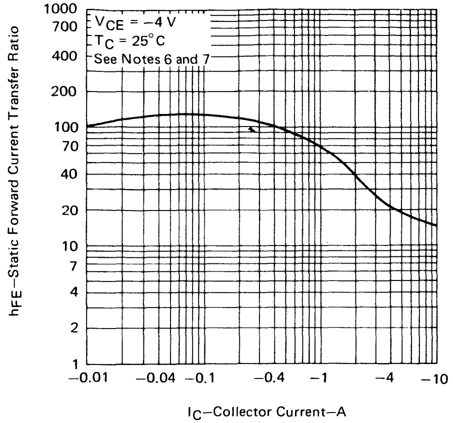


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques, t_w = 300 μs, duty cycle ⩽ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

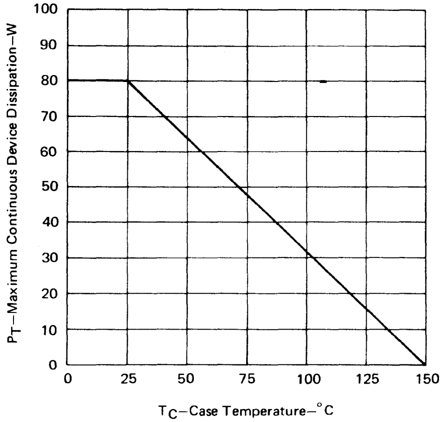


FIGURE 4

MAXIMUM SAFE OPERATING REGION

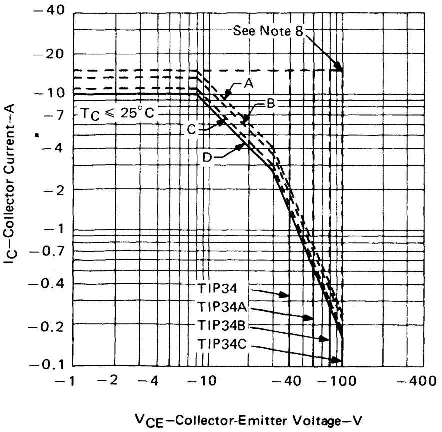


FIGURE 5

KEY FOR FIGURE 5

CURVE	CONDITIONS
A	t_w = 300 μs, d = 0.1 = 10%
B	t_w = 1 ms, d = 0.1 = 10%
C	t_w = 10 ms, d = 0.1 = 10%
D	D-C OPERATION

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP35,TIP35A,TIP35B,TIP35C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

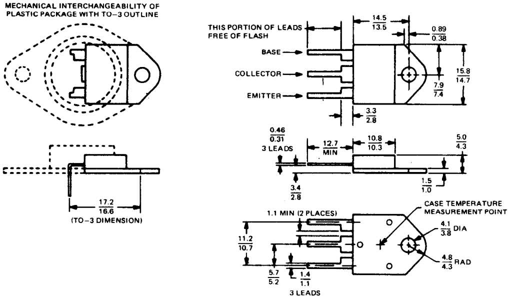
REVISED APRIL 1975

**FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP36, TIP36A, TIP36B, TIP36C**

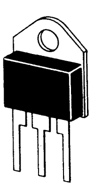
- **125 W at 25°C Case Temperature**
- **25 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP35	TIP35A	TIP35B	TIP35C
Collector-Base Voltage	40 V	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V	100 V
Emitter-Base Voltage	5 V			
Continuous Collector Current	25 A			
Peak Collector Current (See Note 2)	40 A			
Continuous Base Current	5 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	125 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W			
Unclamped Inductive Load Energy (See Note 5)	90 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 1 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP35,TIP35A,TIP35B,TIP35C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP35		TIP35A		TIP35B		TIP35C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	40		60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		1		1					mA
		V_{CE} = 60 V, I_B = 0						1		1	
I_{CES}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = 0		0.7							mA
		V_{CE} = 60 V, V_{BE} = 0				0.7					
		V_{CE} = 80 V, V_{BE} = 0						0.7			
		V_{CE} = 100 V, V_{BE} = 0								0.7	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 1.5 A, See Notes 6 and 7	25		25		25		25		
		V_{CE} = 4 V, I_C = 15 A, See Notes 6 and 7	10	50	10	50	10	50	10	50	
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 15 A, See Notes 6 and 7		2		2		2		2	V
		V_{CE} = 4 V, I_C = 25 A, See Notes 6 and 7		4		4		4		4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.5 A, I_C = 15 A, See Notes 6 and 7		1.8		1.8		1.8		1.8	V
		I_B = 5 A, I_C = 25 A, See Notes 6 and 7		4		4		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 kHz	25		25		25		25		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

thermal characteristics

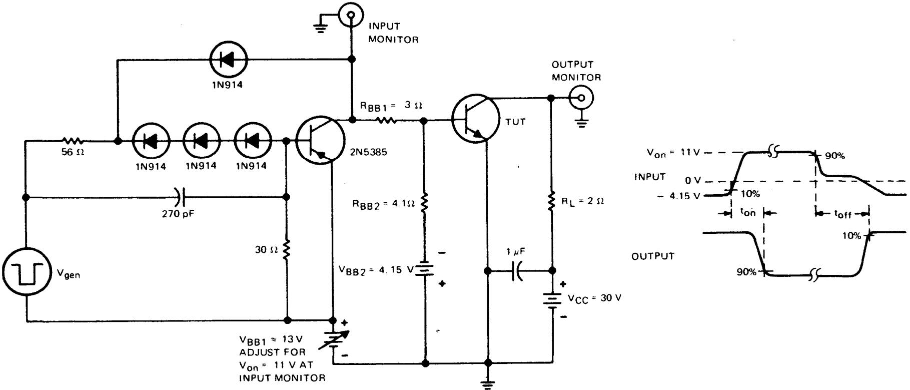
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	I_C = 15 A,	$I_{B(1)}$ = 1.5 A,	$I_{B(2)}$ = −1.5 A,	1.2	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.15 V,	R_L = 2 Ω,	See Figure 1	0.9	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



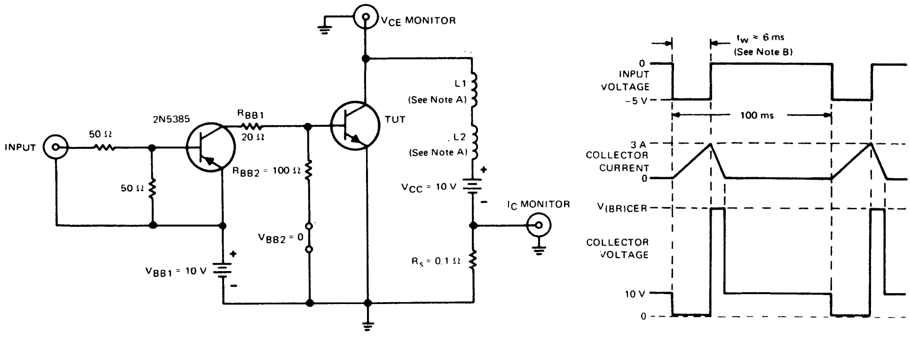
TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ≤ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTES:
- A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
- B. Input pulse width is increased until I_{CM} = 3 A.

FIGURE 2

TIP35,TIP35A,TIP35B,TIP35C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

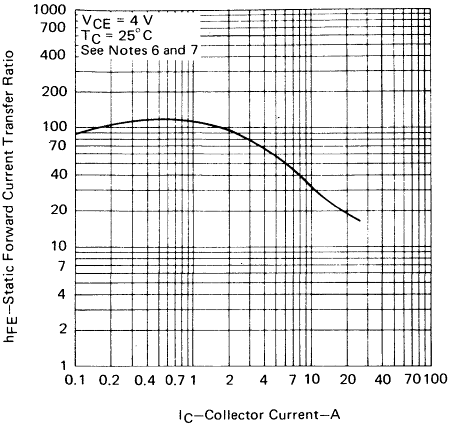


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

THERMAL INFORMATION

DISSIPATION DERATING CURVE

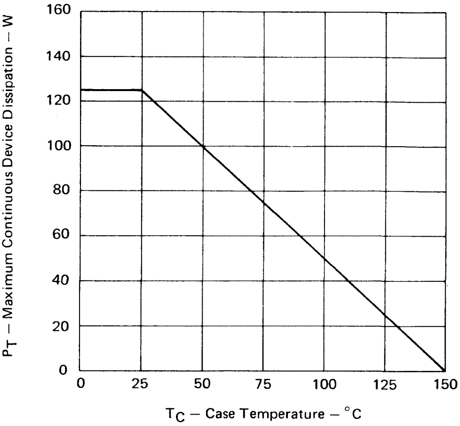


FIGURE 4

MAXIMUM SAFE OPERATING REGION

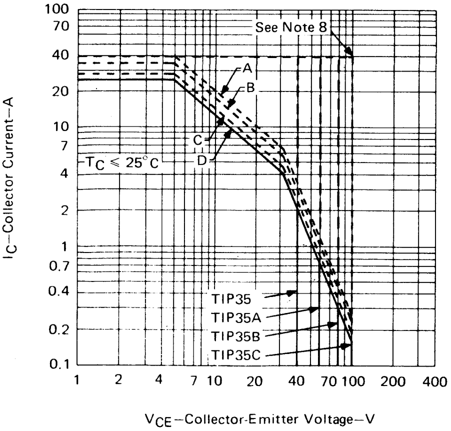


FIGURE 5

KEY FOR FIGURE 5

CURVE	CONDITIONS
A	t_w = 300 μs, d = 0.1 = 10%
B	t_w = 1 ms, d = 0.1 = 10%
C	t_w = 10 ms, d = 0.1 = 10%
D	D-C OPERATION

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP36,TIP36A,TIP36B,TIP36C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

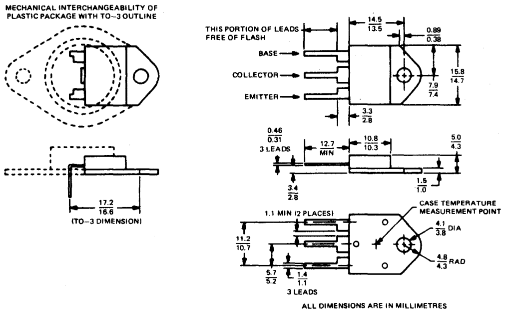
REVISED APRIL 1975

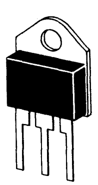
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP35, TIP35A, TIP35B, TIP35C

- **125 W at 25°C Case Temperature**
- **25 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 1 A**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP36	TIP36A	TIP36B	TIP36C
Collector-Base Voltage	−40 V	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V			
Continuous Collector Current	−25 A			
Peak Collector Current (See Note 2)	−40 A			
Continuous Base Current	−5 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	125 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W			
Unclamped Inductive Load Energy (See Note 5)	90 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 1 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C^2 L/2$.

TIP36,TIP36A,TIP36B,TIP36C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP36		TIP36A		TIP36B		TIP36C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−40		−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−1		−1					mA
		$V_{CE} = -60$ V, $I_B = 0$						−1		−1	
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.7							mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.7					
		$V_{CE} = -80$ V, $V_{BE} = 0$						−0.7			
		$V_{CE} = -100$ V, $V_{BE} = 0$								−0.7	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1.5$ A, See Notes 6 and 7	25		25		25		25		
		$V_{CE} = -4$ V, $I_C = -15$ A, See Notes 6 and 7	10	50	10	50	10	50	10	50	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -15$ A, See Notes 6 and 7		−2		−2		−2		−2	V
		$V_{CE} = -4$ V, $I_C = -25$ A, See Notes 6 and 7		−4		−4		−4		−4	
$V_{CE(sat)}$	Collector-Emitter Voltage	$I_B = -1.5$ A, $I_C = -15$ A, See Notes 6 and 7		−1.8		−1.8		−1.8		−1.8	V
		$I_B = -5$ A, $I_C = -25$ A, See Notes 6 and 7		−4		−4		−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 kHz	25		25		25		25		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leqslant 2\%$.

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

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -15$ A, $I_{B(1)} = -1.5$ A, $I_{B(2)} = 1.5$ A,	1.1	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 4.15$ V, $R_L = 2\ \Omega$, See Figure 1	0.8	

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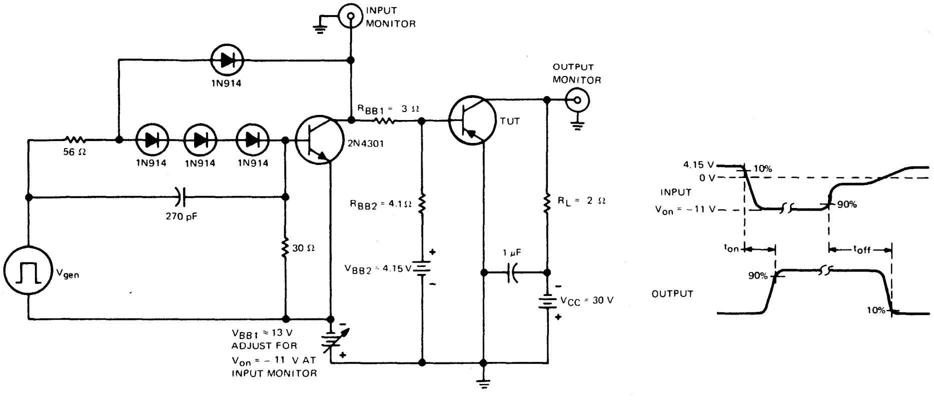
†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

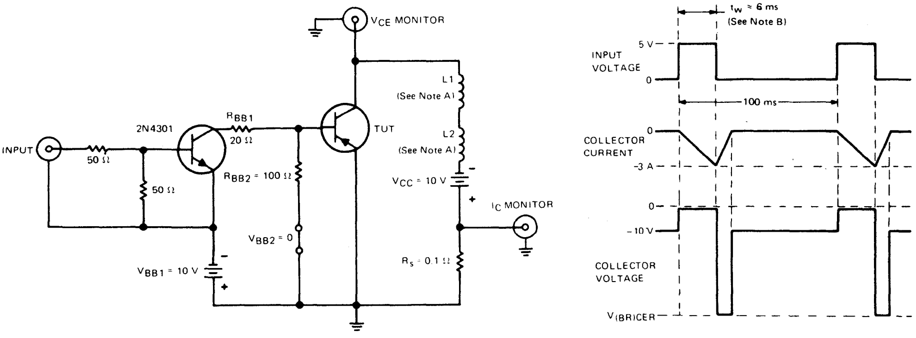


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ≤ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
B. Input pulse width is increased until $I_{CM} = -3$ A.

FIGURE 2

TIP36,TIP36A,TIP36B,TIP36C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

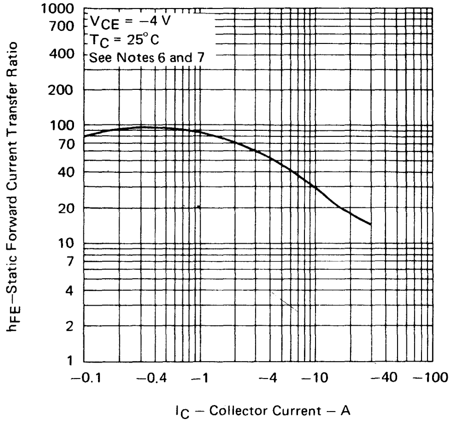


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

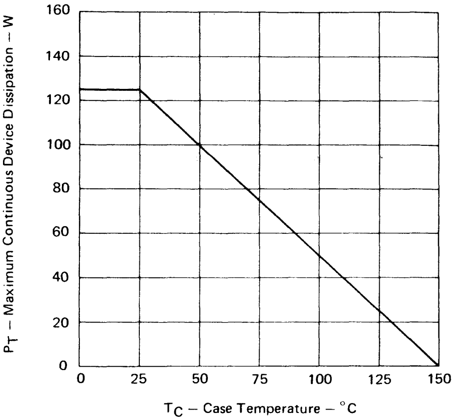


FIGURE 4

MAXIMUM SAFE OPERATING REGION

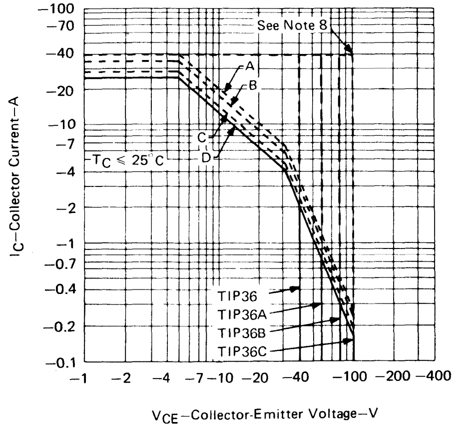


FIGURE 5

KEY FOR FIGURE 5

CURVE	CONDITIONS
A	t_w = 300 μs, d = 0.1 = 10%
B	t_w = 1 ms, d = 0.1 = 10%
C	t_w = 10 ms, d = 0.1 = 10%
D	D-C OPERATION

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP41,TIP41A,TIP41B,TIP41C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

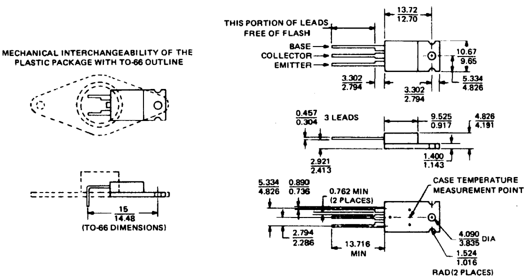
REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP42, TIP42A, TIP42B, TIP42C
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

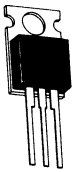
- **65 W at 25°C Case Temperature**
- **6 A Rated Collector Current**
- **Min f_T of 3 MHz at 10 V, 500 mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP41	TIP41A	TIP41B	TIP41C
Collector-Base Voltage	40 V	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V	100 V
Emitter-Base Voltage	◄— 5 V —►			
Continuous Collector Current	◄— 6 A —►			
Peak Collector Current (See Note 2)	◄— 10 A —►			
Continuous Base Current	◄— 3 A —►			
Safe Operating Region at (or below) 25°C Case Temperature	◄— See Figure 5 —►			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄— 65 W —►			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 2 W —►			
Unclamped Inductive Load Energy (See Note 5)	◄— 62.5 mJ —►			
Operating Collector Junction Temperature Range	◄— −65°C to 150°C —►			
Storage Temperature Range	◄— −65°C to 150°C —►			
Lead Temperature 3.2mm from Case for 10 Seconds	◄— 260°C —►			

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.52 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 20 mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP41,TIP41A,TIP41B,TIP41C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP41		TIP41A		TIP41B		TIP41C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	40		60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		0.7		0.7					mA
		V_{CE} = 60 V, I_B = 0						0.7		0.7	
I_{CES}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = 0		0.4							mA
		V_{CE} = 60 V, V_{BE} = 0				0.4					
		V_{CE} = 80 V, V_{BE} = 0						0.4			
		V_{CE} = 100 V, V_{BE} = 0								0.4	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 0.3 A, See Notes 6 and 7	30		30		30		30		
		V_{CE} = 4 V, I_C = 3 A, See Notes 6 and 7	15	75	15	75	15	75	15	75	
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 6 A, See Notes 6 and 7		2		2		2		2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.6 A, I_C = 6 A, See Notes 6 and 7		1.5		1.5		1.5		1.5	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

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

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.92	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 6 A, $I_{B(1)}$ = 0.6 A, $I_{B(2)}$ = −0.6 A, $V_{BE(off)}$ = −4 V, R_L = 5 Ω, See Figure 1	0.6	μs
t_{off}	Turn-Off Time		1	

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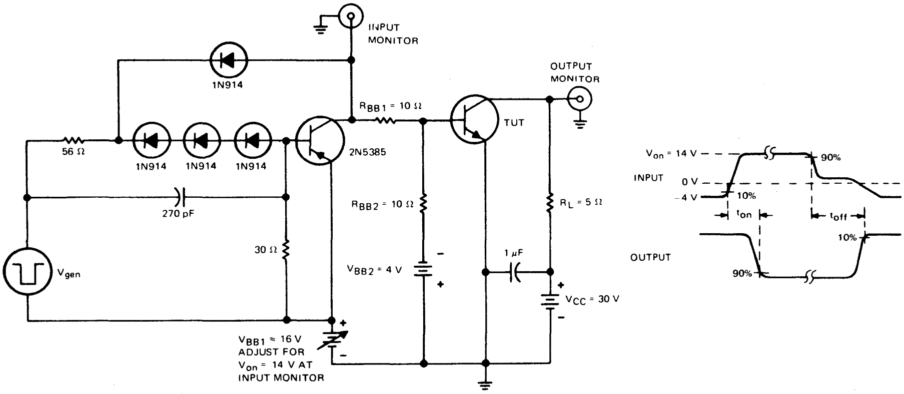
† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

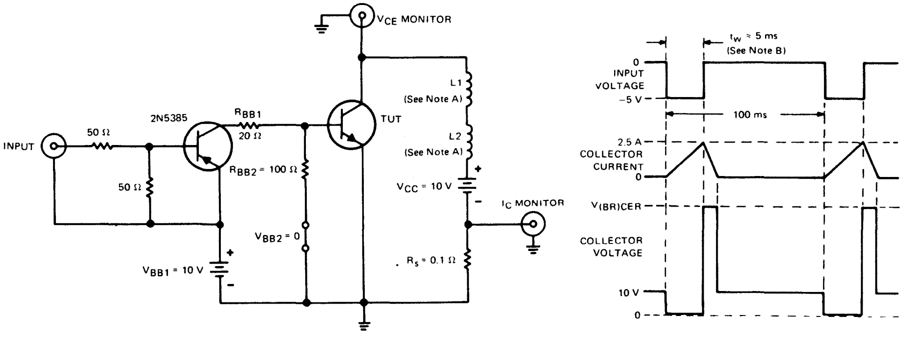


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
- A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
- B. Input pulse width is increased until I_{CM} = 2.5 A.

FIGURE 2

TIP41,TIP41A,TIP41B,TIP41C
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

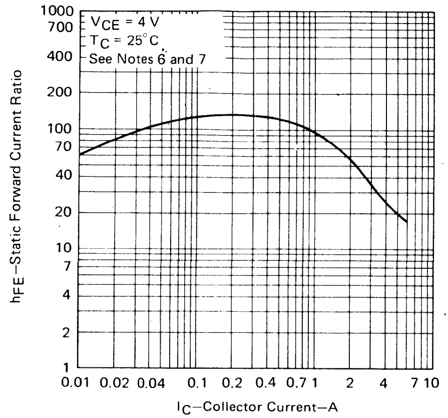


FIGURE 3

NOTES:
6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

THERMAL INFORMATION

DISSIPATION DERATING CURVE

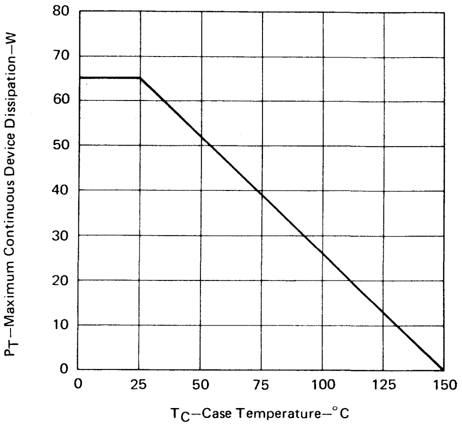


FIGURE 4

MAXIMUM SAFE OPERATING REGION

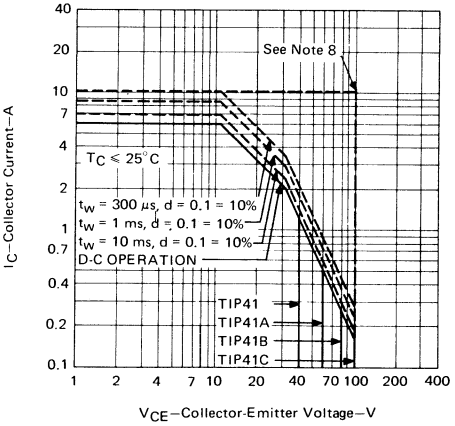


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP42, TIP42A, TIP42B, TIP42C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

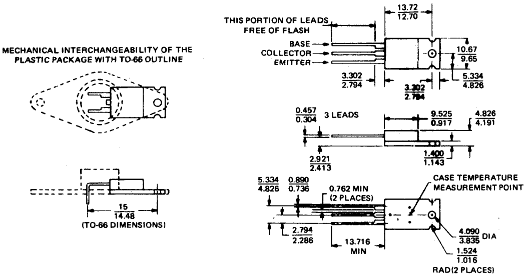
REVISED APRIL 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH TIP41, TIP41A, TIP41B, TIP41C

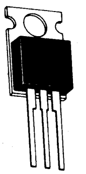
- **65 W at 25°C Case Temperature**
- **6 A Rated Collector Current**
- **Min f_T of 3 MHz at 10V, 500mA**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP42	TIP42A	TIP42B	TIP42C
Collector-Base Voltage	−40 V	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−40 V	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V			
Continuous Collector Current	−6 A			
Peak Collector Current (See Note 2)	−10 A			
Continuous Base Current	−3 A			
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Lead Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:

1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.52 W/°C.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP42,TIP42A,TIP42B,TIP42C
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP42		TIP42A		TIP42B		TIP42C		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−40		−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.7		−0.7					mA
		$V_{CE} = -60$ V, $I_B = 0$						−0.7		−0.7	
I_{CES}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 0$		−0.4							mA
		$V_{CE} = -60$ V, $V_{BE} = 0$				−0.4					
		$V_{CE} = -80$ V, $V_{BE} = 0$						−0.4			
		$V_{CE} = -100$ V, $V_{BE} = 0$								−0.4	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−1		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -0.3$ A, See Notes 6 and 7	30		30		30		30		
		$V_{CE} = -4$ V, $I_C = -3$ A, See Notes 6 and 7	15	75	15	75	15	75	15	75	
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -6$ A, See Notes 6 and 7		−2		−2		−2		−2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.6$ A, $I_C = -6$ A, See Notes 6 and 7		−1.5		−1.5		−1.5		−1.5	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	3		3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle ⩽ 2%.

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

thermal characteristics

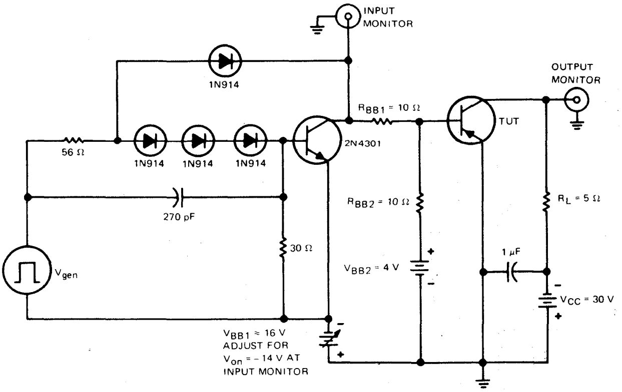
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.92	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

switching characteristics at 25°C case temperature

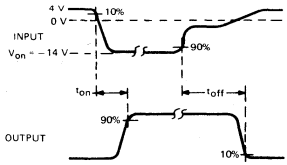
PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = -6$ A,	$I_{B(1)} = -0.6$ A,	$I_{B(2)} = 0.6$ A,	0.4	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 4$ V,	$R_L = 5\ \Omega$,	See Figure 1	0.7	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



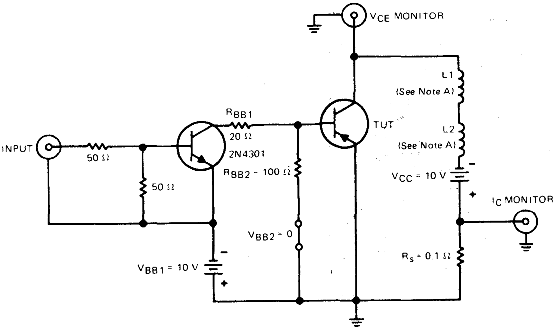
TEST CIRCUIT



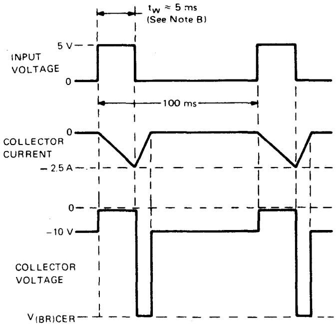
VOLTAGE WAVEFORMS

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTES:
A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
B. Input pulse width is increased until $I_{CM} = -2.5$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

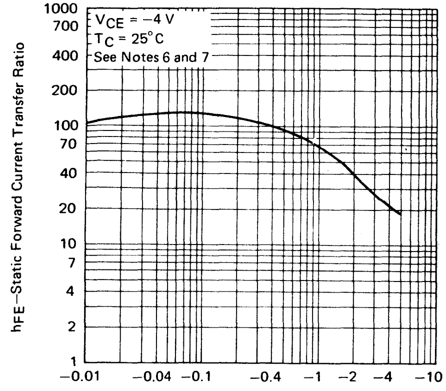


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

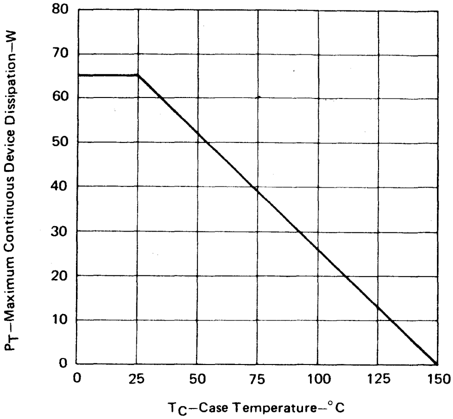


FIGURE 4

MAXIMUM SAFE OPERATING REGION

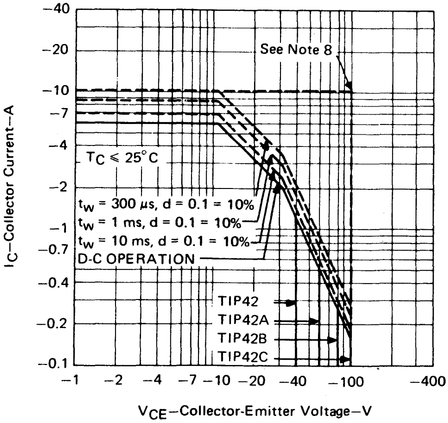


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP47, TIP48, TIP49, TIP50
NPN SILICON POWER TRANSISTORS

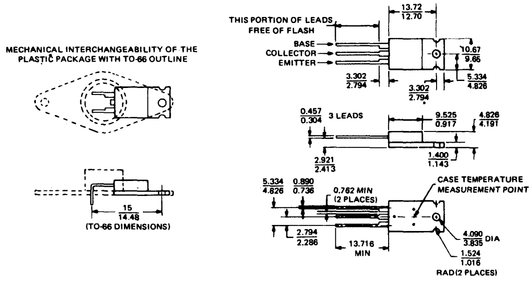
REVISED APRIL 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATION

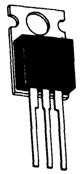
- 20 mJ Reverse-Energy Rating
- 250 V to 400 V Min $V_{(BR)CEO}$
- 40 W at 25°C Case Temperature
- 1-A Rated Collector Current
- 10 MHz Min f_T at 10 V, 0.2 A

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP47	TIP48	TIP49	TIP50
Collector-Base Voltage	350 V	400 V	450 V	500 V
Collector-Emitter Voltage (See Note 1)	250 V	300 V	350 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V	5 V
Continuous Collector Current	1 A			
Peak Collector Current (See Note 2)	2 A			
Continuous Base Current	0.6 A			
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 6 and 7			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	40 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W			
Unclamped Inductive Load Energy (See Note 5)	20 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Terminal Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 1$ ms, duty cycle $\leq 10\%$.
3. For operation above 25°C case temperature, refer to Dissipation Derating Curve, Figure 8.
4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve, Figure 9.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. $L = 100$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TIP47, TIP48, TIP49, TIP50
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP47		TIP48		TIP49		TIP50		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0,	See Note 6	250		300		350		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0			1							mA
		V_{CE} = 200 V, I_B = 0					1					
		V_{CE} = 250 V, I_B = 0							1			
		V_{CE} = 300 V, I_B = 0									1	
I_{CES}	Collector Cutoff Current	V_{CE} = 350 V, V_{BE} = 0			1							mA
		V_{CE} = 400 V, V_{BE} = 0					1					
		V_{CE} = 450 V, V_{BE} = 0							1			
		V_{CE} = 500 V, V_{BE} = 0									1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.3 A	See Notes 6 and 7	30	150	30	150	30	150	30	150	
		V_{CE} = 10 V, I_C = 1 A		10		10		10		10		
V_{BE}	Base-Emitter Voltage	V_{CE} = 10 V, I_C = 1 A	See Notes 6 and 7		1.5		1.5		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.2 A, I_C = 1 A	See Notes 6 and 7		1		1		1		1	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 kHz		25		25		25		25		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 2 MHz		5		5		5		5		

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A,	$I_{B(1)}$ = 100 mA,	$I_{B(2)}$ = −100 mA,	0.2	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −5 V,	R_L = 200 Ω,	See Figure 4	2	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

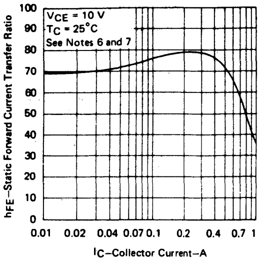


FIGURE 1

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

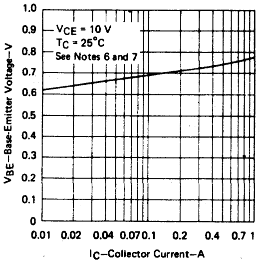


FIGURE 2

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
COLLECTOR CURRENT

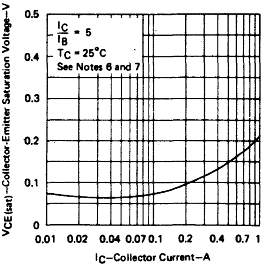
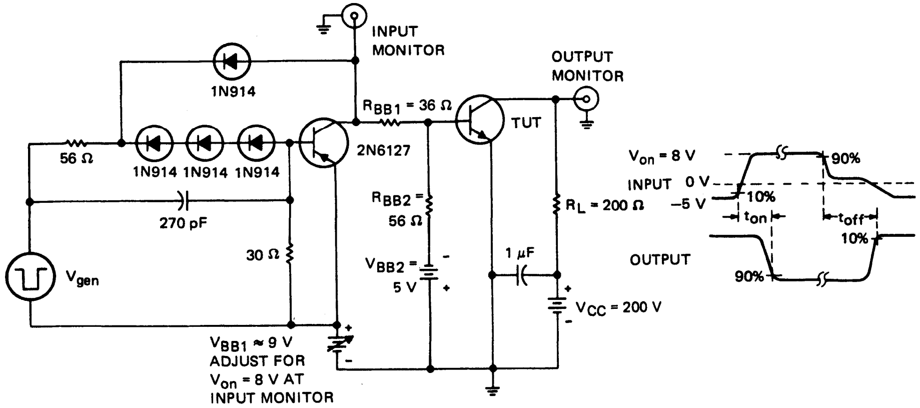


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle < 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30 V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r < 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $< 2\%$.

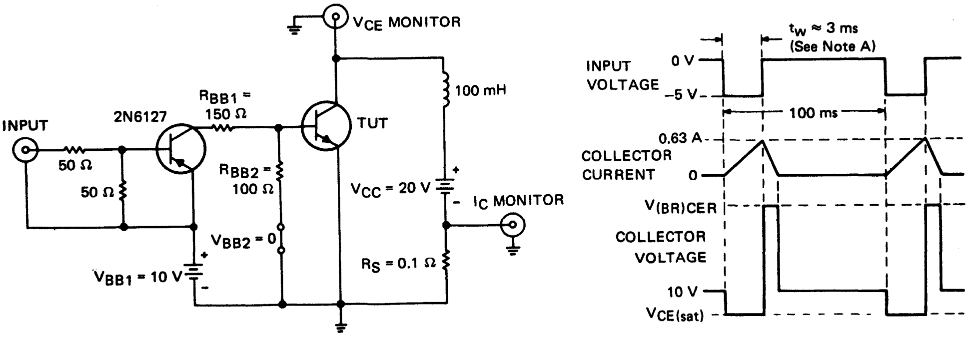
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 0.63 A.

FIGURE 5

TIP47, TIP48, TIP49, TIP50
NPN SILICON POWER TRANSISTORS

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

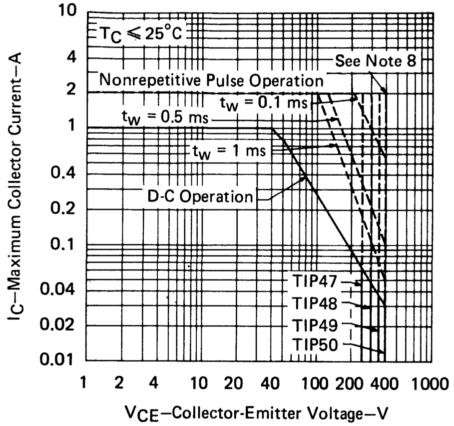


FIGURE 6

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

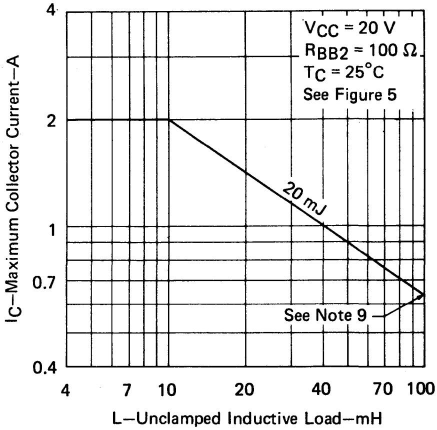


FIGURE 7

NOTES: 8. This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

9. Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

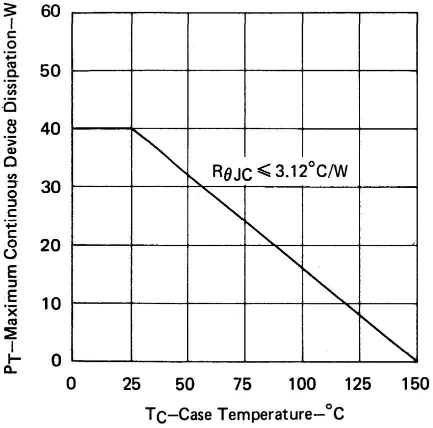


FIGURE 8

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

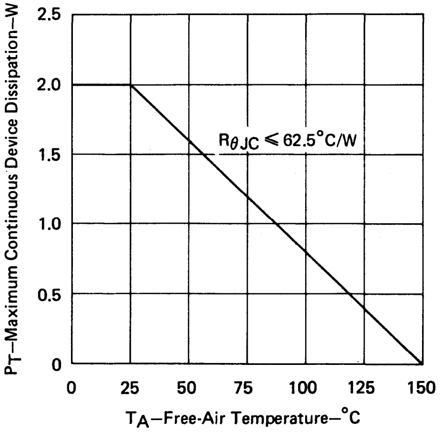


FIGURE 9

TIP 51, TIP 52, TIP 53, TIP 54
NPN SILICON POWER TRANSISTORS

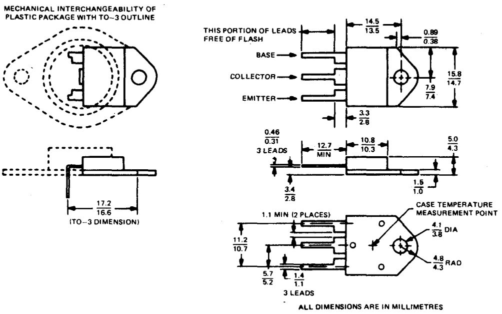
REVISED APRIL 1975

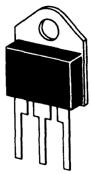
HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATIONS

- 100 mJ Reverse-Energy Rating
- 250 V to 400 V Min $V_{(BR)CEO}$
- 100 W at 25°C Case Temperature
- 5 A Peak Collector Current
- 2.5 MHz Min f_T at 10 V, 0.2 A

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP51	TIP52	TIP53	TIP54
Collector-Base Voltage	350 V	400 V	450 V	500 V
Collector-Emitter Voltage (See Note 1)	250 V	300 V	350 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V	5 V
Continuous Collector Current	◄— 3 A —►			
Peak Collector Current (See Note 2)	◄— 5 A —►			
Continuous Base Current	◄— 0.6 A —►			
Safe Operating Areas at (or below) 25°C Case Temperature	◄— See Figures 6 and 7 —►			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄— 100 W —►			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 3.5 W —►			
Unclamped Inductive Load Energy (See Note 5)	◄— 100 mJ —►			
Operating Collector Junction Temperature Range	◄— −65°C to 150°C —►			
Storage Temperature Range	◄— −65°C to 150°C —►			
Terminal Temperature 3.2mm from Case for 10 Seconds	◄— 260°C —►			

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. For operation above 25°C case temperature, refer to Dissipation Derating Curve, Figure 8.
4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve, Figure 9.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. L = 30 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C^2L/2$.

TIP 51,TIP 52,TIP 53,TIP 54
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP51		TIP52		TIP53		TIP54		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	250		300		350		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0		1							mA
		V_{CE} = 200 V, I_B = 0				1					
		V_{CE} = 250 V, I_B = 0						1			
		V_{CE} = 300 V, I_B = 0								1	
I_{CES}	Collector Cutoff Current	V_{CE} = 350 V, V_{BE} = 0		1							mA
		V_{CE} = 400 V, V_{BE} = 0				1					
		V_{CE} = 450 V, V_{BE} = 0						1			
		V_{CE} = 500 V, V_{BE} = 0								1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.3 A, See Notes 6 and 7	30	150	30	150	30	150	30	150	
		V_{CE} = 10 V, I_C = 3 A, See Notes 6 and 7	10		10		10		10		
V_{BE}	Base-Emitter Voltage	V_{CE} = 10 V, I_C = 3 A, See Notes 6 and 7		1.5		1.5		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.6 A, I_C = 3 A, See Notes 6 and 7		1.5		1.5		1.5		1.5	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 kHz	30		30		30		30		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 MHz	2.5		2.5		2.5		2.5		

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA,	0.25	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −5 V, R_L = 200 Ω, See Figure 4	5	

† Voltage and current values snown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

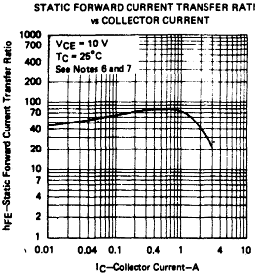


FIGURE 1

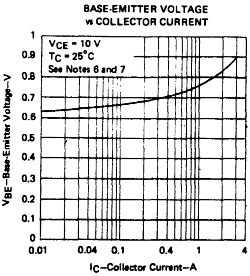


FIGURE 2

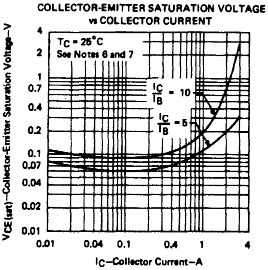
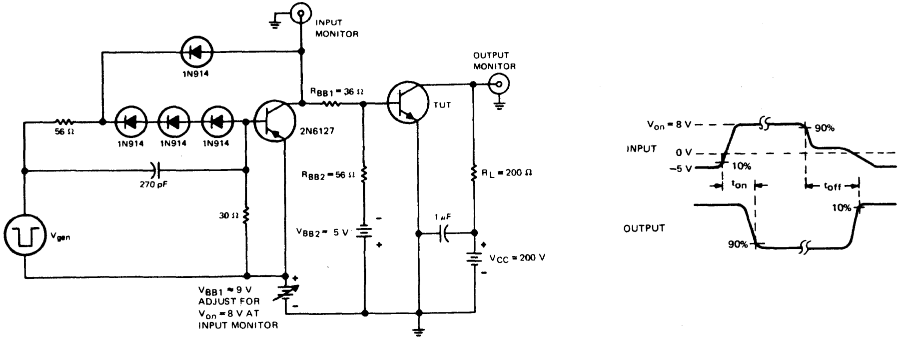


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

PARAMETER MEASUREMENT INFORMATION

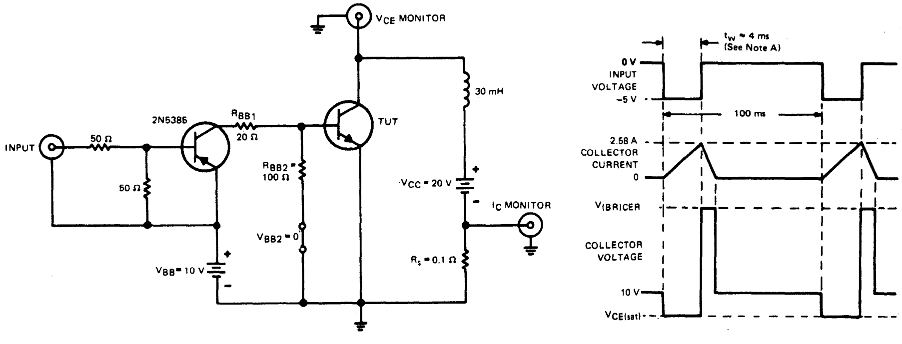


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a −30 V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplies by a generator with the following characteristics: $t_r \leqslant 15$ ns, $Z_{out} = 50$ Ω, $t_w = 20$ μs, duty cycle $\leqslant 2\%$.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until I_{CM} = 2.58 A.

FIGURE 5

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs COLLECTOR-EMITTER VOLTAGE

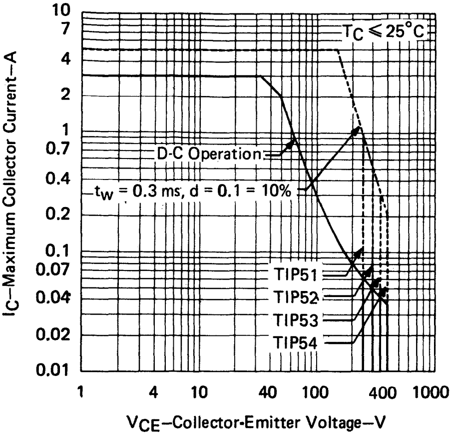


FIGURE 6

MAXIMUM COLLECTOR CURRENT
vs UNCLAMPED INDUCTIVE LOAD

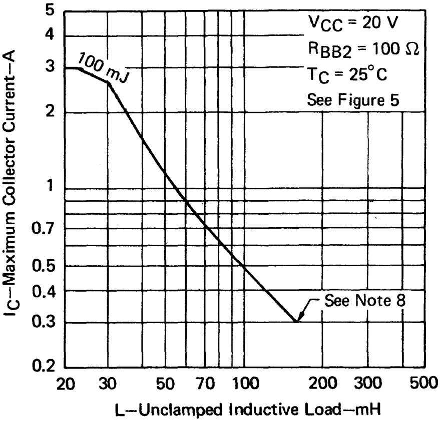


FIGURE 7

NOTE 8: Above this point, the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

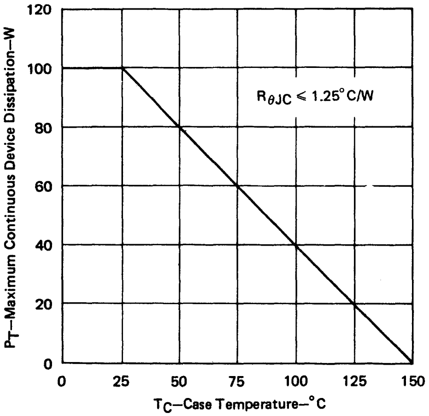


FIGURE 8

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

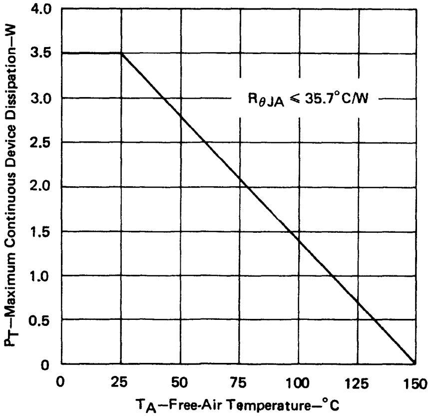


FIGURE 9

TYPES TIP55 THRU TIP58
N-P-N SILICON POWER TRANSISTORS

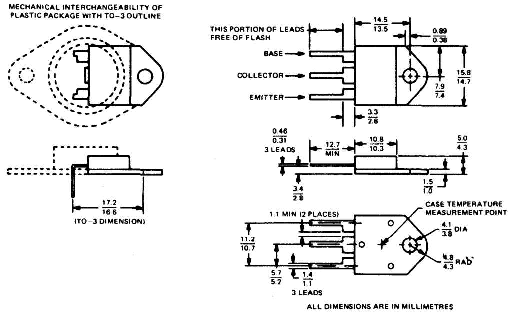
REVISED SEPTEMBER 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATIONS

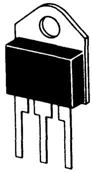
- 100 mJ Reverse-Energy Rating
- 250 V to 400 V Min $V_{(BR)CEO}$
- 125 W at 25°C Case Temperature
- 7.5 A Peak Collector Current
- 10 MHz Min f_T at 10 V, 0.2 A

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP55	TIP56	TIP57	TIP58
Collector-Base Voltage	350 V	400 V	450 V	500 V
Collector-Emitter Voltage (See Note 1)	250 V	300 V	350 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V	5 V
Continous Collector Current	7.5 A			
Peak Collector Current (See Note 2)	10 A			
Continuous Base Current	2 A			
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	125 W			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W			
Unclamped Inductive Load Energy (See Note 5)	100 mJ			
Operating Collector Junction Temperature Range	−65°C to 150°C			
Storage Temperature Range	−65°C to 150°C			
Terminal Temperature 3.2mm from Case for 10 Seconds	260°C			

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. For operation above 25°C case temperature, refer to Dissipation Derating Curve.
4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. $L = 30$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TEXAS INSTRUMENTS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP55		TIP56		TIP57		TIP58		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	250		300		350		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0		1							mA
		V_{CE} = 200 V, I_B = 0				1					
		V_{CE} = 250 V, I_B = 0						1			
		V_{CE} = 300 V, I_B = 0								1	
I_{CES}	Collector Cutoff Current	V_{CE} = 350 V, V_{BE} = 0		2							mA
		V_{CE} = 400 V, V_{BE} = 0				2					
		V_{CE} = 450 V, V_{BE} = 0						2			
		V_{CE} = 500 V, V_{BE} = 0								2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.3 A, See Notes 6 and 7	30	150	30	150	30	150	30	150	
		V_{CE} = 10 V, I_C = 5 A, See Notes 6 and 7	20		20		15		15		
V_{BE}	Base-Emitter Voltage	V_{CE} = 10 V, I_C = 5 A, See Notes 6 and 7		2.0		2.0		2.0		2.0	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.8 A, I_C = 7.5 A, See Notes 6 and 7		2.5		2.5		2.5		2.5	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 kHz	30		30		30		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 MHz	10		10		10		10		

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

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

TYPES TIP65, TIP66
N-P-N SILICON POWER TRANSISTORS

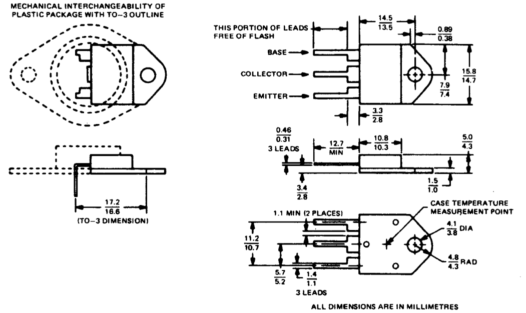
REVISED APRIL 1975

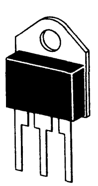
TV HORIZONTAL DEFLECTION TRANSISTORS

- Designed for Line-Operated CRT Deflection Circuits
- 1200-V and 1400-V Collector-Emitter Off-State Voltage Ratings
- Fast Switching . . . Typical t_f of 0.7 μs at 1 A
- 1.5-A Rated Collector Current

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP65	TIP66
Collector-Emitter Voltage (See Note 1)	1200 V	1400 V
Collector-Emitter Voltage (See Note 2)	600 V	600 V
Emitter-Base Voltage	5 V	5 V
Continuous Collector Current	◄——1.5 A——►	
Peak Collector Current (See Note 3)	◄——2 A——►	
Continuous Base Current	◄——1 A——►	
Safe Operating Area at (or below) 25°C Case Temperature	◄—See Figure 4—►	
Continuous Device Dissipation at (or below) 75°C Case Temperature (See Note 4)	◄——40 W——►	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 5)	◄——3.5 W——►	
Unclamped Inductive Load Energy (See Note 6)	◄——25 mJ——►	
Operating Collector Junction Temperature Range	−65°C to 150°C	
Storage Temperature Range	−65°C to 150°C	
Lead Temperature 3.2mm from Case for 10 Seconds	◄——260°C——►	

NOTES:
1. These values apply for $t_w \leqslant 300$ μs, duty cycle $\leqslant$ 2%, and only when the collector-emitter voltage is applied with the transistor in the off-state with the base-emitter voltage $V_{BE} = -1.5$ V as specified.
2. This value applies when the base-emitter diode is open-circuited.
3. This value applies for $t_w \leqslant 300$ μs, duty cycle $\leqslant$ 10%.
4. Derate linearly to 150°C case temperature at the rate of 0.53 W/°C or refer to Dissipation Derating Curve, Figure 5.
5. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C or refer to Dissipation Derating Curve, Figure 6.
6. This rating is based on the capability of the transistor to operate safely in the unclamped inductive-load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.* $L = 50$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 20$ V, $I_{CM} = 1$ A, Energy $\approx I_C^2\ L/2$.

TYPES TIP65, TIP66
N-P-N SILICON POWER TRANSISTORS

electrical characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS	TIP65 MIN	TIP65 MAX	TIP66 MIN	TIP66 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 10 mA, I_B = 0, See Note 7	600		600		V
I_{CEV}	Collector Cutoff Current	V_{CE} = 1200 V, V_{BE} = −1.5 V, See Note 7		1			mA
		V_{CE} = 1400 V, V_{BE} = −1.5 V, See Note 7				1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		10		10	mA
V_{BE}	Base-Emitter Voltage	I_B = 400 mA, I_C = 1 A, See Notes 7 and 8		1.2		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 400 mA, I_C = 1 A, See Notes 7 and 8		5		5	V

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.875	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_f	Fall Time	I_{CM} = 1 A, See Figure 3		0.7	1.2	μs

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

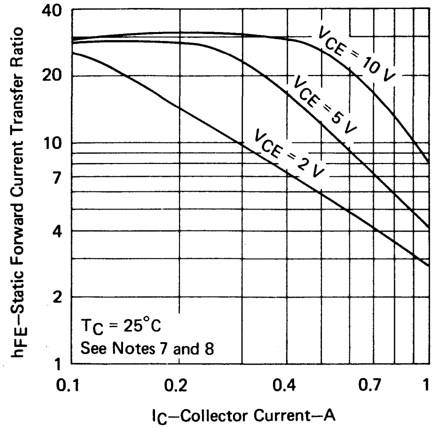


FIGURE 1

BASE-EMITTER VOLTAGE and
COLLECTOR-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

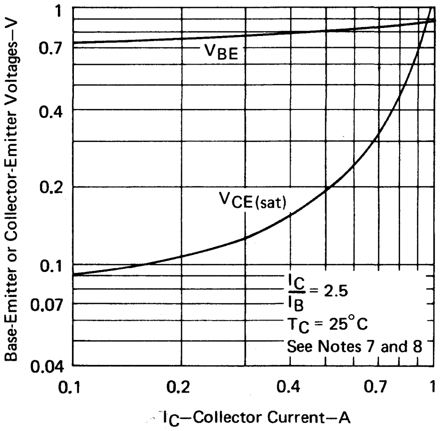
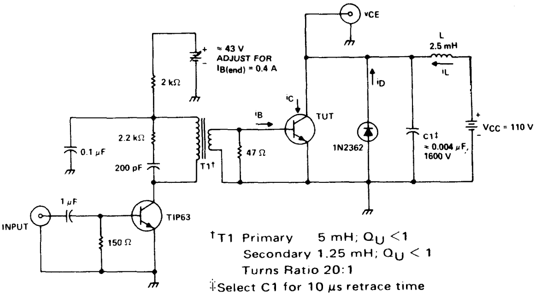


FIGURE 2

NOTES: 7. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

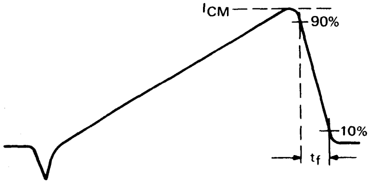
8. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

PARAMETER MEASUREMENT INFORMATION

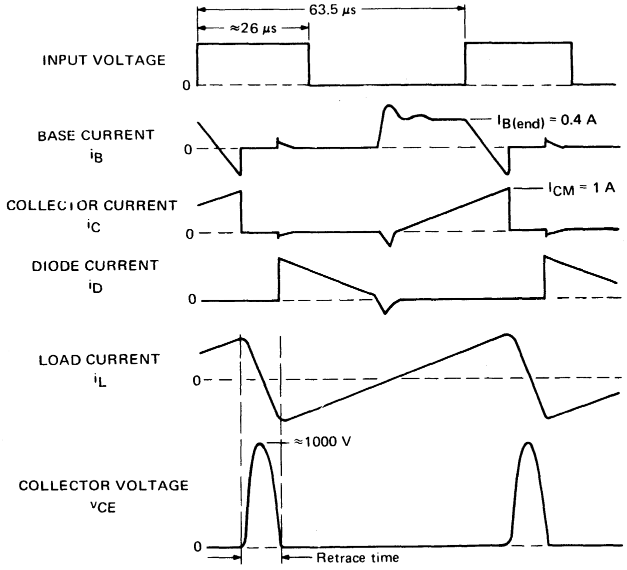


†T1 Primary 5 mH; Q_U <1
Secondary 1.25 mH; Q_U < 1
Turns Ratio 20:1
‡Select C1 for 10 μs retrace time

TEST CIRCUIT



COLLECTOR CURRENT WAVEFORM DETAIL
(with fall time exaggerated)



WAVEFORMS

NOTES: A. Base and collector currents are measured using current probes such as Tektronix types P6019, P6020, P6021, P6042, or the equivalent.
B. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 20$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.

FIGURE 3 – FALL TIME

MAXIMUM SAFE OPERATING AREA

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

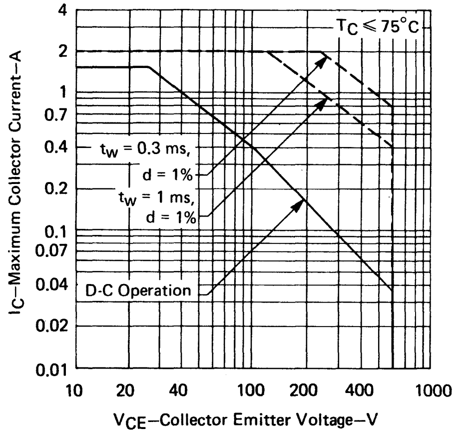


FIGURE 4

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

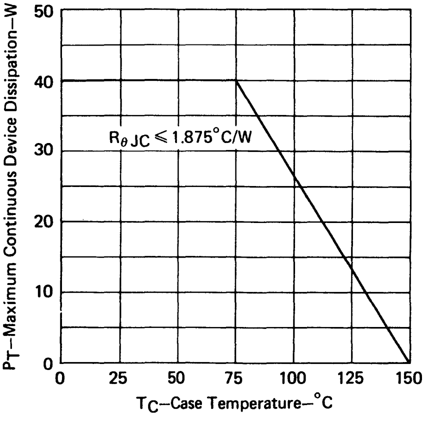


FIGURE 5

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

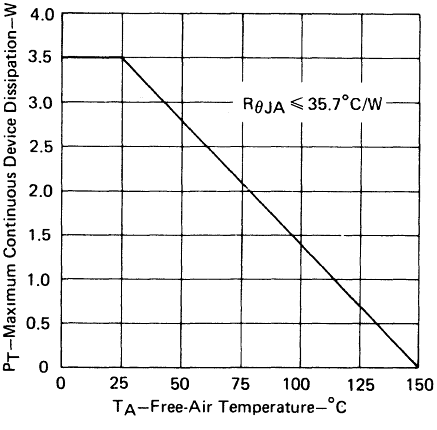


FIGURE 6

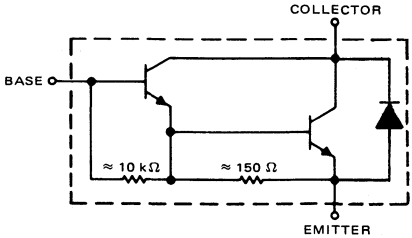
TIP110, TIP111, TIP112
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP115, TIP116, TIP117

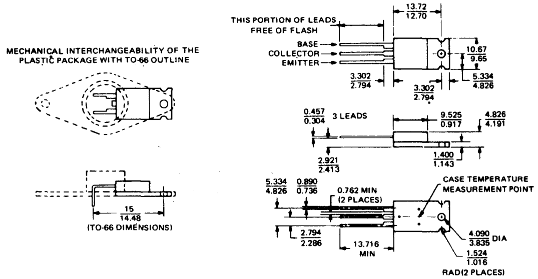
- High SOA Capability, 40 V and 1.25 A
- 50 W at 25°C Case Temperature
- 2-A Rated Collector Current
- Min h_{FE} of 500 at 4 V, 2 A
- 25-mJ Reverse Energy Rating

device schematic

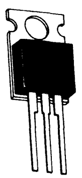


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP110	TIP111	TIP112
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	◄— 2 A —►		
Peak Collector Current (See Note 2)	◄— 4 A —►		
Continuous Base Current	◄— 50 mA —►		
Safe Operating Areas at (or below) 25°C Case Temperature	◄— See Figures 7 and 8 —►		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄— 50 W —►		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 2 W —►		
Unclamped Inductive Load Energy (See Note 5)	◄— 25 mJ —►		
Operating Collector Junction Temperature Range	◄— −65°C to 150°C —►		
Storage Temperature Range	◄— −65°C to 150°C —►		
Lead Temperature 3.2mm from Case for 10 Seconds	◄— 260°C —►		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.4 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TIP110, TIP111, TIP112
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP110		TIP111		TIP112		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		2					mA
		V_{CE} = 40 V, I_B = 0				2			
		V_{CE} = 50 V, I_B = 0						2	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V, I_E = 0		1					mA
		V_{CB} = 80 V, I_E = 0				1			
		V_{CB} = 100 V, I_E = 0						1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		2		2		2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 1 A, See Notes 6 and 7	1000		1000		1000		
		V_{CE} = 4 V, I_C = 2 A	500		500		500		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 2 A, See Notes 6 and 7		2.8		2.8		2.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 8 mA, I_C = 2 A, See Notes 6 and 7		2.5		2.5		2.5	V

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

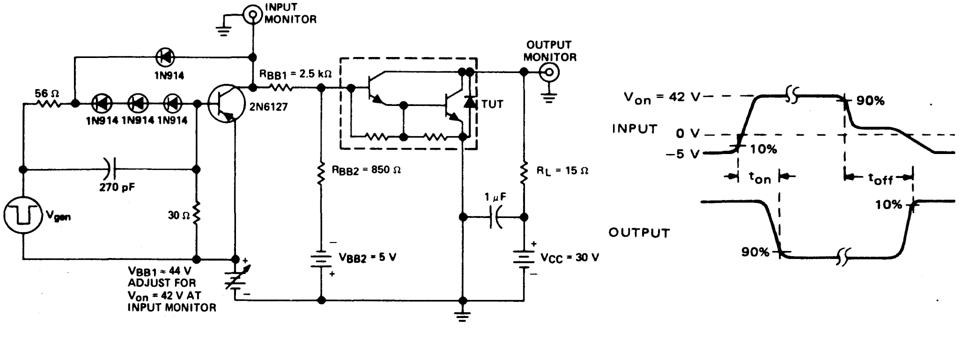
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 2 A, $I_{B(1)}$ = 8 mA, $I_{B(2)}$ = −8 mA, $V_{BE(off)}$ = −5 V, R_L = 15 Ω, See Figure 1	2.6	μs
t_{off}	Turn-Off Time		4.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ≤ 15 ns, t_f ≤ 15 ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ≤ 2%.

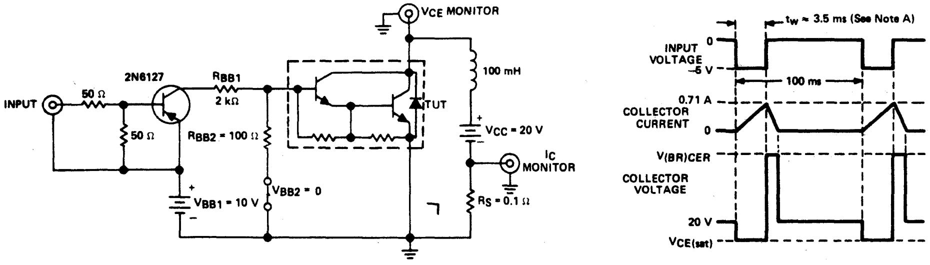
C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ≤ 15 ns, R_{in} ≥ 10 MΩ, C_{in} ≤ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 0.71 A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

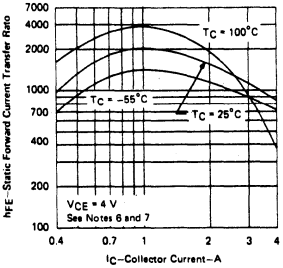


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

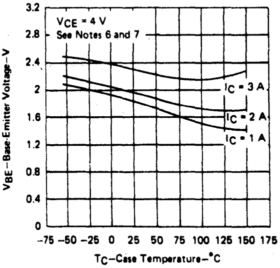


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

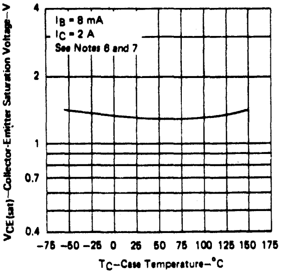


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

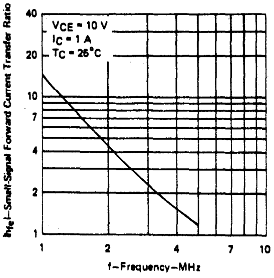


FIGURE 6

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

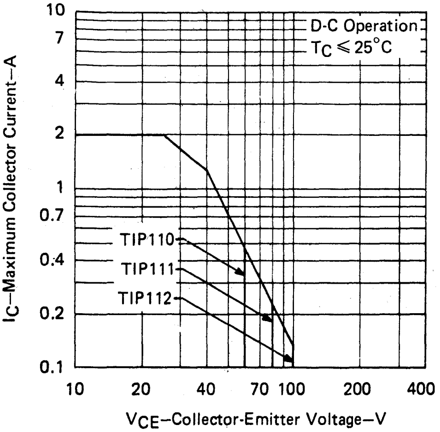


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

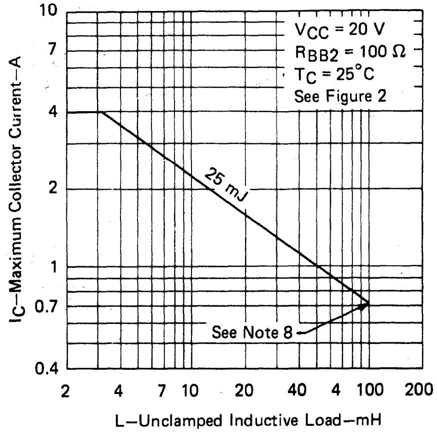


FIGURE 8

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

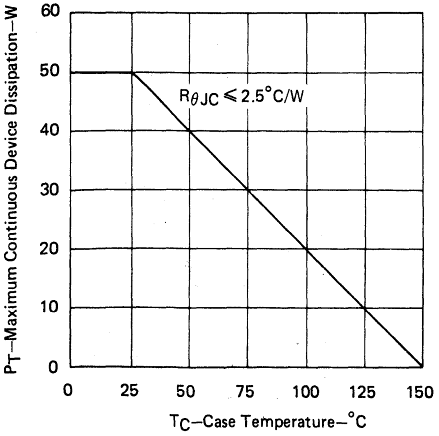


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

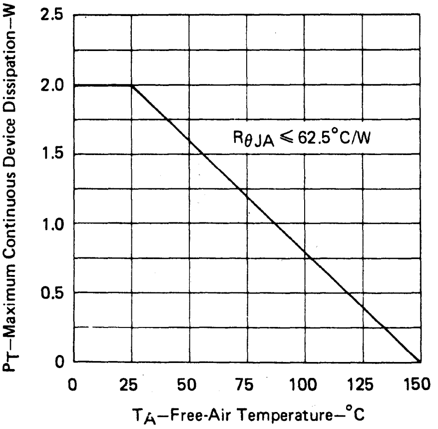


FIGURE 10

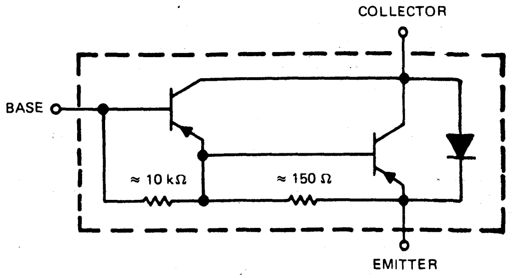
TIP115, TIP116, TIP117
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP110, TIP111, TIP112

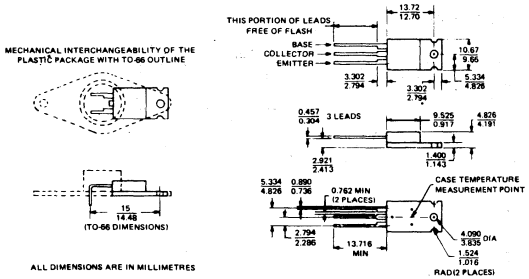
- High SOA Capability, 40 V and 1.25 A
- 50 W at 25°C Case Temperature
- 2-A Rated Collector Current
- Min h_{FE} of 500 at 4 V, 2 A
- 25-mJ Reverse Energy Rating

device schematic

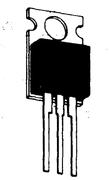


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP115	TIP116	TIP117
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current	−2 A		
Peak Collector Current (See Note 2)	−4 A		
Continuous Base Current	−50 mA		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	50 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W		
Unclamped Inductive Load Energy (See Note 5)	25 mJ		
Operating Collector Junction Temperature Range	−65°C to 150°C		
Storage Temperature Range	−65°C to 150°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.4 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V, Energy ≈ $I_C{}^2L/2$.

TIP115, TIP116, TIP117
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS	TIP115		TIP116		TIP117		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−2					mA
		$V_{CE} = -40$ V, $I_B = 0$				−2			
		$V_{CE} = -50$ V, $I_B = 0$						−2	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$		−1					mA
		$V_{CB} = -80$ V, $I_E = 0$				−1			
		$V_{CB} = -100$ V, $I_E = 0$						−1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−2		−2		−2	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 6 and 7	1000		1000		1000		
		$V_{CE} = -4$ V, $I_C = -2$ A	500		500		500		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 6 and 7		−2.8		−2.8		−2.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -8$ mA, $I_C = -2$ A, See Notes 6 and 7		−2.5		−2.5		−2.5	V

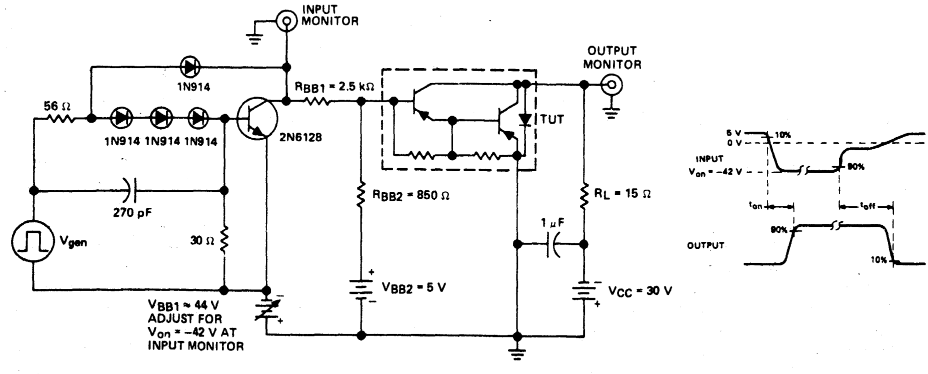
NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leq 2\%$.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -2$ A, $I_{B(1)} = -8$ mA, $I_{B(2)} = 8$ mA, $V_{BE(off)} = 5$ V, $R_L = 15\ \Omega$, See Figure 1	2.6	μs
t_{off}	Turn-Off Time		4.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



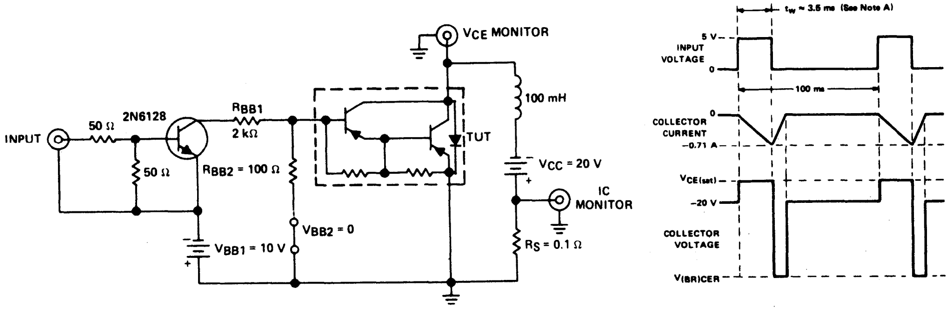
TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leq 2\%$.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until $I_{CM} = -0.71$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

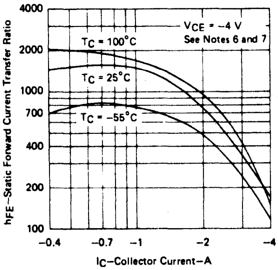

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

FIGURE 3

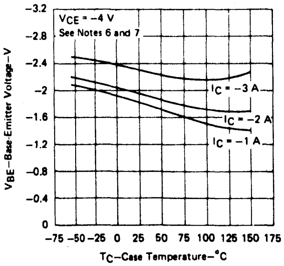

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

FIGURE 4

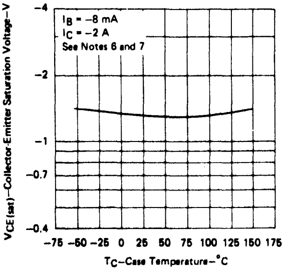

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

FIGURE 5

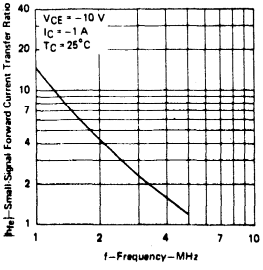

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs FREQUENCY

FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

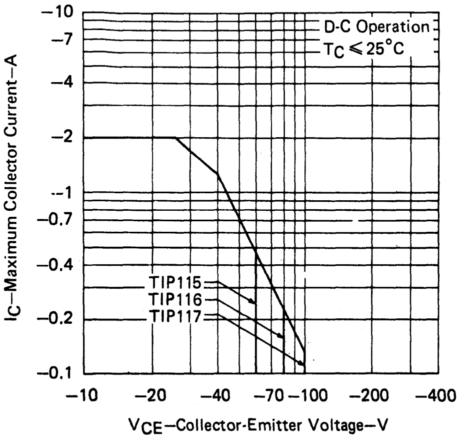


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

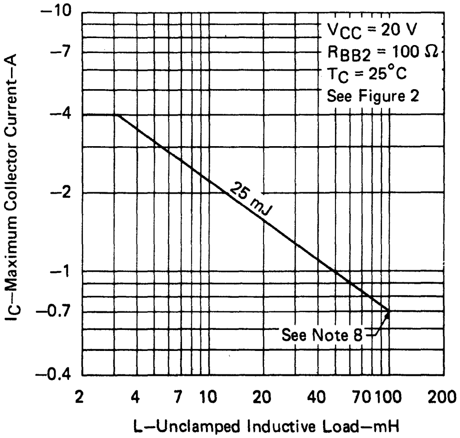


FIGURE 8

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

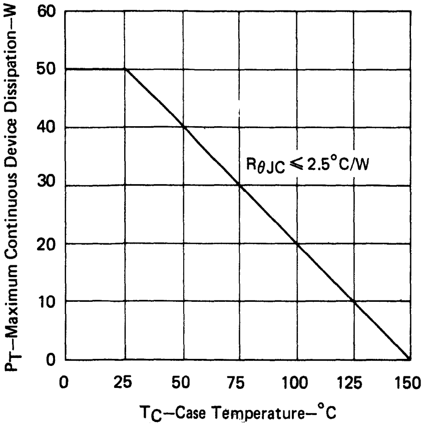


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

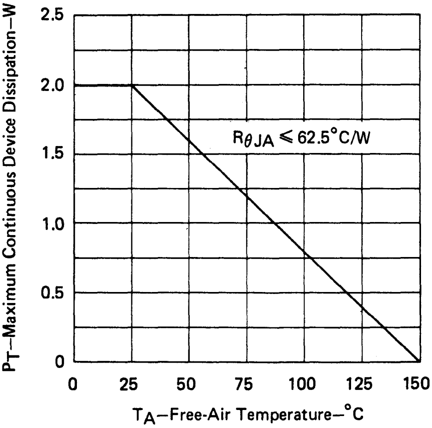


FIGURE 10

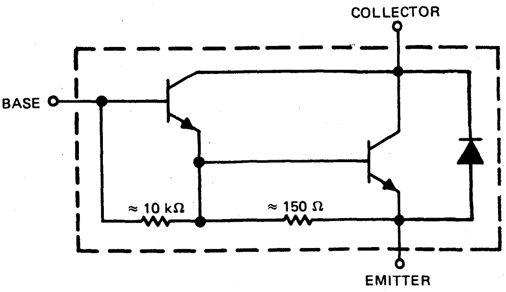
TIP120,TIP121,TIP122
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP125, TIP126, TIP127

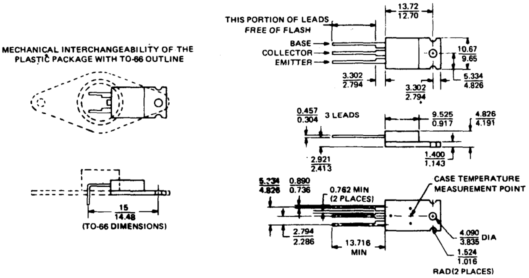
- 65 W at 25°C Case Temperature
- 5 A Rated Collector Current
- Min h_{FE} of 1000 at 3 V, 3 A
- 50 mJ Reverse Energy Rating

device schematic

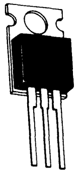


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP120	TIP121	TIP122
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	5 A		
Peak Collector Current (See Note 2)	8 A		
Continuous Base Current	0.1 A		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W		
Unclamped Inductive Load Energy (See Note 5)	50 mJ		
Operating Collector Junction Temperature Range	−65°C to 150°C		
Storage Temperature Range	−65°C to 150°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 0.52 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C{}^2L/2$.

TIP120,TIP121,TIP122
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP120		TIP121		TIP122		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0,	See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0			0.5					mA
		V_{CE} = 40 V, I_B = 0					0.5			
		V_{CE} = 50 V, I_B = 0							0.5	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V, I_E = 0			0.2					mA
		V_{CB} = 80 V, I_E = 0					0.2			
		V_{CB} = 100 V, I_E = 0							0.2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			2		2		2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 3 V, I_C = 0.5 A	See Notes 6 and 7	1000		1000		1000		
		V_{CE} = 3 V, I_C = 3 A		1000		1000		1000		
V_{BE}	Base-Emitter Voltage	V_{CE} = 3 V, I_C = 3 A,	See Notes 6 and 7		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 12 mA, I_C = 3 A	See Notes 6 and 7		2		2		2	V
		I_B = 20 mA, I_C = 5 A			4		4		4	

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

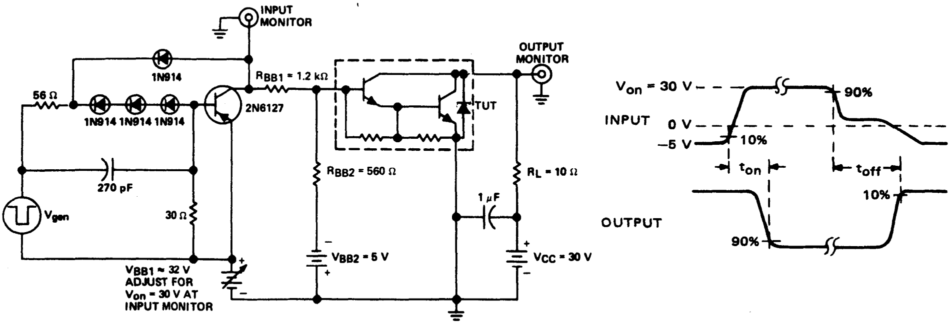
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 3 A, $I_{B(1)}$ = 12 mA, $I_{B(2)}$ = −12 mA,	1.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −5 V, R_L = 10 Ω, See Figure 1	8.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ≤ 15 ns, t_f ≤ 15 ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ≤ 2%.

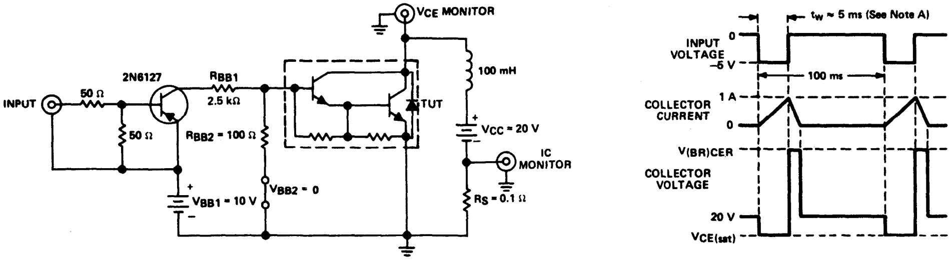
C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ≤ 15 ns, R_{in} ≥ 10 MΩ, C_{in} ≤ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until $I_{CM} = 1$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

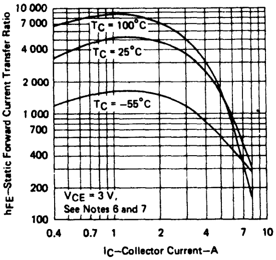


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

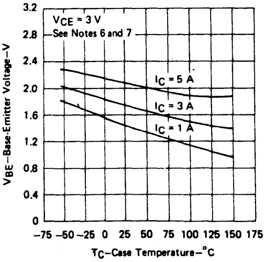


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

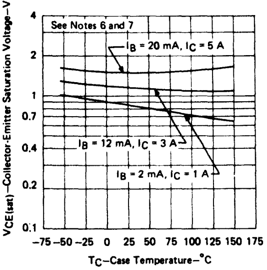


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

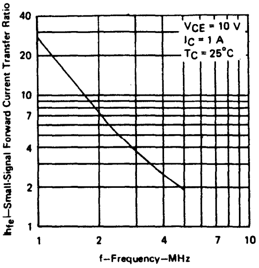


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

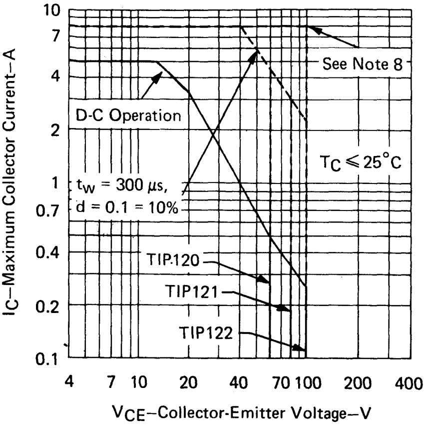


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

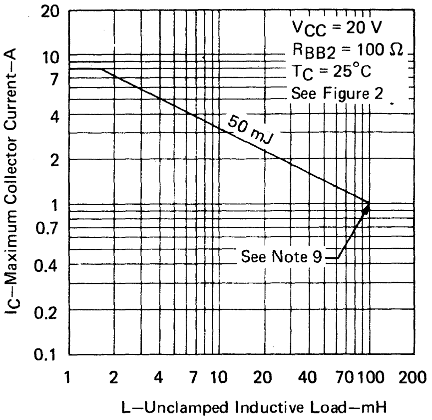


FIGURE 8

NOTES: 8. This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

9. Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

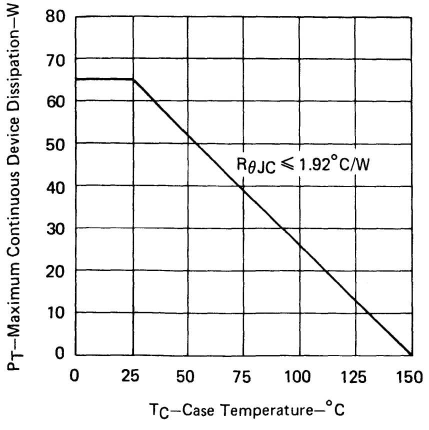


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

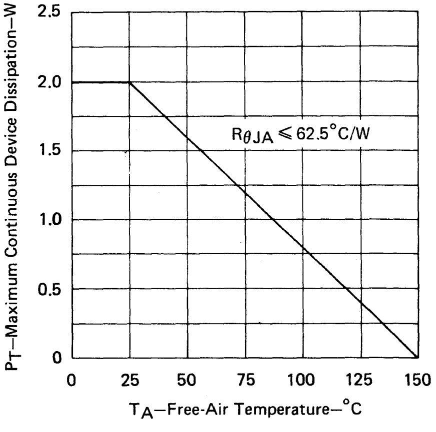


FIGURE 10

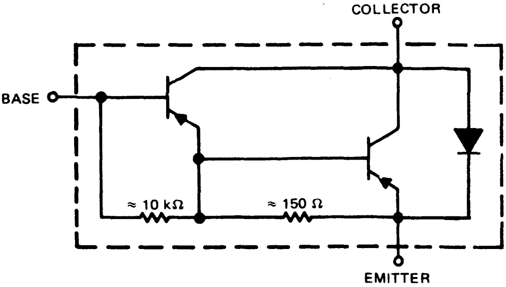
TIP125,TIP126,TIP127
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP120, TIP121, TIP122

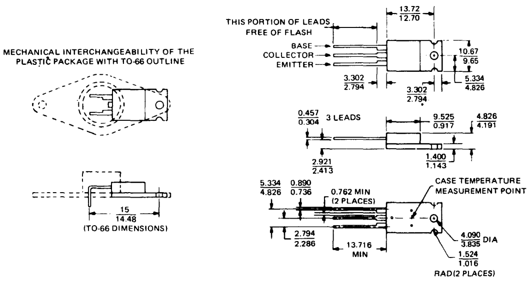
- 65 W at 25°C Case Temperature
- 5 A Rated Collector Current
- Min h_{FE} of 1000 at 3 V, 3 A
- 50 mJ Reverse Energy Rating

device schematic

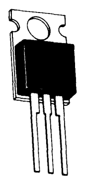


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP125	TIP126	TIP127
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current	−5 A		
Peak Collector Current (See Note 2)	−8 A		
Continuous Base Current	−0.1 A		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W		
Unclamped Inductive Load Energy (See Note 5)	50 mJ		
Operating Collector Junction Temperature Range	−65°C to 150°C		
Storage Temperature Range	−65°C to 150°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.52 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. $L = 100$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TIP125,TIP126,TIP127
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP125		TIP126		TIP127		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−0.5					mA
		$V_{CE} = -40$ V, $I_B = 0$				−0.5			
		$V_{CE} = -50$ V, $I_B = 0$						−0.5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$		−0.2					mA
		$V_{CB} = -80$ V, $I_E = 0$				−0.2			
		$V_{CB} = -100$ V, $I_E = 0$						−0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−2		−2		−2	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -3$ V, $I_C = -0.5$ A, See Notes 6 and 7	1000		1000		1000		
		$V_{CE} = -3$ V, $I_C = -3$ A	1000		1000		1000		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -3$ V, $I_C = -3$ A, See Notes 6 and 7		−2.5		−2.5		−2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -12$ mA, $I_C = -3$ A, See Notes 6 and 7		−2		−2		−2	V
		$I_B = -20$ mA, $I_C = -5$ A		−4		−4		−4	

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

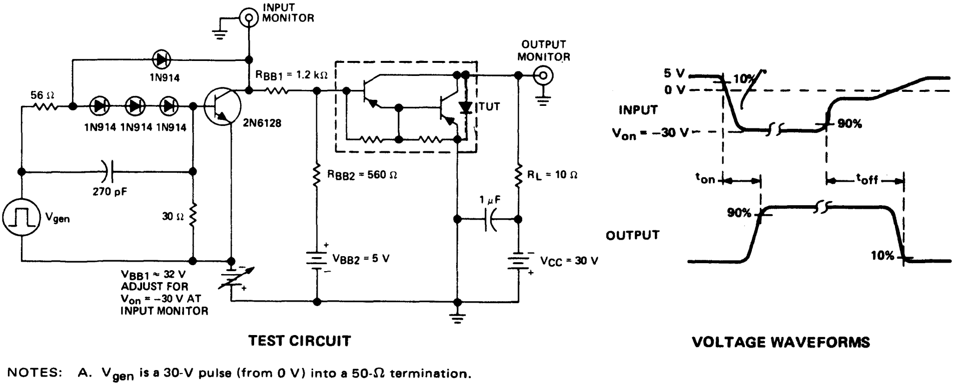
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3,2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -3$ A, $I_{B(2)} = -12$ mA, $I_{B(2)} = 12$ mA, $V_{BE(off)} = 5$ V, $R_L = 10\ \Omega$, See Figure 1	1.5	μs
t_{off}	Turn-Off Time		8.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20$ μs, duty cycle ≤ 2%.

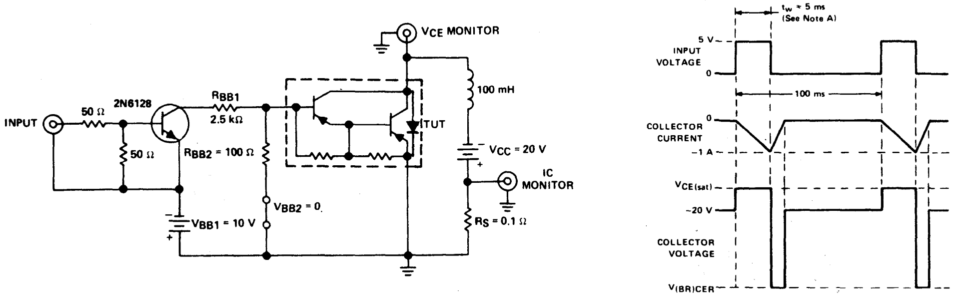
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width in increased until $I_{CM} = -1$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

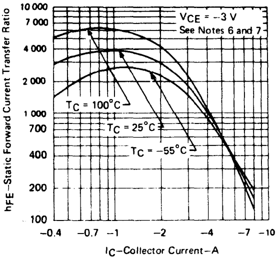


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

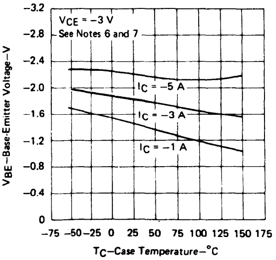


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

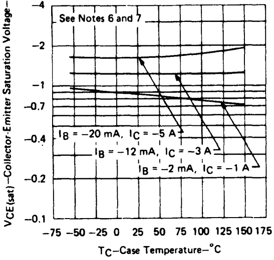


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER
FORWARD-CURRENT TRANSFER RATIO
vs
FREQUENCY

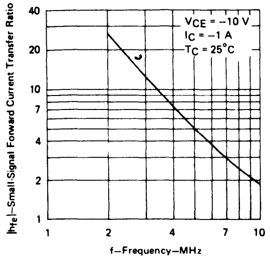


FIGURE 6

NOTES:
6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

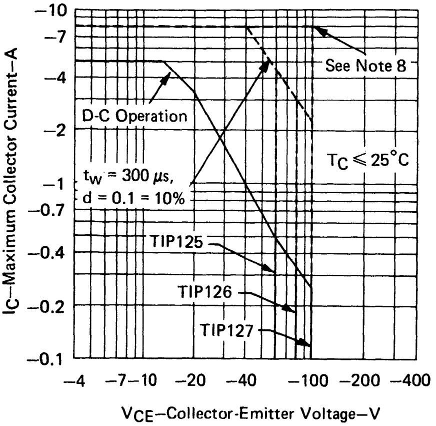


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

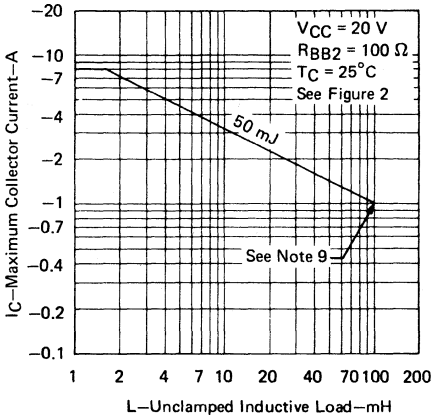


FIGURE 8

NOTES: 8. These combinations of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

9. Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

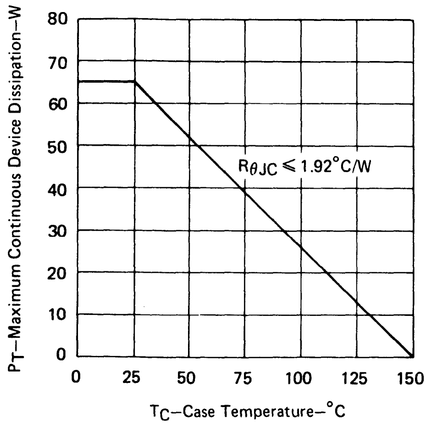


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

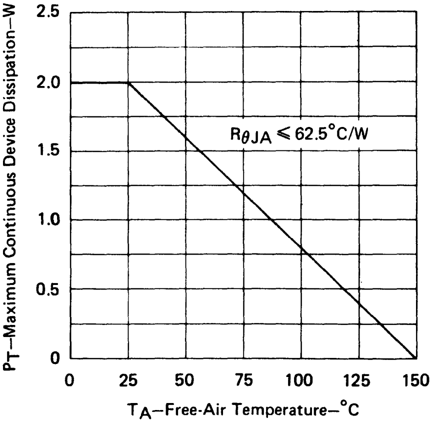


FIGURE 10

TIP130,TIP131,TIP132
NPN SILICON POWER DARLINGTON TRANSISTORS

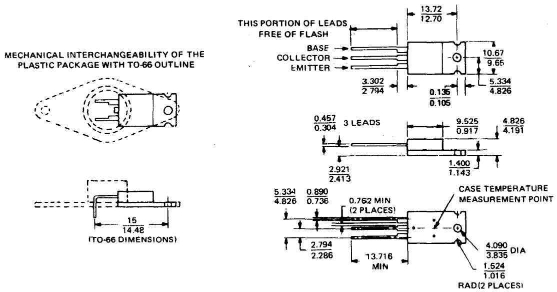
REVISED AUGUST 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP135, TIP136, TIP137

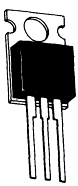
- **70 W at 25 °C Case Temperature**
- **8 A Rated Collector Current**
- **Min H_{FE} of 1000 @ 4 V/4 A**
- **75 mJ Reverse Energy Rating**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	TIP130	TIP131	TIP132
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (see Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	←	8 A	→
Peak Collector Current (see Note 2)	←	12 A	→
Continuous Base Current	←	0.3 A	→
Safe Operating Area at (or below) 25 °C Case Temperature	←	See Figure 1	→
Continuous Device Dissipation at (or below) 25 °C Case Temperature (see Note 3)	←	See Figure 2 70 W	→
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (see Note 4)	←	2 W	→
Unclamped Inductive Load Energy (see Note 5)	←	75 mJ	→
Operating Collector Junction Temperature Range	←	−65 °C to +150 °C	→
Storage Temperature Range	←	−65 °C to +150 °C	→

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150 °C case temperature at the rate of 0.56 W/°C or refer to Dissipation Derating Curve, Figure 2.
4. Derate linearly to 150 °C free-air temperature at the rate of 20 mW/°C or refer to Dissipation Derating Curve.
5. This rating is based on the capability of the transistor to operate safely in a circuit of: L = 20 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V, Energy $\approx I_C{}^2L/2$.

TIP130, TIP131, TIP132
NPN SILICON POWER DARLINGTON TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER		TEST CONDITIONS		TIP130		TIP131		TIP132		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter	I_C = 30 mA,	I_B = 0	60		80		100		V
	Breakdown Voltage	See Note 6								
I_{CEO}	Collector Cutoff	V_{CE} = 30 V,	I_B = 0		0.5					
	Current	V_{CE} = 40 V,	I_B = 0				0.5			mA
		V_{CE} = 50 V,	I_B = 0						0.5	
I_{CBO}	Collector Cutoff	V_{CB} = 60 V,	I_E = 0		0.2					
	Current	V_{CB} = 80 V,	I_E = 0				0.2			mA
		V_{CB} = 100 V,	I_E = 0						0.2	
I_{CBO}	@T_C = 100 °C	60/80/100 V			1		1		1	mA
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0		5		5		5	mA
H_{FE}	Static Forward Current	V_{CE} = 4 V,	I_C = 1 A	500		500		500		
	Transfer Ratio	V_{CE} = 4 V,	I_C = 4 A	1000	15000	1000	15000	1000	15000	
		See Notes 6 an 7								
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V,	I_C = 4 A		2.5		2.5		2.5	V
		See Notes 6 and 7								
$V_{CE(sat)}$	Collector-Emitter	I_B = 16 mA,	I_C = 4 A		2		2		2	
	Saturation Voltage	I_B = 30 mA,	I_C = 6 A		3		3		3	V
		See Notes 6 and 7								
C_{OB}	Collector-Base Capacitance	V_{CB} = 10 V,	I_E = 0		200		200		200	pF

NOTES: 6. These parameters must be measured using pulse techniques, t_w = 300 µs, duty cycle ⩽2%

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

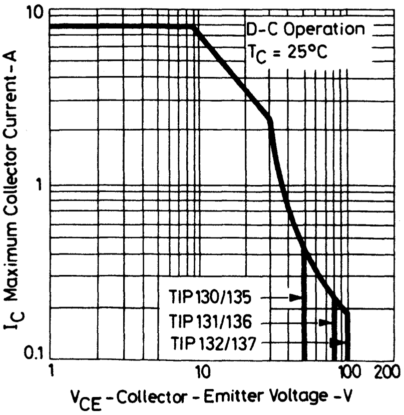


FIGURE 1

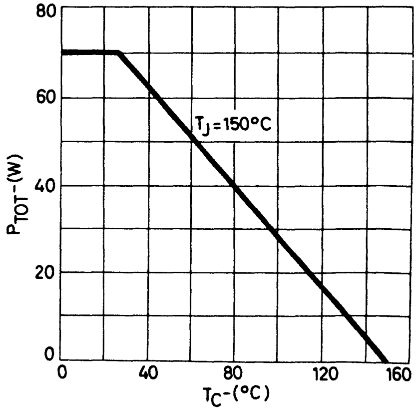
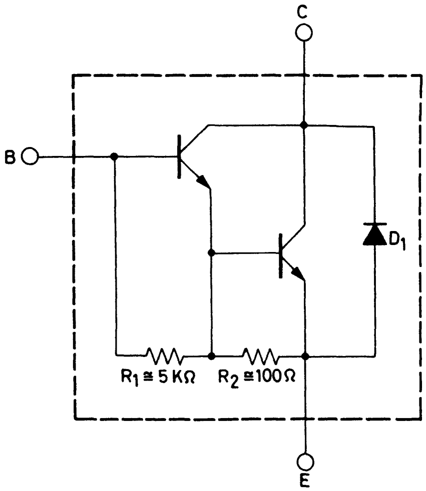


FIGURE 2



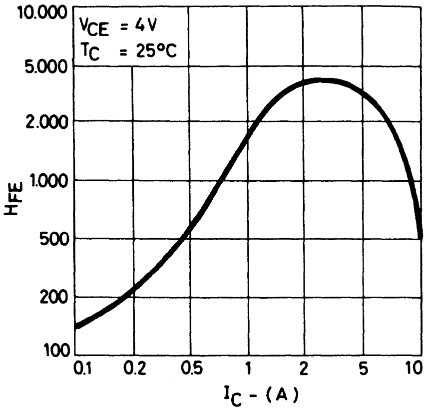


FIGURE 3

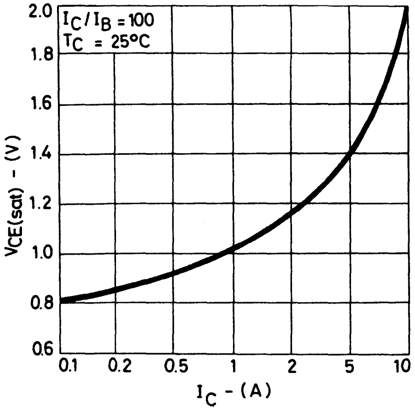


FIGURE 4

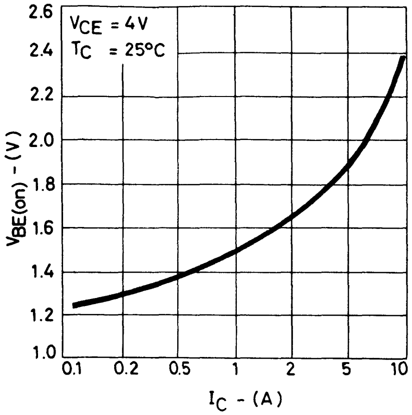


FIGURE 5

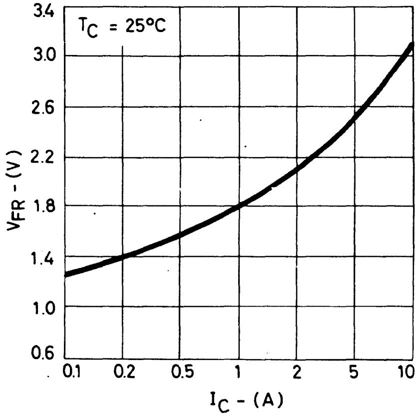


FIGURE 6

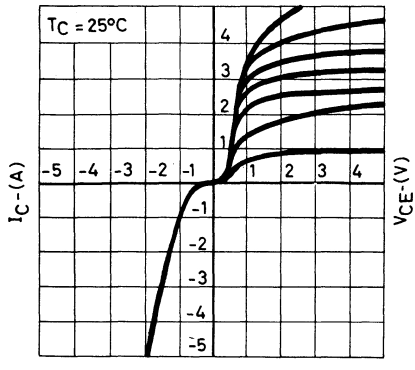


FIGURE 7

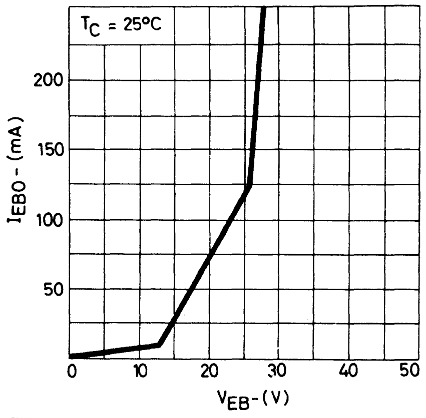


FIGURE 8

TEXAS INSTRUMENTS

TIP135,TIP136,TIP137
PNP SILICON POWER DARLINGTON TRANSISTORS

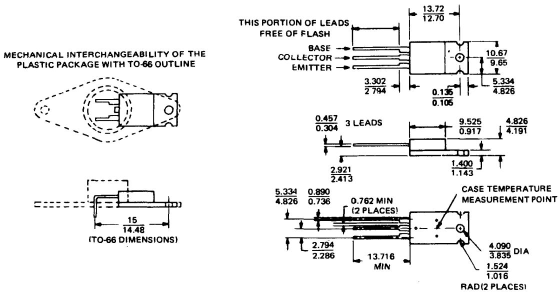
REVISED AUGUST 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP130, TIP131, TIP132

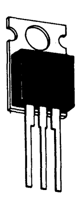
- **70 W at 25 °C Case Temperature**
- **8 A Rated Collector Current**
- **Min H_{FE} of 1000 @ 4 V/4 A**
- **75 mJ Reverse Energy Rating**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25 °C case temperature (unless otherwise noted)

	TIP135	TIP136	TIP137
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (see Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current		−8 A	
Peak Collector Current (see Note 2)		−12 A	
Continuous Base Current		−0.3 A	
Safe Operating Area at (or below) 25 °C Case Temperature		See Figure 1	
Continuous Device Dissipation at (or below) 25 °C Case Temperature (see Note 3)		See Figure 2 70 W	
Continuous Device Dissipation at (or below) 25 °C Free-Air Temperature (see Note 4)		2 W	
Unclamped Inductive Load Energy (see Note 5)		75 mJ	
Operating Collector Junction Temperature Range		−65 °C to +150 °C	
Storage Temperature Range		−65 °C to +150 °C	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150 °C case temperature at the rate of 0.56 W/°C or refer to Dissipation Derating Curve, Figure 2.
4. Derate linearly to 150 °C free-air temperature at the rate of 20 mW/°C or refer to Dissipation Derating Curve.
5. This rating is based on the capability of the transistor to operate safely in a circuit of: $L = 20$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V, Energy $\approx I_C{}^2L/2$.

PRELIMINARY DATA SHEET:
Supplementary data may be published at a later date.

TIP135,TIP136,TIP137
PNP SILICON POWER DARLINGTON TRANSISTORS

electrical characteristics at 25 °C case temperature

PARAMETER		TEST CONDITIONS	TIP135		TIP136		TIP137		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$ See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.5					
		$V_{CE} = 40$ V, $I_B = 0$				0.5			mA
		$V_{CE} = 50$ V, $I_B = 0$						0.5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ V, $I_E = 0$		0.2					
		$V_{CB} = 80$ V, $I_E = 0$				0.2			mA
		$V_{CB} = 100$ V, $I_E = 0$						0.2	
I_{CBO}	@$T_C = 100$ °C	60/80/100 V		1		1		1	mA
I_{EBO}	Emitter Cutoff	$V_{EB} = 5$ V, $I_C = 0$		5		5		5	mA
H_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A	500		500		500		
		$V_{CE} = 4$ V, $I_C = 4$ A See Notes 6 and 7	1000	15000	1000	15000	1000	15000	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 4$ A See Notes 6 and 7		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 16$ mA, $I_C = 4$ A		2		2		2	
		$I_B = 30$ mA, $I_C = 6$ A See Notes 6 and 7		3		3		3	V
C_{OB}	Collector-Base Capacitance	$V_{CB} = 10$ V, $I_E = 0$		200		200		200	pF

NOTES: 6. These parameters must be measured using pulse techniques, $t_w = 300$ μs, duty cycle ⩽2%

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

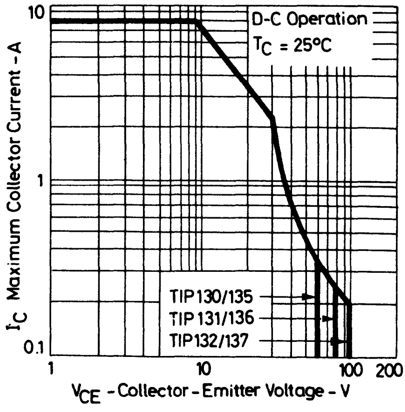


FIGURE 1

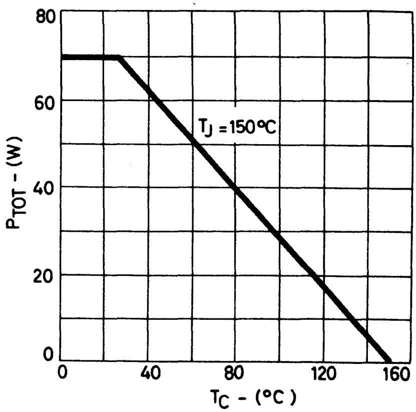
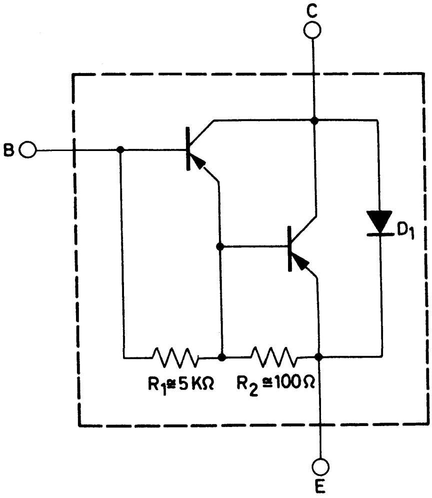


FIGURE 2

TEXAS INSTRUMENTS



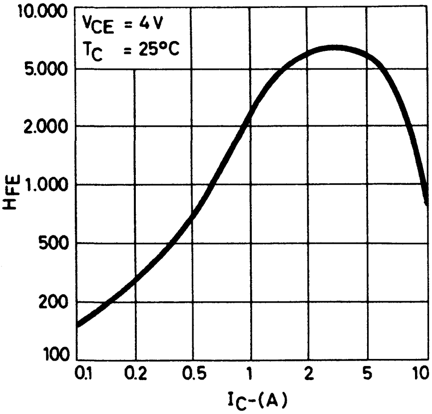


FIGURE 3

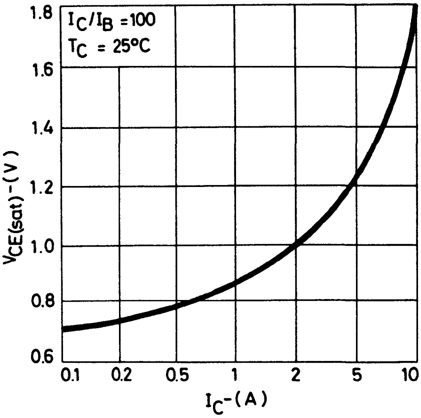


FIGURE 4

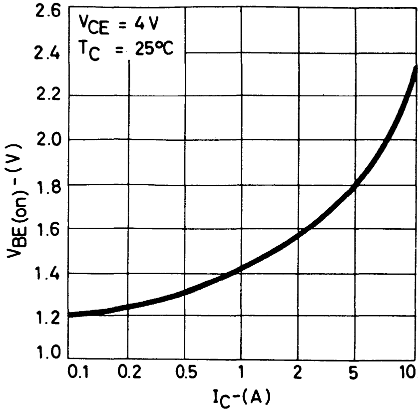


FIGURE 5

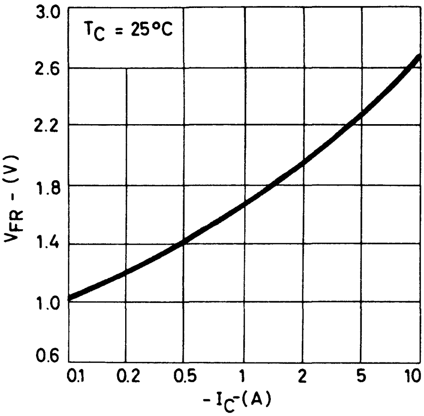


FIGURE 6

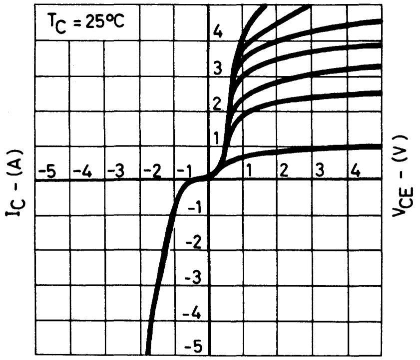


FIGURE 7

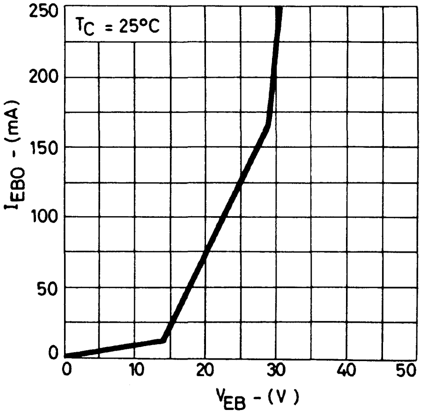


FIGURE 8

TIP140,TIP141,TIP142

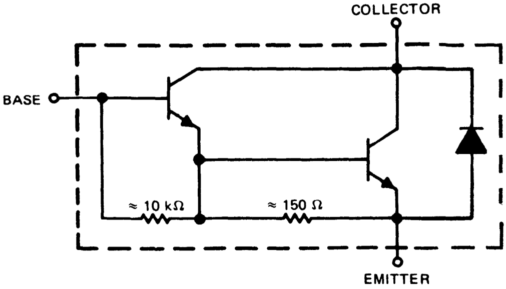
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP145, TIP146, TIP147

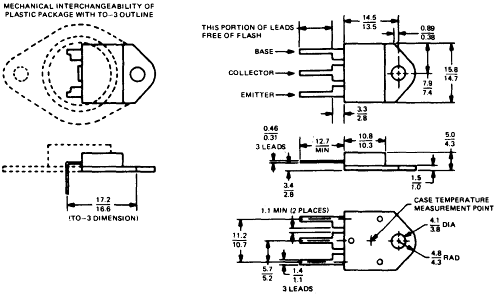
- 125 W at 25°C Case Temperature
- 10-A Rated Collector Current
- Min h_{FE} of 1000 at 4 V, 5 A
- 100-mJ Reverse Energy Rating

device schematic

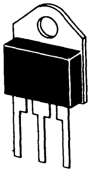


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP140	TIP141	TIP142
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	← 10 A →		
Peak Collector Current (See Note 2)	← 15 A →		
Continuous Base Current	← 0.5 A →		
Safe Operating Areas at (or below) 25°C Case Temperature	← See Figures 7 and 8 →		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 125 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 3.5 W →		
Unclamped Inductive Load Energy (See Note 5)	← 100 mJ →		
Operating Collector Junction Temperature Range	← −65°C to 150°C →		
Storage Temperature Range	← −65°C to 150°C →		
Lead Temperature 3.2mm from Case for 10 Seconds	← 260°C →		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_W \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 150°C case temperature at the rate of 1 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C{}^2L/2$.

TIP 140,TIP 141,TIP 142
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS			TIP140		TIP141		TIP142		UNIT
					MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA,	I_B = 0,	See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V,	I_B = 0			2					mA
		V_{CE} = 40 V,	I_B = 0					2			
		V_{CE} = 50 V,	I_B = 0							2	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V,	I_E = 0			1					mA
		V_{CB} = 80 V,	I_E = 0					1			
		V_{CB} = 100 V,	I_E = 0							1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			2		2		2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 5 A	See Notes 6 and 7	1000		1000		1000		
		V_{CE} = 4 V,	I_C = 10 A		500		500		500		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V,	I_C = 10 A,	See Notes 6 and 7		3		3		3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 10 mA,	I_C = 5 A	See Notes 6 and 7		2		2		2	V
		I_B = 40 mA,	I_C = 10 A			3		3		3	

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

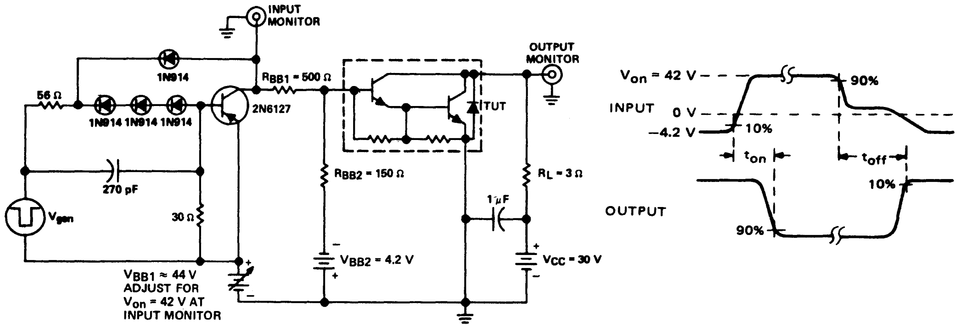
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 10 A, $I_{B(1)}$ = 40 mA, $I_{B(2)}$ = −40 mA,	0.9	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.2 V, R_L = 3 Ω, See Figure 1	11	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ≤ 15 ns, t_f ≤ 15 ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ≤ 2%.

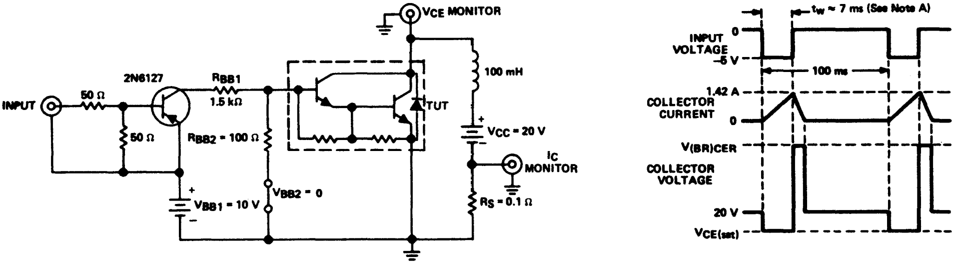
C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ≤ 15 ns, R_{in} ≥ 10 MΩ, C_{in} ≤ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 1.42 A.

FIGURE 2

TYPICAL CHARACTERISTICS

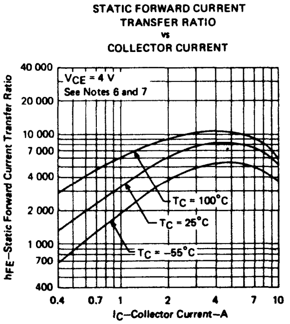

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

FIGURE 3

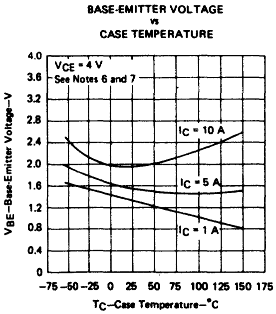

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

FIGURE 4

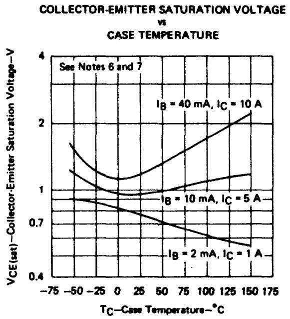

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

FIGURE 5

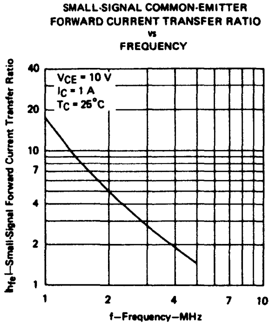
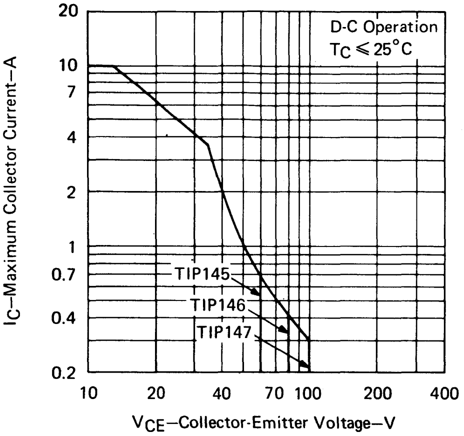

SMALL-SIGNAL COMMON-EMITTER FORWARD CURRENT TRANSFER RATIO vs FREQUENCY

FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques, t_w = 300 μs, duty cycle < 2%.

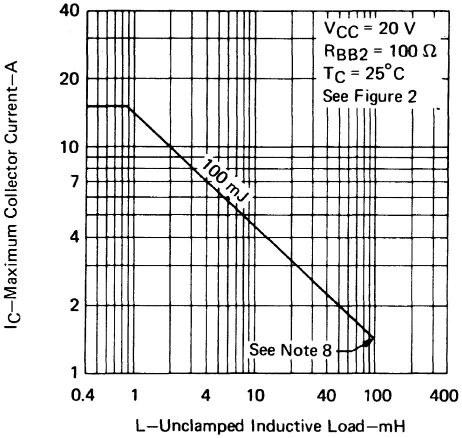
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS



MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

FIGURE 7

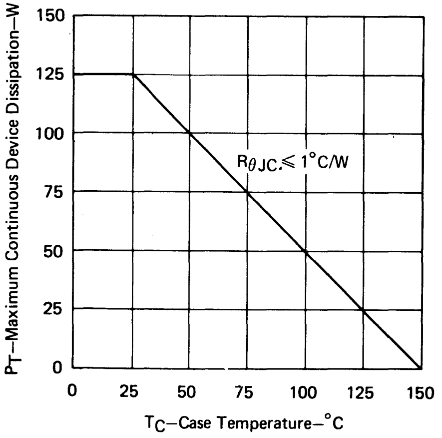


MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

FIGURE 8

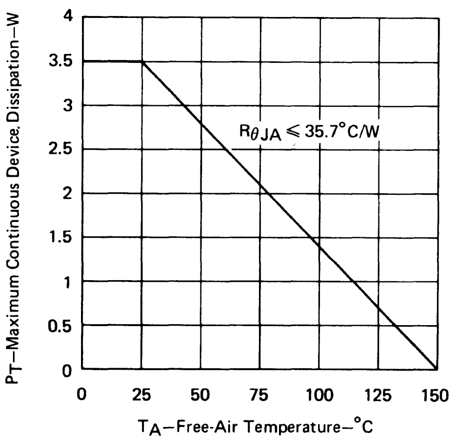
NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION



CASE TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 9



FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 10

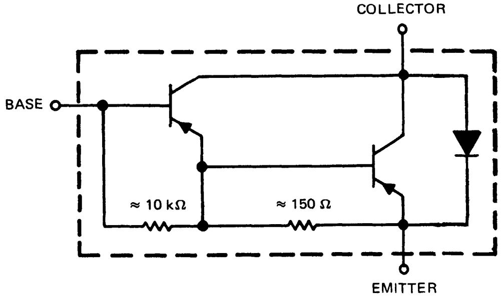
TIP145,TIP146,TIP147
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED APRIL 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP140, TIP141, TIP142

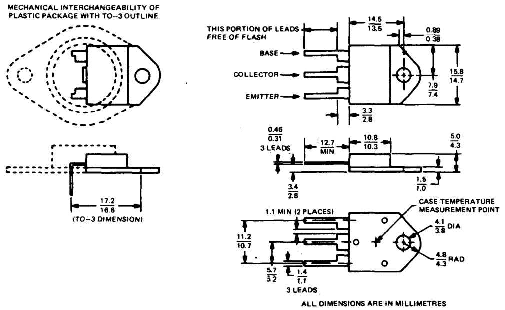
- 125 W at 25°C Case Temperature
- 10-A Rated Collector Current
- Min h_{FE} of 1000 at 4 V, 5 A
- 100 mJ Reverse Energy Rating

device schematic

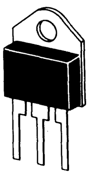


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP145	TIP146	TIP147
Collector-Base Voltage	–60 V	–80 V	–100 V
Collector-Emitter Voltage (See Note 1)	–60 V	–80 V	–100 V
Emitter-Base Voltage	–5 V	–5 V	–5 V
Continuous Collector Current	←–10 A→		
Peak Collector Current (See Note 2)	←–15 A→		
Continuous Base Current	←–0.5 A→		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←125 W→		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←3.5 W→		
Unclamped Inductive Load Energy (See Note 5)	←100 mJ→		
Operating Collector Junction Temperature Range	←–65°C to 150°C→		
Storage Temperature Range	←–65°C to 150°C→		
Lead Temperature 3.2mm from Case for 10 Seconds	←260°C→		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 1 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C{}^2L/2$.

TIP145,TIP146,TIP147
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIP145		TIP146		TIP147		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 6	−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−2					mA
		$V_{CE} = -40$ V, $I_B = 0$				−2			
		$V_{CE} = -50$ V, $I_B = 0$						−2	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$		−1					mA
		$V_{CB} = -80$ V, $I_E = 0$				−1			
		$V_{CB} = -100$ V, $I_E = 0$						−1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−2		−2		−2	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 6 and 7	1000		1000		1000		
		$V_{CE} = -4$ V, $I_C = -10$ A	500		500		500		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -10$ A, See Notes 6 and 7		−3		−3		−3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -10$ mA, $I_C = -5$ A, See Notes 6 and 7		−2		−2		−2	V
		$I_B = -40$ mA, $I_C = -10$ A		−3		−3		−3	

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

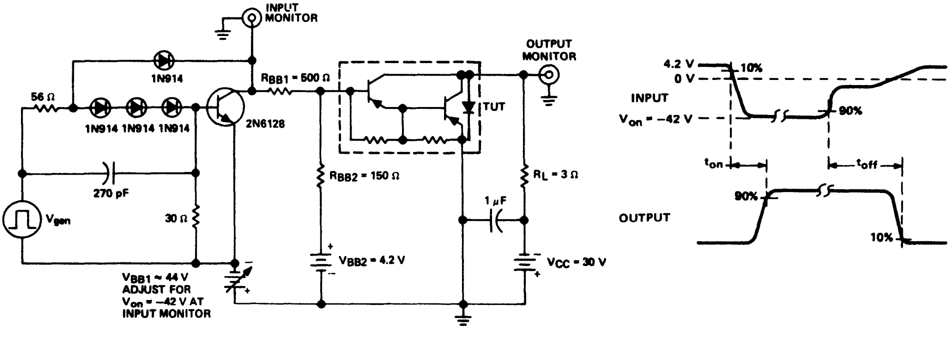
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -10$ A, $I_{B(1)} = -40$ mA, $I_{B(2)} = 40$ mA,	0.9	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 4.2$ V, $R_L = 3$ Ω, See Figure 1	11	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50$ Ω, $t_w = 20$ μs, duty cycle ≤ 2%.

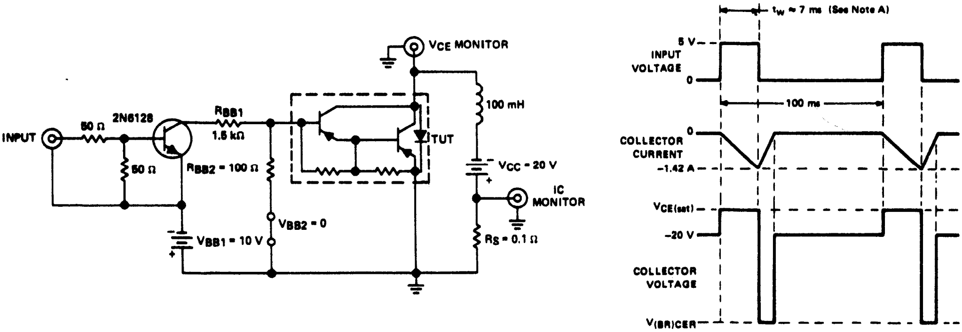
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until $I_{CM} = -1.42$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

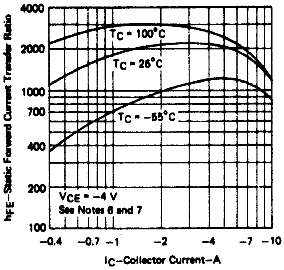


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

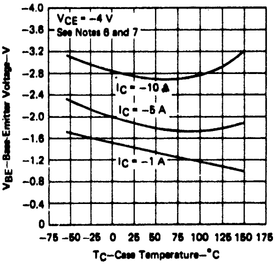


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

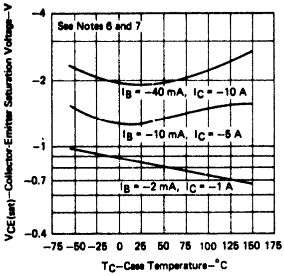


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

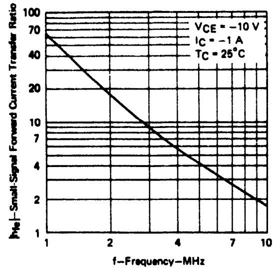


FIGURE 6

NOTES:
6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

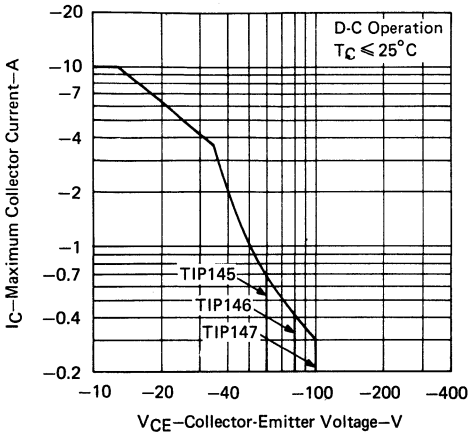


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

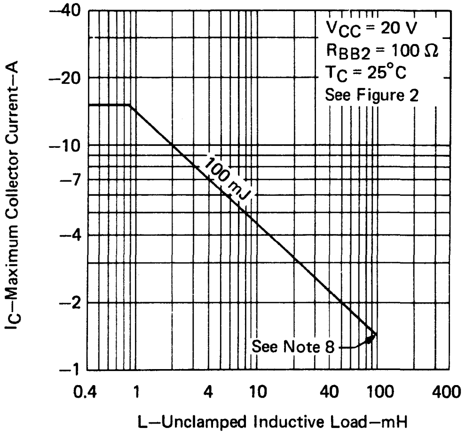


FIGURE 8

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

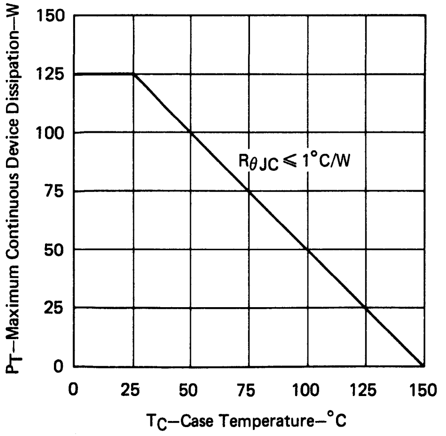


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

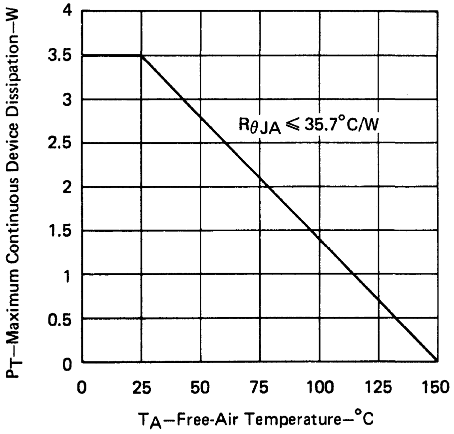


FIGURE 10

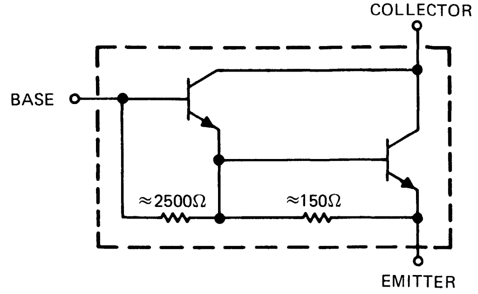
TYPES TIP150,TIP151,TIP152
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED AUGUST 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATIONS

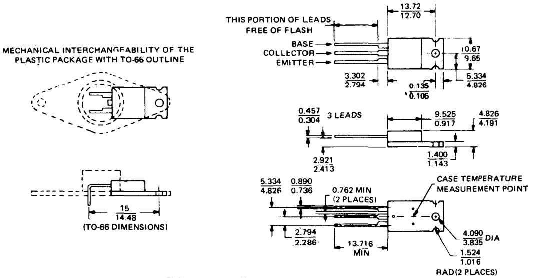
- **50 W at 25°C Case Temperature**
- **2 A Rated Collector Current**
- **Min h_{FE} of 500 at 10 V, 1.5 A**

device schematic

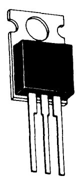


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP150	TIP151	TIP152
Collector-Base Voltage	200 V	300 V	400 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	2 A		
Peak Collector Current (See Note 2)	3 A		
Continuous Base Current	0.1 A		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W		
Operating Collector Junction Temperature Range	−65°C to 150°C		
Storage Temperature Range	−65°C to 150°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 150°C case temperature at the rate of 0.52 W/°C
4. Derate linearly to 150°C free-air temperature at the rate of 16 mW/°C

TYPES TIP150,TIP151,TIP152
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP150		TIP151		TIP152		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$,	See Note 5	200		300		400		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 100$ V, $I_B = 0$			0.5					mA
		$V_{CE} = 200$ V, $I_B = 0$					0.5			
		$V_{CE} = 300$ V, $I_B = 0$							0.5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 250$ V, $I_E = 0$			0.2					mA
		$V_{CB} = 350$ V, $I_E = 0$					0.2			
		$V_{CB} = 450$ V, $I_E = 0$							0.2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$			5		5		5	mA
h_{FE}	Static Forward Current Transfer Ratio		See Notes 5 and 6							
		$V_{CE} = 10$ V, $I_C = 1.5$ A		500		500		500		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 10$ V, $I_C = 1.5$ A,	See Notes 5 and 6		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 6$ mA, $I_C = 1.5$ A	See Notes 5 and 6		2		2		2	V
		$I_B = 8$ mA, $I_C = 2$ A			3		3		3	

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	62.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

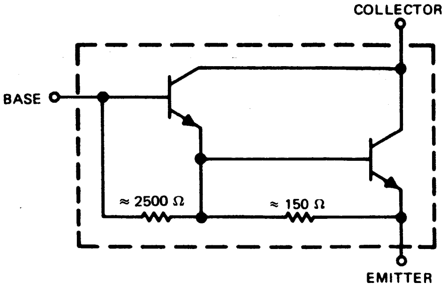
TYPES TIP160, TIP161, TIP162
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED AUGUST 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATIONS

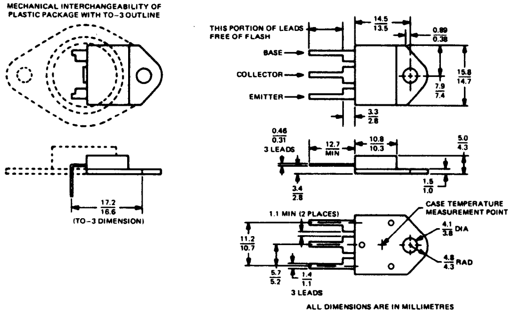
- 125 W at 25°C Case Temperature
- 5 A Rated Collector Current
- Min h_{FE} of 500 at 10 V, 3 A

device schematic

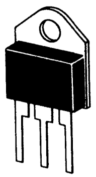


mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP140	TIP141	TIP142
Collector-Base Voltage	200 V	300 V	400 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	◄—	5 A	—►
Peak Collector Current (See Note 2)	◄—	7.5 A	—►
Continuous Base Current	◄—	0.25 A	—►
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄—	125 W	—►
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄—	3.5 W	—►
Operating Collector Junction Temperature Range	◄—	−65°C to 150°C	—►
Storage Temperature Range	◄—	−65°C to 150°C	—►
Lead Temperature 3.2mm from Case for 10 Seconds	◄—	260°C	—►

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle ⩽ 10%.
3. Derate linearly to 150°C case temperature at the rate of 1 W/°C
4. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C

TYPES TIP160, TIP161, TIP162
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS			TIP160		TIP161		TIP162		UNIT
					MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA,	I_B = 0,	See Note 5	200		300		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 100 V,	I_B = 0			2					mA
		V_{CE} = 200 V,	I_B = 0					2			
		V_{CE} = 300 V,	I_B = 0							2	
I_{CBO}	Collector Cutoff Current	V_{CB} = 250 V,	I_E = 0			2					mA
		V_{CB} = 350 V,	I_E = 0					2			
		V_{CB} = 450 V,	I_E = 0							2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			5		5		5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 3 A	See Notes 5 and 6	500		500		500		
		V_{CE} = 10 V,	I_C = 5 A		200		200		200		
V_{BE}	Base-Emitter Voltage	V_{CE} = 10 V,	I_C = 3 A,	See Notes 5 and 6		2		2		2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 30 mA,	I_C = 3 A	See Notes 5 and 6		1.5		1.5		1.5	V

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

TYPES TIP503 THRU TIP506
N-P-N SILICON POWER TRANSISTORS

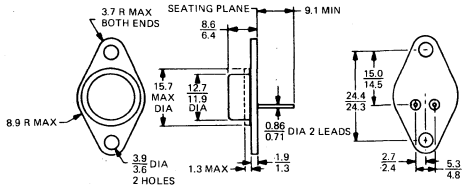
REVISED JUNE 1975

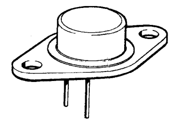
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 120 V and 150 V Min $V_{(BR)CEO}$
- 2-A Rated Continuous Collector Current
- 20 Watts at 100°C Case Temperature
- Min f_T of 70 MHz at 5 V, 0.25 A

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

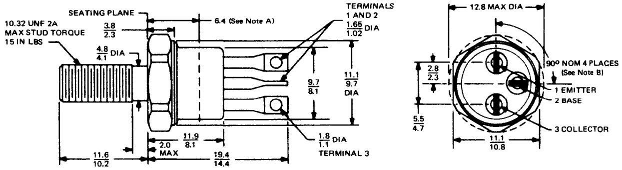


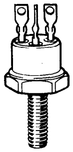


ALL DIMENSIONS ARE IN MILLIMETRES

ALL JEDEC TO-66 DIMENSIONS AND NOTES ARE APPLICABLE

ALL TERMINALS ARE INSULATED FROM THE CASE





ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to the hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in millimetres unless otherwise specified.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP503 TIP505	TIP504 TIP506
Collector-Base Voltage	130 V	160 V
Collector-Emitter Voltage (See Note 1)	120 V	150 V
Emitter-Base Voltage	6 V	6 V
Continuous Collector Current	← 2 A →	
Peak Collector Current (See Note 2)	← 5 A →	
Continuous Base Current	← 1 A →	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 20 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 2 W →	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C →	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.2 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			TIP503 TIP505		TIP504 TIP506		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA,	I_B = 0,	See Note 5	120		150		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 60 V,	I_B = 0			50			µA
		V_{CE} = 75 V,	I_B = 0					50	
I_{CES}	Collector Cutoff Current	V_{CE} = 120 V,	V_{BE} = 0			400			µA
		V_{CE} = 150 V,	V_{BE} = 0					400	
		V_{CE} = 60 V,	V_{BE} = 0,	T_C = 150°C		500			
		V_{CE} = 75 V,	V_{BE} = 0,	T_C = 150°C				500	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 3 V,	I_C = 0			20		20	µA
		V_{EB} = 6 V,	I_C = 0			200		200	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 1 A,	See Notes 5 and 6	40	200	40	200	
		V_{CE} = 4 V,	I_C = 2 A,	See Notes 5 and 6	20		20		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V,	I_C = 2 A,	See Notes 5 and 6		1.4		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.1 A,	I_C = 1 A,	See Notes 5 and 6		0.6		0.6	V
		I_B = 0.2 A,	I_C = 2 A,	See Notes 5 and 6		1.2		1.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V,	I_C = 250 mA,	f = 1 kHz	40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V,	I_C = 250 mA,	f = 10 MHz	7		7		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	

TYPES TIP507, TIP508
P-N-P SILICON POWER TRANSISTORS

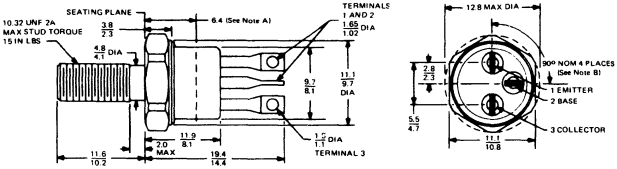
REVISED JUNE 1975

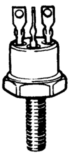
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 150 V Min $V_{(BR)CEO}$
- 2-A Rated Continuous Collector Current
- 20 Watts at 100°C Case Temperature (TIP507)
- 4 Watts at 100°C Case Temperature (TIP508)
- Min f_T of 50 MHz at 5 V, 0.2 A

mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

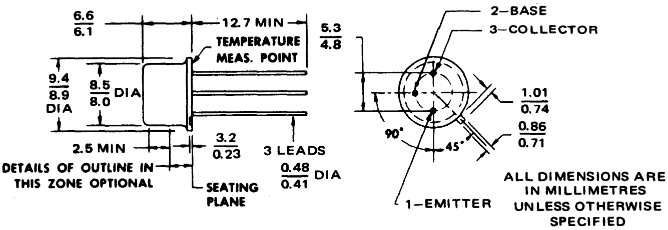


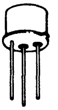


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in mm unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP507	TIP508
Collector-Base Voltage	−150 V	
Collector-Emitter Voltage (See Note 1)	−150 V	
Emitter-Base Voltage	−5 V	
Continuous Collector Current	−2 A	
Peak Collector Current (See Note 2)	−3 A	
Continuous Base Current	−0.6 A	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	20 W	4 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	1 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	300°C	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle ≤ 10%.
3. Derate linearly to 200°C case temperature at the rate of 200 mW/°C for TIP507 and 40 mW/°C for TIP508.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C for TIP507 and 5.7 mW/°C for TIP508.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−150		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -75$ V, $I_B = 0$		−200	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -150$ V, $V_{BE} = 0$		−1	mA
		$V_{CE} = -75$ V, $V_{BE} = 0$, $T_C = 150°C$		−2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V, $I_C = 0$		−100	μA
		$V_{EB} = -5$ V, $I_C = 0$		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 5 and 6	30	120	
		$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.1$ A, $I_C = -1$ A, See Notes 5 and 6		−1	V
		$I_B = -0.4$ A, $I_C = -2$ A, See Notes 5 and 6		−1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.2$ A, f = 1 kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.2$ A, f = 5 MHz	10		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

thermal characteristics

PARAMETER		TIP507	TIP508	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	25	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	175	

MAXIMUM SAFE OPERATING AREA

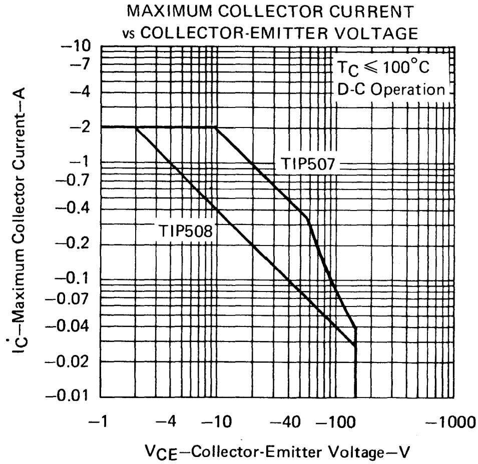

MAXIMUM COLLECTOR CURRENT
vs COLLECTOR-EMITTER VOLTAGE

FIGURE 1

TYPES TIP509 THRU TIP512
N-P-N SILICON POWER TRANSISTORS

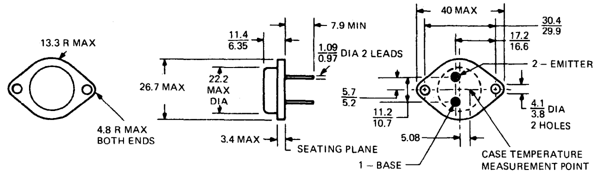
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

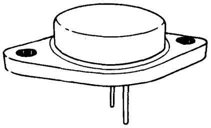
- 120 V and 150 V Min $V_{(BR)CEO}$
- 4-A Rated Continuous Collector Current
- 30 Watts at 100°C Case Temperature
- Min f_T of 70 MHz at 5 V, 0.5 A

mechanical data

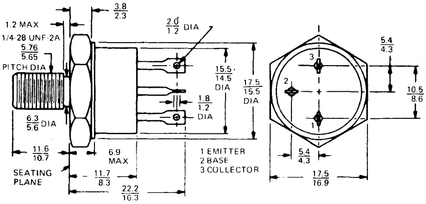
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



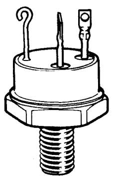
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP509 TIP511	TIP510 TIP512
Collector-Base Voltage	130 V	160 V
Collector-Emitter Voltage (See Note 1)	120 V	150 V
Emitter-Base Voltage	6 V	6 V
Continuous Collector Current	◄— 4 A —►	
Peak Collector Current (See Note 2)	◄— 8 A —►	
Continuous Base Current	◄— 2 A —►	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	◄— 30 W —►	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 4 W —►	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	◄— 300°C —►	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP509 TIP511		TIP510 TIP512		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	120		150		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 60$ V, $I_B = 0$		0.5			mA
		$V_{CE} = 75$ V, $I_B = 0$				0.5	
I_{CES}	Collector Cutoff Current	$V_{CE} = 120$ V, $V_{BE} = 0$		1			mA
		$V_{CE} = 150$ V, $V_{BE} = 0$				1	
		$V_{CE} = 60$ V, $V_{BE} = 0$, $T_C = 150°C$		1			
		$V_{CE} = 75$ V, $V_{BE} = 0$, $T_C = 150°C$				1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V, $I_C = 0$		50		50	µA
		$V_{EB} = 6$ V, $I_C = 0$		500		500	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 2$ A, See Notes 5 and 6	40	200	40	200	
		$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 5 and 6	25		25		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 5 and 6		1.4		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.2$ A, $I_C = 2$ A, See Notes 5 and 6		0.6		0.6	V
		$I_B = 0.4$ A, $I_C = 4$ A, See Notes 5 and 6		1.5		1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ A, $f = 1$ kHz	40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ A, $f = 10$ MHz	7		7		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.33	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.75	

TYPES TIP513, TIP514
P-N-P SILICON POWER TRANSISTORS

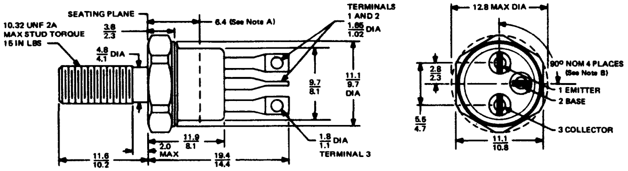
REVISED JUNE 1975

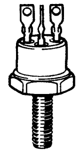
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 150 V Min $V_{(BR)CEO}$
- 5-A Rated Continuous Collector Current
- 30 Watts at 100°C Case Temperature (TIP513)
- 20 Watts at 100°C Case Temperature (TIP514)
- Min f_T of 40 MHz at 5 V, 0.5 A

mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

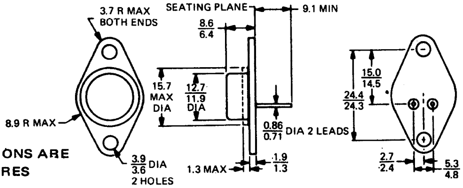




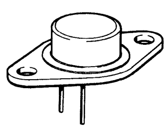
ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
- A. Within this dimension, case diameter may vary.
- B. Position of terminals with respect to the hexagon is not controlled.
- C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
- D. All dimensions are in millimetres unless otherwise specified

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



ALL JEDEC TO-66 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP513	TIP514
Collector-Base Voltage	−150 V	
Collector-Emitter Voltage (See Note 1)	−150 V	
Emitter-Base Voltage	−5 V	
Continuous Collector Current	−5 A	
Peak Collector Current (See Note 2)	−7.5 A	
Continuous Base Current	−2 A	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W	20 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	2 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	300°C	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/°C for TIP513 and 0.2 W/°C for TIP514.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C.

TYPES TIP513, TIP514
P-N-P SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−150		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -75$ V, $I_B = 0$		−300	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -150$ V, $V_{BE} = 0$		−1	mA
		$V_{CE} = -75$ V, $V_{BE} = 0$, $T_C = 150°C$		−2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V, $I_C = 0$		−100	μA
		$V_{EB} = -5$ V, $I_C = 0$		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -2.5$ A, See Notes 5 and 6	30	150	
		$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6	15		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6		−2.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.25$ A, $I_C = -2.5$ A, See Notes 5 and 6		−1	V
		$I_B = -0.5$ A, $I_C = -5$ A, See Notes 5 and 6		−2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ A, f = 1 kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ A, f = 5 MHz	8		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP513	TIP514	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.33	5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	87.5	

MAXIMUM SAFE OPERATING AREA

MAXIMUM COLLECTOR CURRENT

vs

COLLECTOR-EMITTER VOLTAGE

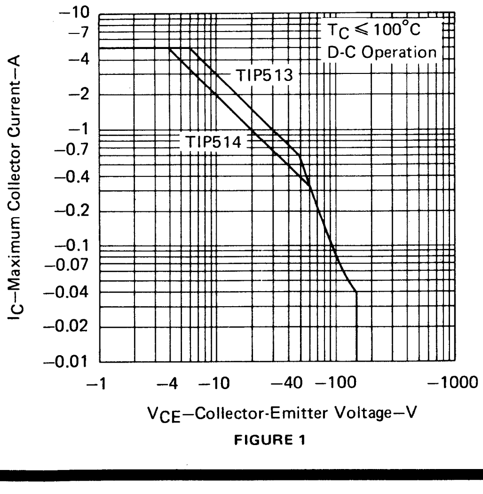


FIGURE 1

TYPES TIP515 THRU TIP518
N-P-N SILICON POWER TRANSISTORS

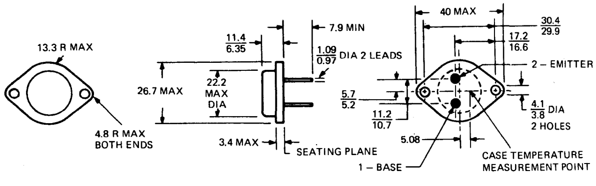
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

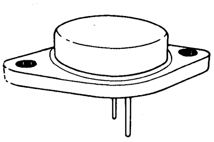
- 120 V and 150 V Min $V_{(BR)CEO}$
- 12-A Rated Continuous Collector Current
- 80 Watts at 100°C Case Temperature
- Min f_T of 70 MHz at 5 V, 1 A

mechanical data

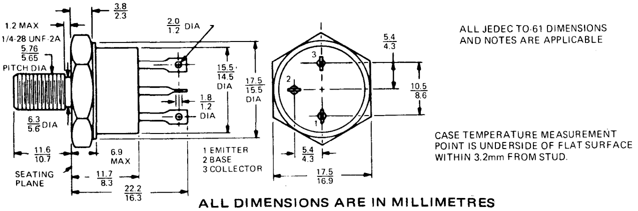
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



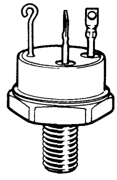
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP515	TIP516	TIP517	TIP518
Collector-Base Voltage	130 V	160 V	130 V	160 V
Collector-Emitter Voltage (See Note 1)	120 V	150 V	120 V	150 V
Emitter-Base Voltage	6 V	6 V	6 V	6 V
Continuous Collector Current	← 12 A →			
Peak Collector Current (See Note 2)	← 25 A →			
Continuous Base Current	← 6 A →			
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	80 W	80 W	80 W	80 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W	4 W	3.5 W	3.5 W
Operating Collector Junction Temperature Range	← −65°C to 200°C →			
Storage Temperature Range	← −65°C to 200°C →			
Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C →			

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.8 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C for TIP515 and TIP516, 20 mW/°C for TIP517 and TIP518.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP515 TIP517		TIP516 TIP518		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 5	120		150		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 60 V, I_B = 0		1			mA
		V_{CE} = 75 V, I_B = 0				1	
I_{CES}	Collector Cutoff Current	V_{CE} = 120 V, V_{BE} = 0		5			mA
		V_{CE} = 150 V, V_{BE} = 0				5	
		V_{CE} = 60 V, V_{BE} = 0, T_C = 150°C		5			
		V_{CE} = 75 V, V_{BE} = 0, T_C = 150°C				5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 3 V, I_C = 0		0.2		0.2	mA
		V_{EB} = 6 V, I_C = 0		2		2	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 6 A, See Notes 5 and 6	40	200	40	200	
		V_{CE} = 4 V, I_C = 12 A, See Notes 5 and 6	30		30		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 12 A, See Notes 5 and 6		1.4		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.6 A, I_C = 6 A, See Notes 5 and 6		0.8		0.8	V
		I_B = 1.2 A, I_C = 12 A, See Notes 5 and 6		1.5		1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, f = 1 kHz	40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, f = 10 MHz	7		7		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle $\leqslant$ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP515 TIP516	TIP517 TIP518	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.25	1.25	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.75	50	

TYPES TIP519, TIP520
P-N-P SILICON POWER TRANSISTORS

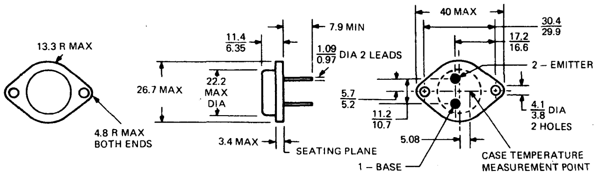
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

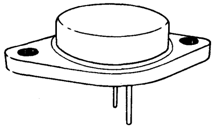
- 150 V Min $V_{(BR)CEO}$
- 8-A Rated Continuous Collector Current
- 50 Watts at 100°C Case Temperature
- Min f_T of 40 MHz at 5 V, 1 A

mechanical data

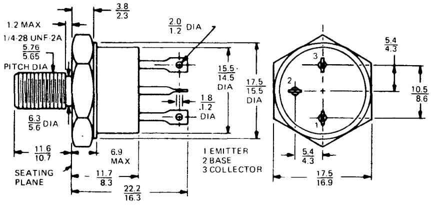
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



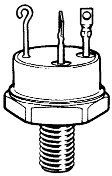
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP519	TIP520
Collector-Base Voltage	◄—–150 V—►	
Collector-Emitter Voltage (See Note 1)	◄—–150 V—►	
Emitter-Base Voltage	◄—–5 V—►	
Continuous Collector Current	◄—–8 A—►	
Peak Collector Current (See Note 2)	◄—–12 A—►	
Continuous Base Current	◄—–3 A—►	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	◄—50 W—►	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	◄—300°C—►	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C for TIP519 and 20 mW/°C for TIP520.

TYPES TIP519, TIP520
P-N-P SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−150		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -75$ V, $I_B = 0$		−500	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -150$ V, $V_{BE} = 0$		−1	mA
		$V_{CE} = -75$ V, $V_{BE} = 0$, $T_C = 150°C$		−3	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V, $I_C = 0$		−100	μA
		$V_{EB} = -5$ V, $I_C = 0$		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -4$ A, See Notes 5 and 6	30	150	
		$V_{CE} = -4$ V, $I_C = -8$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -8$ A, See Notes 5 and 6		−2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.4$ A, $I_C = -4$ A, See Notes 5 and 6		−1	V
		$I_B = -1.6$ A, $I_C = -8$ A, See Notes 5 and 6		−2.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = 1$ A, f = 1 kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -1$ A, f = 5 MHz	8		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP519	TIP520	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2	2	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.8	50	

MAXIMUM SAFE OPERATING AREA

MAXIMUM COLLECTOR CURRENT
vs COLLECTOR-EMITTER VOLTAGE

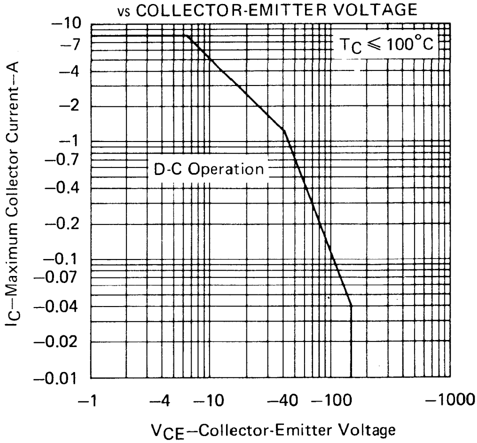


FIGURE 1

TEXAS INSTRUMENTS

TYPES TIP521, TIP522
P-N-P SILICON POWER TRANSISTORS

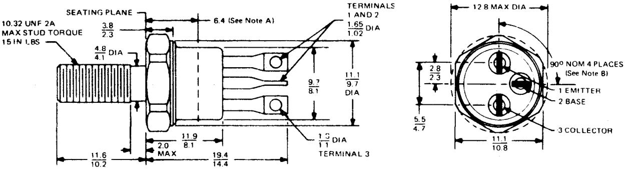
REVISED JUNE 1975

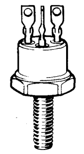
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 200 V Min $V_{(BR)CEO}$
- 2-A Rated Continuous Collector Current
- 20 Watts at 100°C Case Temperature (TIP521)
- 4 Watts at 100°C Case Temperature (TIP522)
- Min f_T of 50 MHz at 5 V, 0.2 A

mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

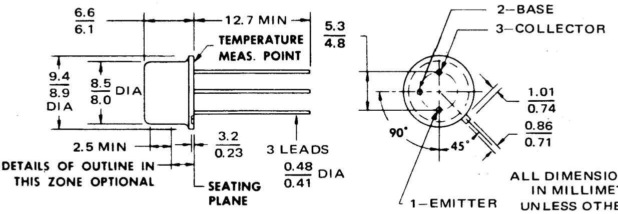




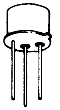
ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in mm unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE SPECIFIED



ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP521	TIP522
Collector-Base Voltage	←−200 V→	
Collector-Emitter Voltage (See Note 1)	←−200 V→	
Emitter-Base Voltage	←−5 V→	
Continuous Collector Current	←−2 A→	
Peak Collector Current (See Note 2)	←−3 A→	
Continuous Base Current	←−0.6 A→	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	20 W	4 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	1 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	←300°C→	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 200 mW/°C for TIP521 and 40 mW/°C for TIP522.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C for TIP521 and 5.7 mW/°C for TIP522.

TYPES TIP521, TIP522
P-N-P SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−200		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -100$ V, $I_B = 0$		−200	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -200$ V, $V_{BE} = 0$		−1	mA
		$V_{CE} = -100$ V, $V_{BE} = 0$, $T_C = 150°C$		−2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V, $I_C = 0$		−100	μA
		$V_{EB} = -5$ V, $I_C = 0$		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 5 and 6	20	100	
		$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6		−2.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.1$ A, $I_C = -1$ A, See Notes 5 and 6		−1.5	V
		$I_B = -0.5$ A, $I_C = -2$ A, See Notes 5 and 6		−2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.2$ A, f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.2$ A, f = 5 MHz	10		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2. inch from the device body.

thermal characteristics

PARAMETER		TIP521	TIP522	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	25	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	175	

MAXIMUM SAFE OPERATING AREA

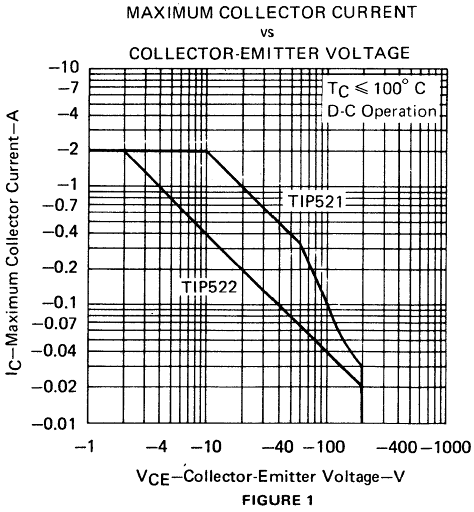


FIGURE 1

TIP523,TIP524
PNP SILICON POWER TRANSISTORS

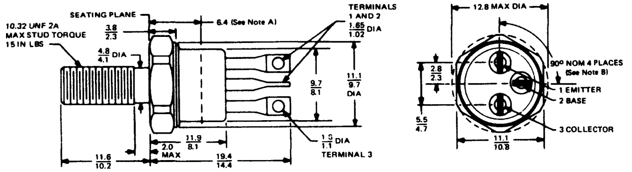
REVISED JUNE 1975

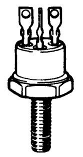
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 200 V Min $V_{(BR)CEO}$
- 5-A Rated Continuous Collector Current
- 30 Watts at 100°C Case Temperature (TIP523)
- 6 Watts at 100°C Case Temperature (TIP524)
- Min f_T of 40 MHz at 5 V, 0.5 A

mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

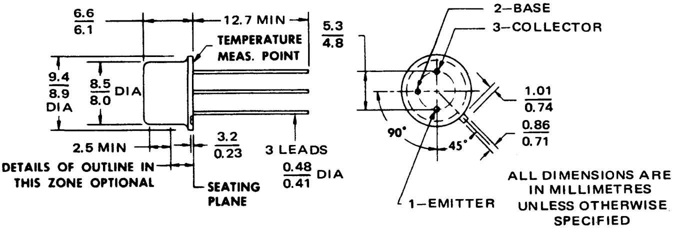


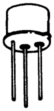


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2 mm of the stud.
D. All dimensions are in mm unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP523	TIP524
Collector-Base Voltage	◄— −200 V —►	
Collector-Emitter Voltage (See Note 1)	◄— −200 V —►	
Emitter-Base Voltage	◄— −5 V —►	
Continuous Collector Current	◄— −5 A —►	
Peak Collector Current (See Note 2)	◄— −7.5 A —►	
Continuous Base Current	◄— −2 A —►	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W	6 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	1 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	◄— 300°C —►	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle ≤ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.3 mW/°C for TIP523 and 60 mW/°C for TIP524.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C for TIP523 and 5.7 mW/°C for TIP524.

TIP523,TIP524
PNP SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−200		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -100$ V, $I_B = 0$		−300	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -200$ V, $V_{BE} = 0$		−1	mA
		$V_{CE} = -100$ V, $V_{BE} = 0$, $T_C = 150°C$		−2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V, $I_C = 0$		−100	μA
		$V_{EB} = -5$ V, $I_C = 0$		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -2.5$ A, See Notes 5 and 6	20	100	
		$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6		−2.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.25$ A, $I_C = -2.5$ A, See Notes 5 and 6		−1.5	V
		$I_B = -1.25$ A, $I_C = -5$ A, See Notes 5 and 6		−2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ A, f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ A, f = 5 MHz	8		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP523	TIP524	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3.33	16.7	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	175	

MAXIMUM SAFE OPERATING AREA

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

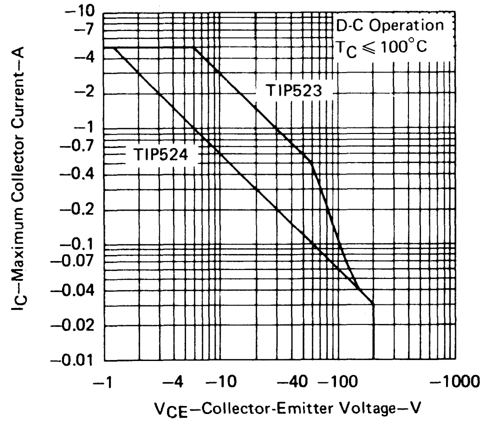


FIGURE 1

TIP525,TIP526
NPN SILICON POWER TRANSISTORS

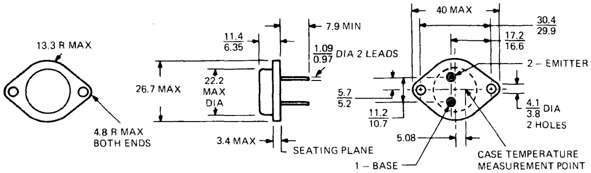
REVISED JUNE 1975

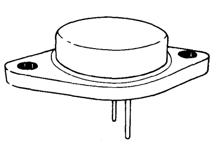
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 200 V Min $V_{(BR)CEO}$
- 5-A Rated Continuous Collector Current
- 60 Watts at 100°C Case Temperature
- Min f_T of 40 MHz at 5 V, 0.5 A

mechanical data

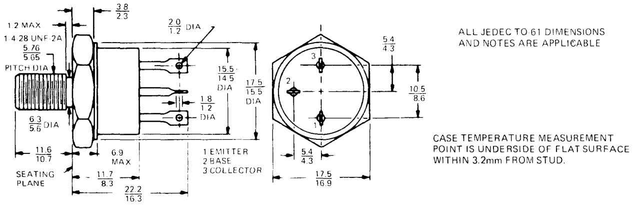
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE

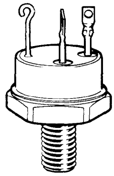




ALL DIMENSIONS ARE IN MILLIMETRES

ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP525	TIP526
Collector-Base Voltage	250 V	
Collector-Emitter Voltage (See Note 1)	200 V	
Emitter-Base Voltage	6 V	
Continuous Collector Current	5 A	
Peak Collector Current (See Note 2)	10 A	
Continuous Base Current	2 A	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	60 W	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	300°C	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.6 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C for TIP525 and 20 mW/°C for TIP526.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA,	$I_B = 0$,	See Note 5	200		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 100$ V,	$I_B = 0$			500	µA
I_{CES}	Collector Cutoff Current	$V_{CE} = 250$ V,	$V_{BE} = 0$			1	mA
		$V_{CE} = 125$ V,	$V_{BE} = 0$,	$T_C = 150°C$		2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			100	µA
		$V_{EB} = 6$ V,	$I_C = 0$			1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 2.5$ A,	See Notes 5 and 6	30	150	
		$V_{CE} = 4$ V,	$I_C = 5$ A,	See Notes 5 and 6	20		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V,	$I_C = 5$ A,	See Notes 5 and 6		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.25$ A,	$I_C = 2.5$ A,	See Notes 5 and 6		1.2	V
		$I_B = 0.5$ A,	$I_C = 5$ A,	See Notes 5 and 6		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 0.5$ A,	f = 1 kHz	30		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 0.5$ A,	f = 5 MHz	8		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP525	TIP526	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.67	1.67	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.8	50	

TIP527, TIP528
NPN SILICON POWER TRANSISTORS

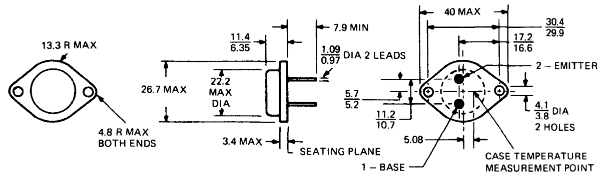
REVISED JUNE 1975

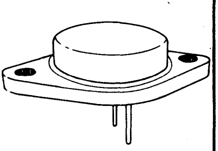
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 200 V Min $V_{(BR)CEO}$
- 8-A Rated Continuous Collector Current
- 60 Watts at 100°C Case Temperature
- Min f_T of 40 MHz at 5 V, 1 A

mechanical data

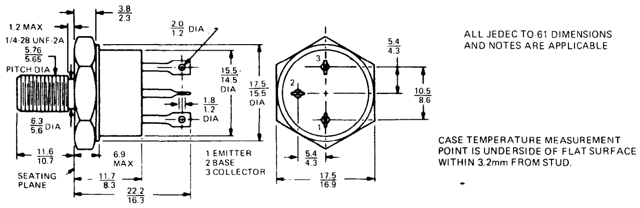
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

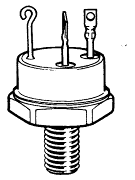




ALL DIMENSIONS ARE IN MILLIMETRES

ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP527	TIP528
Collector-Base Voltage	← −200 V →	
Collector-Emitter Voltage (See Note 1)	← −200 V →	
Emitter-Base Voltage	← −5 V →	
Continuous Collector Current	← −8 A →	
Peak Collector Current (See Note 2)	← −12 A →	
Continuous Base Current	← −2 A →	
Safe Operating Area at (or below) 100°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 60 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C →	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.6 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C for TIP527 and 20 mW/°C for TIP528.

TIP527, TIP528
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA,	$I_B = 0$,	See Note 5	−200		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -100$ V,	$I_B = 0$			−500	µA
I_{CES}	Collector Cutoff Current	$V_{CE} = -200$ V,	$V_{BE} = 0$			−1	mA
		$V_{CE} = -100$ V,	$V_{BE} = 0$,	$T_C = 150°C$		−3	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -2.5$ V,	$I_C = 0$			−100	µA
		$V_{EB} = -5$ V,	$I_C = 0$			−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -4$ A,	See Notes 5 and 6	20	100	
		$V_{CE} = -4$ V,	$I_C = -8$ A,	See Notes 5 and 6	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V,	$I_C = -8$ A,	See Notes 5 and 6		−2.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.4$ A,	$I_C = -4$ A,	See Notes 5 and 6		−1.5	V
		$I_B = -2$ A,	$I_C = -8$ A,	See Notes 5 and 6		−2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V,	$I_C = -1$ A,	f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V,	$I_C = -1$ A,	f = 5 MHz	8		

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP527	TIP528	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.67	1.67	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.8	50	

MAXIMUM SAFE OPERATING AREA

MAXIMUM COLLECTOR CURRENT

vs

COLLECTOR-EMITTER VOLTAGE

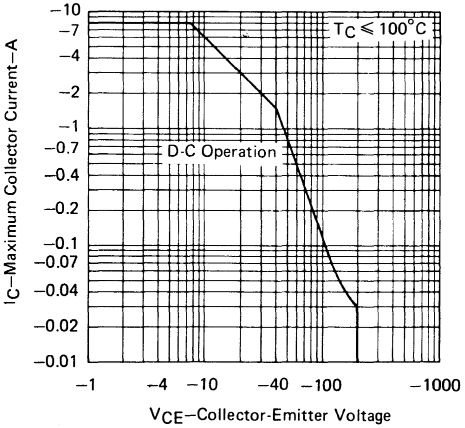


FIGURE 1

TIP 529, TIP 530
NPN SILICON POWER TRANSISTORS

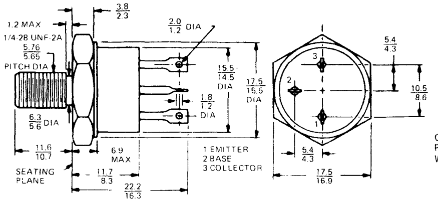
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 300 V Min $V_{(BR)CEO}$
- 3-A Rated Continuous Collector Current
- 67 Watts at 100°C Case Temperature (TIP529)
- 20 Watts at 100°C Case Temperature (TIP530)
- Min f_T of 20 MHz at 5 V, 0.5 A

mechanical data

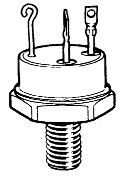
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



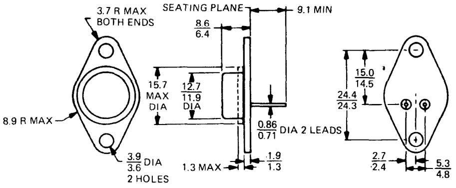
ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

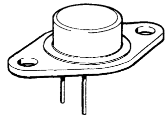
ALL DIMENSIONS ARE IN MILLIMETRES



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
ALL JEDEC TO-66 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP529	TIP530
Collector-Base Voltage	400 V	
Collector-Emitter Voltage (See Note 1)	300 V	
Emitter-Base Voltage	6 V	
Continuous Collector Current	3 A	
Peak Collector Current (See Note 2)	10 A	
Continuous Base Current	1.5 A	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	67 W	20 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W	2 W
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead or Terminal Temperature 1.588mm from Case for 10 Seconds	300°C	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.67 W/°C for TIP529 and 0.2 W/°C for TIP530.
4. Derate linearly to 200°C free-air temperature at the rate of 22.8 mW/°C for TIP529 and 11.4 mW/°C for TIP530.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 5	300		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0		100	μA
I_{CES}	Collector Cutoff Current	V_{CE} = 400 V, V_{BE} = 0		100	μA
		V_{CE} = 200 V, V_{BE} = 0, T_C = 150°C		1	mA
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		100	μA
		V_{EB} = 6 V, I_C = 0		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 1.5 A, See Notes 5 and 6	25	125	
		V_{CE} = 4 V, I_C = 3 A, See Notes 5 and 6	8		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 3 A, See Notes 5 and 6		1.7	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.15 A, I_C = 1.5 A, See Notes 5 and 6		1	V
		I_B = 0.6 A, I_C = 3 A, See Notes 5 and 6		2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 0.5 A, f = 1 kHz	25		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 0.5 A, f = 5 MHz	4		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		TIP529	TIP530	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.5	5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	43.75	87.5	

TIP531, TIP532, TIP533, TIP534
NPN SILICON POWER TRANSISTORS

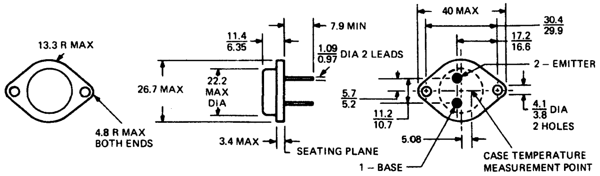
REVISED JUNE 1975

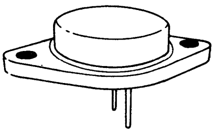
FOR POWER- AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **300 V and 400 V Min $V_{(BR)CEO}$**
- **15 A Rated Continuous Collector Current**
- **150 Watts at 100°C Case Temperature**
- **Min f_T of 50 MHz at 10 V, 1 A**

mechanical data

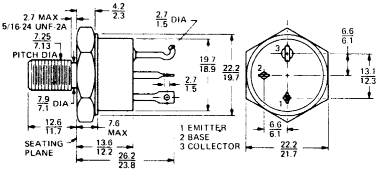
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





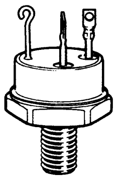
ALL DIMENSIONS ARE IN MILLIMETRES

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD



ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP531 TIP533	TIP532 TIP534
Collector-Base Voltage	340 V	450 V
Collector-Emitter Voltage (See Note 1)	300 V	400 V
Emitter-Base Voltage	6 V	6 V
Continuous Collector Current	←15 A→	
Peak Collector Current (See Note 2)	←25 A→	
Continuous Base Current	← 4 A→	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 150 W→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W→	
Operating Collector Junction Temperature Range	−65°C to 175°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C→	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 175°C case temperature at the rate of 2 W/°C.
4. Derate linearly to 175°C free-air temperature at the rate of 26.7 mW/°C.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP531 TIP533		TIP532 TIP534		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltagw	I_C = 100 mA, I_B = 0, See Note 5	300		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0		2			mA
		V_{CE} = 200 V, I_B = 0				2	
I_{CES}	Collector Cutoff Current	V_{CE} = 300 V, V_{BE} = 0		1			mA
		V_{CE} = 400 V, V_{BE} = 0				1	
		V_{CE} = 150 V, V_{BE} = 0, T_C = 150°C		6			
		V_{CE} = 200 V, V_{BE} = 0, T_C = 150°C				6	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 4 V, I_C = 0		0.5		0.5	mA
		V_{EB} = 6 V, I_C = 0		10		10	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 7.5 A, See Notes 5 and 6	20	120	20	120	
		V_{CE} = 4 V, I_C = 15 A, See Notes 5 and 6	5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 15 A, See Notes 5 and 6		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.75 A, I_C = 7.5 A, See Notes 5 and 6		1.5		1.5	V
		I_B = 4 A, I_C = 15 A, See Notes 5 and 6		2		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 5 MHz	10		10		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		ALL TYPES	UNIT
		MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	0.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	37.5	

TIP535,TIP536,TIP537
NPN SILICON POWER TRANSISTORS

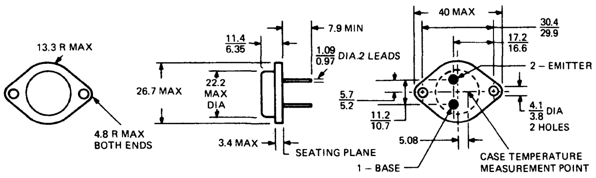
REVISED JUNE 1975

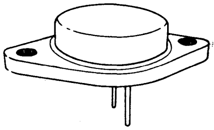
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- 200 V, 300 V, 400 V Min $V_{(BR)CEO}$
- 7.5-A Rated Continuous Collector Current
- 100 Watts at 100°C Case Temperature
- Min f_T of 10 MHz at 10 V, 1 A

mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP535	TIP536	TIP537
Collector-Base Voltage	300 V	400 V	500 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	← 7.5 A →		
Peak Collector Current (See Note 2)	← 15 A →		
Continuous Base Current	← 3 A →		
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 100 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 5 W →		
Operating Collector Junction Temperature Range	← −65°C to 200°C →		
Storage Temperature Range	← −65°C to 200°C →		
Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C →		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 1 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.

TIP535,TIP536,TIP537
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP535		TIP536		TIP537		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 5	200		300		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 100 V, I_B = 0		1					mA
		V_{CE} = 150 V, I_B = 0				1			
		V_{CE} = 200 V, I_B = 0						1	
I_{CES}	Collector Cutoff Current	V_{CE} = 300 V, I_B = 0		1					mA
		V_{CE} = 400 V, I_B = 0				1			
		V_{CE} = 500 V, I_B = 0						1	
		V_{CE} = 150 V, I_B = 0, T_C = 150°C		5					
		V_{CE} = 200 V, I_B = 0, T_C = 150°C				5			
		V_{CE} = 250 V, I_B = 0, T_C = 150°C						5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 4 V, I_C = 0		0.5		0.5		0.5	mA
		V_{EB} = 5 V, I_C = 0		1		1		1	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 5 A, See Notes 5 and 6	20	100	20	100	20	100	
		V_{CE} = 4 V, I_C = 7.5 A	5		5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 7.5 A, See Notes 5 and 6		2		2		2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.5 A, I_C = 5 A, See Notes 5 and 6		1.2		1.2		1.2	V
		I_B = 1.8 A, I_C = 7.5 A		2.5		2.5		2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 kHz	20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 5 MHz	2		2		2		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35	

TIP538, TIP539, TIP540
NPN SILICON POWER TRANSISTORS

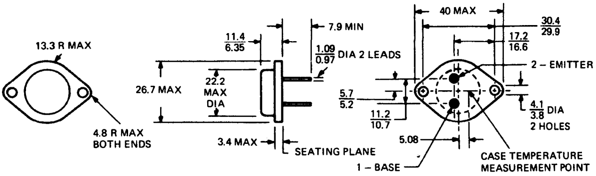
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

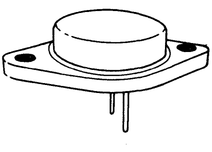
- 200 V, 300 V, 400 V Min $V_{(BR)CEO}$
- 15-A Rated Continuous Collector Current
- 125 Watts at 100°C Case Temperature
- Min f_T of 10 MHz at 10 V, 1 A

mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE·
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP538	TIP539	TIP540
Collector-Base Voltage	300 V	400 V	500 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	◄— 15 A —►		
Peak Collector Current (See Note 2)	◄— 25 A —►		
Continuous Base Current	◄— 5 A —►		
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	◄— 125 W —►		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 5 W —►		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Terminal Temperature 1.588mm from Case for 10 Seconds	◄— 300°C —►		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1.25 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.

TIP538, TIP539, TIP540
NPN SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP538		TIP539		TIP540		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 5	200		300		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 100 V, I_B = 0		2					mA
		V_{CE} = 150 V, I_B = 0				2			
		V_{CE} = 200 V, I_B = 0						2	
I_{CES}	Collector Cutoff Current	V_{CE} = 300 V, I_B = 0		1					mA
		V_{CE} = 400 V, I_B = 0				1			
		V_{CE} = 500 V, I_B = 0						1	
		V_{CE} = 150 V, I_B = 0, T_C = 150°C		10					
		V_{CE} = 200 V, I_B = 0, T_C = 150°C				10			
		V_{CE} = 250 V, I_B = 0, T_C = 150°C						10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 4 V, I_C = 0		0.5		0.5		0.5	mA
		V_{EB} = 5 V, I_C = 0		1		1		1	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 7.5 A, See Notes 5 and 6	20	100	20	100	20	100	
		V_{CE} = 4 V, I_C = 15 A	5		5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 15 A, See Notes 5 and 6		2		2		2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.75 A, I_C = 7.5 A, See Notes 5 and 6		0.75		0.75		0.75	V
		I_B = 3.75 A, I_C = 15 A		2.5		2.5		2.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 kHz	20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 5 MHz	2		2		2		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	0.8	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35	

TIP542
NPN SILICON POWER TRANSISTOR

JUNE 1975

RADIATION-TOLERANT TRANSISTOR FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

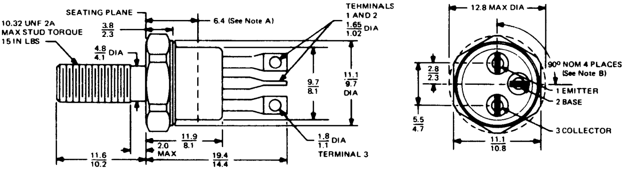
- **Min h_{FE} of 10 at 4 V, 8 A after 5 X 10^{14} Fast Neutrons/cm^2**
- **40 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.8 V at I_C = 10 A**
- **Min f_T of 150 MHz at 5 V, 1 A**
- **4 mJ Reverse Energy Rating**

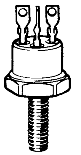
description

The TIP542 transistor offers a significant advance in radiation-tolerant-device technology. Unique construction techniques produce transistors which maintain useful characteristics after fast-neutron radiation fluences through 5 X 10^{14} n/cm^2.

mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE





ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
- A. Within this dimension, case diameter may vary.
- B. Position of terminals with respect to hexagon is not controlled.
- C. The case temperature may be measured anywhere on the seating plane within 3.2 mm of the stud.
- D. All dimensions are in mm unless otherwise specified.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	50 V
Collector-Emitter Voltage (See Note 1)	45 V
Emitter-Base Voltage	5 V
Continuous Collector Current	10 A
Peak Collector Current (See Note 2)	20 A
Continuous Base Current	5 A
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	40 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Unclamped Inductive Load Energy (See Note 5)	4 mJ
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1.588mm from Case for 10 Seconds	300°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.4 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ L = 125 μH, R_{BB1} = 5 Ω, R_{BB2} = 100 Ω, V_{BB1} = 10 V, V_{BB2} = 0 V, R_L = 0.1 Ω, V_{CC} = 20 V, I_{CM} = 8 A, Energy ≈ $I_C{}^2L/2$.

‡This circuit appears on page 5-1 of The Power Semiconductor Data Book for Design Engineers, CC404.

TIP542
NPN SILICON POWER TRANSISTOR

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	45		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 20 V, I_B = 0		5	mA
I_{CES}	Collector Cutoff Current	V_{CE} = 50 V, V_{BE} = 0		2	mA
		V_{CE} = 25 V, V_{BE} = 0, T_C = 150°C		4	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 4 V, I_C = 0		0.2	mA
		V_{EB} = 5 V, I_C = 0		2	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 5 A, See Notes 6 and 7	40	200	
		V_{CE} = 4 V, I_C = 8 A	70		
		V_{CE} = 4 V, I_C = 10 A	70		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 10 A, See Notes 6 and 7		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.5 A, I_C = 5 A, See Notes 6 and 7		0.5	V
		I_B = 1 A, I_C = 10 A		0.8	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, f = 1 kHz	35		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, f = 10 MHz	15		

post-irradiation electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	RADIATION FLUENCE†	MIN	MAX	UNIT
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 8 A, See Notes 6 and 7	5 X 10^{14} n/cm^2	10		

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	

†Radiation is fast neutrons (n) at E ⩾ 10 keV (reactor spectrum).

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

TIP543
NPN SILICON POWER TRANSISTOR

RADIATION-TOLERANT TRANSISTOR FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

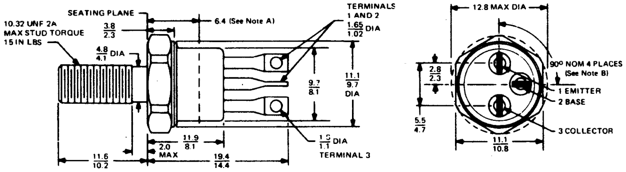
- **Min h_{FE} of 10 at 4 V, 5 A after 2 X 10^{14} Fast Neutrons/cm^2**
- **40 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.8 V at I_C = 10 A, I_B = 1 A**
- **Min f_T of 120 MHz at 5 V, 1 A**
- **4 mJ Reverse Energy Rating**

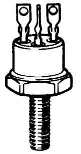
description

The TIP543 transistor offers a significant advance in radiation-tolerant-device technology. Unique construction techniques produce transistors which maintain useful characteristics after fast-neutron radiation fluences through 2 X 10^{14} n/cm^2.

mechanical data

ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE





ALL TERMINALS ARE INSULATED FROM THE CASE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured any where on the seating plane within 3.2 mm of the stud.
D. All dimensions are in mm unless otherwise specified.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	75 V
Collector-Emitter Voltage (See Note 1)	65 V
Emitter-Base Voltage	5 V
Continuous Collector Current	10 A
Peak Collector Current (See Note 2)	20 A
Continuous Base Current	5 A
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	40 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Unclamped Inductive Load Energy (See Note 5)	4 mJ
Operating Collector Junction Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Terminal Temperature 1.588mm from Case for 10 Seconds	300°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.4 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C.
5. This rating is based on the capability of the transistor to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 125\ \mu H$, $R_{BB1} = 5\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 20$ V, $I_{CM} = 8$ A, Energy $\approx I_C{}^2L/2$.

‡This circuit appears on page 5-1 of The Power Semiconductor Data Book for Design Engineers, CC404.

TIP543
NPN SILICON POWER TRANSISTOR

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA,	$I_B = 0$,	See Note 6	65		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V,	$I_B = 0$			2	mA
I_{CES}	Collector Cutoff Current	$V_{CE} = 75$ V,	$V_{BE} = 0$			1	mA
		$V_{CE} = 40$ V,	$V_{BE} = 0$,	$T_C = 150°C$		2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 3$ V,	$I_C = 0$			0.2	mA
		$V_{EB} = 5$ V,	$I_C = 0$			1	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 5$ A,	See Notes 6 and 7	40	200	
		$V_{CE} = 4$ V,	$I_C = 10$ A,	See Notes 6 and 7	40		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V,	$I_C = 10$ A,	See Notes 6 and 7		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A,	$I_C = 5$ A,	See Notes 6 and 7		0.5	V
		$I_B = 1$ A,	$I_C = 10$ A,	See Notes 6 and 7		0.8	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 1$ A,	f = 1 kHz	40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 1$ A,	f = 10 MHz	12		

post-irradiation electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	RADIATION FLUENCE†	MIN	MAX	UNIT
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 5$ A, See Notes 6 and 7	2×10^{14} n/cm^2	10		

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	2.5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	

†Radiation is fast neutrons (n) at E ⩾ 10 keV (reactor spectrum).

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

TIP544, TIP545, TIP546
PNP SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED JUNE 1975

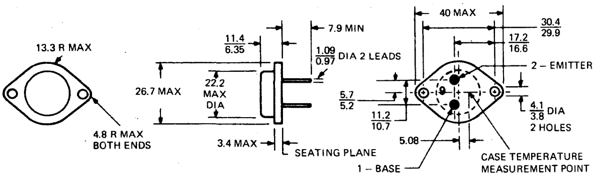
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS RECOMMENDED FOR COMPLEMENTARY USE WITH 2N5758, 2N5759, 2N5760

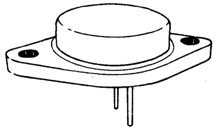
- 150 W at 25°C Case Temperature
- 6-A Rated Continuous Collector Current
- Min f_T of 1 MHz at 20 V, 0.5 A

mechanical data

The case outline falls within JEDEC TO-3.

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP544	TIP545	TIP546
Collector-Base Voltage	−100 V	−120 V	−140 V
Collector-Emitter Voltage (See Note 1)	−100 V	−120 V	−140 V
Emitter-Base Voltage	−7 V	−7 V	−7 V
Continuous Collector Current	←— −6 A —→		
Peak Collector Current (See Note 2)	←— −10 A —→		
Continuous Base Current	←— −4 A —→		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←— 150 W —→		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←— 5 W —→		
Operating Collector Junction Temperature Range	←— −65°C to 200°C —→		
Storage Temperature Range	←— −65°C to 200°C —→		
Terminal Temperature 1.588mm from Case for 10 Seconds	←— 235°C —→		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.857 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.

TIP544, TIP545, TIP546
PNP SINGLE-DIFFUSED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIP544		TIP545		TIP546		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 5	−100		−120		−140		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -100$ V, $I_E = 0$		−1					mA
		$V_{CB} = -120$ V, $I_E = 0$				−1			
		$V_{CB} = -140$ V, $I_E = 0$						−1	
I_{CEO}	Collector Cutoff Current	$V_{CE} = -50$ V, $I_B = 0$		−5					mA
		$V_{CE} = -60$ V, $I_B = 0$				−5			
		$V_{CE} = -70$ V, $I_B = 0$						−5	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -100$ V, $V_{BE} = 1.5$ V		−1					mA
		$V_{CE} = -120$ V, $V_{BE} = 1.5$ V				−1			
		$V_{CE} = -140$ V, $V_{BE} = 1.5$ V						−1	
		$V_{CE} = -100$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$		−5					
		$V_{CE} = -120$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$				−5			
		$V_{CE} = -140$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$						−5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -7$ V, $I_C = 0$		−1		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V, $I_C = -3$ A, See Notes 5 and 6	25	100	20	80	15	60	
		$V_{CE} = -2$ V, $I_C = -6$ A	5		5		5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V, $I_C = -3$ A, See Notes 5 and 6		−1.5		−1.5		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.3$ A, $I_C = -3$ A, See Notes 5 and 6		−1		−1		−1	V
		$I_B = -1.2$ A, $I_C = -6$ A		−2		−2		−2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -2$ A, f = 1 kHz	15		15		15		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -20$ V, $I_C = -0.5$ A, f = 0.5 MHz	2		2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, f = 0.1 to 1 MHz		300		300		300	pF

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

TYPES TIP554, TIP555, TIP556
N-P-N SILICON POWER TRANSISTORS

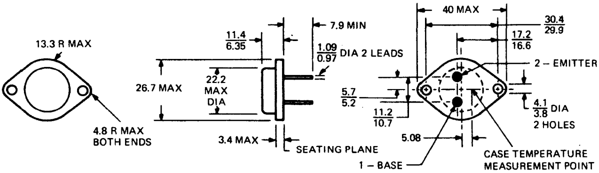
REVISED JUNE 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND CONSUMER APPLICATIONS

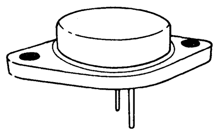
- 100 mJ Reverse-Energy Rating
- 300 V to 400 V Min $V_{(BR)CEO}$
- 100 W at 100°C Case Temperature
- 5 A Peak Collector Current
- 2.5 MHz Min f_T at 10 V, 0.2 A

mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP554	TIP555	TIP556
Collector-Base Voltage	400 V	450 V	500 V
Collector-Emitter Voltage (See Note 1)	300 V	350 V	400 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	3 A		
Peak Collector Current (See Note 2)	5 A		
Continuous Base Current	0.6 A		
Safe Operating Areas	See Figures 6 and 7		
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	100 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W		
Unclamped Inductive Load Energy (See Note 5)	100 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Lead Temperature 1.588mm from Case for 10 Seconds	300°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 1 W/°C or refer to Dissipation Derating Curve, Figure 8.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/°C or refer to Dissipation Derating Curve, Figure 9.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. L = 30 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TYPES TIP554, TIP555, TIP556
N-P-N SILICON POWER TRANSISTORS

electrical characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS	TIP554		TIP555		TIP556		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 6	300		350		400		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 200 V, I_B = 0		1					mA
		V_{CE} = 250 V, I_B = 0				1			
		V_{CE} = 300 V, I_B = 0						1	
I_{CES}	Collector Cutoff Current	V_{CE} = 400 V, V_{BE} = 0		1					mA
		V_{CE} = 450 V, V_{BE} = 0				1			
		V_{CE} = 500 V, V_{BE} = 0						1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.3 A, See Notes 6 and 7	30	150	30	150	30	150	
		V_{CE} = 10 V, I_C = 3 A, See Notes 6 and 7	10		10		10		
V_{BE}	Base-Emitter Voltage	V_{CE} = 10 V, I_C = 3 A, See Notes 6 and 7		1.5		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.6 A, I_C = 3 A, See Notes 6 and 7		1.5		1.5		1.5	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 kHz	30		30		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 MHz	2.5		2.5		2.5		

switching characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA,	0.25	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −5 V, R_L = 200 Ω, See Figure 4	5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

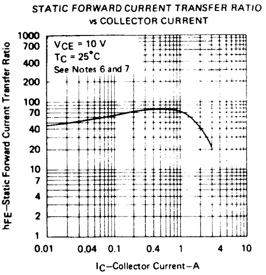

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

FIGURE 1

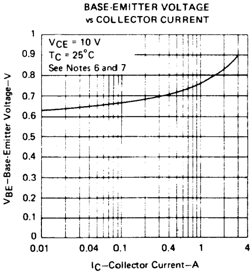

BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT

FIGURE 2

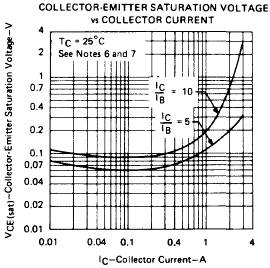
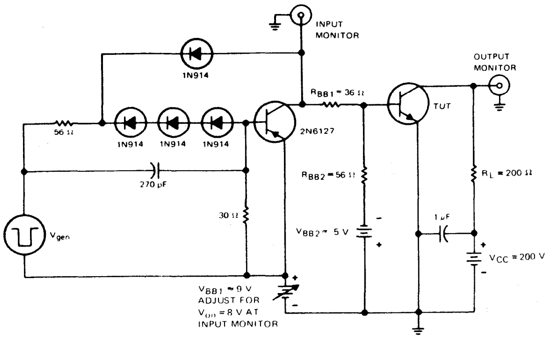

COLLECTOR-EMITTER SATURATION VOLTAGE vs COLLECTOR CURRENT

FIGURE 3

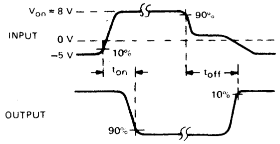
NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30 V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplies by a generator with the following characteristics: $t_r \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.

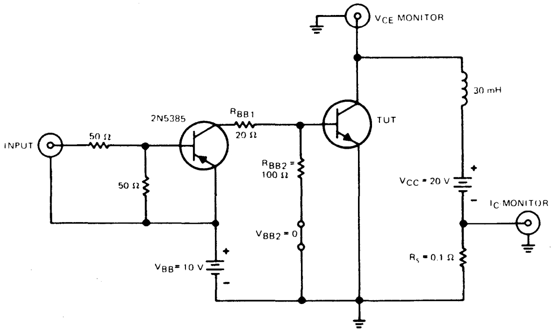
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

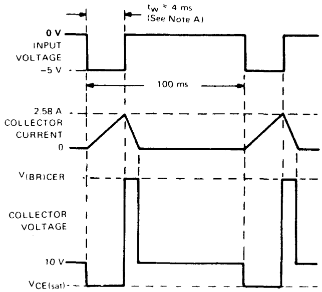
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 2.58 A.

FIGURE 5

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

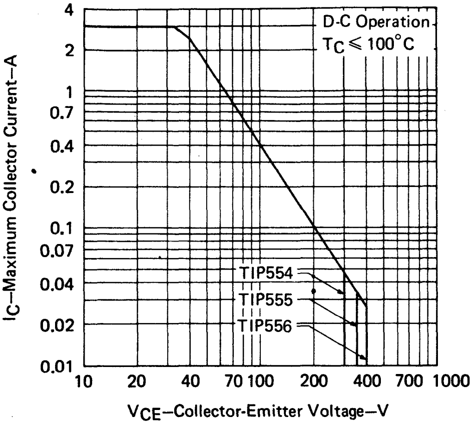


FIGURE 6

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

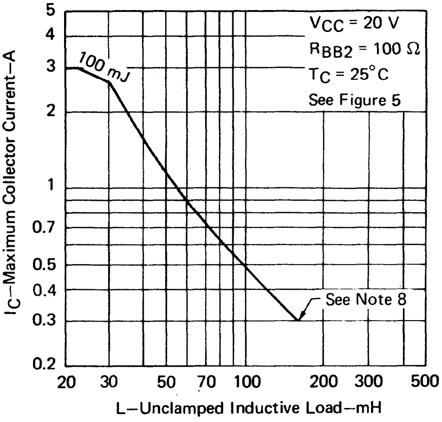


FIGURE 7

NOTE 8: Above this point, the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

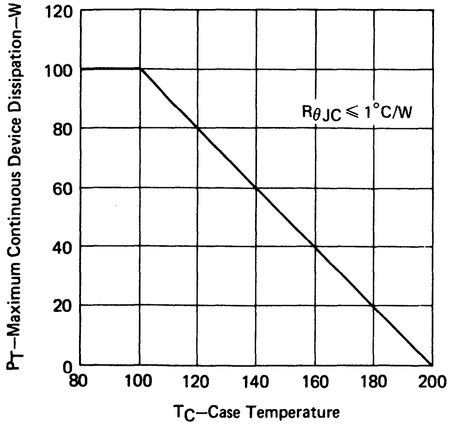


FIGURE 8

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

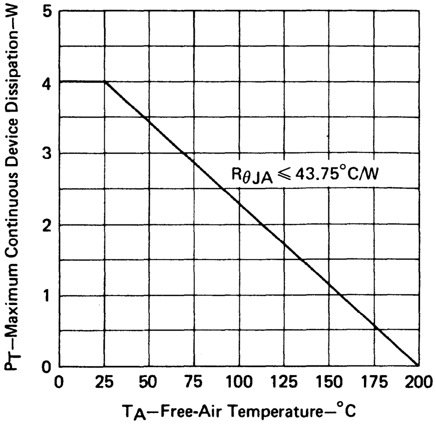


FIGURE 9

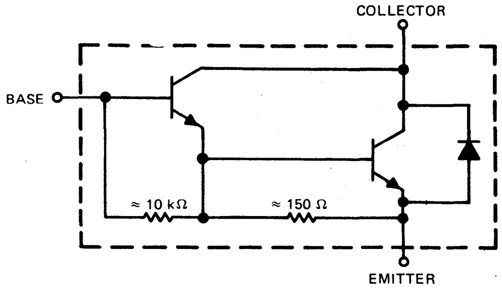
TYPES TIP620, TIP621, TIP622
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED JUNE 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP625, TIP626, TIP627

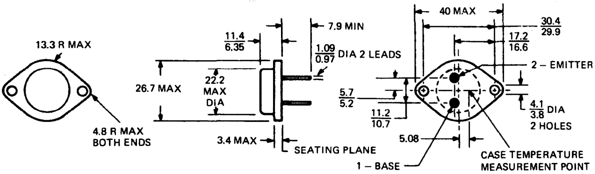
- 65 W at 25°C Case Temperature
- 5 A Rated Collector Current
- Min h_{FE} of 1000 at 3 V, 3 A
- 50 mJ Reverse Energy Rating

device schematic

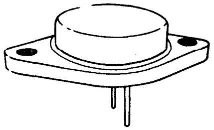


mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP620	TIP621	TIP622
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	5 A		
Peak Collector Current (See Note 2)	8 A		
Continuous Base Current	0.1 A		
Safe Operating Area at (or below) 100°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W		
Unclamped Inductive Load Energy (See Note 5)	50 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.37 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 200°C free-air temperature at the rate of 23 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TYPES TIP620, TIP621, TIP622
N-P-N DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP620		TIP621		TIP622		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0,	See Note 6	60		80		100		V
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V, I_E = 0			0.2					mA
		V_{CB} = 80 V, I_E = 0					0.2			
		V_{CB} = 100 V, I_E = 0							0.2	
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0			0.5					mA
		V_{CE} = 40 V, I_B = 0					0.5			
		V_{CE} = 50 V, I_B = 0							0.5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			2		2		2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 3 V, I_C = 0.5 A	See Notes 6 and 7	1000		1000		1000		
		V_{CE} = 3 V, I_C = 3 A		1000		1000		1000		
V_{BE}	Base-Emitter Voltage	V_{CE} = 3 V, I_C = 3 A,	See Notes 6 and 7		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 12 mA, I_C = 3 A	See Notes 6 and 7		2		2		2	V
		I_B = 20 mA, I_C = 5 A			4		4		4	

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

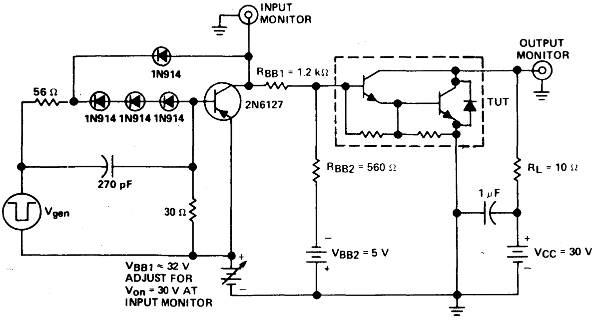
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

switching characteristics at 25°C case temperature

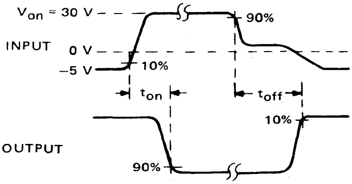
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 3 A, $I_{B(1)}$ = 12 mA, $I_{B(2)}$ = −12 mA, $V_{BE(off)}$ = −5 V, R_L = 10 Ω, See Figure 1	1.5	μs
t_{off}	Turn-Off Time		8.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ⩽ 15 ns, t_f ⩽ 15 ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ⩽ 2%.

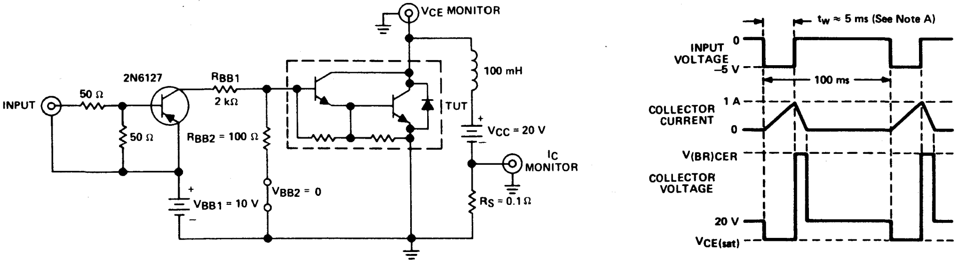
C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ⩽ 15 ns, R_{in} ⩾ 10 MΩ, C_{in} ⩽ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 1 A.

FIGURE 2

TYPICAL CHARACTERISTICS

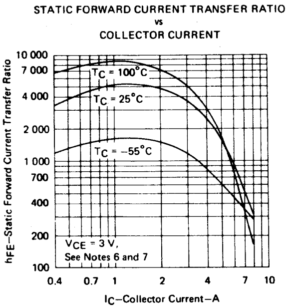


FIGURE 3

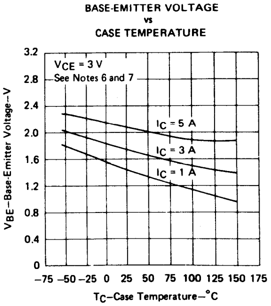


FIGURE 4

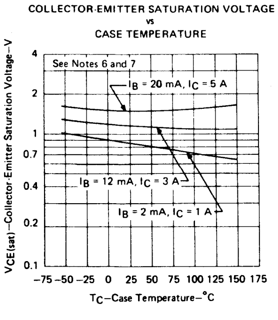


FIGURE 5

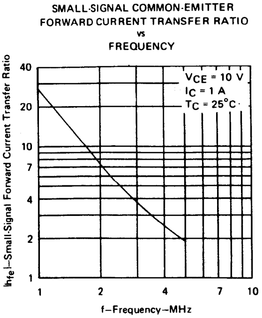


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT vs COLLECTOR-EMITTER VOLTAGE

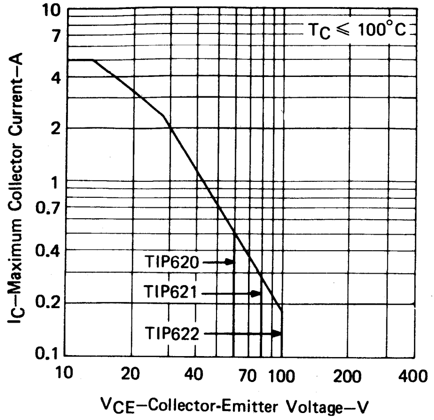


FIGURE 7

MAXIMUM COLLECTOR CURRENT vs UNCLAMPED INDUCTIVE LOAD

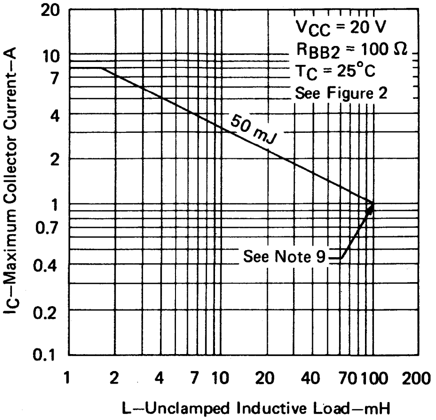


FIGURE 8

NOTES: 8. This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

9. Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE DISSIPATION DERATING CURVE

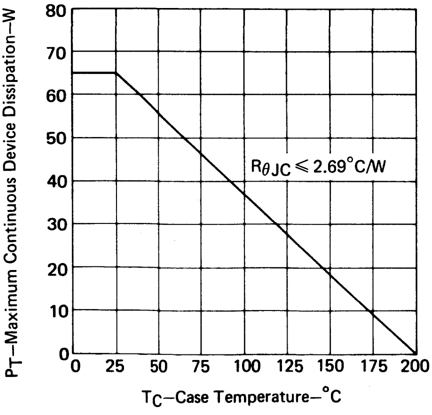


FIGURE 9

FREE-AIR TEMPERATURE DISSIPATION DERATING CURVE

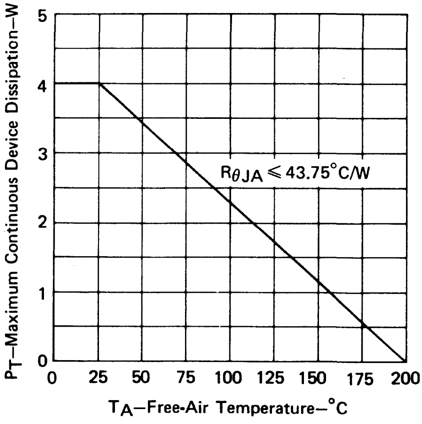


FIGURE 10

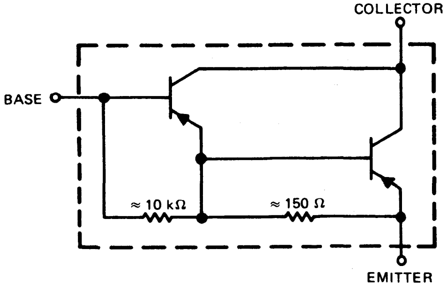
TYPES TIP625, TIP626, TIP627
P-N-P DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED JULY 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP620, TIP621, TIP622

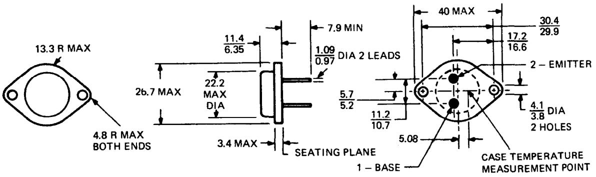
- 65 W at 25°C Case Temperature
- 5 A Rated Collector Current
- Min h_{FE} of 1000 at 3 V, 3 A
- 50 mJ Reverse Energy Rating

device schematic

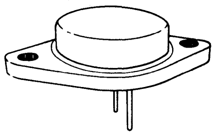


mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP625	TIP626	TIP627
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current	−5 A		
Peak Collector Current (See Note 2)	−8 A		
Continuous Base Current	−0.1 A		
Safe Operating Area at (or below) 100°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	65 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	4 W		
Unclamped Inductive Load Energy (See Note 5)	50 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.37 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 200°C free-air temperature at the rate of 23 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TYPES TIP625, TIP626, TIP627
P-N-P DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP625		TIP626		TIP627		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$,	See Note 6	−60		−80		−100		V
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$			−0.2					mA
		$V_{CB} = -80$ V, $I_E = 0$					−0.2			
		$V_{CB} = -100$ V, $I_E = 0$							−0.2	
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$			−0.5					mA
		$V_{CE} = -40$ V, $I_B = 0$					−0.5			
		$V_{CE} = -50$ V, $I_B = 0$							−0.5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$			−2		−2		−2	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -3$ V, $I_C = -0.5$ A	See Notes 6 and 7	1000		1000		1000		
		$V_{CE} = -3$ V, $I_C = -3$ A		1000		1000		1000		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -3$ V, $I_C = -3$ A,	See Notes 6 and 7		−2.5		−2.5		−2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -12$ mA, $I_C = -3$ A	See Notes 6 and 7		−2		−2		−2	V
		$I_B = -20$ mA, $I_C = -5$ A			−4		−4		−4	

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

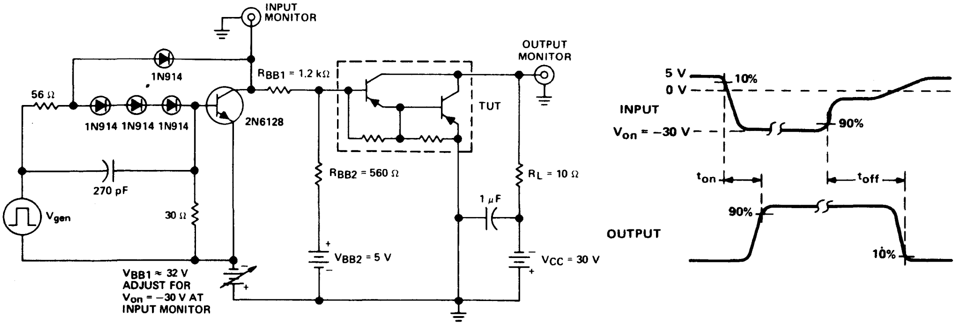
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -3$ A, $I_{B(1)} = -12$ mA, $I_{B(2)} = 12$ mA,	1.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 5$ V, $R_L = 10\ \Omega$, See Figure 1	8.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20$ μs, duty cycle ≤ 2%.

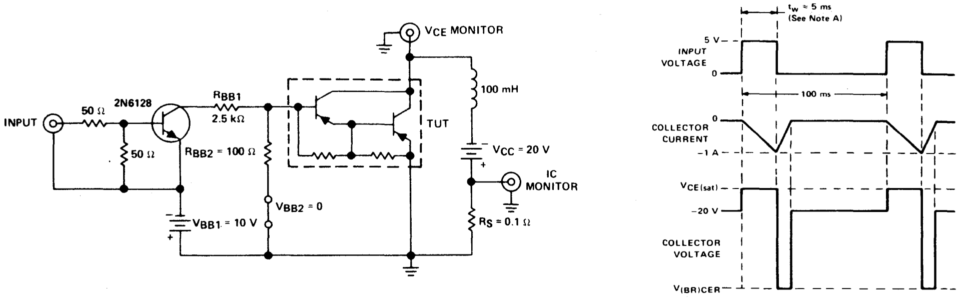
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width in increased until $I_{CM} = -1$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

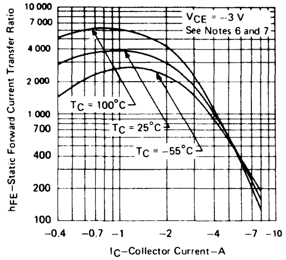


FIGURE 3

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

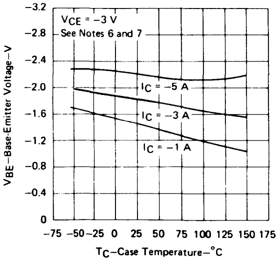


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

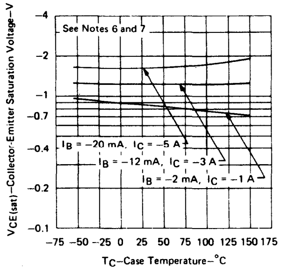


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER FORWARD-CURRENT TRANSFER RATIO vs FREQUENCY

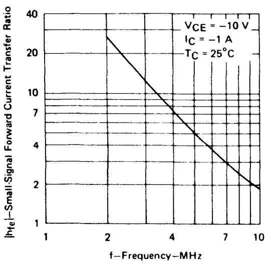


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

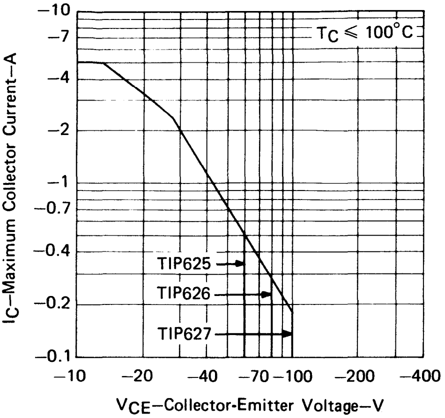


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

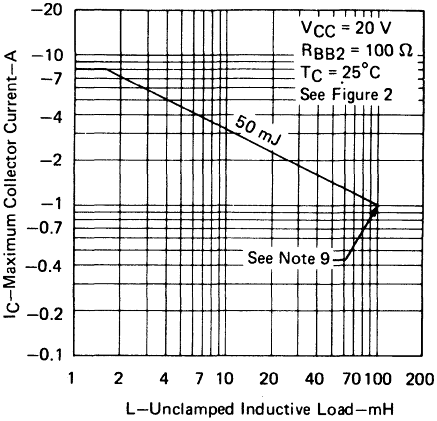


FIGURE 8

NOTES: 8. These combinations of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.
9. Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

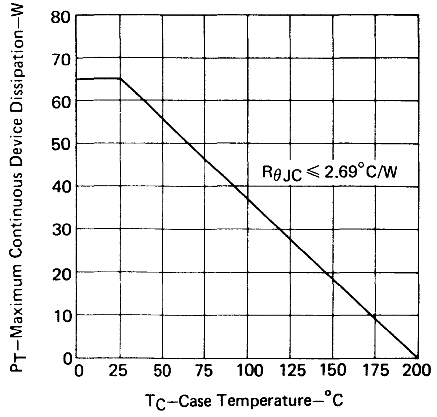


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

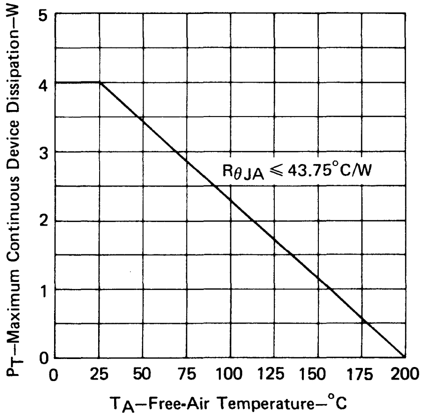


FIGURE 10

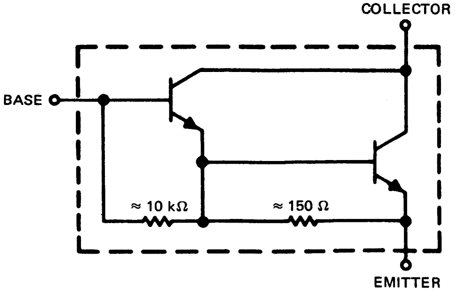
TIP640, TIP641, TIP642
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED JUNE 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP645, TIP646, TIP647

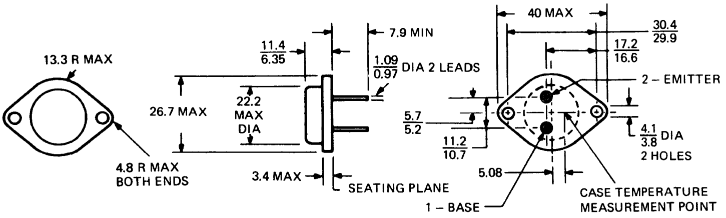
- 175 W at 25°C Case Temperature
- 10-A Rated Collector Current
- Min h_{FE} of 1000 at 4 V, 5 A
- 100-mJ Reverse Energy Rating

device schematic

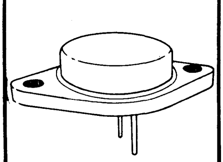


mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP640	TIP641	TIP642
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	10 A		
Peak Collector Current (See Note 2)	15 A		
Continuous Base Current	0.5 A		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	175 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W		
Unclamped Inductive Load Energy (See Note 5)	100 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Lead Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle ≤ 10%.
3. Derate linearly to 200°C case temperature at the rate of 1 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 100 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C^2L/2$.

TIP640, TIP641, TIP642
NPN DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP640		TIP641		TIP642		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0,	See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0			2					mA
		V_{CE} = 40 V, I_B = 0					2			
		V_{CE} = 50 V, I_B = 0							2	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V, I_E = 0			1					mA
		V_{CB} = 80 V, I_E = 0					1			
		V_{CB} = 100 V, I_E = 0							1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			2		2		2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V, I_C = 5 A	See Notes 6 and 7	1000		1000		1000		
		V_{CE} = 4 V, I_C = 10 A		500		500		500		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V, I_C = 10 A,	See Notes 6 and 7		3		3		3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 10 mA, I_C = 5 A	See Notes 6 and 7		2		2		2	V
		I_B = 40 mA, I_C = 10 A			3		3		3	

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

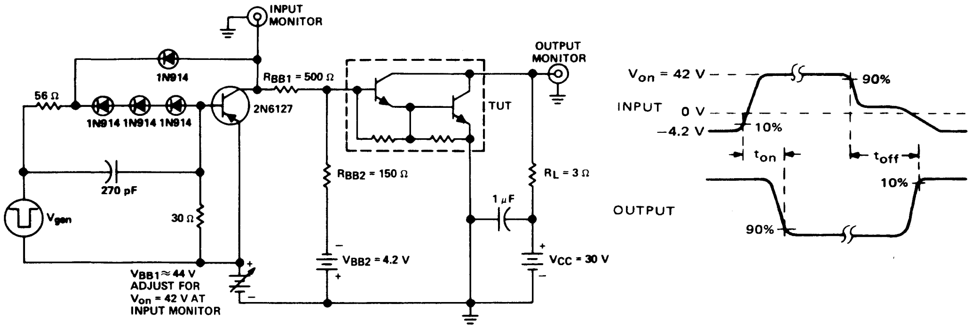
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 10 A, $I_{B(1)}$ = 40 mA, $I_{B(2)}$ = −40 mA, $V_{BE(off)}$ = −4.2 V, R_L = 3 Ω, See Figure 1	0.9	μs
t_{off}	Turn-Off Time		11	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT　　**VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ⩽ 15 ns, t_f ⩽ 15 ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ⩽ 2%.

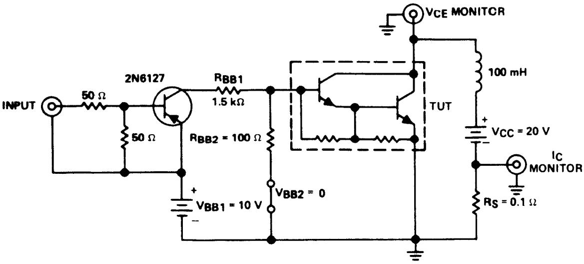
C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ⩽ 15 ns, R_{in} ⩾ 10 MΩ, C_{in} ⩽ 11.5 pF.

D. Resistors must be noninductive types.

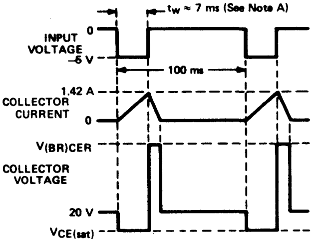
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT



VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 1.42 A.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

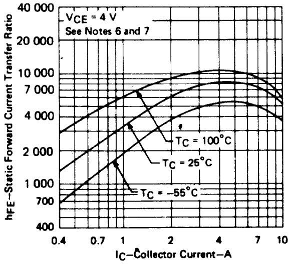


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

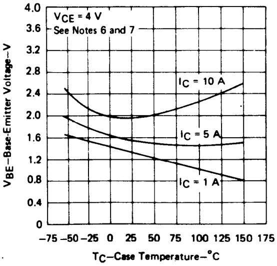


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

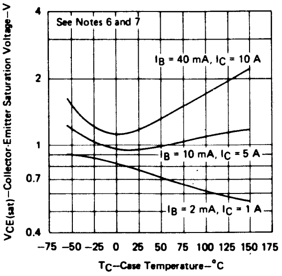


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

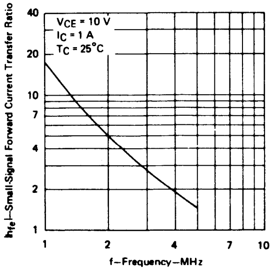


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

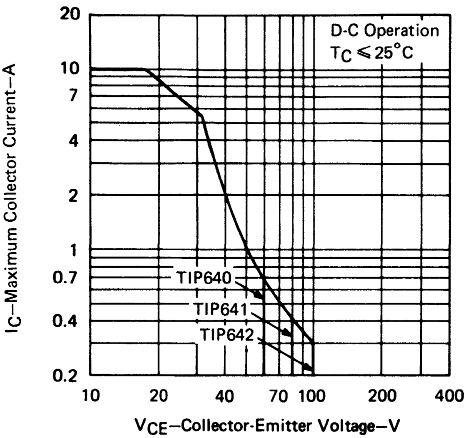


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

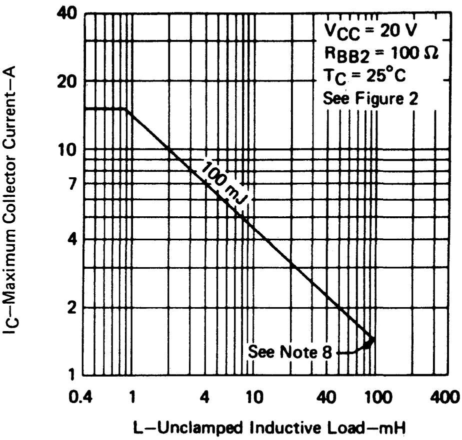


FIGURE 8

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

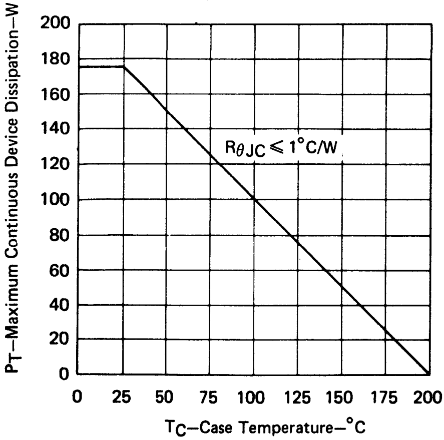


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

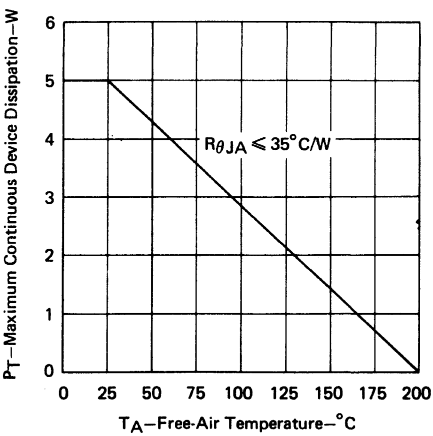


FIGURE 10

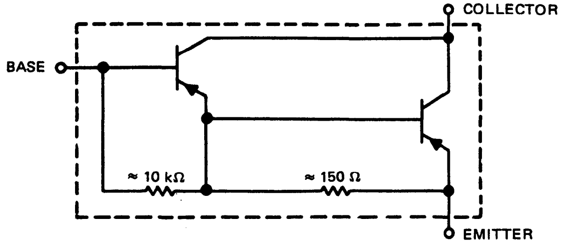
TIP645, TIP646, TIP647
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

REVISED JULY 1975

DESIGNED FOR COMPLEMENTARY USE WITH TIP640, TIP641, TIP642

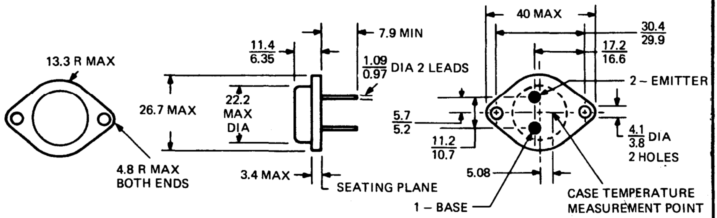
- **175 W at 25°C Case Temperature**
- **10-A Rated Collector Current**
- **Min h_{FE} of 1000 at 4 V, 5 A**
- **100 mJ Reverse Energy Rating**

device schematic

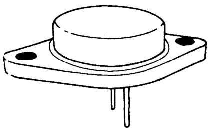


mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	TIP645	TIP646	TIP647
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current	−10 A		
Peak Collector Current (See Note 2)	−15 A		
Continuous Base Current	−0.5 A		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 7 and 8		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	175 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W		
Unclamped Inductive Load Energy (See Note 5)	100 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Terminal Temperature 3.2mm from Case for 10 Seconds	260°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w < 0.3$ ms, duty cycle $< 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1 W/°C or refer to Dissipation Derating Curve, Figure 9.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 10.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. $L = 100$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V. Energy $\approx I_C{}^2L/2$.

TIP645,TIP646,TIP647
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		TIP645		TIP646		TIP647		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = −30 mA, I_B = 0,	See Note 6	−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = −30 V, I_B = 0			−2					mA
		V_{CE} = −40 V, I_B = 0					−2			
		V_{CE} = −50 V, I_B = 0							−2	
I_{CBO}	Collector Cutoff Current	V_{CB} = −60 V, I_E = 0			−1					mA
		V_{CB} = −80 V, I_E = 0					−1			
		V_{CB} = −100 V, I_E = 0							−1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = −5 V, I_C = 0			−2		−2		−2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = −4 V, I_C = −5 A	See Notes 6 and 7	1000		1000		1000		
		V_{CE} = −4 V, I_C = −10 A		500		500		500		
V_{BE}	Base-Emitter Voltage	V_{CE} = −4 V, I_C = −10 A,	See Notes 6 and 7		−3		−3		−3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = −10 mA, I_C = −5 A	See Notes 6 and 7		−2		−2		−2	V
		I_B = −40 mA, I_C = −10 A			−3		−3		−3	

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ≤ 2%.

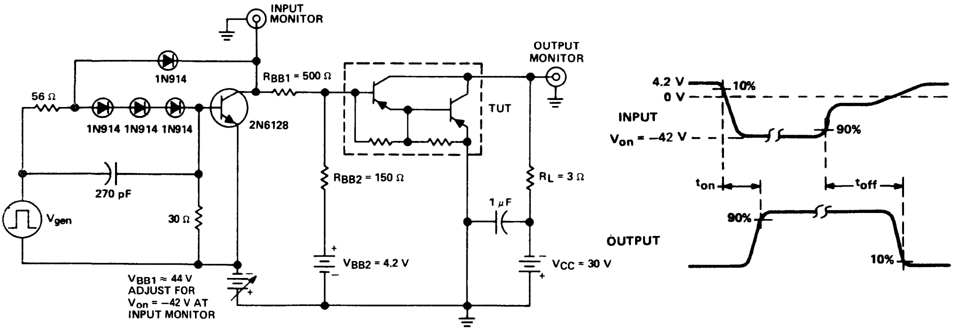
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = −10 A, $I_{B(1)}$ = −40 mA, $I_{B(2)}$ = 40 mA,	0.9	µs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = 4.2 V, R_L = 3 Ω, See Figure 1	11	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ≤ 15 ns, t_f ≤ 15 ns, Z_{out} = 50 Ω, t_w = 20 µs, duty cycle ≤ 2%.

C. Waveforms are monitored on an oscilloscope with the following characteristics: t_r ≤ 15 ns, R_{in} ≥ 10 MΩ, C_{in} ≤ 11.5 pF.

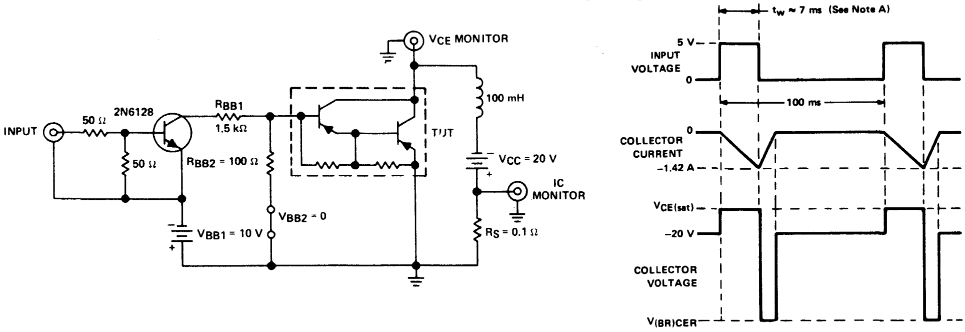
D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TIP645,TIP646,TIP647
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

INDUCTIVE LOAD SWITCHING



NOTE A: Input pulse width is increased until $I_{CM} = -1.42$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

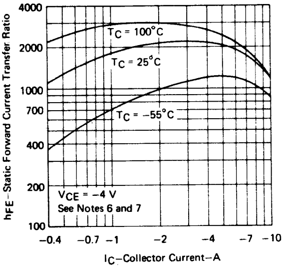


FIGURE 3

BASE EMITTER VOLTAGE
vs
CASE TEMPERATURE

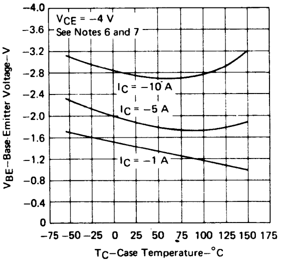


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

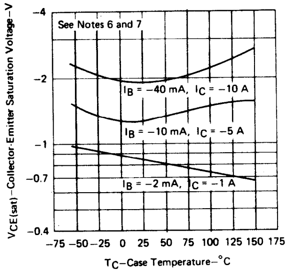


FIGURE 5

SMALL-SIGNAL COMMON-EMITTER
FORWARD CURRENT TRANSFER RATIO
vs
FREQUENCY

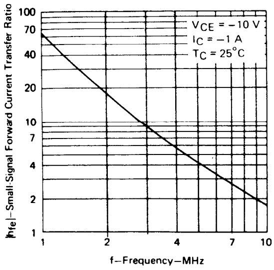


FIGURE 6

NOTES:
6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

TIP645, TIP646, TIP647
PNP DARLINGTON-CONNECTED SILICON POWER TRANSISTORS

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

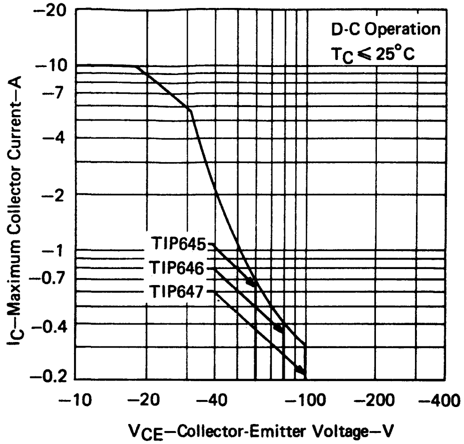


FIGURE 7

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

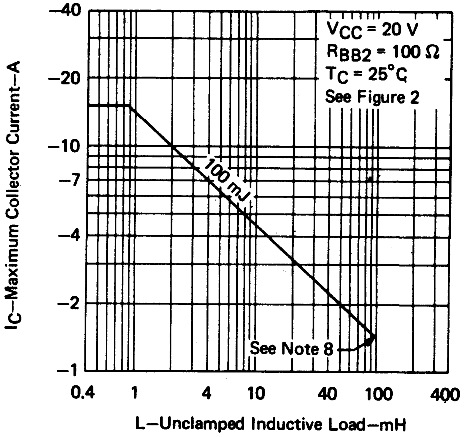


FIGURE 8

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

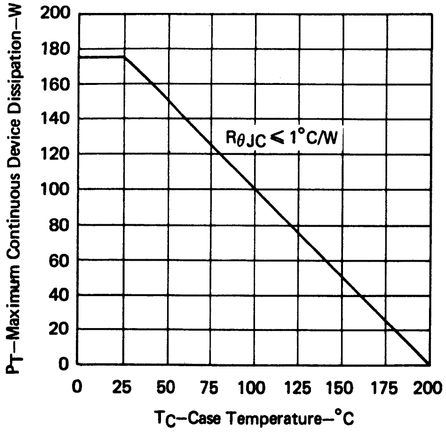


FIGURE 9

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

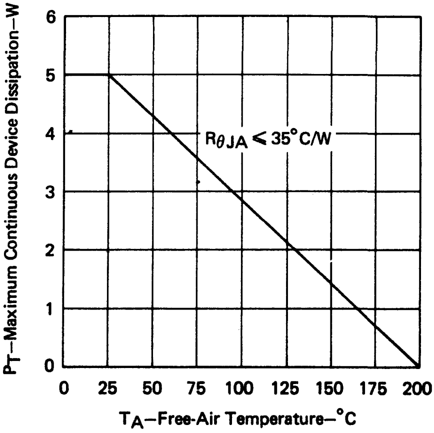


FIGURE 10

TIP2955
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

REVISED JULY 1975

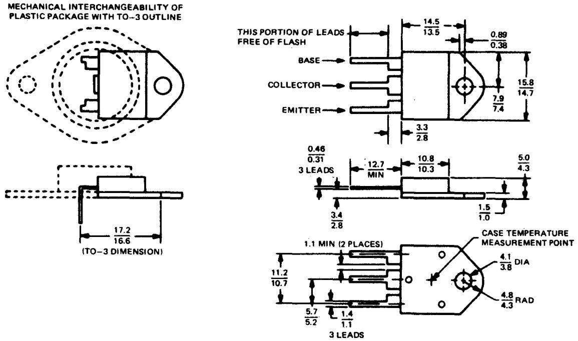
For power-amplifier and high-speed-switching applications
Plastic case replacement for 2N3055

- **90 Watts at 25°C case temperature**
- **10A rated collector current**

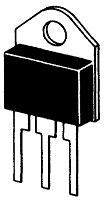
Designed for complementary use with TIP3055

Mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB



ALL DIMENSIONS ARE IN MILLIMETRES



Absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−70 V
Emitter-Base Voltage	−7 V
Continuous Collector Current	−15 A
Continuous Base Current	−7 A
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	90 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	3.5 W
Unclamped Inductive Load Energy (See Note 4)	62.5 mJ
Operating Collector Junction Temperature Range	−65°C to 150°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 3.2mm from Case For 10 Seconds	260°C

NOTES:
1. This value applies when the base emitter resistance R_{BE} = 100Ω
2. Derate linearly to 150°C case temperature at the rate of 0.72W/°C
3. Derate linearly to 150°C free air temperature at the rate of 28mW/°C
4. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L=20mH, R_{BB1}=100Ω V_{BB2}=0V, R_S=0.1Ω, V_{CC}=10V. Energy ≈$I_C^2L/2$.

TEXAS INSTRUMENTS

TIP2955
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

Electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C=−30 mA, I_B = 0, See Note 5	−60		V
I_{CEO}	Collector Cutoff Current	V_{CE}=−30 V, I_B = 0		−0.7	mA
I_{CEV}	Collector Cutoff Current	V_{CE}=−100 V, V_{BE} = −1.5 V		−5	mA
I_{EBO}	Emitter Cutoff Current	V_{EB}=−5 V, I_C = 0		−5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE}=−4 V, I_C=−4 A, See Notes 5 and 6	20		
		V_{CE}=−4 V, I_C=−10 A, See Notes 5 and 6	5		
V_{BE}	Base-Emitter Voltage	V_{CE}=−4 V, I_C=−4 A, See Notes 5 and 6		−1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B=−400 mA, I_C=−4 A, See Notes 5 and 6		−1.1	V
		I_B=−3.3 A, I_C=−10 A, See Notes 5 and 6		−3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −10 I_C = −0.5 f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −10 I_C = −0.5	3		MHz

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

Thermal characteristics

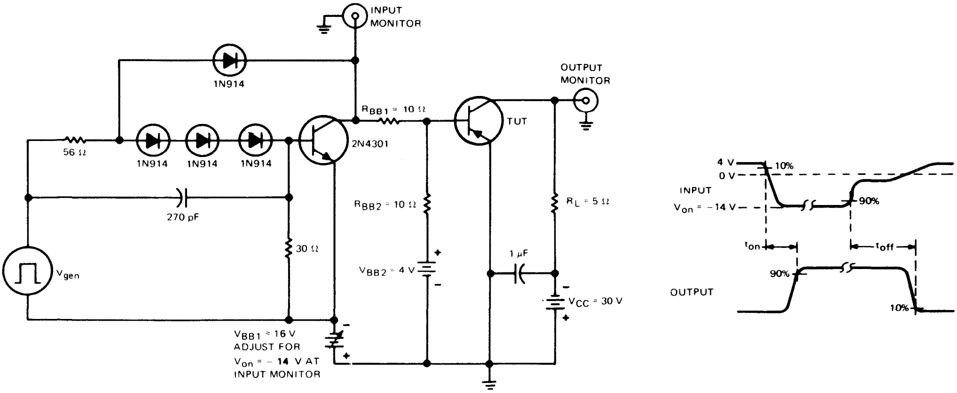
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.39	C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

Switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C=−6 A, $I_{B(1)}$=−0.6 A, $I_{B(2)}$ = 0.6 A,	0·4	µs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = 4 V, R_L = 5 Ω, See Figure 1	0·7	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

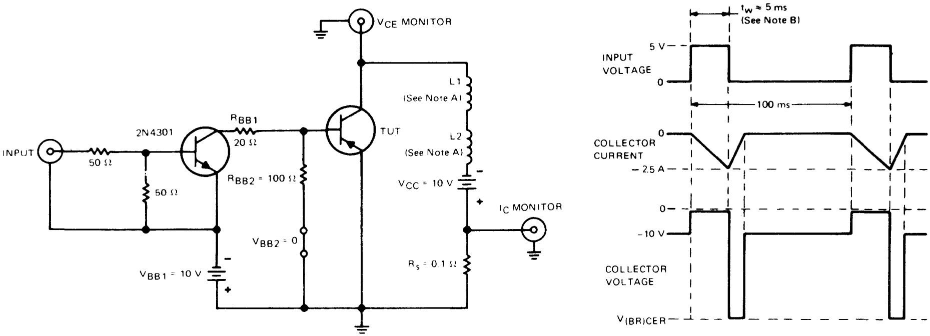


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
B. Input pulse width is increased until $I_{CM} = -2.5$ A.

FIGURE 2

TIP2955
PNP SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIC
vs
COLLECTOR CURRENT

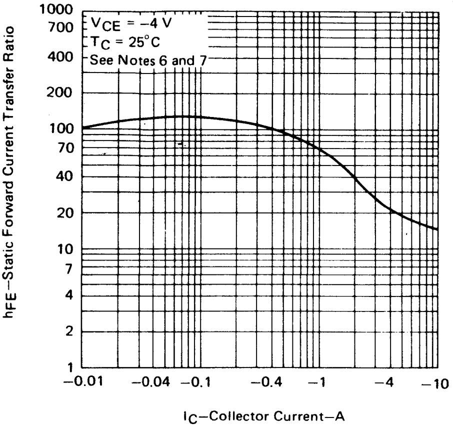


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

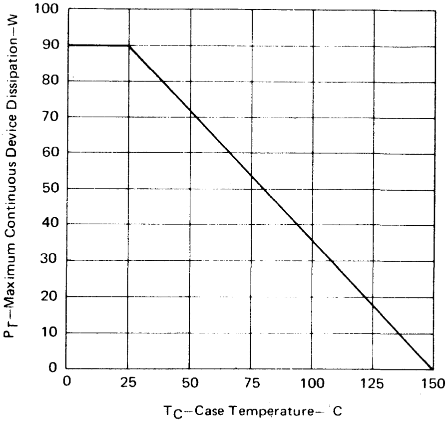


FIGURE 4

MAXIMUM SAFE OPERATING REGION

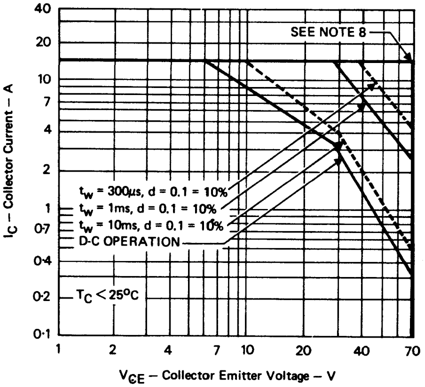


FIGURE 5

NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

TIP3055
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

REVISED JUNE 1975

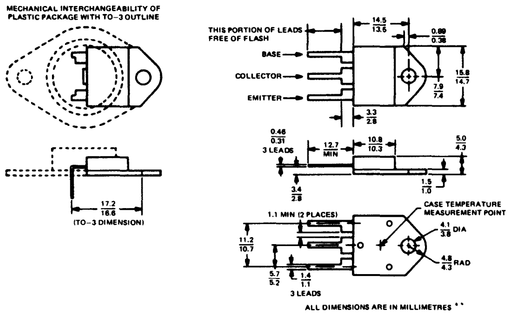
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
PLASTIC-CASE REPLACEMENT FOR 2N3055

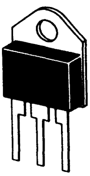
- **90 Watts at 25°C Case Temperature**
- **15 A Rated Collector Current**

DESIGNED FOR COMPLEMENTARY USE WITH TIP2955

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE MOUNTING TAB





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	70 V
Emitter-Base Voltage	7 V
Continuous Collector Current	15 A
Continuous Base Current	7 A
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 5
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	90 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	3.5 W
Unclamped Inductive Load Energy (See Note 4)	62.5 mJ
Operating Collector Junction Temperature Range	−65°C to 150°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 3.2mm from Case for 10 Seconds	260°C

NOTES:
1. This value applies when the base-emitter resistance $R_{BE} = 100\ \Omega$
2. Derate linearly to 150°C case temperature at the rate of 0.72 W/°C.
3. Derate linearly to 150°C free-air temperature at the rate of 28 mW/°C.
4. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 20$ mH, $R_{BB1} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

TIP3055
NPN SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	60		V
I_{CER}	Collector Cutoff Current	$V_{CE} = 70$ V, $R_{BE} = 100\ \Omega$		1	mA
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 100$ V, $V_{BE} = -1.5$ V		5	mA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ V, $I_C = 0$		5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 5 and 6	20	70	
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 5 and 6		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 400$ mA, $I_C = 4$ A, See Notes 5 and 6		1.1	V
		$I_B = 3.3$ A, $I_C = 10$ A, See Notes 5 and 6		3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	15		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, $f = 1$ MHz, See Note 7	3		MHz

NOTES:
5. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leqslant 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.
7. f_{hfe} is the frequency at which the magnitude of the small-signal forward current transfer ratio is 0.707 of its low-frequency value. For this device, the reference measurement is made at 1 kHz.

thermal characteristics

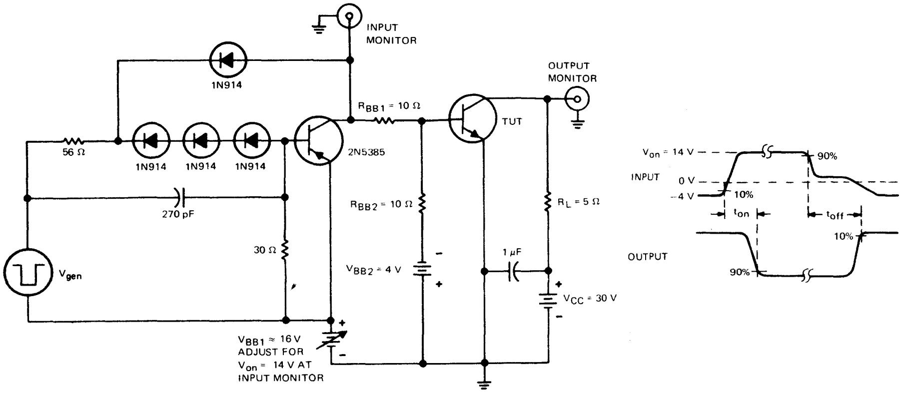
PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	1.39	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	35.7	

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 6$ A, $I_{B(1)} = 0.6$ A, $I_{B(2)} = -0.6$ A,	0.6	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4$ V, $R_L = 5\ \Omega$, See Figure 1	1	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

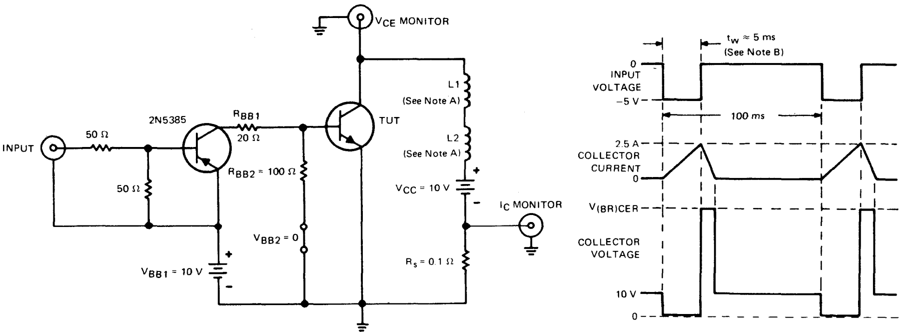


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTES:
A. L1 and L2 are 10 mH, 0.11 Ω, Chicago Standard Transformer Corporation C-2688, or equivalent.
B. Input pulse width is increased until I_{CM} = 2.5 A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

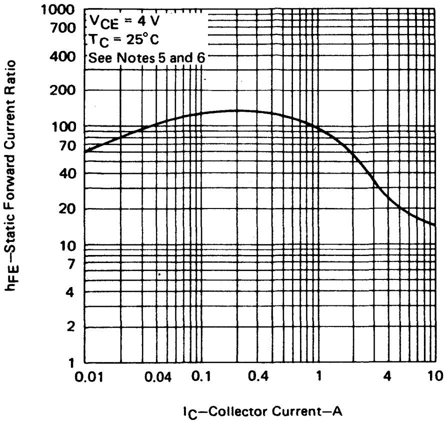


FIGURE 3

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

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

THERMAL INFORMATION

DISSIPATION DERATING CURVE

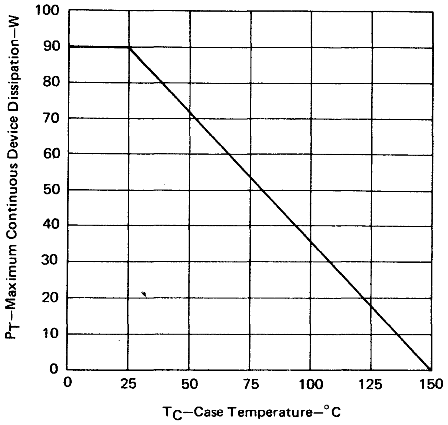


FIGURE 4

MAXIMUM SAFE OPERATING REGION

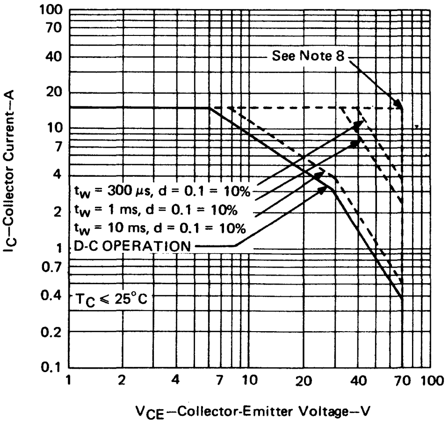


FIGURE 5

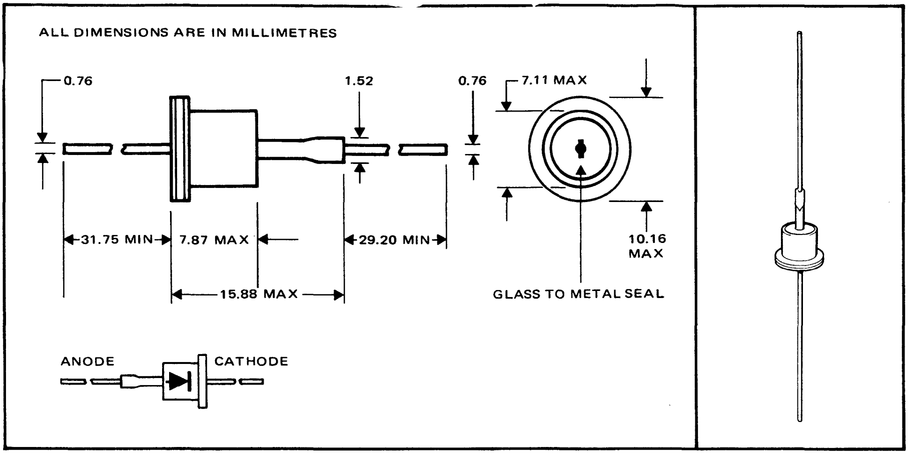
NOTE 8: This combination of maximum voltage and current may be achieved only when switching from saturation to cutoff with a clamped inductive load.

SERIES 1AS027,1AS029
SILICON AVALANCHE RECTIFIER

REVISED AUGUST 1975

- 1.5 Amperes
- 800 & 1000 Volts P.I.V.
- Approved to BS9300 – C476 and C645

mechanical data: Outline conforms to VASCO SO-16



absolute maximum ratings (Temperatures are ambient)

		1AS027	1AS029	Units
P.I.V.	Peak Inverse Voltage −65°C to +150°C	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current −65°C to +25°C	1·5	1·5	A
I_{FRM}	Recurrent Peak Forward Current + 25°C	20	20	A
I_{FSM}	Peak Surge Current, one half cycle at 50 Hz +25°C	125	125	A
P_{Rm}	Non-Repetitive Peak Reverse Power 10 μsec Square Pulse +25°C	4	4	kW
T_{amb}	Operating Temperature Range	−55 to +175		°C
T_{stg}	Storage Temperature Range	−55 to +175		°C

electrical characteristics (absolute limits)

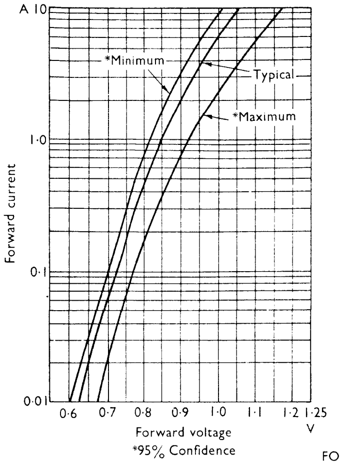
		1AS027	1AS029	Units
V_{AR}	Maximum Avalanche Voltage at I_R = 1 mA +25°C	1500	1750	V
V_{AR}	Minimum Avalanche Voltage at I_R = 1 mA +25°C	1000	1250	V
I_R	Maximum Reverse Current at P.I.V. at +25°C	1	1	μA
I_R	Maximum Reverse Current at P.I.V. at +100°C	50	50	μA
V_F	Maximum Forward-Voltage Drop at +25°C ; I_F = 5·0 A (note 1)	1·25	1·25	V

Note

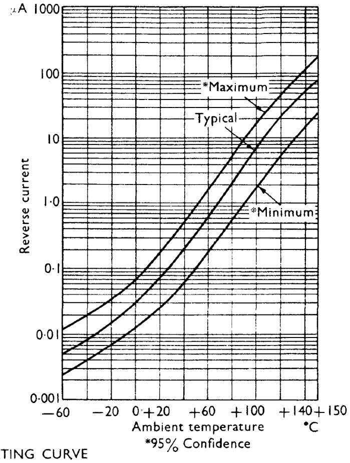
1. The forward voltage drop is a pulse measurement on these devices.

SERIES 1AS027, 1AS029
SILICON AVALANCHE RECTIFIER

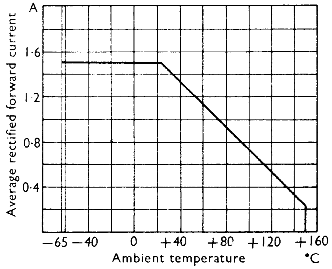
FORWARD CHARACTERISTICS AT 25 C



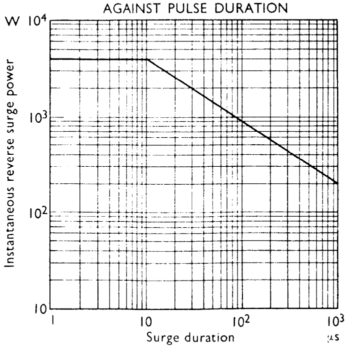
VARIATION OF REVERSE CURRENT WITH TEMPERATURE AT P.I.V.



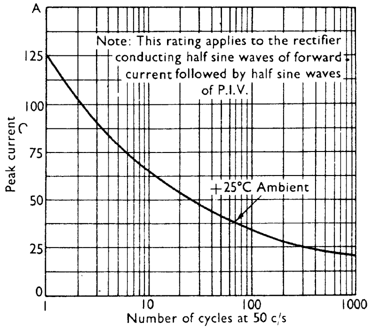
FORWARD CURRENT DERATING CURVE



NON-REPETITIVE PEAK REVERSE POWER AGAINST PULSE DURATION



NON-REPETITIVE SURGE CURRENT RATING



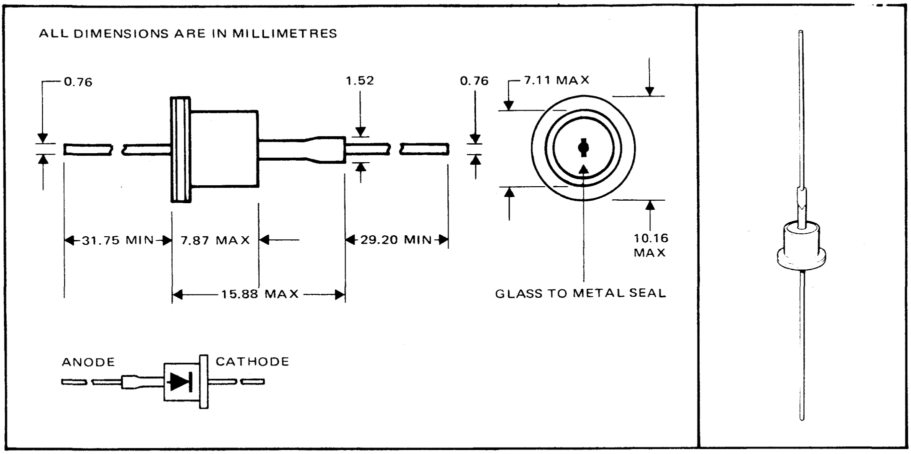
TYPES IN536, IN537, IN538, IN539, IN540, IN547, IN1095 AND IN1096
GENERAL PURPOSE DIFFUSED SILICON RECTIFIERS

REVISED AUGUST 1975

mechanical data

Welded case with glass-to-metal hermetic seal between case and anode lead. Devices will meet all military and commercial soldering requirements. Approximate weight is 1.6 grams. Operating position — any.

Conforms to JEDEC outline D-01



absolute maximum ratings at 25°C ambient temperature (unless otherwise specified)

	parameters	1N536	1N537	1N538	1N539	1N540	1N1095	1N547 1N1096	unit
V_{RRM}	Peak Rev. Voltage at —65° to 150°C	50	100	200	300	400	500	600	V
$I_{F(AV)}$	Avg. Rectified Fwd. Current at + 50°C	750	750	750	750	750	750	750	mA
$I_{F(AV)}$	Avg. Rectified Fwd. Current at + 150°C	250	250	250	250	250	250	250	mA
I_{FRM}	Rep. Peak Fwd. Current at + 150°C	1	1	1	1	1	1	1	amp
I_{FSM}	Surge Current for a 2 msec "turn on" transient.	35	35	35	35	35	35	35	amp
I_{FSM}	Surge Current — MIL-E-1 device operating at 150°C. Surge duration of 1 cycle every minute for 10 minutes.	15	15	15	15	15	15	15	amp
T_A	Operating temp, ambient	−55 to +175							°C
	Altitude	70,000							Ft.
T_{STG}	Storage Temp.	−55 to +175							°C

electrical characteristics at 25°C ambient temperature (unless otherwise specified)

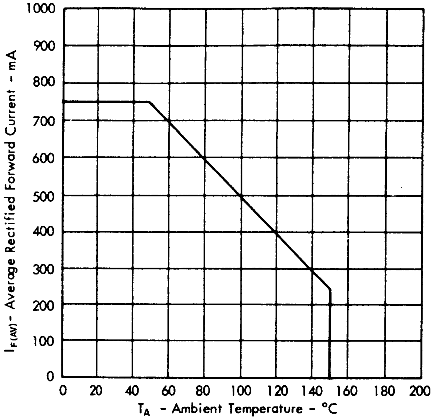
	parameters	1N536	1N537	1N538	1N539	1N540	1N1095	1N1096 1N547	unit
B_{VR}	Min. breakdown voltage at + 25° to + 150°C	60	120	240	360	480	600	720	V
I_R	Max. Reverse Current at $V_R = V_{RRM}$	10	10	10	10	10	10	10	μA
I_R	Max. Reverse Current at $V_R = V_{RRM}$ + 150°C	200	200	200	200	200	200	200	μA
V_F	Max Fwd. Voltage Drop at 25°C at I_F = 500 mA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	V
I_{RM}	Max. Reverse Current High Temperature Operating Test T = 150°C I = 250 mA V_r as shown	300 35 V AC	300 70 V AC	300 140 V AC	300	300 280 V AC	300	300 420 V AC	μA

TYPES IN536, IN537, IN538, IN539, IN540, IN547, IN1095 AND IN1096 GENERAL PURPOSE DIFFUSED SILICON RECTIFIERS

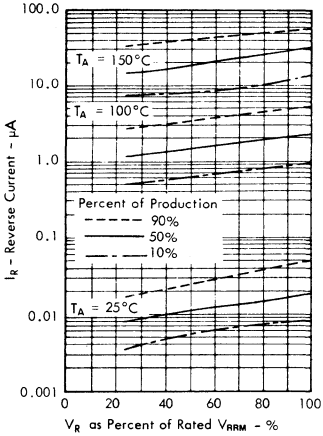
soldering techniques

Care should be exercised during the soldering operation to prevent possible damage to the rectifier. It is suggested that a heat sink be used between the case and the soldering point so that some of the heat may be absorbed. When dip soldering is used for printed circuit boards, the temperature of the solder should not exceed 255°C for a maximum immersion period of 10 seconds, and the leads should not be immersed any closer than 12.7mm from the rectifier body.

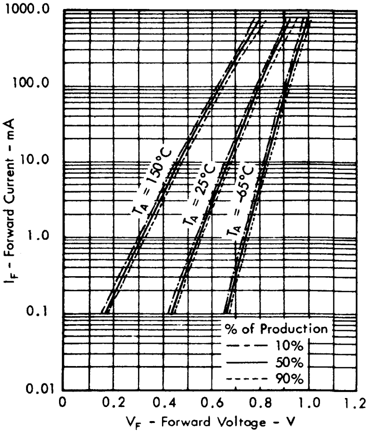
AVERAGE RECTIFIED FORWARD CURRENT
TEMPERATURE RATING CURVE



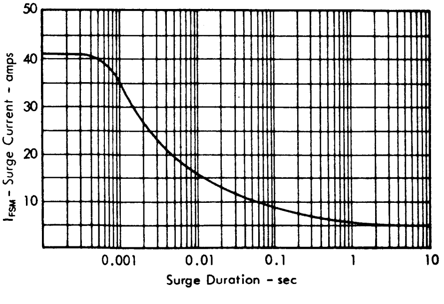
STATIC REVERSE CHARACTERISTICS



STATIC FORWARD CHARACTERISTICS



NON-RECURRENT SURGE CURRENT RATINGS AT 50°C



TYPES 1N550, 1N551, 1N552, 1N553, 1N554 and 1N555
DIFFUSED SILICON RECTIFIERS

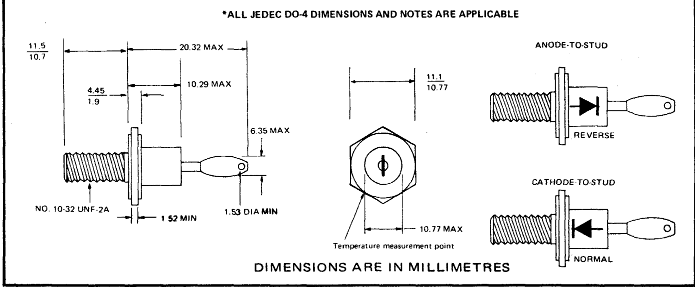
REVISED AUGUST 1975

500 mA • 100-600 Volts PIV

- **Designed for All General Purpose Applications**
- **Low Forward Voltage Drop and Low Reverse Current**
- **Rugged Construction for Complete Environmental Protection**

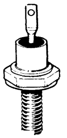
mechanical data

Welded case with glass-to-metal hermetic seal between case lead. Approximate weight is 4.36 grams. Cathode to stud is the standard configuration. Anode to stud device is designated by the addition of R suffix to the type number; e.g. 1N550R.



*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE

DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

	1N550	1N551	1N552	1N553	1N554	1N555	Unit
V_R Peak Inverse Voltage	100	200	300	400	500	600	V
$I_{F(AV)}$ Average Rectified Forward Current at 100°C	500						mA
I_{FRM} Recurrent Peak Forward Current	1.5						A
I_{FSM} Surge Current (3 millisec. or less)	4						A
T_A Operating Temperature Range	−55 to +175						°C
T_{stg} Storage Temperature Range	−55 to +175						°C

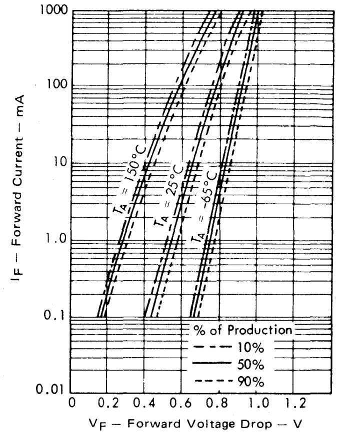
electrical characteristics at 25°C ambient temperature (unless otherwise noted)

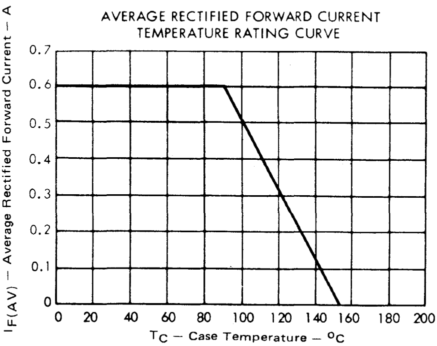
BV_R Minimum Breakdown Voltage	120	240	360	480	600	720	V
I_R Maximum Reverse Current at V_r, $T_A = 125°C$	25	50	75	125	175	250 200	μA μA
I_R Maximum Reverse Current at V_R	0.5	1.0	1.5	2.5	3.5	5.0	μA
V_F Forward Voltage Drop $I_F = 400$ mA $T_A = 125°C$	1.1						V
V_F Forward Voltage Drop $I_F = 500$ mA	1.2						V

TEXAS INSTRUMENTS

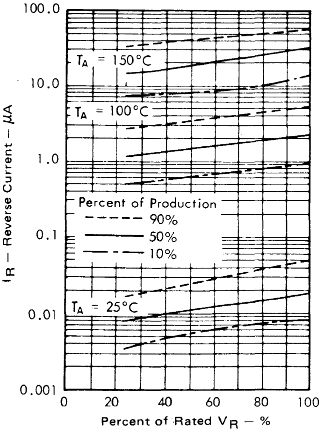
TYPES 1N550, 1N551, 1N552, 1N553, 1N554 and 1N555
DIFFUSED SILICON RECTIFIERS

STATIC FORWARD CHARACTERISTICS

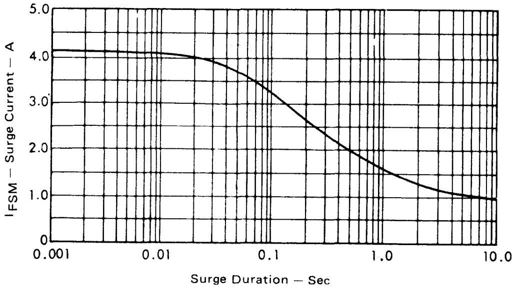



AVERAGE RECTIFIED FORWARD CURRENT TEMPERATURE RATING CURVE

STATIC REVERSE CHARACTERISTICS



NON-RECURRENT SURGE CURRENT RATINGS AT 50°C



TYPES 1N560, 1N561
DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED AUGUST 1975

800 AND 1000 VOLTS • 1 AMP DC

- **Designed to Meet Stringent Military Requirements**
- **Applications: High-Voltage Power Supplies, Stacks and Multiphase Rectifier Operation**

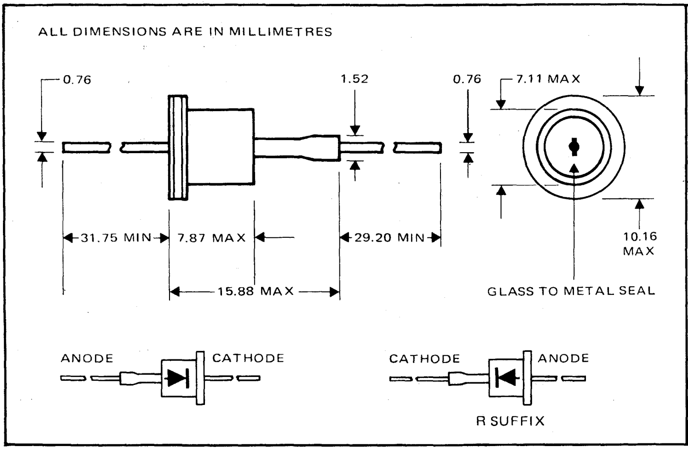
environmental tests

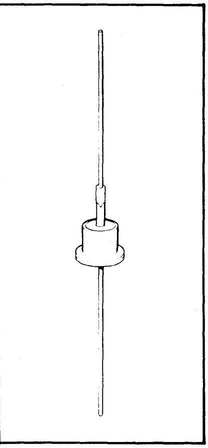
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

- The hermetic seal is verified for all devices by use of both helium and gross leak tests.
- Production samples are life tested under maximum operating conditions at regularly scheduled periods to ensure maximum reliability.

mechanical data

The devices have a hermetically sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 1.6 grams. Cathode-to-case is the standard configuration. Anode-to-case configuration is designated by the addition of R suffix to the type number; e.g. 1N560R.





absolute maximum ratings at 25°C ambient‡ temperature (unless otherwise noted)

PARAMETER		1N560	1N561	UNIT
V_{RRM}	Working Peak Reverse Voltage (See Note 1)	800*	1000*	V
V_{RSM}	Repetitive Peak Reverse Voltage (See Note 2)	1000	1250	V
V_R	Steady State Reverse Voltage	800*	1000*	V
$I_{F(AV)}$	Average Rectified Forward Current at 100°C Ambient Temperature (See Note 1)	250* 500†		mA
$I_{F(AV)}$	Average Rectified Forward Current at (or below) 50°C Ambient Temperature (See Note 1)	750		mA
I_{FRM}	Repetitive Peak Forward Current	1.5*		A
I_{FSM}	Nonrepetitive Surge Current for 2 msec Square Wave (See Note 3)	2* 35†		A
I_{FSM}	Surge Current, One Cycle (See Note 4)	25		A
P_D	Power Dissipation	0.4* 1.3†		W
$T_{A(opr)}$	Operating Ambient Temperature Range	−55 to +175		°C
T_{stg}	Storage Temperature Range	−55 to +175		°C

NOTES: 1. These values may be applied continuously under single-phase, 60Hz, half-sine-wave operation with resistive load. At elevated ambient temperatures, derate $I_{F(AV)}$ according to Figure 1.

2. These values apply for 100 μsec pulses, 60 pps, superimposed on single-phase, 60Hz, half-sine-waves.

3. These values apply for the fault current or overvoltage condition superimposed on the device operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to thermal equilibrium.
4. This value applies for one 60 Hz half-sine-wave when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to thermal equilibrium.

*Indicates JEDEC registered data.

†Texas Instruments guarantees these values in addition to the JEDEC registered values which are also shown.

‡The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling is used.

electrical characteristics at 25°C ambient‡ temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TYPE	MAX	UNIT
I_R	Static Reverse Current	V_R = 800 V		1N560	5† 15*	µA
		V_R = 1000V		1N561	5† 20*	
		V_R = 800V, T_A = 150°C		1N560	300	
		V_R = 1000V, T_A = 150°C		1N561	300	
		V_R = 800V, T_A = 175°C		1N560	500	
		V_R = 1000V, T_A = 175°C		1N561	500	
$I_{R(avg)}$	Average Reverse Current	$I_{F(AV)}$ = 250mA, f = 60Hz T_A = 150°C	V_{RRM} = 800V	1N560	200	µA
			V_{RRM} = 1000V	1N561	200	
		$I_{F(AV)}$ = 750mA, f = 60 cps, T_A = 50°C	V_{RRM} = 800V	1N560	200	
			V_{RRM} = 1000V	1N561	200	
V_F	Static Forward Voltage	I_F = 500 mA			1.1	V
V_{FM}	Peak Forward Voltage	$I_{F(AV)}$ = 250mA f = 60Hz	V_{RRM} = 800V	1N560	1.75*	V
			V_{RRM} = 1000V	1N561	1.75*	
		$I_{F(AV)}$ = 750mA f = 60Hz T_A = 50°C	V_{RRM} = 800V	1N560	1.75	
			V_{RRM} = 1000V	1N561	1.75	
$V_{F(avg)}$	Average Forward Voltage	$I_{F(AV)}$ = 250mA f = 60Hz T_A = 150°C	V_{RRM} = 800V	1N560	0.5	V
			V_{RRM} = 1000V	1N561	0.5	

THERMAL CHARACTERISTICS

FORWARD CURRENT DERATING CURVE

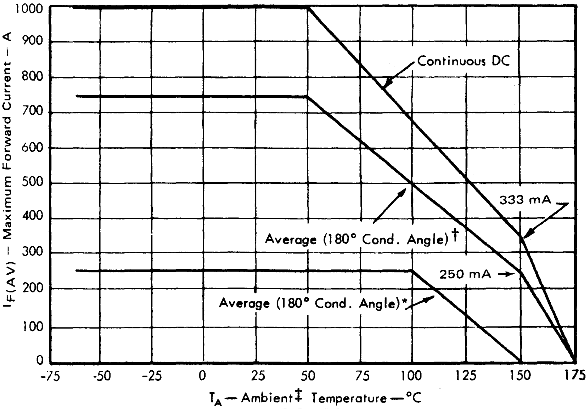


FIGURE 1

*Indicates JEDEC registered data.

†Texas Instruments guarantees these values in addition to the JEDEC registered values which are also shown.

‡The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling is used.

TYPES 1N588, 1N589
DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED AUGUST 1975

1500 VOLTS PIV • 0.75 AMP DC

- **Designed to Meet Stringent Environmental Requirements**
- **Applications: High-Voltage Power Supplies, Stacks and Multiphase Rectifier Operation**

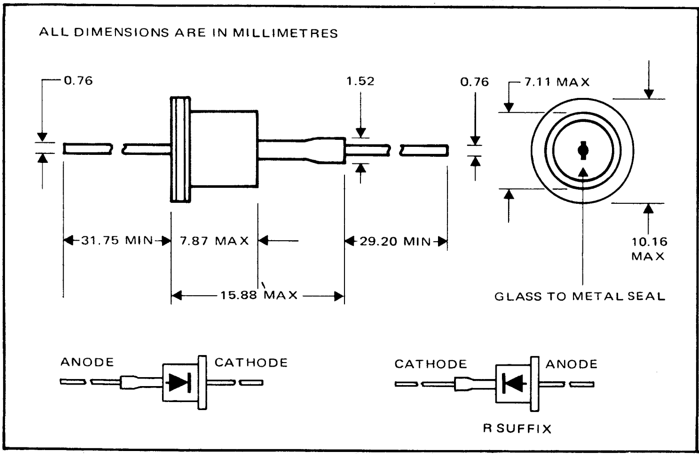
environmental tests

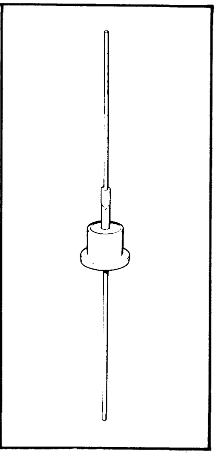
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

- The hermetic seal is verified for all devices by use of both helium and gross leak tests. Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.

mechanical data

The devices have a hermetically sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 1.6 grams. Cathode-to-case is the standard configuration. Anode-to-case configuration is designated by the addition of R suffix to the type number; e.g. 1N588R.





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

		1N588	1N589	UNIT
V_{RRM}	Working Peak Reverse Voltage (See Note 1)	1500*		V
V_R	Steady State Reverse Voltage	1500*		V
$I_{F(AV)}$	Average Rectified Forward Current at (or below) 50°C Ambient Temperature (See Note 1)	500‡ 100*	500‡ 250*	mA
I_{FSM}	Surge Current, One Cycle (See Note 2)	10‡ 5*	10*	A
$T_{A(opr)}$	Operating Ambient Temperature Range	−55 to +175*		°C
T_{stg}	Storage Temperature Range	−55 to +175*		°C
	Lead Temperature 12.7mm from Case for 10 Seconds	255*		°C

NOTES: 1. These values may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 50°C derate $I_{F(AV)}$ linearly to 0 at 175°C ambient temperature. See Figure 1.

2. These values apply for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

* Indicates JEDEC registered data.

†The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling is used.

‡TI guarantees these values in addition to the JEDEC registered values which are also shown.

TYPES 1N588, 1N589
DIFFUSED-JUNCTION SILICON RECTIFIERS

*electrical characteristics at specified ambient† temperatures

PARAMETER		TEST CONDITIONS	1N588	1N589	UNIT
			MAX	MAX	
I_R	Static Reverse Current	V_R = 1500V, T_A = 50°C	50	50	μA
		V_R = 1500V, T_A = 150°C	300	300	
$I_{R(avg)}$	Average Reverse Current	V_{RM} = 1500V, $I_{F(AV)}$ = 100mA f = 60Hz, T_A = 50°C	100		μA
		V_{RM} = 1500V, $I_{F(AV)}$ = 250mA f = 60Hz, T_A = 50°C		100	
V_F	Static Forward Voltage	I_F = 100mA, T_A = −65°C to +50°C	1.5		V
		I_F = 250mA, T_A = −65°C to +50°C		1.5	
V_{FM}	Peak Forward Voltage	$I_{F(AV)}$ = 100mA, V_{RRM} = 1500V, f = 60Hz, T_A = −65°C to +50°C	1.75		V
		$I_{F(AV)}$ = 250mA, V_{RRM} = 1500V, f = 60Hz, T_A = −65°C to +50°C		1.75	

*Indicates JEDEC registered data.

†The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling is used.

THERMAL CHARACTERISTICS

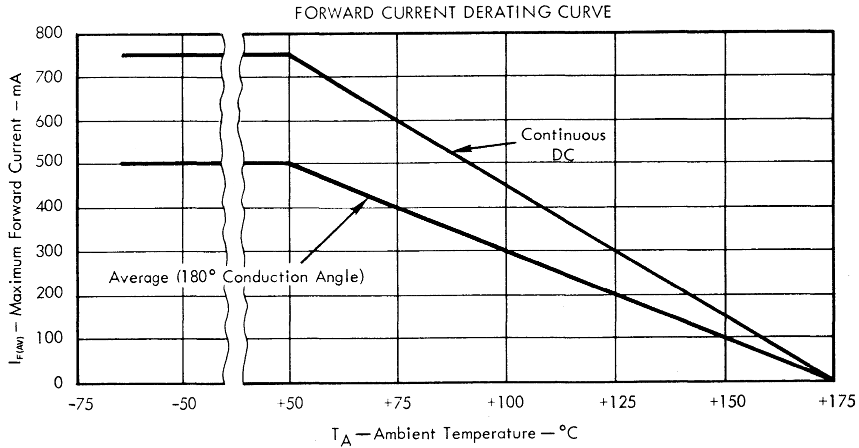


FIGURE 1

TYPES 1N607, 1N608, 1N609, 1N610, 1N611, 1N612, 1N613, 1N614, 1N607A, 1N608A, 1N609A, 1N610A, 1N611A, 1N612A, 1N613A, 1N614A
DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED AUGUST 1975

800 mA • 50 to 600 Volts PIV

- **Low leakage characteristics**
- **Stud mounted**
- **Available with anode to stud or cathode to stud**
- **Applications: Designed for power supplies, magnetic amplifiers**

environmental tests

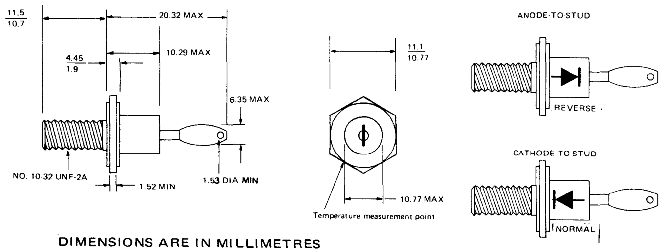
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

- The hermetic seal is verified for all devices by the use of both helium and gross leak tests.
- Production samples are life tested under maximum operating conditions at regularly scheduled periods to ensure maximum reliability.

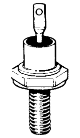
mechanical data

The device has a hermetically-sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 4.5 grams. Cathode-to-stud is the standard configuration. Anode-to-stud configuration is designated by the addition of R suffix to the type number; e.g. 1N607AR.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at specified case temperature

		1N607 1N607A	1N608 1N608A	1N609 1N609A	1N610 1N610A	1N611 1N611A	1N612 1N612A	1N613 1N613A	1N614 1N614A	UNIT
V_{RRM}	Peak or Steady State Reverse Voltage from − 65°C to + 150°C	50*	100*	150*	200*	300*	400*	500*	600*	V
$I_{F(AV)}$	Average Rectified Forward Current from − 65°C to + 100°C, See Fig. 3	800*								mA
I_{FSM}	Nonrecurrent Surge Current, ½ Cycle, 60 Hz Sine Wave, See Fig. 4	3* 10†								A
$T_{C(opr.)}$	Operating Case Temperature Range	−55 to +175*								°C
T_{stg}	Storage Temperature Range	−55 to +175*								°C

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITION	1N607 1N607A	1N608 1N608A	1N609 1N609A	1N610 1N610A	1N611 1N611A	1N612 1N612A	1N613 1N613A	1N614 1N614A	UNIT
			MAXIMUM VALUE								
I_R	Reverse Current	$V_R = V_{RRM}$	25* 5†								μA
I_R	Reverse Current for Suffix "A" Rectifiers	$V_R = V_{RRM}$	1.0*					1.5*	2.0*	2.5*	μA
V_F	Static Forward Voltage	I_F = 200 mA	1.5* 1.2†								V
V_F	Static Forward Voltage Suffix "A" Rectifiers	I_F = 400 mA	1.5* 1.2†								V

*Indicates JEDEC registered data.

†Texas Instruments guarantees these values in addition to the JEDEC registered values which are also shown

TYPES 1N607, 1N608, 1N609, 1N610, 1N611, 1N612, 1N613, 1N614, 1N607A, 1N608A, 1N609A, 1N610A, 1N611A, 1N612A, 1N613A, 1N614A
DIFFUSED-JUNCTION SILICON RECTIFIERS

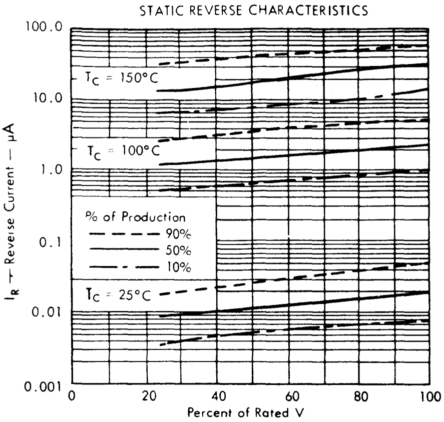


FIGURE 1

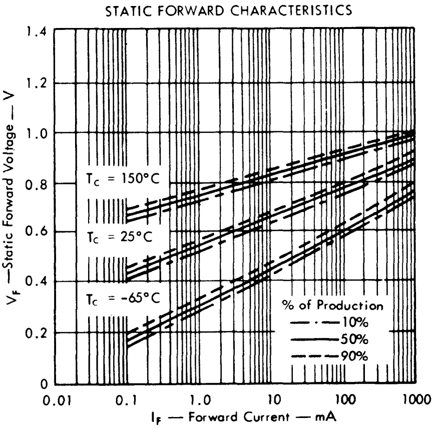


FIGURE 2

THERMAL CHARACTERISTICS

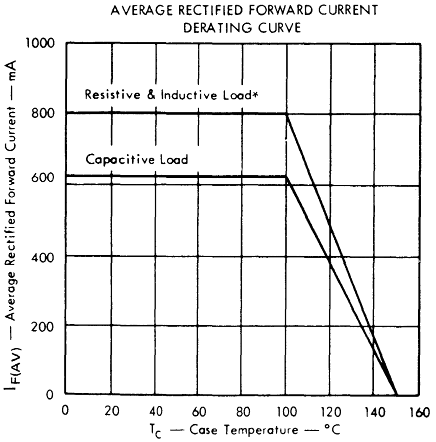


FIGURE 3

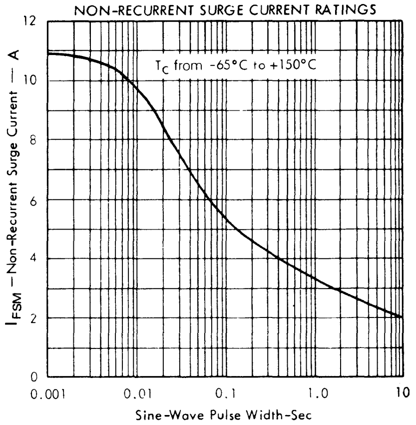


FIGURE 4

TYPES 1N1124, 1N1125, 1N1126, 1N1127, 1N1128
DIFFUSED SILICON RECTIFIERS

REVISED AUGUST 1975

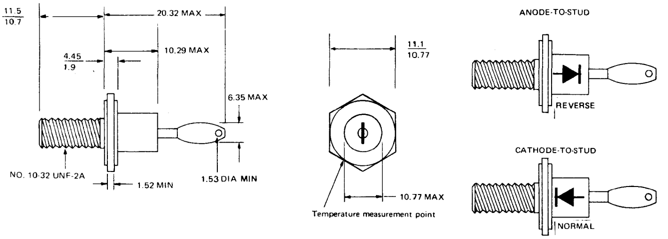
3 AMPERES . 200 to 600 VOLTS PIV

- All welded construction
- Designed to meet stringent military requirements
- High forward conductance
- Designed for all medium power applications
- Available with anode to stud or cathode to stud

mechanical data

Welded case with glass-to-metal hermetic seal between case and anode lead. Approximate weight is 4.36 grams.

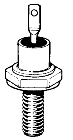
*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES



maximum ratings

		1N1124 1N1124R	1N1125 1N1125R	1N1126 1N1126R	1N1127 1N1127R	1N1128 1N1128R	unit
PIV	Peak Inverse Voltage at −65° to +150°C	200	300	400	500	600	Volt
$I_{F(AV)}$	*Average Rectified Forward Current at +50°C	3	3	3	3	3	Amp
$I_{F(AV)}$	*Average Rectified Forward Current at+150°C	1	1	1	1	1	Amp
I_{FRM}	*Recurrent Peak Forward Current at+50°C	10	10	10	10	10	Amp
I_{FSM}	Surge Current, 1 Cycle at 60 Cycles at +50°C	25	25	25	25	25	Amp
T_A	Operating Temperature, Ambient	−55 to +175					°C
	Altitude	70,000					ft

Anode-to-stud units denoted by "R" suffix to type number.

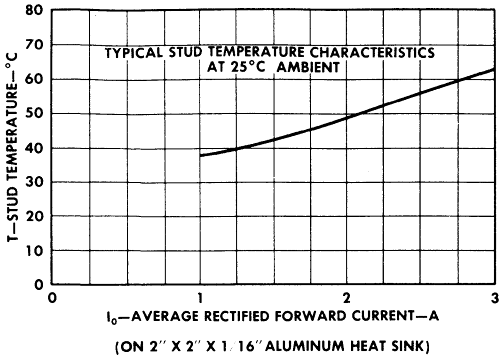
specifications

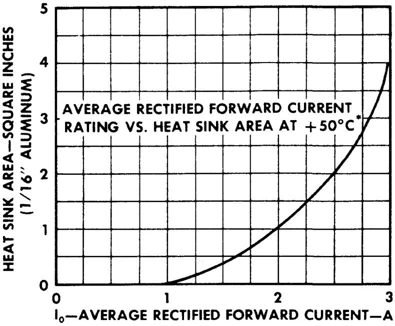
$I_{R(AV)}$	*†Max. Full Cycle Avg. Reverse Current at +150°C	0.3	0.3	0.3	0.3	0.3	mA
I_R	Max. Reverse Current at PIV at +25°C	10	10	10	10	10	μA
VDM	Max. Forward Voltage Drop at I_F = 1 Amp at +25°C	1.1	1.1	1.1	1.1	1.1	Volt

* Rectifier mounted on 5cm x 5cm Heat Sink, 1.6mm aluminium.

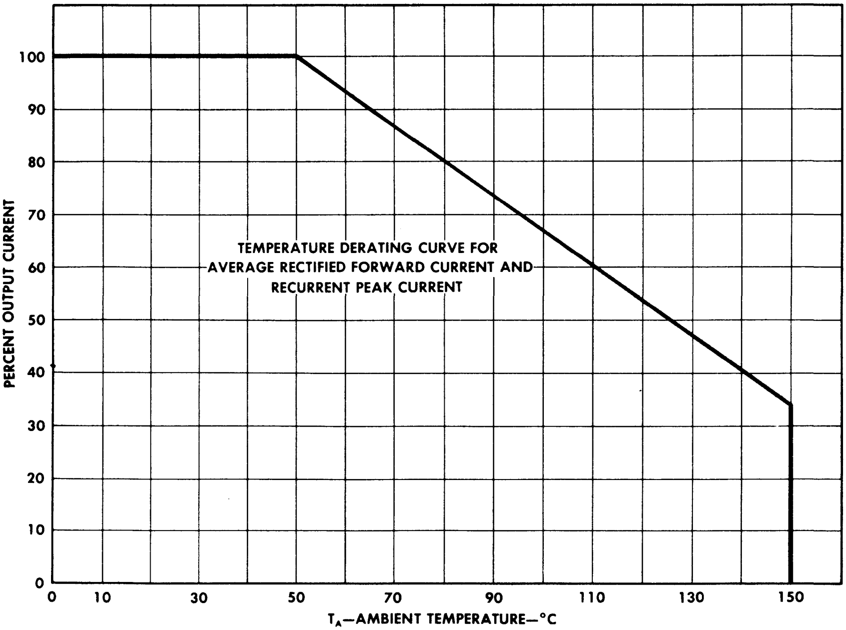
† Measured under operating conditions for the full cycle average with resistive or inductive load at T_A = 150°C, I_F = 1 Amp, E_{pp} = 0.707 PIV @ 60 Hz.

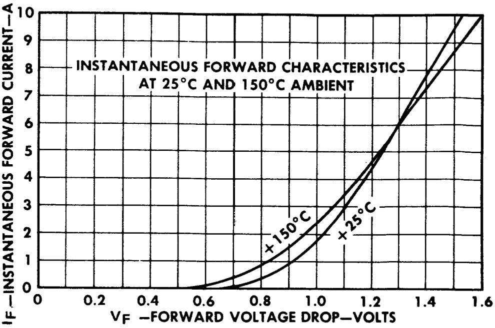
TEXAS INSTRUMENTS

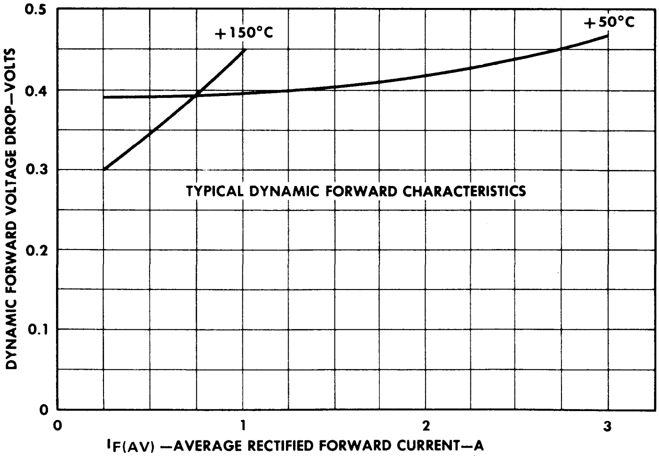


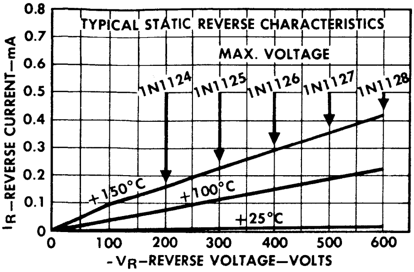


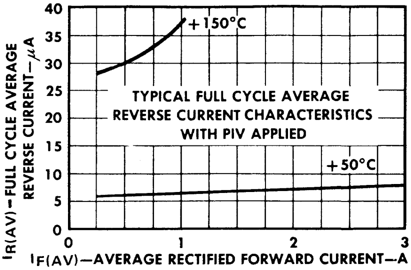
*CALCULATE CURRENTS AT OTHER TEMPERATURES FROM TEMPERATURE DERATING CURVE

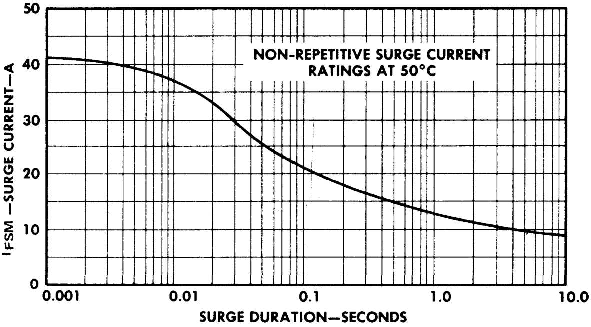



INSTANTANEOUS FORWARD CHARACTERISTICS
AT 25°C AND 150°C AMBIENT
+150°C
+25°C
IF—INSTANTANEOUS FORWARD CURRENT—A
0
1
2
3
4
5
6
7
8
9
10
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
VF —FORWARD VOLTAGE DROP—VOLTS


+150°C
+50°C
TYPICAL DYNAMIC FORWARD CHARACTERISTICS
DYNAMIC FORWARD VOLTAGE DROP—VOLTS
0
0.1
0.2
0.3
0.4
0.5
0
1
2
3
IF(AV) —AVERAGE RECTIFIED FORWARD CURRENT—A


TYPICAL STATIC REVERSE CHARACTERISTICS
MAX. VOLTAGE
1N1124
1N1125
1N1126
1N1127
1N1128
+150°C
+100°C
+25°C
I_R—REVERSE CURRENT—mA
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
$-V_R$—REVERSE VOLTAGE—VOLTS


+150°C
TYPICAL FULL CYCLE AVERAGE REVERSE CURRENT CHARACTERISTICS WITH PIV APPLIED
+50°C
$I_{R(AV)}$—FULL CYCLE AVERAGE REVERSE CURRENT—μA
40
35
30
25
20
15
10
5
0
0
1
2
3
$I_{F(AV)}$—AVERAGE RECTIFIED FORWARD CURRENT—A


NON-REPETITIVE SURGE CURRENT RATINGS AT 50°C
I_{FSM} —SURGE CURRENT—A
50
40
30
20
10
0
0.001
0.01
0.1
1.0
10.0
SURGE DURATION—SECONDS

TYPES 1N1130 AND 1N1131
DIFFUSED SILICON RECTIFIERS

REVISED AUGUST 1975

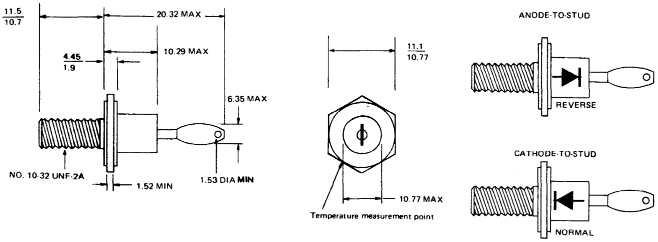
1500 VOLTS • 300 mA

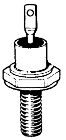
Designed to meet stringent military requirements
Available with anode to stud or cathode to stud

mechanical data

Welded case with glass-to-metal hermetic seal between case and lead. Approximate weight is 4.36 grams. Cathode to stud is the standard configuration. Anode to stud device is designated by 1N1131.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





NOTES*: A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base

DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C (unless otherwise specified)

V_{RRM}	Recurrent Peak Inverse Voltage	1500 V
$I_{F(AV)}$	Average Rectified Forward Current (See Note 1)	300 mA
I_{FRM}	Recurrent Peak Current at −55°C to +175°C (See Note 1)	1 A
	Stud Temperature	165°C
	Altitude (See Note 2)	70,000 ft
T_A	Operating Temperature, Ambient	−55°C to +175°C

electrical characteristics at 25°C ambient (unless otherwise specified)

D.C. Test

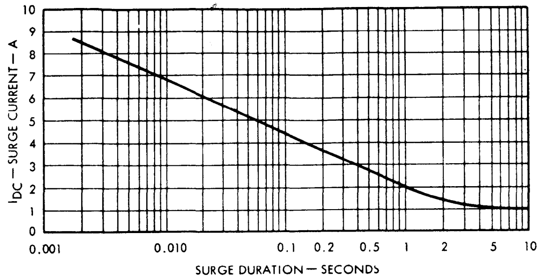
I_R	Maximum Reverse Leakage Current at $V_R = -1500$ Vdc	50 µA
V_F	Maximum Forward Voltage Drop at $I_F = 300$ mA	15 V (TI MAX 1·5 v)

NOTE 1. Mounted on a 63.5 x 63.5 x 1.59mm aluminium heat sink.
2. Refer to characteristic curves.
3. Typical values presented are to define areas of TI device revisions.

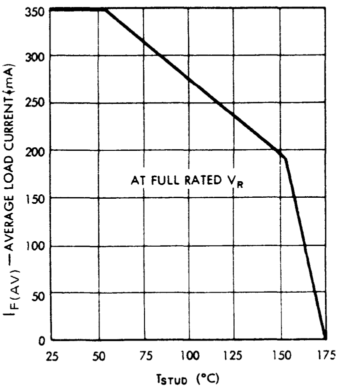
OPERATING VOLTAGE AND CURRENT RATINGS WITH TEMPERATURE

(MOUNTED ON A 63.5 x 63.5 x 1.59mm ALUMINIUM HEAT SINK)

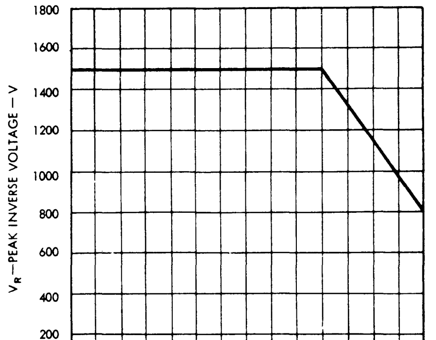
NON-REPETITIVE SURGE CURRENT RATINGS AT 25°C



TEMPERATURE DERATING CURVE

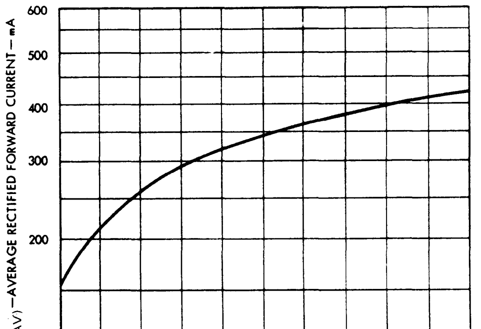


PEAK INVERSE VOLTAGE RATING WITH ALTITUDE



AVERAGE RECTIFIED CURRENT VERSUS HEAT SINK AREA

(STILL AIR: T_A = 25°C)



TYPES 1N1199A THRU 1N1206A
DIFFUSED-JUNCTION SILICON RECTIFIERS

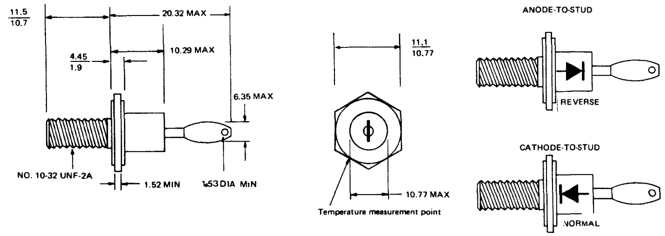
REVISED AUGUST 1975

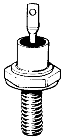
50-600 VOLTS • 12 AMPS AVG
MEDIUM POWER RECTIFIERS

- **High Operating Case Temperature Rating**
- **Low Forward Voltage Drop**
- **High Current with Minimum Space Requirements**

mechanical data

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES

*absolute maximum ratings

		1N1199A	1N1200A	1N1201A	1N1202A	1N1203A	1N1204A	1N1205A	1N1206A	UNIT
V_{RWM}	Working Peak Reverse Voltage from −55°C to +175°C Case Temperature (See Note 1)	50	100	150	200	300	400	500	600	V
V_{RRM}	Repetitive Peak Reverse Voltage from −55°C to +175°C Case Temperature (See Note 2)	50	100	150	200	300	400	500	600	V
V_{RSM}	Nonrepetitive Peak Reverse Voltage from 0°C to 200°C Junction Temperature (PW ≤ 5 msec)	100	200	300	350	450	600	700	800	V
V_R	Steady State Reverse Voltage from 25°C to 150°C Case Temperature	50	100	150	200	300	400	500	600	V
$I_{F(AV)}$	Average Rectified Forward Current from −65°C to 150°C Case Temperature (See Note 1)	12								A
I_{FSM}	Peak Surge Current, One Cycle (See Note 3)	240								A
$T_{C(opr)}$	Operating Case Temperature Range	−55 to +175								°C
T_{stg}	Storage Temperature Range	−55 to +175								°C

NOTES: 1. These values may be applied continuously under single-phase 60 Hz half-sine-wave operation with resistive load. The peak reverse voltage and average current ratings apply simultaneously. Above 150°C, derate I_o according to Figure 1.

2. These values apply for 100-μsec pulses, 60 pps, superimposed on single-phase, 60 Hz half sine waves.

3. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to original thermal equilibrium.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TYPE	MAX	UNIT
$I_{R(avg)}$	Average Reverse Current	$I_{F(AV)} = 12A$ $T_C = 150°C$	$V_{RRM} = 50V$	1N1199A	3	mA
			$V_{RRM} = 100V$	1N1200A	2.5	
			$V_{RRM} = 150V$	1N1201A	2.25	
			$V_{RRM} = 200V$	1N1202A	2	
			$V_{RRM} = 300V$	1N1203A	1.75	
			$V_{RRM} = 400V$	1N1204A	1.5	
			$V_{RRM} = 500V$	1N1205A	1.25	
			$V_{RRM} = 600V$	1N1206A	1	
V_{FM}	Peak Forward Voltage	$I_{F(AV)} = 12A$	V_{RRM} = Rated V_{RRM}	All	1.35	V

*Indicates JEDEC registered data.

THERMAL INFORMATION

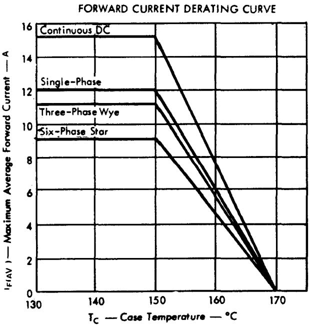


FIGURE 1

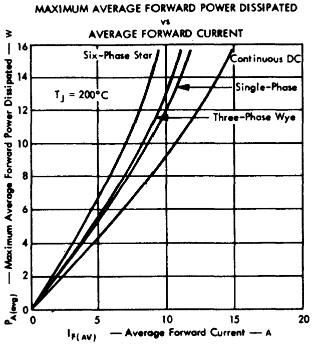


FIGURE 2

1N1612, 1N1613, 1N1614, 1N1615, 1N1616
DIFFUSED SILICON RECTIFIERS

JULY 1975

15 Amperes • 50 to 600 Volts PIV
- **All welded construction**
- **Meet stringent military requirements**
- **High forward conductance**
- **Designed for all medium power applications**
- **Available with anode or cathode to stud**

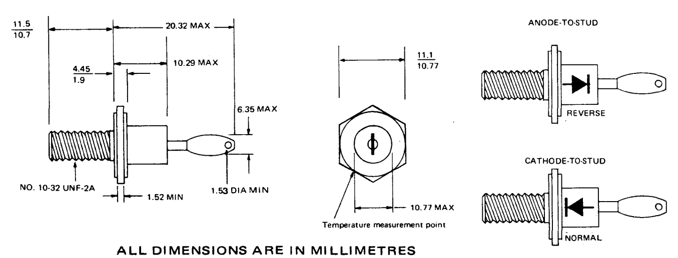
environmental tests

All rectifiers are designed to meet the environmental requirements of MIL-S-19500/104 (Navy).

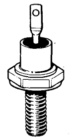
mechanical data

Welded case with glass-to-metal hermetic seal between case and lead. Approximate weight is 4.36 grams. Cathode to stud is the standard configuration. Anode to stud is designated by an "R" suffixed to the type number, e.g., 1N1612R.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C ambient temperature (unless otherwise noted)

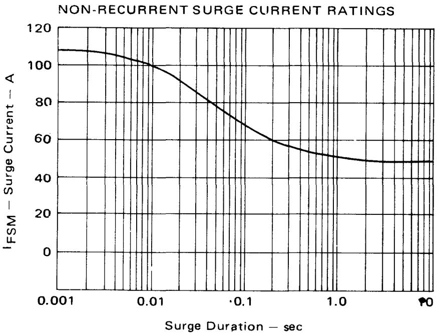
		1N1612	1N1613	1N1614	1N1615	1N1616	UNIT
V_R	Reverse Voltage over Operating Temperature Range	50	100	200	400	600	V
$I_{F(AV)}$	Average Rectified Forward Current at 50°C	5*					A
		15†					A
$I_{F(AV)}$	Average Rectified Forward Current at 150°C	5*					A
		5†					A
I_{FRM}	Recurrent Peak Forward Current Current at 50°C	15*					A
		50†					A
I_{FSM}	Surge Current, ½ Cycle, 60cps Sine Wave	100					A
T_A	Operating Temperature Range	−55 to +175					°C
T_{stg}	Storage Temperature Range	−55 to +175					°C

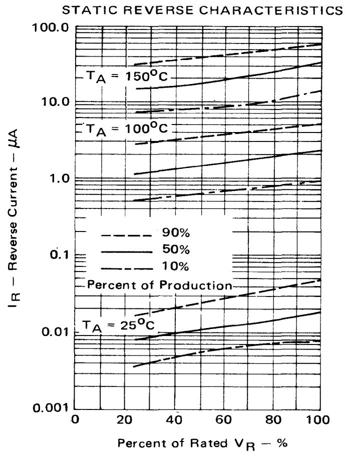
1N1612, 1N1613, 1N1614, 1N1615, 1N1616
DIFFUSED SILICON RECTIFIERS

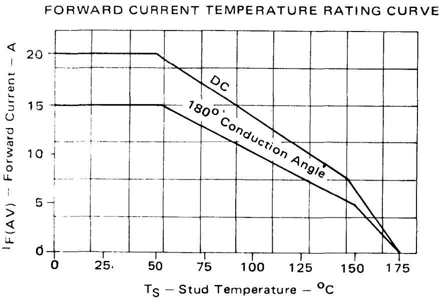
electrical characteristics at 25°C ambient temperature (unless otherwise noted)

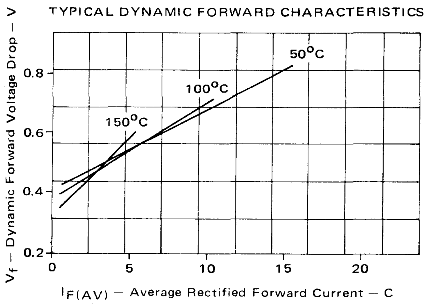
SYMBOL	PARAMETER	TEST CONDITION	1N1612	1N1613	1N1614	1N1615	1N1616	UNIT
BV_R	Minimum Breakdown Voltage	$I_R = 100\mu A$	60	120	240	480	720	V
I_R	Reverse Current	V_R	10					µA
I_R	Reverse Current	V_R at 150°C	1.0*					mA
			0.2†					mA
I_R	Reverse Current (Full Cycle Average)	V_R at 60 cps at 150°C	0.3					mA
V_F	Forward Voltage Drop	$I_F = 10A$	1.5					V

NOTES: *EIA Registered Values
†TI Guaranteed Values in addition to, or an improvement over, EIA-Registered Values









1N2970 THRU 1N3015
DIFFUSED SILICON POWER REGULATORS

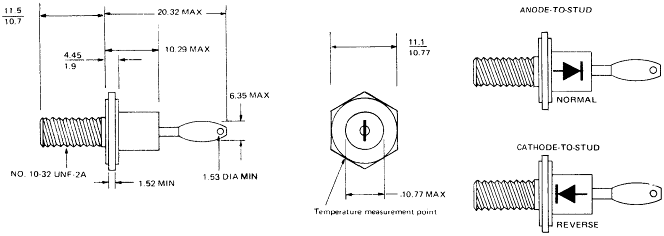
REVISED AUGUST 1975

10 WATTS 6.8 TO 200 VOLTS
- Guaranteed Zener Impedance
- Available in 5%, 10% and 20% tolerances normal are reverse polarity
- Designed to meet the most stringent military requirements
- –55°C to +175°C operation

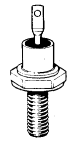
mechanical data

Welded case with glass-to-metal hermetic seal between case and anode lead. Approximate weight is 4.36 grams.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



maximum ratings

Nominal Zener Voltage	V_Z	6.8 to 200	Volts
Power Dissipation (See Curve)	P_D	10	Watts
Storage Temperature (Stud)	T_{STG}	—65 to + 175	°C
Altitude		100,000	Feet

specifications

Maximum Forward Voltage Drop at 2.0 Amps	V_F	1.5	Volts

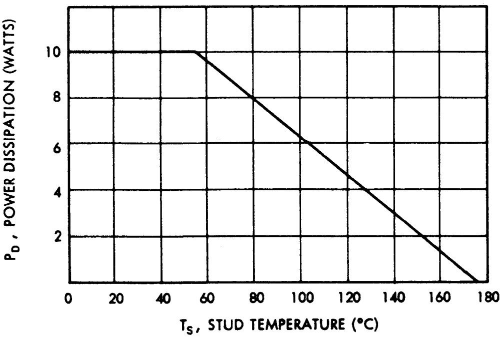
For Remaining Specifications See Table I.

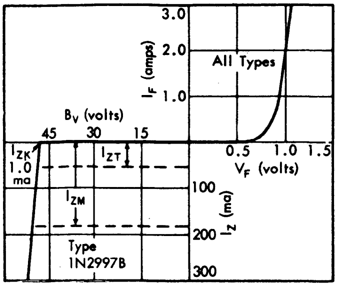
1N2970 THRU 1N3015
DIFFUSED SILICON POWER REGULATORS

Type No.	V_Z Zener Voltage Nominal	I_{ZT} Test Current	Z_{ZT} Zener Impedance Max.	Z_{ZK} Zener Impedance Max. ($I_{ZK} = 1.0$ ma)	I_{ZM} Max. DC Current	IZ Surge Current $T_A = 25°C$
	Volts	ma	Ohms	Ohms	ma	ma
1N2970	6.8	370	1.2	500	1500	7500
1N2971	7.5	335	1.3	250	1350	6750
1N2972	8.2	305	1.5	250	1180	5900
1N2973	9.1	275	2.0	250	1100	5500
1N2974	10	250	3.0	250	980	4900
1N2975	11	230	3.0	250	890	4450
1N2976	12	210	3.0	250	820	4100
1N2977	13	190	3.0	250	750	3750
1N2979	15	170	3.0	250	640	3200
1N2980	16	155	4.0	250	605	3000
1N2982	18	140	4.0	250	525	2600
1N2984	20	125	4.0	250	480	2400
1N2985	22	115	5.0	250	435	2180
1N2986	24	105	5.0	250	400	2000
1N2988	27	95	7.0	250	340	1700
1N2989	30	85	8.0	300	320	1600
1N2990	33	75	9.0	300	300	1500
1N2991	36	70	10.0	300	260	1300
1N2992	39	65	11.0	300	240	1200
1N2993	43	60	12.0	400	220	1100
1N2995	47	55	14.0	400	200	1000
1N2997	51	50	15.0	500	185	925
1N2999	56	45	16.0	500	170	850
1N3000	62	40	17	600	150	750
1N3001	68	37	18	600	137	685
1N3002	75	33	22	600	125	625
1N3003	82	30	25	700	115	575
1N3004	91	28	35	800	97	485
1N3005	100	25	40	900	91	450
1N3007	110	23	55	1100	82	410
1N3008	120	20	75	1200	77	380
1N3009	130	19	100	1300	71	350
1N3011	150	17	175	1500	62	310
1N3012	160	16	200	1600	58	290
1N3014	180	14	260	1850	52	260
1N3015	200	12	300	2000	46	230

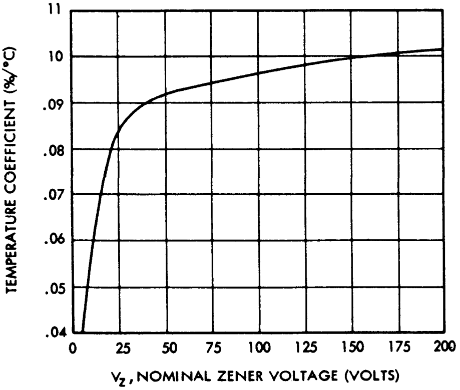
(1) Standard polarity is anode to stud. R suffix denotes cathode to stud.

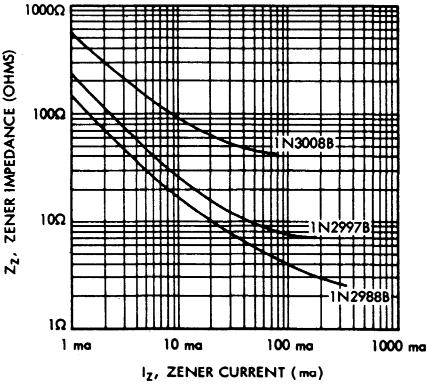
(2) Type number suffixed by A denotes ±10% tolerance. ±5% tolerance is denoted by B suffix. Normal tolerance ±20%.


POWER DERATING CURVE


TYPICAL CHARACTERISTICS

TYPICAL CHARACTERISTICS


TEMPERATURE COEFFICIENT CURVE


ZZ ZENER IMPEDANCE vs IZ ZENER CURRENT

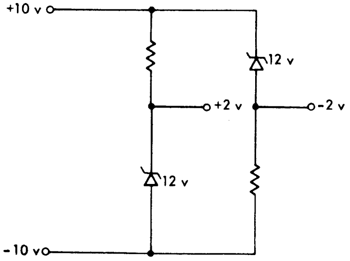
1N2970 THRU 1N3015
DIFFUSED SILICON POWER REGULATORS

Notes

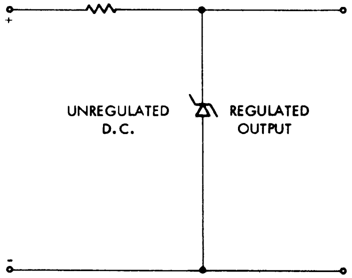
1. Inspection Conditions. Unless otherwise specified, all inspections shall be correlated to stud temperature (T_S) of 30°C ± 1°C.
2. Polarity. Standard units have the anode connected to the base. The symbol R added to the unit number shall indicate a reverse (cathode to base) polarity.
3. Zener Voltage shall be specified at the current given in Col. 3 of Table I.
4. Zener Impedance shall be determined by reading the AC voltage developed across the unit when operated in a specified DC condition with an AC current applied equal to 10% of the DC current applied. Z_Z is then the AC voltage read, divided by the AC current applied.
5. Max. DC Current is the maximum steady state current at 25°C.
6. Typical Thermal Resistance is 5°C per watt.
7. Surge Current. The currents specified in Col. 7 of Table I can be applied in the Zener region. This current shall be imposed on the quarter power current (I_{ZT}) for a total of 5 surges at 1 minute intervals. Each surge shall be a ½ square wave pulse of 1/120 second duration.

TYPICAL CIRCUITS

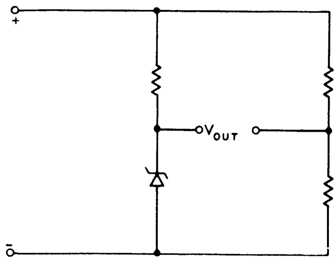
SHORT CIRCUIT PROOF
LOW-VOLTAGE POWER SUPPLY



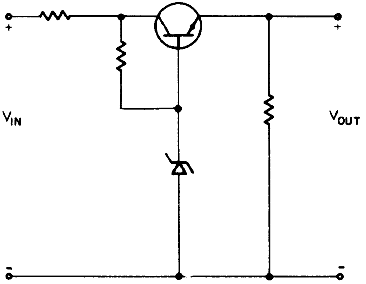
BASIC SUPPLY



IMPEDANCE COMPENSATING CIRCUIT



EMITTER FOLLOWER REGULATOR



TYPES 1N3879, 1N3880, 1N3881, 1N3882, 1N3883
DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED AUGUST 1975

50-400 Volts • 6 Amps

- **Designed for High-Frequency Operation**
- **Low Recovery Time — 70 nsec typical, 200 nsec max**
- **Designed to meet stringent environmental requirements**
- **Applications: High-Frequency Power Supplies, High-Speed Power Switch and Multiphase Rectifier Operation**
- **Available as BS9331-F027 (see separate data sheet)**

environmental tests

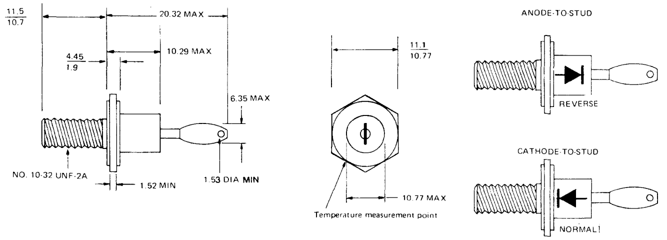
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

- The hermetic seal is verified for all devices by the use of both helium and gross leak tests.
- Production samples are life tested under maximum operating conditions at regularly scheduled periods to ensure maximum reliability.

mechanical data

The device has a hermetically sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 4.5 grams. Cathode-to-stud is the standard configuration. Anode-to-stud configuration is designated by the addition of R suffix to the type number; e.g. 1N3879R.

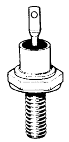
*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES



•Indicates JEDEC registered data.

TYPES 1N3879, 1N3880, 1N3881, 1N3882, 1N3883
DIFFUSED-JUNCTION SILICON RECTIFIERS

*absolute maximum ratings at specified case temperature

		1N3879	1N3880	1N3881	1N3882	1N3883	UNIT
V_{RRM}	Peak Reverse Voltage from − 65°C to + 150°C (See Note 1)	50	100	200	300	400	V
V_R	Steady State Reverse Voltage from − 65°C to + 100°C	50	100	200	300	400	V
$I_{F(AV)}$	Average Rectified Forward Current from − 65°C to + 100°C (See Note 1)	← 6 →					A
I_{FRM}	Surge Current, 10 cycles at (or below) 100°C (See Note 2)	← 35 →					A
I_{FSM}	Surge Current, ½ cycle, at (or below) 100°C (See Note 2)	← 75 →					A
$T_{C(opr)}$	Operating Case Temperature Range	← −55 to +175 →					°C
T_{stg}	Storage Temperature Range	← −55 to +175 →					°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TYPE	TYP.	MAX	UNIT
I_R	Reverse Current		V_R = 50 V	1N3879		15*	μA
			V_R = 100 V	1N3880			
			V_R = 200 V	1N3881			
			V_R = 300 V	1N3882			
			V_R = 400 V	1N3883			
I_R	Reverse Current	T_C = 100°C	V_R = 50 V	1N3879		1.0*	mA
			V_R = 100 V	1N3880			
			V_R = 200 V	1N3881			
			V_R = 300 V	1N3882			
			V_R = 400 V	1N3883			
$I_{R(avg)}$	Average Reverse Current	$I_{F(AV)}$ = 6A f = 60Hz T_C = 100°C	V_{RM} = 50 V	1N3879		3.0*	mA
			V_{RM} = 100 V	1N3880			
			V_{RM} = 200 V	1N3881			
			V_{RM} = 300 V	1N3882			
			V_{RM} = 400 V	1N3683			
V_F	Static Forward Voltage	I_F = 6A (See Note 3)		ALL		1.4*	V
V_{FM}	Peak Forward Voltage	$I_{F(AV)}$ = 6A f = 60Hz T_C = −65°C to + 100°C	V_{RM} = 50 V	1N3879		1.5*	V
			V_{RM} = 100 V	1N3880			
			V_{RM} = 200 V	1N3881			
			V_{RM} = 300 V	1N3882			
			V_{RM} = 400 V	1N3883			
C_{total}	Capacitance	f = 1 MHz V_R = 30 V		1N3879	100		pF
				1N3880	75		
				1N3881	50		
				1N3882	40		
				1N3883	35		

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYPE	TYP.	MAX	UNIT
t_{rr}	Reverse Recovery Time (See Figures 1 and 2)	I_F = 1.0A to V_R = 30V	ALL	70	200*	nsec
I_{rr}	Reverse Recovery Current (See Figures 1 and 2)	I_F = 1.0A to V_R = 30V	ALL		2*	A

thermal characteristics

PARAMETER		TEST CONDITIONS	TYPE	TYP.	MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance		ALL	5		C°/W

NOTES: 1. These values may be applied continuously under single-phase, 60 Hz, half-sine-wave operation with resistive load. Above 100°C, derate $I_{F(AV)}$ according to figure 3.

2. These values apply for 60 Hz half-sine-waves when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surges may be repeated after the device has returned to thermal equilibrium.

3. This parameter must be measured using pulse techniques. PW ≤ 300 μsec, Duty Cycle ≤ 2%.

*Indicates JEDEC registered data.

PARAMETER MEASUREMENT INFORMATION

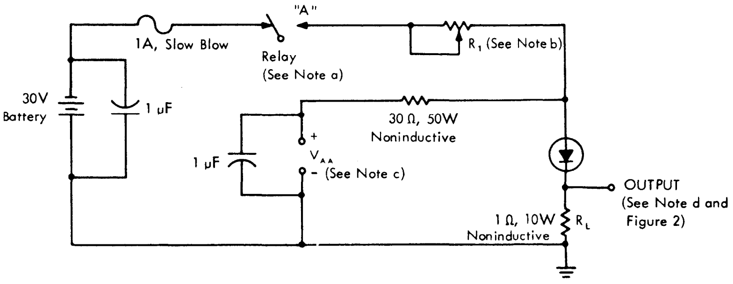


FIGURE 1* — REVERSE RECOVERY TEST CIRCUIT

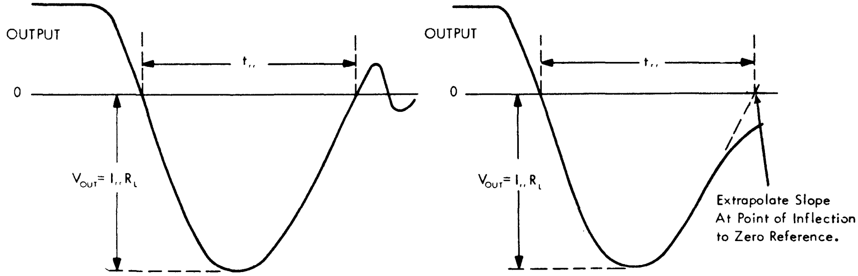


FIGURE 2* — TYPICAL REVERSE RECOVERY VOLTAGE WAVEFORMS

NOTES: a. Relay is a make-before-break, mercury-wetted-contact type driven by 60 Hz sine wave. The relay conducts for approximately 640 μsec and is open for approximately 7.7 msec.

b. Resistor R_1 is a 3 Ω 25W rheostat adjusted for a total resistance value of 1.4 Ω from anode to relay contact A. Measured inductance between these points is 38 μH.

c. V_{AA} supply has an output impedance $Z_O \leq 0.5\ \Omega$ from 0-2kHz and is adjusted for $I_F = 1.0A$.

d. Output waveform is monitored on an oscilloscope with the following characteristics : $t_r \leq 14$ nsec, $R_{in} = 9\ M\Omega$, $C_{in} \leq 12$ pF, L_{in} (series) $\leq$ 0.5 μH.

*Indicates JEDEC registered data.

THERMAL CHARACTERISTICS

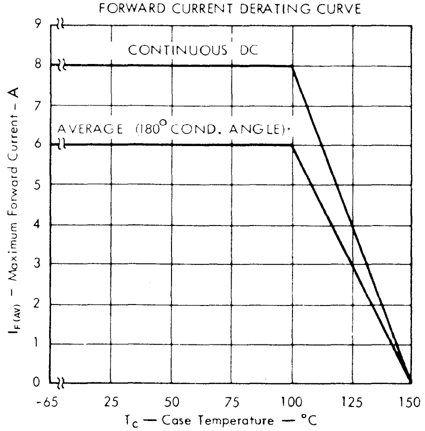


FIGURE 3

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

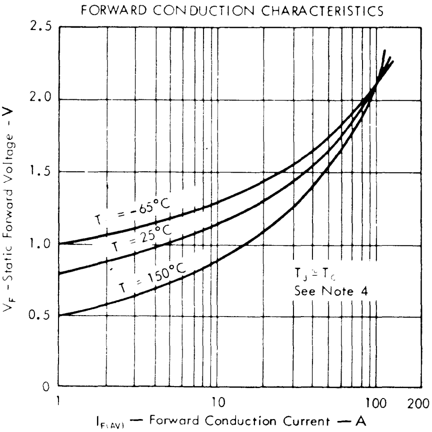


FIGURE 4

Note 4: This parameter was measured using pulse techniques. PW ≤ 300 μsec, Duty cycle ≤ 2%.

TYPES 1N3889, 1N3890, 1N3891, 1N3892, 1N3893
DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED AUGUST 1975

HIGH FREQUENCY, FAST RECOVERY

- **50-400 Volts, 12 Amps**
- **200 nsec Max Recovery Time**
- **Exceptional Efficiency at High Frequency**
- **Designed to Meet Stringent Environmental Requirements**
- **Applications: High-Frequency Power Supplies, High-Speed Power Switch and Multiphase Rectifier Operation**

environmental tests

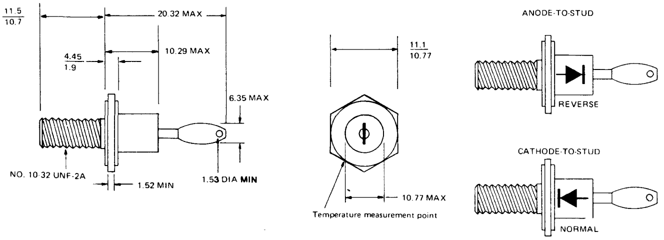
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

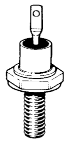
- The hermetic seal is verified for all devices by the use of both helium and gross leak tests.
- Production samples are life tested at regularly scheduled periods to ensure maximum reliability under extreme operating conditions.

mechanical data

The device has a hermetically sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 4.7 grams. Cathode-to-stud is the standard configuration. Anode-to-stud configuration is designated by the addition of R suffix to the type number; e.g. 1N3889R.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurment is the centre

ALL DIMENSIONS ARE IN MILLIMETRES

*Indicates JEDEC registered data.

TYPES 1N3889, 1N3890, 1N3891, 1N3892, 1N3893
DIFFUSED-JUNCTION SILICON RECTIFIERS

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

			1N3889	1N3890	1N3891	1N3892	1N3893	UNIT
V_{RWM}	Peak Reverse Voltage	(See Note 1)	50	100	200	300	400	V
V_R	Steady State Reverse Voltage		50	100	200	300	400	V
$I_{F(AV)}$	Average Rectified Forward Current from −65°C to + 100°C Case Temperature	(See Note 1)	12					A
I_{FRM}	Peak Surge Current, 10 cycles, at (or below) 100°C Case Temperature	(See Note 2)	70					A
I_{FSM}	Peak Surge Current, ½ cycle, at (or below) 100°C Case Temperature	(See Note 2)	150					A
$T_{C(opr)}$	Operating Case Temperature Range		−55 to +175					°C
T_{stg}	Storage Temperature Range		−55 to +175					°C

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TYPE	TYP	MAX	UNIT
I_R	Static Reverse Current		$V_R = 50$ V	1N3889		25	μA
			$V_R = 100$ V	1N3890			
			$V_R = 200$ V	1N3891			
			$V_R = 300$ V	1N3892			
			$V_R = 400$ V	1N3893			
I_R	Static Reverse Current	$T_C = 100$°C	$V_R = 50$ V	1N3889		3	mA
			$V_R = 100$ V	1N3890			
			$V_P = 200$ V	1N3891			
			$V_R = 300$ V	1N3892			
			$V_R = 400$ V	1N3893			
$I_{R(avg)}$	Average Reverse Current	$I_{F(AV)} = 12$A f = 60Hz, $T_C = 100$°C	$V_{RM} = 50$ V	1N3889		5	mA
			$V_{RM} = 100$ V	1N3890			
			$V_{RM} = 200$ V	1N3891			
			$V_{RM} = 300$ V	1N3892			
			$V_{RM} = 400$ V	1N3893			
V_F	Static Forward Voltage	$I_F = 12$A,		ALL	0.9	1.4	V
V_{FM}	Peak Forward Voltage	$I_{F(AV)} = 12$A f = 60Hz, $T_C = -65$°C to + 100°C	$V_{RM} = 50$ V	1N3889		1.5	V
			$V_{RM} = 100$ V	1N3890			
			$V_{RM} = 200$ V	1N3891			
			$V_{RM} = 300$ V	1N3892			
			$V_{RM} = 400$ V	1N3893			
C_T	Total Capacitance	$V_R = 30$ V, f = 1 MHz		ALL	50		pF

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYPE	MAX	UNIT
t_{rr}	Reverse Recovery Time (See Figures 1 and 2)	$I_F = 1$A to $V_R = 30$V	ALL	200	nsec
I_{rr}	Reverse Recovery Current (See Figures 1 and 2)	$I_F = 1$A to $V_R = 30$V	ALL	2	A

NOTES: 1. These values may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 100°C, derate $I_{F(AV)}$ according to Figure 3.

2. These values apply to 60-Hz half sine waves when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surges may be repeated after the device has returned to original thermal equilibrium.

*Indicates JEDEC registered data (typical data excluded)

PARAMETER MEASUREMENT INFORMATION

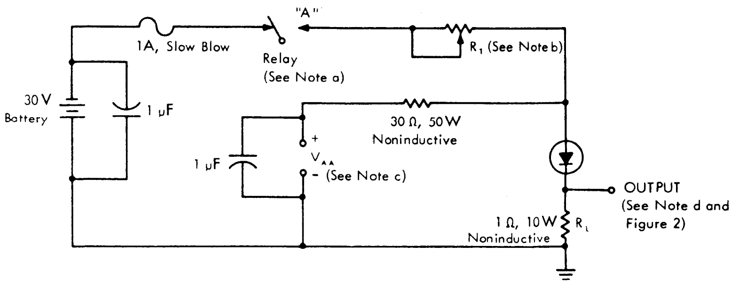


FIGURE 1* — REVERSE RECOVERY TEST CIRCUIT

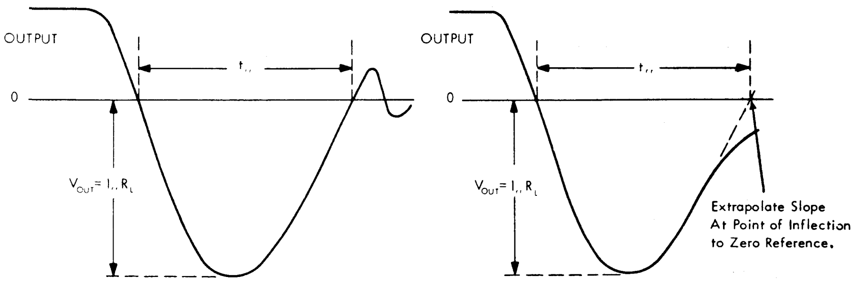


FIGURE 2* — TYPICAL REVERSE RECOVERY VOLTAGE WAVEFORMS

NOTES:
- a. Relay is a make-before-break, mercury-wetted-contact type driven by 60Hz sine wave. The relay conducts for approximately 640 μsec and is open for approximately 7.7 msec.
- b. Resistor R_1 is a 3Ω, 25W rheostat adjusted for a total resistance value of 1.4Ω from anode to relay contact A. Measured inductance between these points is 38μH.
- c. V_{AA} supply has an output impedance $Z_O \leqslant 0.5\Omega$ from 0-2kHz, and is adjusted for $I_F = 1A$.
- d. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ nsec, $R_{in} = 9M\Omega$, $C_{in} \leqslant 12pF$, L_{in} (series) $\leqslant 0.5\mu H$.

*Indicates JEDEC registered data.

FORWARD CURRENT DERATING CURVE

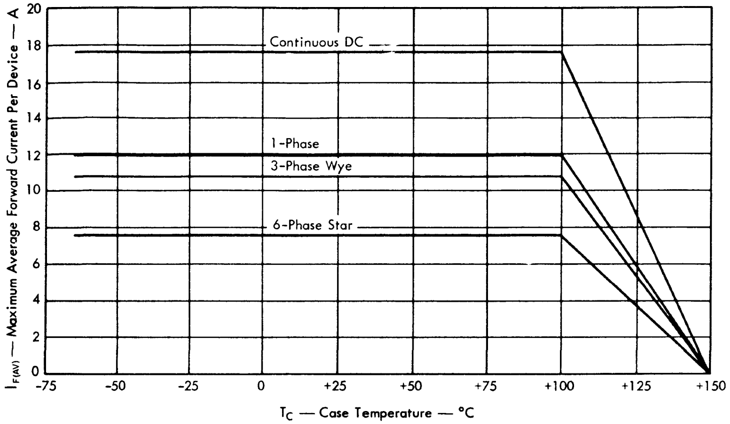


FIGURE 3

TYPICAL CHARACTERISTICS

FORWARD CONDUCTION CHARACTERISTICS

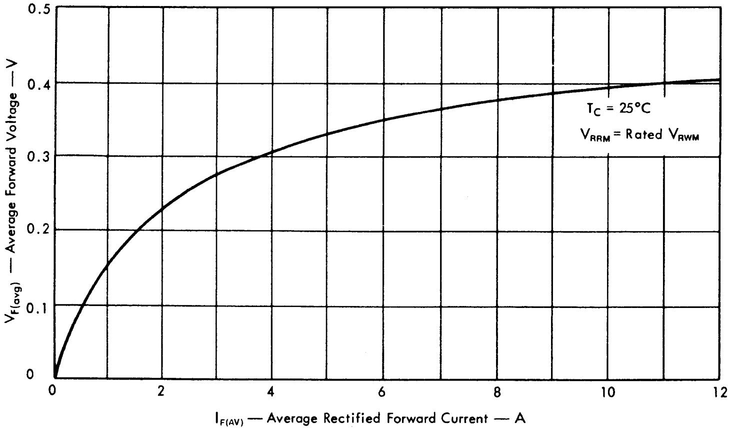


FIGURE 4

TYPES 1N4364, 1N4365, 1N4366, 1N4367, 1N4368, 1N4369

UNI-VERSATILE‡ DIFFUSED-JUNCTION SILICON RECTIFIERS

REVISED JULY 1975

100-600 VOLTS • 1 AMP DC

Designed to Meet Stringent Environmental Requirements

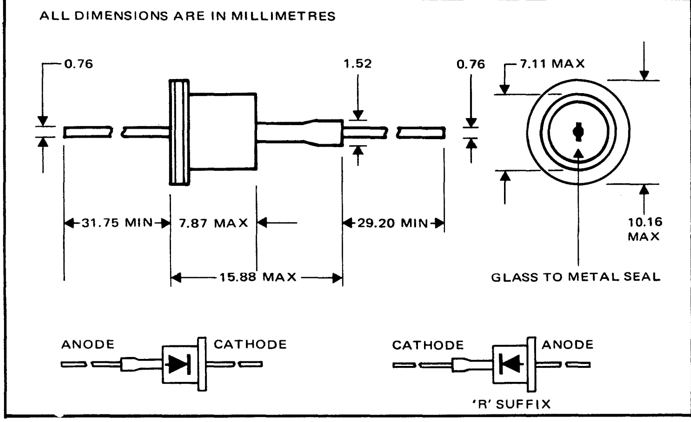
environmental tests

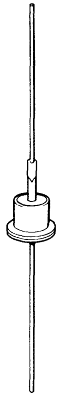
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

- The hermetic seal is verified for all devices by the use of both helium and gross leak tests.
- Production samples are life tested under maximum operating conditions at regularly scheduled periods to ensure maximum reliability.

mechanical data

The devices have a hermetically-sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 1.6 grams. Cathode-to-case is the standard configuration. Anode-to-case configuration is designated by the addition of R suffix to the type number; e.g. 1N4364R.





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

		1N4364	1N4365	1N4366	1N4367	1N4368	1N4369	UNIT
V_{RWM}	Working Peak Reverse Voltage (See Note 1)	100	200	300	400	500	600	V
V_{RRM}	Repetitive Peak Reverse Voltage (See Note 2)	120	240	360	480	600	720	V
V_{RSM}	Nonrepetitive Peak Reverse Voltage (See Note 3)	120	240	360	480	600	720	V
V_R	Steady State Reverse Voltage	100	200	300	400	500	600	V
$I_{F(AV)}$	Average Rectified Forward Current from −65°C to +50°C Ambient† Temperature, (See Note 1)	← 750 →						mA
I_{FSM}	Nonrepetitive Surge Current for 8 msec Square Wave (See Notes 4 & 5)	← 13 →						A
I_{FSM}	Nonrepetitive Surge Current for 2 msec Square Wave (See Notes 4 & 5)	← 35 →						A
I_{FSM}	Surge Current, One Cycle, (See Notes 3 & 5)	← 20 →						A
$T_{A(opr)}$	Operating Ambient† Temperature Range	← −65 to +175 →						°C
T_{stg}	Storage Temperature Range	← −65 to +175 →						°C

NOTES: 1. These values may be applied continuously under single-phase 60 Hz half-sine-wave operation with resistive load. Above 50°C, derate $I_{F(AV)}$ according to Figure 1.

2. These values apply for 100 usec pulses, 60 pps, superimposed on single-phase, 60 Hz, half-sine-waves.

3. These values apply for one 60 Hz half-sine-wave when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to thermal equilibrium.

TYPES 1N4364, 1N4365, 1N4366, 1N4367, 1N4368, 1N4369
DIFFUSED-JUNCTION SILICON RECTIFIERS

4. These values apply for the fault current superimposed on the device operating at (or below) rated values of peak reverse voltage and average rectified forward current. For other pulse widths, see Figure 2. Surge mav be repeated after the device has returned to thermal equilibrium.
5. These JEDEC registered surge ratings apply at 50°C ambient temperature. Texas Instruments extends these ratings to apply over the opercting ambient temperature range.

*Indicates JEDEC registered data.

† The ambient temperature is measured at a point 50.8mm below the device. Natural-air-cooling shall be used.

‡Trademark of Texas Instruments Incorporated

*electrical characteristics at 25°C ambient† temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MAX	UNIT
I_R	Static Reverse Current	V_R = Max Rated V_R		1	μA
I_R	Static Reverse Current	T_A = 150°C	V_R = Max Rated V_R	100	μA
I_R	Static Reverse Current	T_A = 175°C	V_R = Max Rated V_R	300	μA
$I_{R(avg)}$	Average Reverse Current	$I_{F(AV)}$ = 750 mA, f = 60 Hz , T_A = 50°C	V_{RM} = Max Rated $V_{RM(wkg)}$	100	μA
V_F	Static Forward Voltage	I_F = 750 mA		1.1	V
V_F	Static Forward Voltage	I_F = 500 mA		1.0	V
V_{FM}	Peak Forward Voltage	$I_{F(AV)}$ = 750 mA, f = 60 Hz T_A = −65°C to +50°C		1.5	V

thermal characteristics

PARAMETER			TYP	UNIT
$\theta_{J\text{-}A}$	Junction-to-Ambient† Thermal Resistance		70	C°/W

THERMAL CHARACTERISTICS

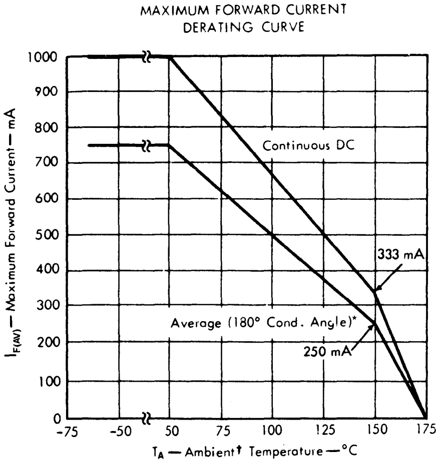


Figure 1

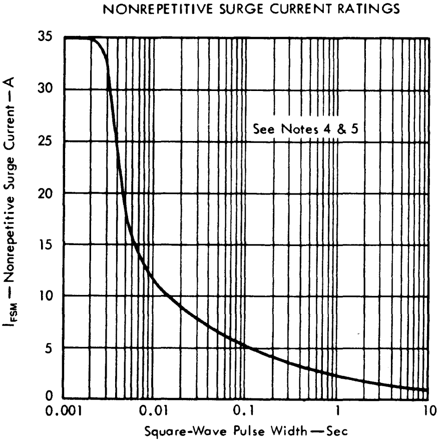


Figure 2

*Indicates JEDEC registered data.

† The ambient temperature is measured at a point 50.8mm below the device. Natural-air-cooling shall be used.

TYPE 1N4374
DIFFUSED-JUNCTION SILICON RECTIFIER

REVISED AUGUST 1975

1500 VOLTS PIV • 1 AMP DC

- **Designed for Applications Requiring Low-Leakage Currents**
- **High Forward Conductance**
- **Rugged Construction for Complete Environmental Protection**

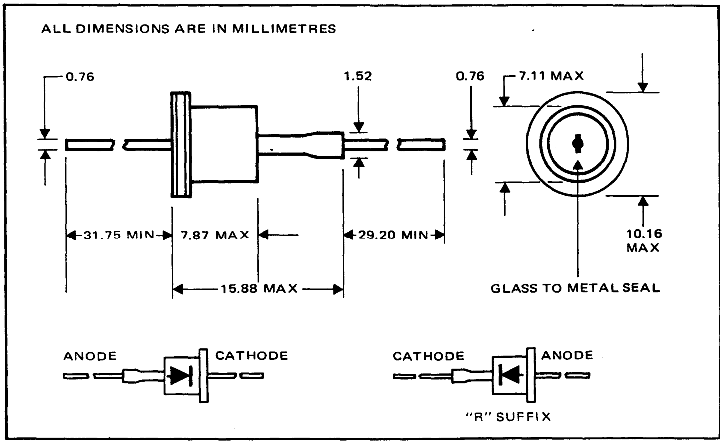
environmental tests

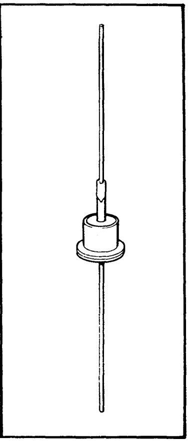
To ensure maximum integrity, stability, and long life, finished devices are subjected to the following tests and conditions prior to thorough testing for rigid adherence to the specified characteristics.

• The hermetic seal is verified for all devices by the use of both helium and gross leak tests. Production samples are life tested under maximum rated operating conditions at regularly schedlued periods to ensure maximum reliability.

mechanical data

The device has a hermetically-sealed welded case with a glass-to-metal seal between case and terminal. Approximate weight is 1.6 grams. Cathode-to-case is the standard configuration. Anode-to-case configuration is designated 1N4374R.





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

V_{RWM}	Working Peak Reverse Voltage (See Note 1)	1500 V
V_{RRM}	Repetitive Peak Reverse Voltage (See Note 2)	2000 V
V_{RSM}	Nonrepetitive Peak Reverse Voltage (See Note 3)	2000 V
V_R	Steady State Reverse Voltage from −65°C to +150°C	1500 V
V_R	Steady State Reverse Voltage from +150°C to +175°C	1200 V
$I_{F(AV)}$	Average Rectified Forward Current from −65°C to +50°C Ambient Temperature (See Note 1)	0.75 A
$I_{F(AV)}$	Average Rectified Forward Current at 150°C Ambient Temperature (See Note 1)	0.25 A
I_{FSM}	Surge Current, One Cycle, at 50°C Ambient Temperature (See Note 3)	15 A
$T_{A(opr)}$	Operating Ambient Temperature Range	−65°C to 175°C
T_{stg}	Storage Temperature Range	−65°C to 175°C

NOTES: 1. These values may be applied continuously under single-phase, 60 Hz, half-sine-wave operation with resistive load. At elevated temperature, derate $I_{F(AV)}$ according to Figure 1.

2. This value applies for 100 μsec pulses, 60 pps, superimposed on single-phase, 60 Hz, half-sine-waves.

3. This value applies for one 60 Hz half-sine-wave when the device is operating at (or below) rated values of peak reverse voltage and average rectified forward current. Surge may be repeated after the device has returned to thermal equilibrium.

*Indicates JEDEC registered data.

†The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling shall be used.

TYPE 1N4374
DIFFUSED-JUNCTION SILICON RECTIFIER

electrical characteristics at 25°C ambient† temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MAX	UNIT
*I_R	Static Reverse Current	$V_R = 1500V,\ T_A = 150°C$	300	µA
		$V_R = 1200V,\ T_A = 175°C$	300	
*$I_{R(avg)}$	Average Reverse Current	$V_{RRM} = 1500V,\ I_{F(AV)} = 750\ mA,$ $f = 60Hz,\ T_A = 50°C$	100	µA
V_F	Static Forward Voltage	$I_F = 500\ mA$	1.5	V
*V_{FM}	Peak Forward Voltage	$I_{F(AV)} = 750\ mA,\ f = 60\ Hz$ $T_A = -65°C\ to\ +50°C$	1.75	V

THERMAL CHARACTERISTICS

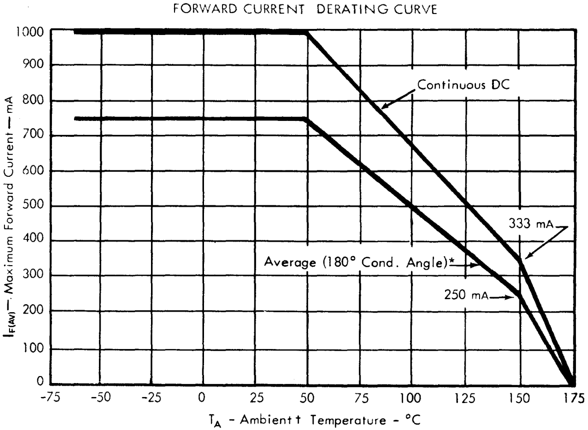


FIGURE 1

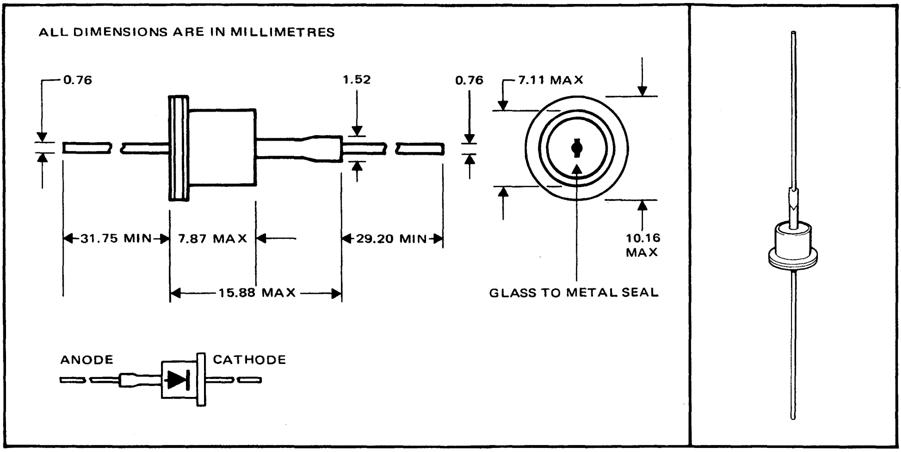
*Indicates JEDEC registered data.
†The ambient temperature is measured at a point 50.8mm below the device. Natural-air cooling shall be used.

SERIES 1S020
DIFFUSED SILICON RECTIFIER

REVISED AUGUST 1975

- 1.5 Amperes
- 100 to 1000 Volts P.I.V.

mechanical data: Outline conforms to VASCA SO-16



absolute maximum ratings (Temperatures are ambient)

		1S020	1S021	1S023	1S025	1S027	1S029	Units
P.I.V.	Peak Inverse Voltage −65°C to +150°C (note 2)	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current +25°C	1.5	1.5	1.5	1.5	1.5	1.5	A
I_{FRM}	Recurrent Peak Forward Current +25°C	20	20	20	20	20	20	A
I_{FSM}	Peak Surge Current, one half cycle at 50 c.p.s. +25°C	125	125	125	125	125	125	A
T_{amb}	Operating Temperature Range	−55°C to +175°C						°C
T_{stg}	Storage Temperature Range	−55°C to +175°C.						°C

electrical characteristics (absolute limits)

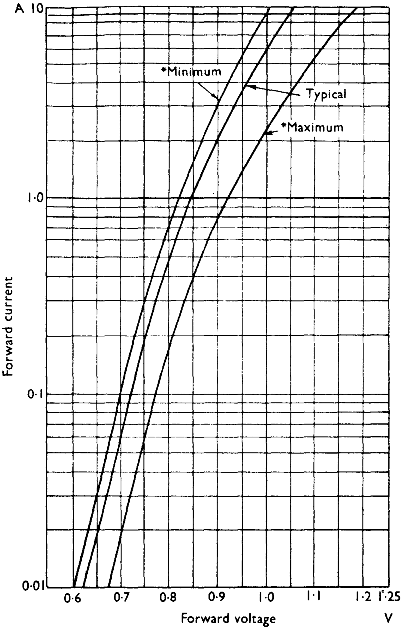
		1S020	1S021	1S023	1S025	1S027	1S029	Units
I_R	Maximum Reverse Current at P.I.V. +25°C	1	1	1	1	1	1	μA
I_R	Maximum Reverse Current at P.I.V. +100°C	50	50	50	50	50	50	μA
V_F	Maximum Forward Voltage Drop at I_F 5·0A at 25°C (note 1)	1.25	1.25	1.25	1.25	1.25	1.25	V

Notes

1. The forward voltage drop is a pulse measurement on these devices.
2. For this series of rectifiers the Crest Working Voltage, Recurrent Voltage and Peak Transient Voltage rating are all equal (here described as P.I.V. for clarity).

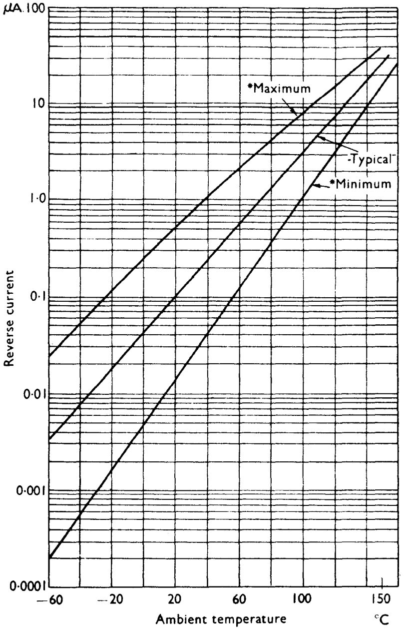
SERIES 1S020
DIFFUSED SILICON RECTIFIER

FORWARD CHARACTERISTICS AT 25°C



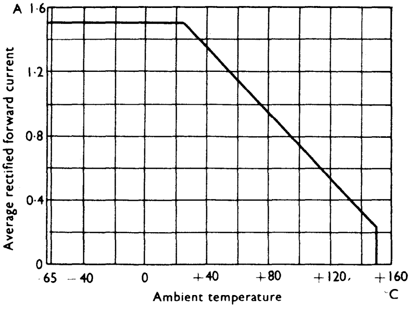
*95% Confidence

VARIATION OF REVERSE CURRENT
WITH TEMPERATURE AT P.I.V.

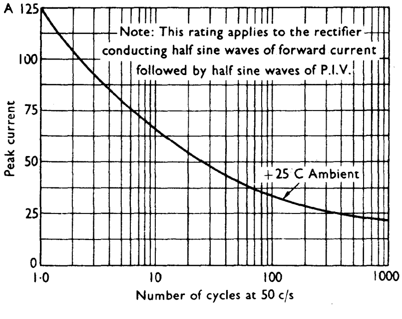


*95% Confidence

FORWARD CURRENT DERATING CURVE



NON-REPETITIVE SURGE CURRENT RATING



Note: This rating applies to the rectifier conducting half sine waves of forward current followed by half sine waves of P.I.V.

TEXAS INSTRUMENTS

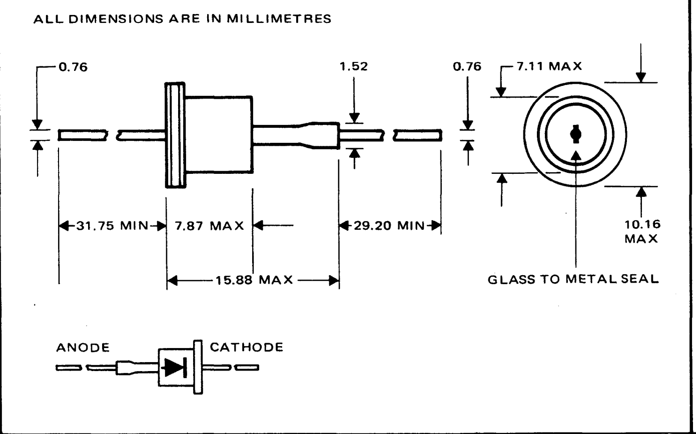
SERIES 1S030
DIFFUSED SILICON RECTIFIERS

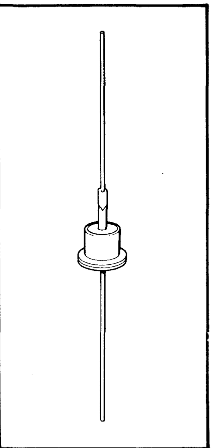
REVISED AUGUST 1975

average rectified forward current 750mA
crest working voltage 50 to 800 volts
peak transient reverse voltage 100 to 1600 volts
metal to glass hermetic seal
approximate weight 1·6 grams

mechanical data

welded case with glass-to-metal seal between case (cathode connection) and anode lead. Approximate weight is 1·6 grams. Outline conforms to VASCA SO-16.





absolute maximum ratings (T_{amb} = 25°C unless otherwise stated)

		1S030	1S031	1S032	1S034	1S036	1S038	Units
C.W.V.	Crest Working Voltage	50	100	200	400	600	800	V
P.T.R.V.	Peak Transient Rev. Volts (Note 1)	100	200	400	800	1200	1600	V
$I_{F(AV)}$	Average Rectified Forward Current at 50°C	750	750	750	750	750	750	mA
$I_{F(AV)}$	Average Rectified Forward Current at 100°C	500	500	500	500	500	500	mA
I_{FRM}	Recurrent Peak Forward Current	10	10	10	10	10	10	A
I_{FRM}	Recurrent Peak Forward Current at +100°C	6·5	6·5	6·5	6·5	6·5	6·5	A
I_{FSM}	Overload Current Peak ½ sine wave at 50 cps.	40	40	40	40	40	40	A
I_{FSM}	Overload Current Peak ½ sine wave at 50 cps at 100°C	26	26	26	26	26	26	A
T_{amb}	Operating and Storage Temperature Range	−40 to +150°C						

electrical characteristics, absolute limits (T_{amb} = 25°C)

I_R	Maximum Reverse Current at C.W.V.	2	2	2	2	2	2	μA
V_F	Maximum Forward Voltage Drop at I_F=2·0A	1·25	1·25	1·25	1·25	1·25	1·25	V

notes

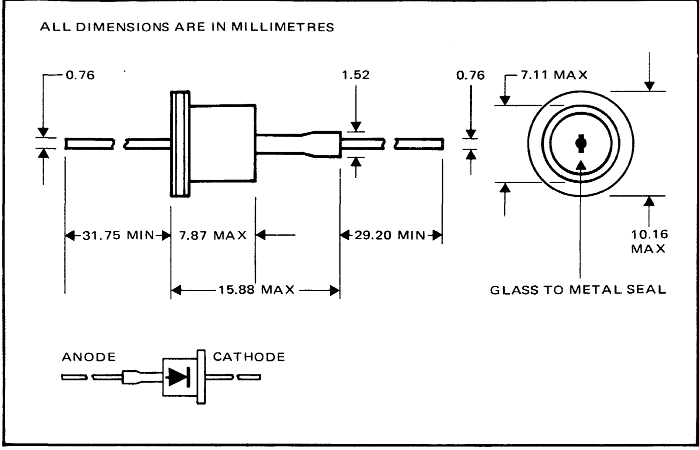
1. Maximum duration of occasional voltage overload is 10 milliseconds.
2. Maximum frequency of operation at which these ratings apply is 2,500 Hz.
3. Average rectified forward current derates by 5 mA/°C from 50°C from 50°C to 150°C.

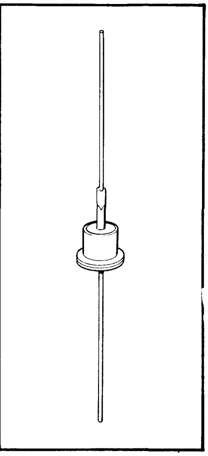
SERIES 1S100
DIFFUSED SILICON RECTIFIERS

REVISED AUGUST 1975

- **750mA**
- **100 to 1000V P.I.V**
- **Available as CV7026 to CV7030**

mechanical data: Outline conforms to VASCA SO-16





absolute maximum ratings (Temperatures are ambient)

		1S100	1S101	1S103	1S105	1S107	1S109	Units
P.I.V.	Peak Inverse Voltage −65°C to +150°C	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current 50°C	750	750	750	750	750	750	mA
I_{FRM}	Recurrent Peak Forward Current at 50°C	10	10	10	10	10	10	A
I_{FSM}	Peak Surge Current, one half cycle at 50 Hz + 25°C	40	40	40	40	40	40	A
T_{amb}	Operating Temperature	−65 to +150						°C
T_{stg}	Storage Temperature	−65 to +150						°C

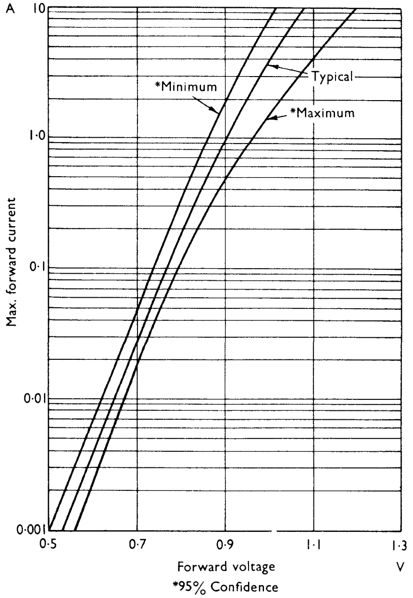
electrical characteristics (absolute limits)

		1S100	1S101	1S103	1S105	1S107	1S109	Unit
I_R	Maximum Reverse Current at P.I.V. at + 25°C	1	1	1	1	1	1	μA
I_R	Maximum Reverse Current at P.I.V. at +100°C	50	50	50	50	50	50	μA
V_F	Maximum Forward Voltage Drop at I_F 2·0A at 25°C	1·25	1·25	1·25	1·25	1·25	1·25	V

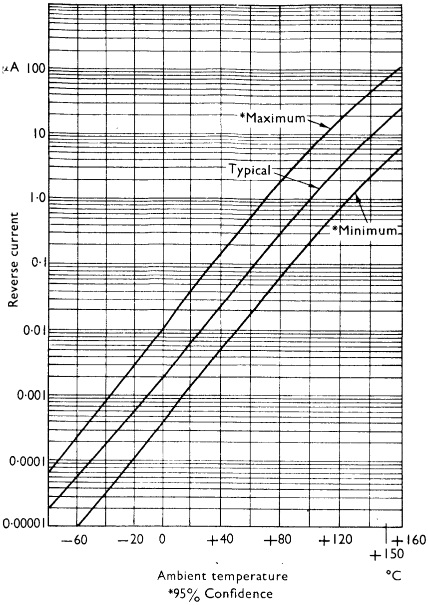
Notes

1. For this series of rectifiers the Crest Working Voltage, Recurrent Voltage and Peak Transient Voltage rating are all equal (here described as P.I.V. for clarity).
2. Maximum frequency of operation at which these ratings apply is 2,500 Hz.
3. The forward volt drop is a pulse measurement on these devices.

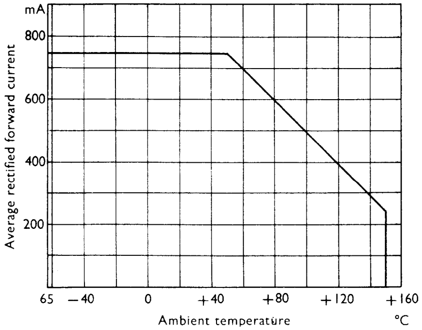
FORWARD CHARACTERISTICS AT 25°C



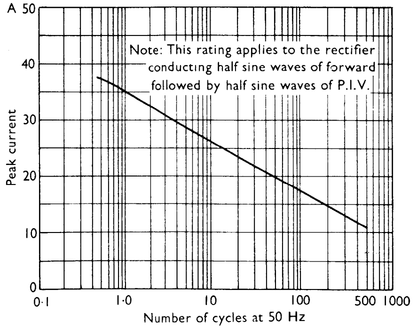
VARIATION OF REVERSE CURRENT WITH TEMPERATURE AT P.I.V.



FORWARD CURRENT DERATING CURVE



NON-REPETITIVE SURGE CURRENT RATING
$T_{amb} = 25°C$



SERIES 1S410
DIFFUSED SILICON RECTIFIERS

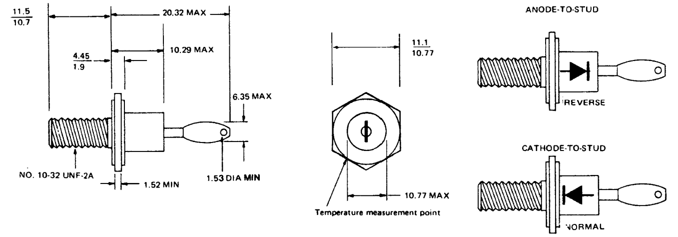
REVISED AUGUST 1975

3 Amperes • 100 to 1000V P.I.V.
- All Welded Construction
- Low Forward Resistance
- Designed for all Medium Power Industrial Applications
- Available with Anode to Stud or Cathode to Stud
- CV approved as CV7311 to CV7320

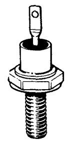
Mechanical data

Welded case with glass-to-metal hermetic seal between case and anode lead. Approximate weight is 4·36 grams.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



Maximum ratings

SYMBOL		1S410 1S410R	1S411 1S411R	1S413 1S413R	1S415 1S415R	1S417 1S417R	1S419 1S419R	UNITS
PIV	Peak Inverse Voltage from —40°C to +125°C	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current at 125°C	3	3	3	3	3	3	A
$I_{F(AV)}$	Average Rectified Forward Current at 145°C	1	1	1	1	1	1	A
I_{FRM}	Recurrent Peak Forward Current at +125°C	15	15	15	15	15	15	A
T_{amb}	Storage Temperature, Ambient	—40°C to +150°C						

Characteristics

SYMBOL		1S410 1S410R	1S411 1S411R	1S413 1S413R	1S415 1S415R	1S417 1S417R	1S419 1S419R	UNITS
I_R	Max. Reverse Current at P.I.V. at +25°C	5	5	5	5	5	5	μA
I_R	Max. Reverse Current at P.I.V. at 150°C	300	300	300	300	300	300	μA
V_F	Max. Voltage Drop at I_F = 10 A at 25°C	1·6	1·6	1·6	1·6	1·6	1·6	V

ALL TEMPERATURES QUOTED ARE STUD TEMPERATURES UNLESS OTHERWISE STATED.

NOTES

1. To determine the heatsink area for any required output current the following formula is used:–

$$\frac{T_{stud} - T_{amb}}{P} = \text{thermal resistance}$$

T_{stud} = stud temperature, T_{amb} = ambient temperature, P = power loss.
The total heat sink area is then given by Fig.3.
Example: Required output current 3A,
$T_{amb} = 25^oC$, $T_{stud} = 125^oC$, P = 4.5W.
∴ Thermal resistance is 22°C/W, fin area required = 51.62cm^2 = a fin 5.08cm x 5.08cm x 0.16cm aluminium.

2. In marginal designs the stud temperature should be checked with a thermocouple monted in a copper washer under the rectifier.

FIGURE 1

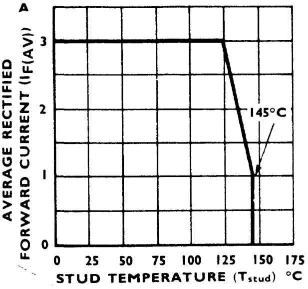


FIGURE 2

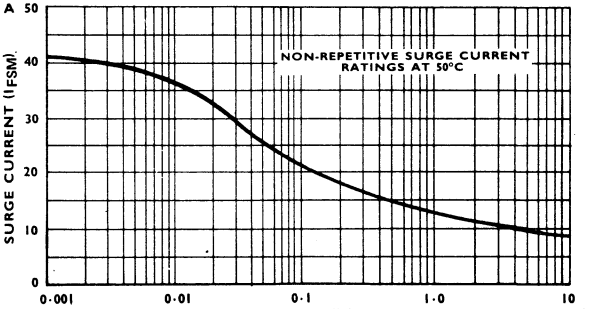


FIGURE 3

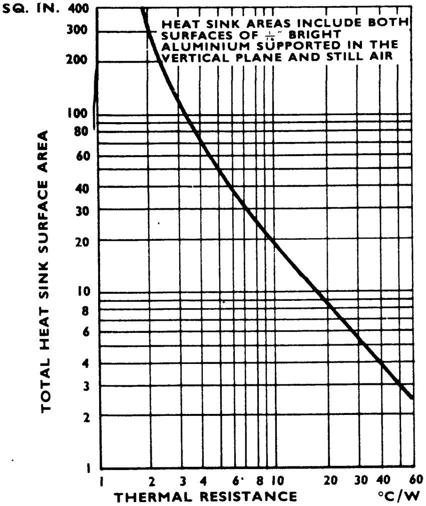
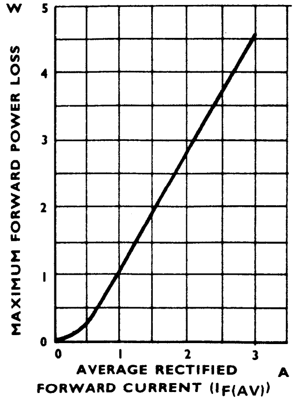


FIGURE 4



SERIES 1S420
DIFFUSED SILICON RECTIFIERS

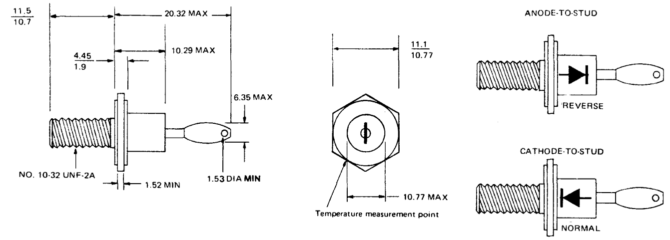
REVISED JULY 1975

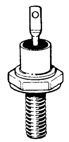
- 10 Amperes 100V to 1000V P.I.V.
- Designed for Medium Power Industrial Applications
- Available with Anode to Stud or Cathode to Stud
- CV and BS approved as BS9300 C 379 to C388

mechanical data

Welded case with glass-to-metal hermetic seal between case and anode lead. Approximate weight is 4·36 grams. Conforms to Vasca SO 10 Outline.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





ALL DIMENSIONS ARE IN MILLIMETRES

NOTES* A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

maximum ratings (all temperatures refer to stud)

		1S420 1S420R	1S421 1S421R	1S423 1S423R	1S425 1S425R	1S427 1S427R	IS429 IS429R	UNITS
P.I.V.	Peak Inverse Voltage at −65°C to 175°C	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current at 100°C	10	10	10	10	10	10	A
I_{FRM}	Recurrent Peak Forward Current at 25°C	50	50	50	50	50	50	A
I_{FSM}.	Peak Surge Current, one half cycle at 50 c.p.s. at 25°C	200	200	200	200	20	20	A
T_{amb}	Storage Temperature Range	−65°C to +175°C						

electrical characteristics

V_F	Max. Forward Voltage Drop at 25°C Forward Current 30 amps	1·5	1·5	1·5	1·5	1·5	1.5	V
I_R	Max. Reverse Leakage Current at P.I.V. and 100°C	50	50	50	50	50	50	μA

Note

This series of Rectifiers replaces the 1S401 series of Rectifiers and may be used in all applications for which the 1S401 series were formerly used.

FORWARD CURRENT DERATING CURVE
WITH PIV APPLIED

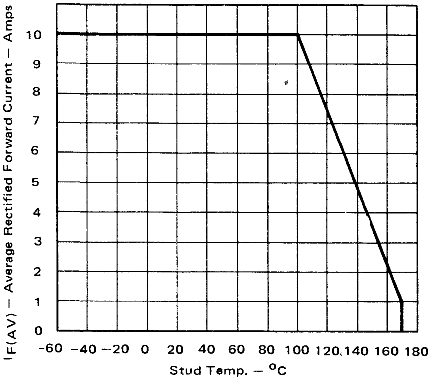


FIGURE 1.

NATURAL CONVECTION COOLED HEATSINKS

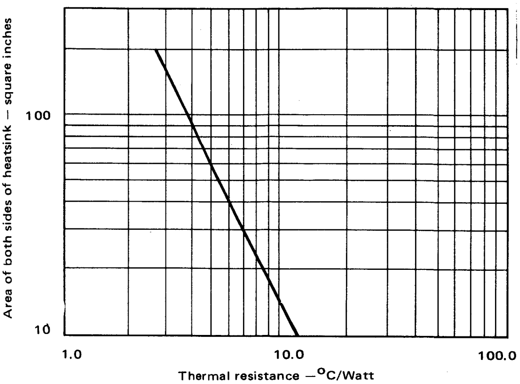


FIGURE 2.

Devices mounted in centre of
3.2mm thick bright aluminium, heatsinks
are square and mounted vertically

FORWARD POWER DISSIPATION

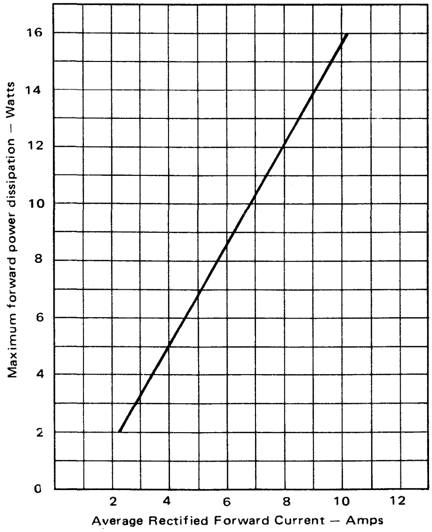


FIGURE 3.

Notes:

1. To determine the heat sink area for any required output current the following formula is used:—

$$\frac{T_{stud} - T_{amb}}{P} = \text{Thermal resistance}$$

T_{stud} = stud temperature, T_{amb} = ambient temperature

P = power dissipated, determined from Fig. 3.

The total heat sink area is given by Fig. 2.

2. In marginal designs the stud temperature should be checked with a thermocouple mounted in a copper washer under the rectifier.

SERIES 1S430
DIFFUSED SILICON RECTIFIERS

REVISED AUGUST 1975

average rectified forward current 3A

crest working voltage 50 to 800 volts

peak transient reverse voltage 100 to 1600 volts

low forward resistance

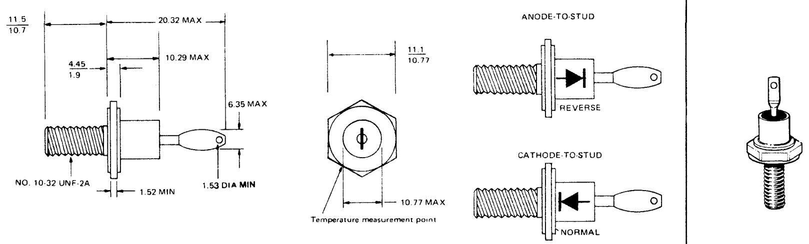
designed for all medium power industrial applications

available with anode to stud—Suffix R
or cathode to stud—No Suffix

mechanical data

welded case with glass-to-metal hermetic seal between case and anode lead. Approximate weight is 4·36 grams. Conforms to VASCA SO-10 outline.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



NOTES*

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES

maximum ratings (all temperatures refer to stud)

		1S430 1S430R	1S431 1S431R	1S432 1S432R	1S434 1S434R	1S436 1S436R	1S438 1S438R	Units
V_{RRM}	Repetitive Peak Reverse Voltage	50	100	200	400	600	800	V
V_{RSM}	Non-Repetitive Peak Reverse Voltage	100	200	400	800	1200	1600	V
$I_{F(AV)}$	Average Rectified Forward Current at 125°C	3	3	3	3	3	3	A
$I_{F(AV)}$	Average Rectified Forward Current at 145°C	1	1	1	1	1	1	A
I_{FRM}	Recurrent Peak Forward Current at +125°C	15	15	15	15	15	15	A
T_{amb}	Storage Temperature, Ambient	−40°C to +150°C						

characteristics

I_R	Max. Reverse Current at V_{RRM} at +25°C	5	5	5	5	5	5	μA
I_R	Max. Reverse Current at V_{RRM} at 150°C	300	300	300	300	300	300	μA
V_F	Max. Voltage Drop at I_F =10A at 25°C	1·6	1·6	1·6	1·6	1·6	1·6	V

notes

1. Maximum duration of occasional voltage overload is 10 milliseconds.

SERIES 1S440
DIFFUSED SILICON RECTIFIERS

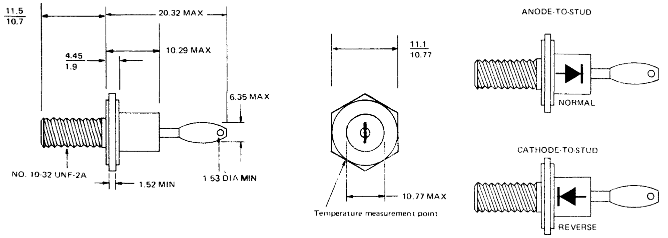
REVISED AUGUST 1975

- **Transient Voltage Suppression**
- **Low Voltage Rectification**
  - **300 Watts Reverse Power Capability**
  - **12-120 Volts, Peak Inverse**
  - **Guaranteed Min-Max "Avalanche" Voltages**

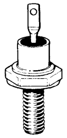
mechanical data

Metal case with glass-to-metal hermetic seal. Approximate weight is 4·36 grams.

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings (all temperatures are stud temperatures)

		1S441	1S442	1S443	1S444	1S445	1S446	Units
P.I.V.	Peak Inverse Voltage (when used as a rectifier)	12	20	40	60	80	120	V
I_O	Average Rectified Forward Current at +100°C	3	3	3	3	3	3	A
$\hat{I}_{FO/L}$	Peak Forward Surge Current ½ cycle at 50 c.p.s. +100°C	40	40	40	40	40	40	A
$\hat{I}_{FR}$	Recurrent Peak Forward Current at +100°C	15	15	15	15	15	15	A
I_{sur}	Max. Peak Reverse Surge Current 200 μSecs duration +25°C	11	5·9	3·6	2·7	1·8	1·5	A
$\hat{P}_{RS}$	Peak Reverse Power for 200 μSecs duration + 25°C	300	300	300	300	300	300	W
T_{amb}	Operating and Storage Temperature Range	−65 to +150						°C

electrical characteristics (all temperatures are stud temperatures)

		1S441	1S442	1S443	1S444	1S445	1S446	Units
V_{AR}	Max. Avalanche Voltage at +25°C at I_T	27	51	82	110	160	220	V
V_{AR}	Min. Avalanche Voltage at +25°C at I_T	15	24	47	75	100	150	V
I_T	Avalanche Test Current Pulse	100	50	50	20	20	10	mA
V_F	Maximum Forward Voltage Drop at 3 A at +25°C	1·5	1·5	1·5	1·5	1·5	1·5	V
$\theta_{J\text{-}C}$	Maximum Thermal Resistance Junction-Case	12						°C/W
	Typical Temperature Coefficient of V_{AR}.	0·06	0·07	0·08	0·09	0·1	0·1	%/°C

For reverse polarity devices follow type number with suffix R.

SERIES 1S440
DIFFUSED SILICON RECTIFIERS

FIGURE I

FORWARD CURRENT DERATING CURVE

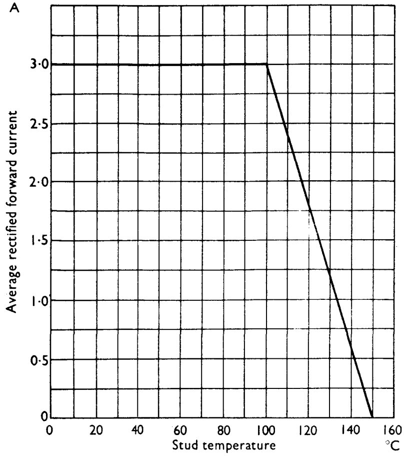
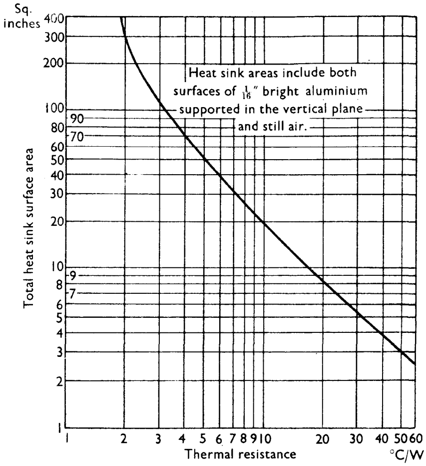
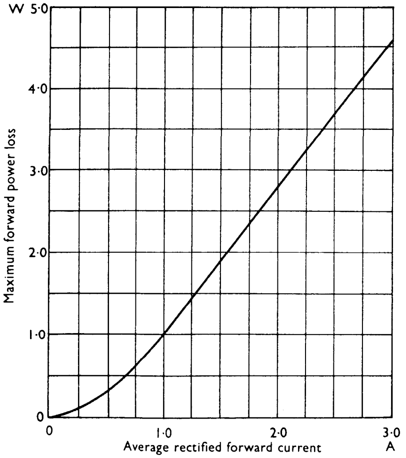


FIGURE 2



Heat sink areas include both surfaces of $\frac{1}{16}$" bright aluminium supported in the vertical plane and still air.

FIGURE 3



Notes

1. To determine the heat sink area for any required output current the following formula is used:—

$$\frac{T_{stud} - T_{amb}}{P} = \text{Thermal Resistance}$$

T_{stud} = stud temperature.

T_{amb} = ambient temperature

P = Power Loss

The total heat sink area is then given by Fig. 2.

Example:—Required output current 3A

$T_{amb} = 25°C$, $T_{stud} = 100°C$, $P = 4{\cdot}5W$

$\therefore$ Thermal Resistance = 16·7°C/W

fin area required = 10 sq. in. = a fin $\sqrt{5} \times \sqrt{5}$ ins × $\frac{1}{16}$" aluminium.

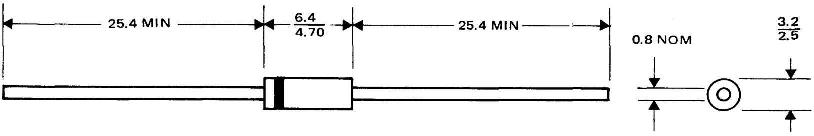
2. In marginal designs stud temperature should be checked with a thermocouple mounted in a copper washer under the rectifier.

1S3000 SERIES
SILICON VOLTAGE REGULATORS

REVISED JULY 1975

- 1.3 watts at +25°C,
- 5% nominal tolerance
- 7.5 to 200 Volts
- −65°C to +175°C operation

Mechanical Data



Dimensions are in mm.

Cathode denoted by Colour Band

Absolute Maximum Ratings (all temperatures are ambient)

P_{TOT}	Power Dissipation at −65°C to +25°C	1.3 Watts
P_{TOT}	Power Dissipation at +50°C	1.1 Watts
P_{SUR}	Zener Surge Power at 0.1mS at 25°C	500W
	Operating and Storage Temperature	−55°C to +175°C

Thermal Characteristics

θj−amb	Thermal resistance junction to ambient	115°C/W

Electrical Characteristics (at 25°C ambient unless otherwise stated)

V_F	Forward Voltage Drop at I_F = 100mA	1.1V Max

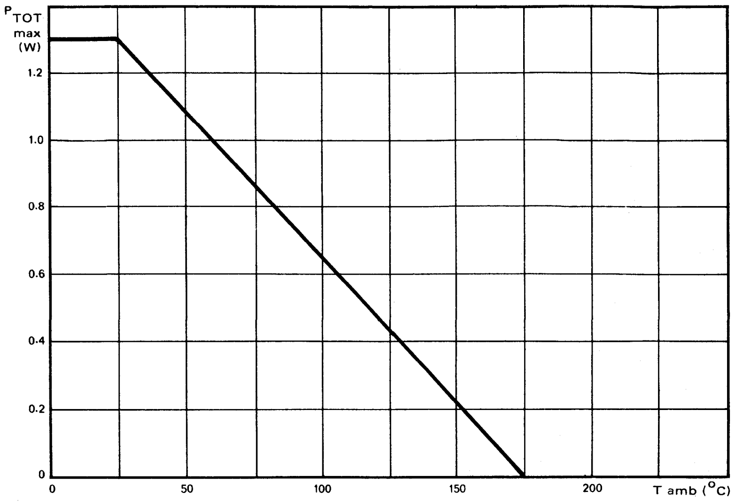
TEXAS INSTRUMENTS

1S3000 SERIES
SILICON VOLTAGE REGULATORS

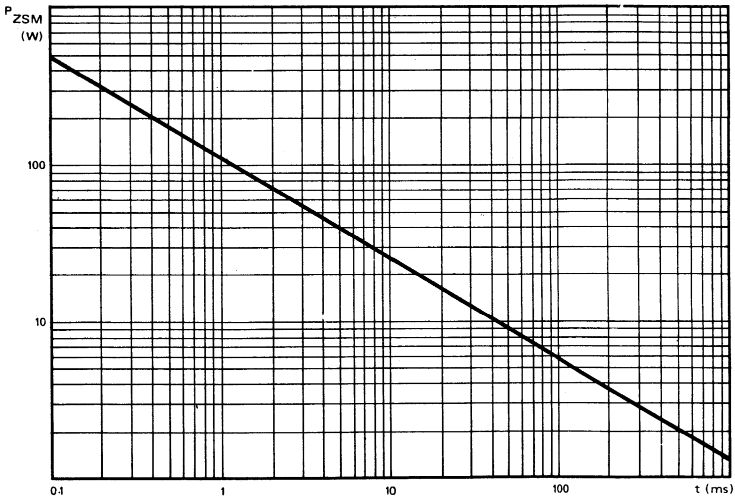
1S3000A Series (± 5% Nominal Tolerance)

Breakdown Voltage V_Z at I_Z pulsed. Note 1				Test Current I_Z	Zener Differential resistance r_Z at I_Z Note 2	Leakage Current I_R at V_R	Test Voltage V_R	Temperature Coefficient over range +25°C to +60°C at I_Z
Type No.	Nom.	Max.	Min		Max	Max		Typ
	V	V	V	mA	ohms	µA	V	%/°C
IS3007A	7.5	7.9	7.1	20	6.0	5	3	+0.04
IS3008A	8.2	8.7	7.7	20	7.5	5	3	+0.04
IS3009A	9.1	9.6	8.6	20	8.0	5	5	+0.05
IS3010A	10	10.6	9.4	20	8.5	5	7	+0.05
IS3011A	11	11.6	10.4	20	9.0	5	7	+0.05
IS3012A	12	12.6	11.4	20	9.0	5	8	+0.05
IS3013A	13	14.1	12.4	20	10	5	9	+0.05
IS3015A	15	15.6	13.9	20	14	5	10	+0.06
IS3016A	16	17.1	15.4	10	16	5	11	+0.06
IS3018A	18	19.1	16.9	10	20	5	13	+0.06
IS3020A	20	21.2	18.9	10	22	5	14	+0.06
IS3022A	22	23.3	20.8	10	23	5	15	+0.06
IS3024A	24	25.9	22.7	10	25	5	17	+0.06
IS3027A	27	28.9	25.1	10	35	5	19	+0.06
IS3030A	30	32	28	10	40	5	21	+0.07
IS3033A	33	35	31	10	45	5	23	+0.07
IS3036A	36	38	34	10	50	5	25	+0.07
IS3039A	39	41	37	5	60	5	27	+0.07
IS3043A	43	45	40	5	70	5	30	+0.07
IS3047A	47	50	44	5	80	5	33	+0.08
IS3051A	51	54	48	5	95	5	36	+0.08
IS3056A	56	60	53	5	105	5	39	+0.08
IS3062A	62	66	58	5	110	5	43	+0.08
IS3068A	68	72	64.	5	120	5	48	+0.08
IS3075A	75	79	71	5	135	5	52	+0.08
IS3082A	82	87	77	5	175	5	55	+0.09
IS3091A	91	96	86	5	200	5	60	+0.095
IS3100A	100	106	94	5	220	5	66	+0.095
IS3110A	110	116	104	5	250	5	70	+0.10
IS3120A	120	127	114	5	270	5	80	+0.10
IS3130A	130	141	124	5	300	5	90	+0.10
IS3150A	150	156	138	2	950	5	100	+0.12
IS3160A	160	171	153	2	1000	5	110	+0.12
IS3180A	180	191	168	2	1100	5	120	+0.12
IS3200A	200	212	188	2	1250	5	140	+0.12

MAXIMUM TOTAL POWER DISSIPATION



MAX SURGE POWER vs TIME

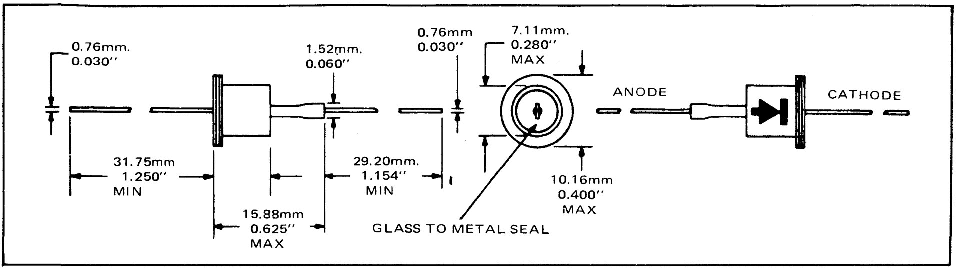


1S4000 SERIES
SILICON VOLTAGE REGULATOR

AUGUST 1974

- Full CV and BS9300 approval up to 75 volts
- Diffused Avalanche Wafer
- All welded construction/Nitrogen environment
- 500 Watt surge capability

mechanical data (outline conforms to VASCA SO-16)



absolute maximum ratings

P_{tot}	Power Dissipation at – 65°C to + 25°C	1.5 Watts
P_{tot}	Power Dissipation at + 100°C	0.6 Watts
P_{sur}	Surge Power 0.1 mS at + 25°C	500 Watts
T_{amb}	Operating and Storage Temperature Range	–55°C to +175°C

electrical characteristics

V_F	Forward Voltage Drop at 2A at + 25°C	1.25 Volts

1S4000A series (± 5% nominal tolerance)

Type No.	Breakdown Voltage Vz at + 25°C 100 mS pulse at Iz			Test Current Iz mA	Max. Slope Impedance Zz at + 25°C		Slope Impedance Zz at Iz + 25°C		Temperature Coeff. over range + 25°C to + 100°C at Iz			CV▪ No.
	Nom. V	Max. V	Min. V		at Iz ohm	at 1mA ohm	Typ. ohm	Min.* ohm	Typ. %/°C	Max.* %/°C	Min.* %/°C	
1S4006A	6.8	7.2	6.4	50	1.5	60^{Δ}	0.9	0.6	.04	.045	.03	7413
1S4007A	7.5	7.9	7.1	50	2	60^{Δ}	1.2	.6	.045	.05	.035	7414
1S4008A	8.2	8.7	7.7	50	3.5	55^{Δ}	1.5	.6	.05	.055	.04	7415
1S4009A	9.1	9.6	8.6	20	5	175	2.1	.9	.05	.06	.04	7416
1S4010A	10	10.6	9.4	20	5	150	2.3	1	.055	.06	.05	7417
1S4011A	11	11.6	10.4	20	6	150	2.4	1.3	.06	.065	.05	7418
1S4012A	12	12.6	11.4	20	8	125	2.5	1.4	.065	.07	.055	7419
1S4013A	13	14.1	12.4	20	10	125	4.6	1.5	.07	.08	.06	7420
1S4015A	15	15.6	13.9	20	10	125	5.4	2	.08	.09	.07	7421
1S4016A	16	17.1	15.4	20	15	125	6	2.5	.08	.09	.07	7422
1S4018A	18	19.1	16.9	20	20	125	7.5	3	.08	.09	.07	7423
1S4020A	20	21.2	18.9	10	30	125	8	3	.085	.09	.07	7424
1S4022A	22	23.3	20.8	10	30	125	10	3	.085	.09	.07	7425
1S4024A	24	25.9	22.7	10	30	120	18	3.5	.085	.09	.07	7426
1S4027A	27	28.9	25.1	10	40	150	19	3.5	.085	.09	.07	7427
1S4030A	30	32	28	10	40	150	21	4	.085	.09	.07	7428
1S4033A	33	35	31	10	40	200	24	4.5	.085	.09	.07	7429
1S4036A	36	38	34	10	70	200	27	6	.085	.095	.075	7841
1S4039A	39	41	37	5	70	300	30	9	.085	.095	.075	7842
1S4043A	43	45	40	5	100	300	35	12	.085	.095	.075	7843
1S4047A	47	50	44	5	100	350	38	18	.085	.095	.075	7844
1S4051A	51	54	48	5	100	350	41	25	.085	.1	.08	7845
1S4056A	56	60	53	5	100	400	46	28	.085	.1	.08	7846
1S4062A	62	66	58	5	150	450	52	30	.085	.1	.08	7847
1S4068A	68	72	64	5	150	450	60	32	.085	.1	.08	7848
1S4075A	75	79	71	5	150	500	68	34	.09	.11	.08	7849
1S4082A	82	87	77	5	150	500	78	35	.09	.11	.08	
1S4091A	91	96	86	2	300	600	86	38	.1	.12	.09	
1S4100A	100	106	94	2	300	700	96	45	.1	.12	.09	
1S4110A	110	116	104	2	300	800	107	55	.1	.12	.09	
1S4120A	120	126	114	2	500	800	230	70	.1	.12	.09	
1S4130A	130	141	124	2	550	900	265	85	.1	.12	.09	
1S4150A	150	156	139	2	600	1200	300	125	.1	.12	.09	
1S4160A	160	171	154	2	700	1400	395	150	.1	.12	.09	
1S4180A	180	191	169	2	900	1500	468	220	.1	.12	.09	
1S4200A	200	212	189	2	1100	1600	560	300	.1	.12	.09	

* For both 5% and 10% ranges. Minimum Zz and Maximum and Minimum Temperature Coefficients are 95% Confidence.

▪ See Short Form catalogue for more CV information. $^{\Delta}$ Measured at 5mA

1S4000 SERIES
SILICON VOLTAGE REGULATOR

1S4000 series (± 10% nominal tolerance)

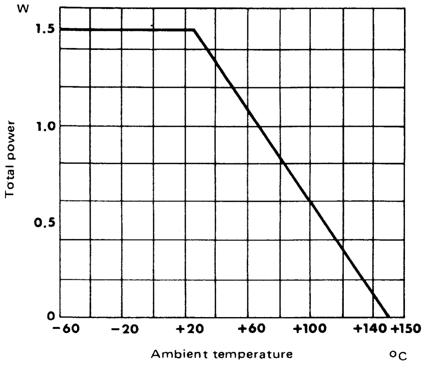
	Breakdown Voltage Vz at + 25°C 100 mS pulse at Iz			Test Current Iz mA	Max. Slope Impedance Zz at Iz + 25°C		Slope Impedance Zz		Temperature Coeff. over range + 25°C to + 100°C at Iz		
Type No.	Nom. V	Max. V	Min. V		at Iz ohm	at 1mA ohm	Typ. ohm	Min.* ohm	Typ. %/°C	Max.* %/°C	Min.* %/°C
1S4006	6.8	7.6	6.1	50	2	65 △	0.9	.4	.04	.045	.03
1S4007	7.5	8.3	6.7	50	2.5	65 △	1.5	.4	.045	.05	.035
1S4008	8.2	9.2	7.4	50	4	60 △	2	.4	.05	.055	.04
1S4009	9.1	10.1	8.1	20	5.5	225	2.1	.8	.05	.06	.04
1S4010	10	11.1	9	20	5.5	200	2.3	.9	.055	.06	.05
1S4011	11	12.1	9.9	20	9	200	2.4	.9	.06	.065	.05
1S4012	12	13.1	10.9	20	9	175	2.5	.9	.065	.07	.05
1S4013	13	15.1	11.9	20	12	175	4.6	1.4	.07	.08	.06
1S4015	15	16.1	12.9	20	12	175	5.4	1.8	.08	.09	.07
1S4016	16	18.5	14.5	20	18	175	6	2.3	.08	.09	.07
1S4018	18	20.5	15.5	20	25	175	7.5	2.8	.08	.09	.07
1S4020	20	22.5	17.5	10	35	175	8	2.8	.085	.09	.07
1S4022	22	24.5	19.5	10	35	175	10	2.8	.085	.09	.07
1S4024	24	27.5	21.5	10	35	200	18	3.2	.085	.09	.07
1S4027	27	30.5	23.5	10	50	200	19	3.2	.085	.09	.07
1S4030	30	33.5	265	10	50	200	21	3.6	.085	.09	.07
1S4033	33	37	29	10	50	275	24	4	.085	.09	.07
1S4036	36	40	32	10	85	275	27	5.5	.085	.095	.075
1S4039	39	44	35	5	85	400	30	8	.085	.095	.075
1S4043	43	48	38	5	120	400	35	11	.085	.095	.075
1S4047	47	52	42	5	120	450	38	16	.085	.095	.075
1S4051	51	57	46	5	120	450	41	22	.085	.1	.08
1S4056	56	63	50	5	120	550	46	25	.085	.1	.08
1S4062	62	69	55	5	180	600	52	27	.085	.1	.08
1S4068	68	76	61	5	180	600	60	29	.085	.1	.08
1S4075	75	83	67	5	180	650	68	31	.09	.11	.08
1S4082	82	92	74	5	180	700	78	31	.09	.11	.08
1S4091	91	101	81	2	350	800	86	34	.1	.12	.09
1S4100	100	111	90	2	350	900	96	35	.1	.12	.09
1S4110	110	121	99	2	350	1000	107	40	.1	.12	.09
1S4120	120	131	109	2	550	1100	230	47	.1	.12	.09
1S4130	130	151	119	2	600	1200	265	70	.1	.12	.09
1S4150	150	161	129	2	750	1500	300	110	.1	.12	.09
1S4160	160	185	145	2	850	1700	395	130	.1	.12	.09
1S4180	180	205	155	2	1100	1800	468	190	.1	.12	.09
1S4200	200	225	175	2	1300	1900	560	260	.1	.12	.09

* For both 5% and 10% ranges. Minimum Zz and Maximum and Minimum Temperature Coefficients are 95% Confidence.

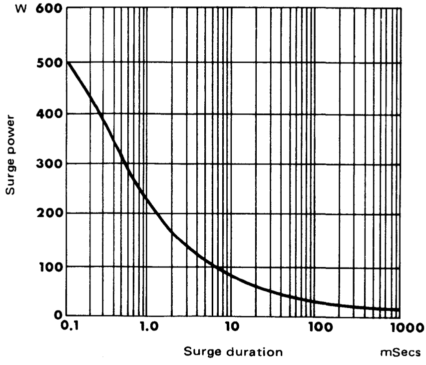
△ Measured at 5mA

Customer Specials on any parameter — enquire on Bedford 67466

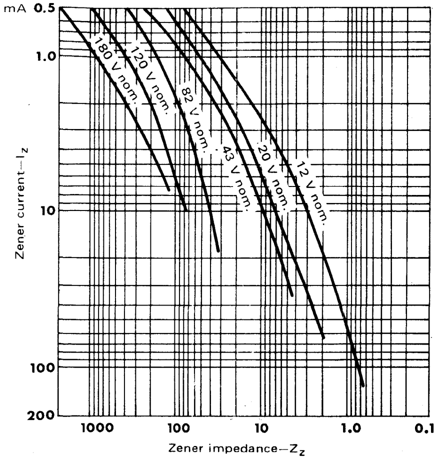
MAXIMUM TOTAL POWER DISSIPATION

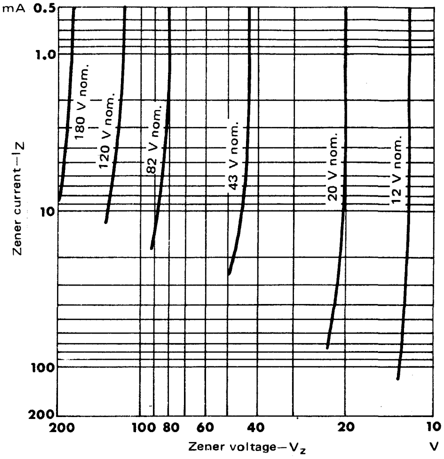


NON-REPETITIVE REVERSE SURGE POWER RATING 25°C

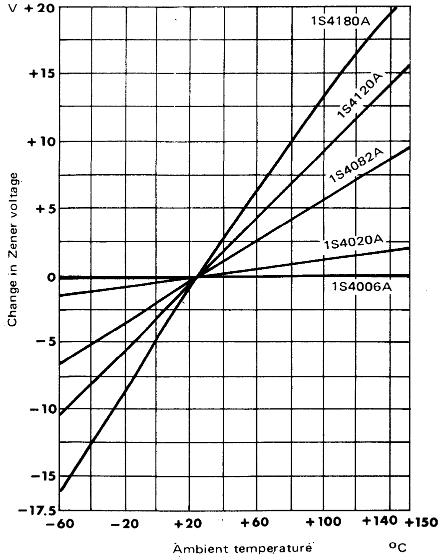


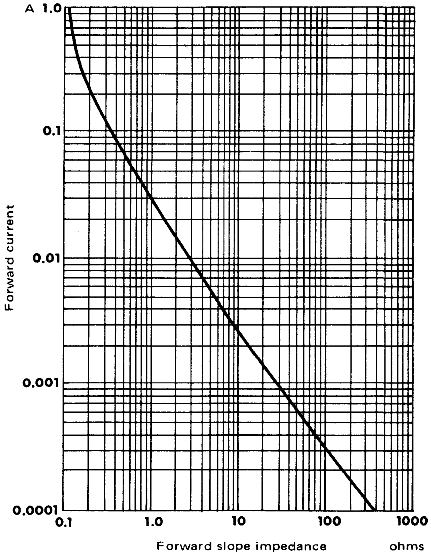
1S4000 SERIES
SILICON VOLTAGE REGULATOR


TYPICAL VARIATION OF ZENER IMPEDANCE WITH I_Z AT 25°C


TYPICAL VARIATION OF V_Z WITH CONTINUOUS DC I_Z AT 25°C

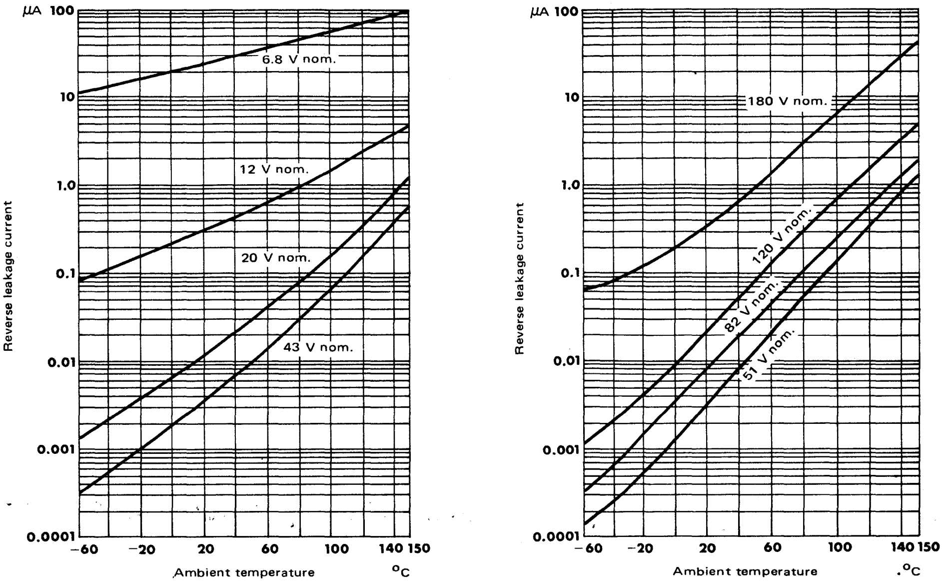
The above graphs can be used to establish typical values of Z_Z at specific circuit conditions of V_Z and I_Z.


TYPICAL VARIATION OF ZENER VOLTAGE WITH TEMPERATURE AT I_Z

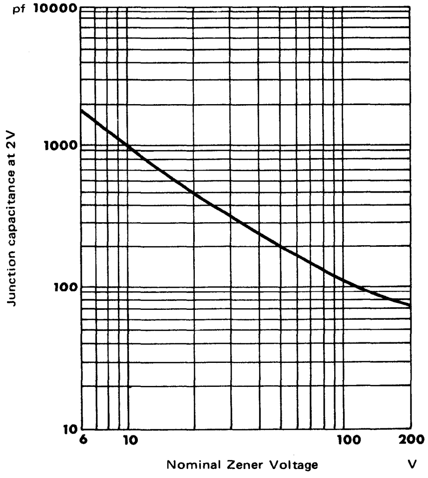

TYPICAL FORWARD SLOPE IMPEDANCE AT 25°C

TEXAS INSTRUMENTS

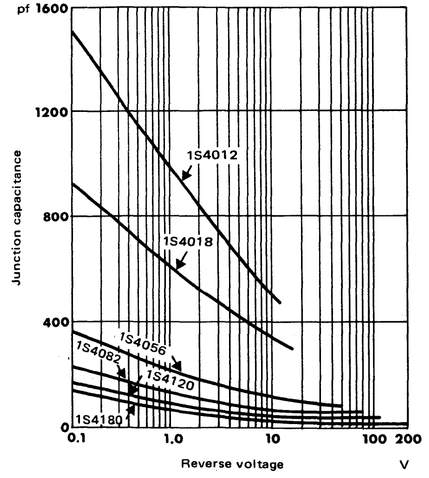
TYPICAL REVERSE CURRENT VARIATION WITH TEMPERATURE AT V_R 75% OF NOMINAL V_Z AT I_Z



TYPICAL JUNCTION CAPACITANCE AT 25°C



TYPICAL JUNCTION CAPACITANCE AT 25°C



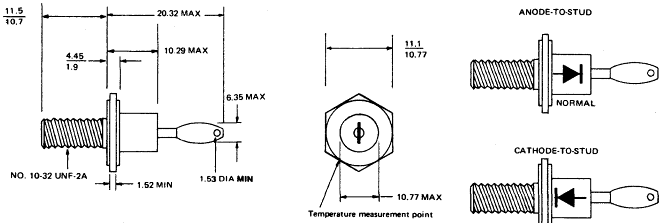
1S5000 SERIES
SILICON VOLTAGE REGULATORS

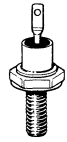
REVISED SEPTEMBER 1975

- 10 watts at +100°C
- Available 5% and 10% nominal tolerance
- 6.8 to 200 volts
- −65°C to +150°C operation

Mechanical Data

*ALL JEDEC DO-4 DIMENSIONS AND NOTES ARE APPLICABLE





NOTES*:

A. Maximum tension at right angles to axis of unit on insulated terminal is 45N for 20 seconds.
B. Maximum unlubricated stud torque is 1.7Nm.
C. Reference point for case temperature measurement is the centre of a flat on the hexagonal base.

DIMENSIONS ARE IN MILLIMETRES

Absolute Maximum Ratings (all temperatures are stud temperatures)

P_{TOT}	Power Dissipation at −65°C to +100°C	10 Watts
P_{TOT}	Power Dissipation at +125°C	5 Watts
P_{SUR}	Zener Surge Power at 0.1mS at 25°C	500W
	Operating and Storage Temperature	−55 to +175°C

Thermal Characteristics

θj−mb	Thermal resistance junction to mounting base	5°C/W
θj−amb	Thermal resistance junction to ambient	50°C/W

Electrical Characteristics (at 25°C stud temperature unless otherwise stated)

V_F	Forward Voltage Drop at I_F = 2A	1.5V Max

1S5000 SERIES
SILICON VOLTAGE REGULATORS

TABLE 1

IS5000A Series (± 5% Nominal Tolerance)

Breakdown Voltage V_z at I_z pulsed. Note 1				Test Current I_z	Zener Differential resistance r_z at I_z Note 2		Leakage Current I_R at V_R Max	Test Voltage V_R	Temperature Coefficient over range +25°C to +60°C at I_z Note 1		
Type No.	Nom. V	Max V	Min V	mA	Typ ohms	Max ohms	µA	V	Typ %/°C	Max Note 3 %/°C	Min Note 3 %/°C
IS5006A	6.8	7.2	6.4	200	0.2	1.5	200	3.7	0.04	0.08	-0.01
IS5007A	7.5	7.9	7.1	200	0.25	1.5	150	4.3	0.05	0.09	-0.01
IS5008A	8.2	8.7	7.7	200	0.3	2	100	4.7	0.05	0.09	0.00
IS5009A	9.1	9.6	8.6	200	0.3	2	100	5.2	0.06	0.10	0.02
IS5010A	10	10.6	9.4	200	0.3	2	50	5.7	0.06	0.10	0.02
IS5011A	11	11.6	10.4	200	0.4	3	50	6.3	0.06	0.10	0.02
IS5012A	12	12.6	11.4	200	0.5	3	50	6.9	0.07	0.105	0.025
IS5013A	13	14.1	12.4	200	0.6	3	20	7.5	0.07	0.105	0.025
IS5015A	15	15.6	13.9	50	1.0	4	20	8.4	0.075	0.11	0.03
IS5016A	16	17.1	15.4	50	1.0	5	20	9.3	0.075	0.11	0.03
IS5018A	18	19.1	16.9	50	2.0	5	20	10.2	0.075	0.11	0.03
IS5020A	20	21.2	18.9	50	2.0	5	20	11.4	0.075	0.11	0.03
IS5022A	22	23.3	20.8	50	2.0	5	20	12.5	0.075	0.11	0.03
IS5024A	24	25.9	22.7	50	2.5	5	20	13.7	0.075	0.11	0.03
IS5027A	27	28.9	25.1	50	2.5	5	20	14.7	0.075	0.11	0.03
IS5030A	30	32	28	50	3	8	20	16.8	0.075	0.11	0.03
IS5033A	33	35	31	50	3	8	20	18.6	0.075	0.11	0.03
IS5136A	36	38	34	50	3	8	20	21	0.075	0.11	0.03
IS5039A	39	41	37	50	3	8	20	23	0.075	0.11	0.03
IS5043A	43	45	40	50	4	10	20	24	0.08	0.12	0.04
IS5047A	47	50	44	50	5	10	20	27	0.08	0.12	0.04
IS5051A	51	54	48	50	6	10	20	29	0.08	0.12	0.04
IS5056A	56	60	53	50	6	10	20	32	0.08	0.12	0.04
IS5062A	62	66	58	50	7	15	20	36	0.09	0.13	0.05
IS5068A	68	72	64	50	8	15	20	40	0.09	0.13	0.05
IS5075A	75	79	71	50	10	30	20	43	0.09	0.13	0.05
IS5082A	82	87	77	50	11	30	20	47	0.09	0.13	0.05
IS5091A	91	96	86	50	14	40	20	52	0.09	0.13	0.05
IS5100A	100	106	94	50	17	40	20	57	0.10	0.14	0.06
IS5110A	110	116	104	50	21	40	20	63	0.10	0.14	0.06
IS5120A	120	126	114	50	26	50	20	69	0.10	0.14	0.06
IS5130A	130	141	124	50	30	60	20	75	0.10	0.14	0.06
IS5150A	150	156	139	50	38	80	20	84	0.10	0.14	0.06
IS5160A	160	171	154	20	45	120	20	93	0.10	0.14	0.06
IS5180A	180	191	169	20	60	140	20	102	0.10	0.14	0.06
IS5200A	200	212	189	20	90	180	20	114	0.10	0.14	0.06

1S5000 SERIES
SILICON VOLTAGE REGULATORS

TABLE 2

IS5000 Series (± 10% Nominal Tolerance)

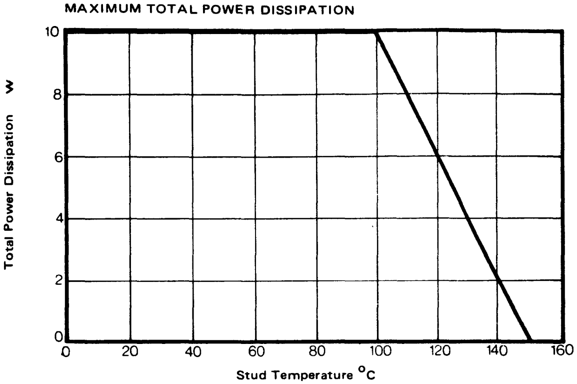
	Breakdown Voltage V_z at I_z pulsed Note 1			Test Current I_z	Zener Differential resistance r_z at I_z Note 2		Leakage Current I_R at V_R	Test Voltage V_R	Temperature Coefficient over range +25°C to +60°C at I_z Note 1		
Type No.	Nom V	Max V	Min V	mA	Typ ohms	Max ohms	µA	V	Typ %/°C	Max Note 3 %/°C	Min Note 3 %/°C
IS5006	6.8	7.6	6.1	200	0.2	1.5	200	3.7	0.04	0.08	-0.01
IS5007	7.5	8.3	6.7	200	0.25	1.5	150	4.3	0.05	0.09	-0.01
IS5008	8.2	9.2	7.4	200	0.3	2	100	4.7	0.05	0.09	0.00
IS5009	9.1	10.1	8.1	200	0.3	2	100	5.2	0.06	0.10	0.02
IS5010	10	11.1	9.0	200	0.3	2	50	5.7	0.06	0.10	0.02
IS5011	11	12.1	9.9	200	0.4	3	50	6.3	0.06	0.10	0.02
IS5012	12	13.1	10.9	200	0.5	3	50	6.9	0.07	0.105	0.025
IS5013	13	15.1	11.9	200	0.6	3	20	7.5	0.07	0.105	0.025
IS5015	15	16.1	12.9	50	1.0	4	20	8.4	0.075	0.11	0.03
IS5016	16	18.5	14.5	50	1.0	5	20	9.3	0.075	0.11	0.03
IS5018	18	20.5	15.5	50	2.0	5	20	10.2	0.075	0.11	0.03
IS5020	20	22.5	17.5	50	2.0	5	20	11.4	0.075	0.11	0.03
IS5022	22	24.5	19.5	50	2.0	5	20	12.5	0.075	0.11	0.03
IS5024	24	27.5	21.5	50	2.5	5	20	13.7	0.075	0.11	0.03
IS5027	27	30.5	23.5	50	2.5	5	20	14.7	0.075	0.11	0.03
IS5030	30	33.5	26.5	50	3	8	20	16.8	0.075	0.11	0.03
IS5033	33	37	29	50	3	8	20	18.6	0.075	0.11	0.03
IS5036	36	40	32	50	3	8	20	21	0.075	0.11	0.03
IS5039	39	44	35	50	3	8	20	23	0.075	0.11	0.03
IS5043	43	48	38	50	4	10	20	24	0.08	0.12	0.04
IS5047	47	52	42	50	5	10	20	27	0.08	0.12	0.04
IS5051	51	57	46	50	6	10	20	29	0.08	0.12	0.04
IS5056	56	63	50	50	6	10	20	32	0.08	0.12	0.04
IS5062	62	69	55	50	7	15	20	36	0.09	0.13	0.05
IS5068	68	76	61	50	8	15	20	40	0.09	0.13	0.05
IS5075	75	83	67	50	10	30	20	43	0.09	0.13	0.05
IS5082	82	92	74	50	11	30	20	47	0.09	0.13	0.05
IS5091	91	101	81	50	14	40	20	52	0.09	0.13	0.05
IS5100	100	111	90	50	17	40	20	57	0.10	0.14	0.06
IS5110	110	121	99	50	21	40	20	63	0.10	0.14	0.06
IS5120	120	131	109	50	26	50	20	69	0.10	0.14	0.06
IS5130	130	151	119	50	30	60	20	75	0.10	0.14	0.06
IS5150	150	161	129	50	38	80	20	84	0.10	0.14	0.06
IS5160	160	185	145	20	45	120	20	93	0.10	0.14	0.06
IS5180	180	205	155	20	60	140	20	102	0.10	0.14	0.06
IS5200	200	225	175	20	90	180	20	114	0.10	0.14	0.06

Notes : see overleaf

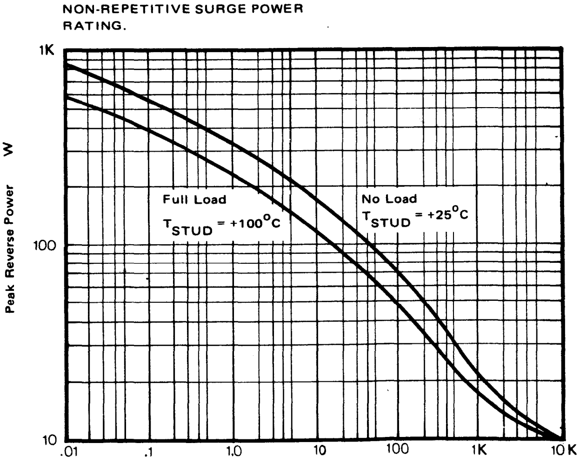
Note 1:- V_z is measured using pulse methods, so that the values obtained are for a T_j very near to T_{case} specified.

Note 2;- Slope impedance r_z, is measured by superimposing on the specified I_z continuous D.C. test current, an A.C. current at 50Hz the r.m.s. value of this being 10% I_z.

Note 3:- The values given in these columns are 95% confidence, and as such should not be used for acceptance purposes.



1



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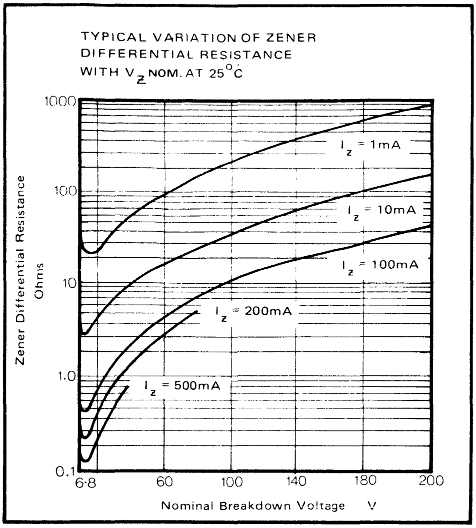
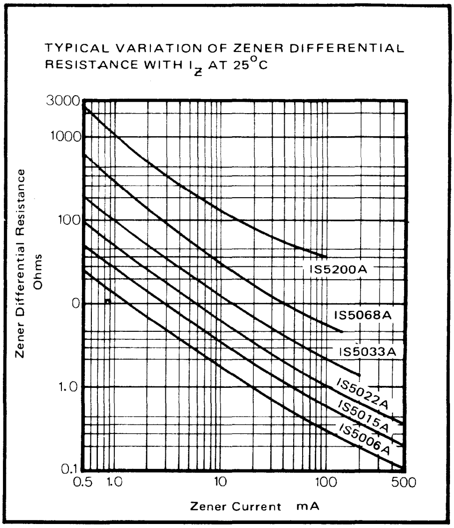
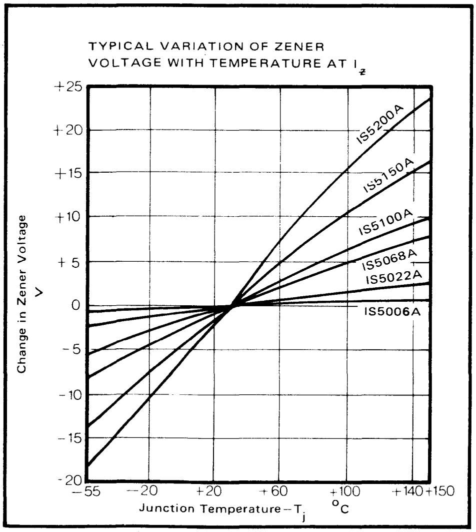

TYPICAL VARIATION OF ZENER DIFFERENTIAL RESISTANCE WITH V_Z NOM. AT 25°C
Zener Differential Resistance Ohms
1000
100
10
1.0
0.1
I_z = 1mA
I_z = 10mA
I_z = 100mA
I_z = 200mA
I_z = 500mA
6·8
60
100
140
180
200
Nominal Breakdown Voltage V

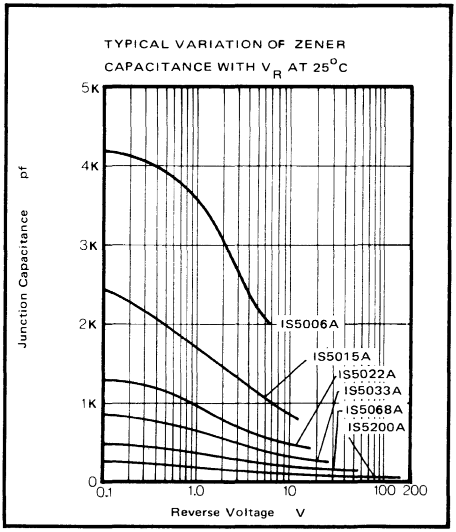
3


TYPICAL VARIATION OF ZENER DIFFERENTIAL RESISTANCE WITH I_Z AT 25°C
Zener Differential Resistance Ohms
3000
1000
100
0
1.0
0.1
IS5200A
IS5068A
IS5033A
IS5022A
IS5015A
IS5006A
0.5
1.0
10
100
500
Zener Current mA

4

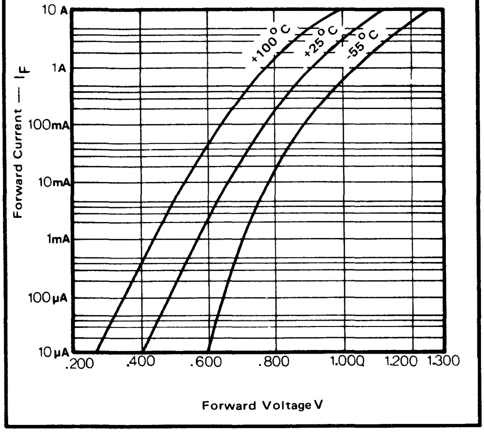

TYPICAL VARIATION OF ZENER VOLTAGE WITH TEMPERATURE AT I_Z
Change in Zener Voltage V
+25
+20
+15
+10
+5
0
-5
-10
-15
-20
IS5200A
IS5150A
IS5100A
IS5068A
IS5022A
IS5006A
−55
−20
+20
+60
+100
+140
+150
Junction Temperature − T_j °C

5


TYPICAL VARIATION OF ZENER CAPACITANCE WITH V_R AT 25°C
Junction Capacitance pf
5K
4K
3K
2K
1K
0
IS5006A
IS5015A
IS5022A
IS5033A
IS5068A
IS5200A
0.1
1.0
10
100
200
Reverse Voltage V

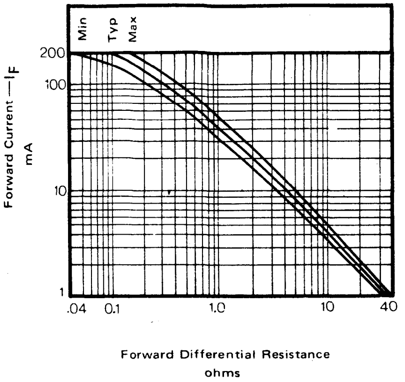
6

TYPICAL FORWARD CHARACTERISTIC VARIATION WITH I_F



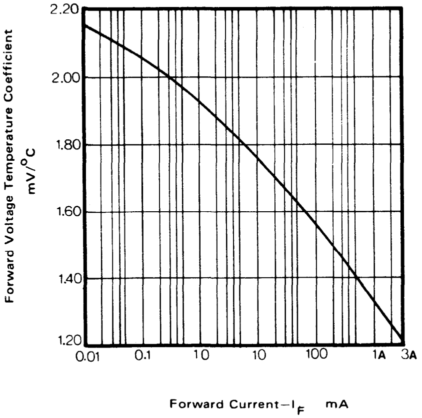
7

TYPICAL FORWARD DIFFERENTIAL RESISTANCE AT 25°C



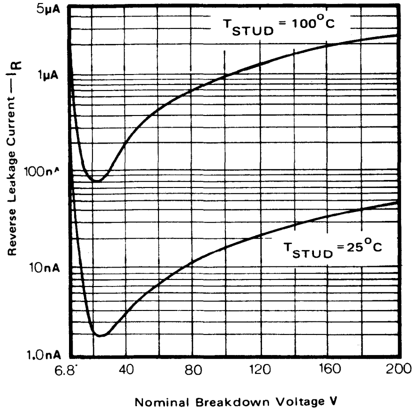
8

TYPICAL FORWARD VOLTAGE TEMPERATURE COEFFICIENT



9

TYPICAL VARIATION OF REVERSE LEAKAGE CURRENT WITH V_z NOM.AT V_R = 60% V_z MIN.



10

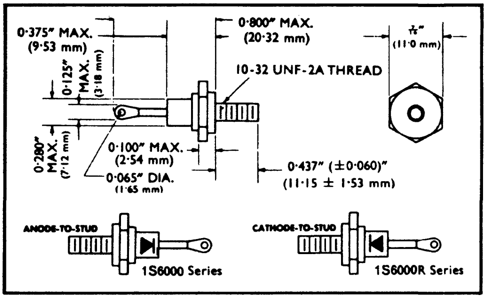
1S6000 SERIES
SILICON VOLTAGE REGULATORS

AUGUST 1974

- 6.8 to 200 volts
- 10 watts at + 100°C
- Full CV and BS9300 approval
- Available in 5% and 10% tolerance
- –65°C to +150°C operation

mechanical data

metal case with glass-to-metal hermetic seal between case and anode lead. approximate weight is 4·36 grams.



'R' Suffix = Reverse Polarity

absolute maximum ratings
(all temperatures are stud temperatures)

P_{TOT}	Power Dissipation at 100°C	10 W
P_{TOT}	Power Dissipation at 125°C	5 W
P_{SUR}	Surge Power 0·1 mS at 25°C	500 W
	Operating and Storage Temperature	−65°C to +150°C

electrical characteristics
(all temperatures are stud temperatures)

V_F Forward Voltage Drop at 2A at 25°C 1·5 V Max.

1S6000A Series (±5% Nominal Tolerance)

Type No.	Breakdown Voltage V_Z at 100 C, 100 mS pulse at I_Z			Test Current I_Z mA	Max. Slope Impedance Z_Z at 25 C		CV Equivalent	
	Nom. V	Max. V	Min. V		at I_Z ohm	at 1 mA ohm	Stud Anode	Stud Cathode
1S6006A	6·8	7·2	6·4	200	4·0	150*	CV7199	CV7241
1S6007A	7·5	7·9	7·1	200	2·5	150*	CV7200	CV7242
1S6008A	8·2	8·7	7·7	200	2·5	100*	CV7201	CV7243
1S6009A	9·1	9·6	8·6	200	2·5	250	CV7202	CV7244
1S6010A	10	10·6	9·4	200	2·5	250	CV7203	CV7245
1S6011A	11	11·6	10·4	200	2·5	250	CV7204	CV7246
1S6012A	12	12·6	11·4	200	2·5	250	CV7205	CV7247
1S6013A	13	14·1	12·4	200	2·5	250	CV7206	CV7248
1S6015A	15	15·6	13·9	100	5·0	250	CV7207	CV7249
1S6016A	16	17·1	15·4	100	5·0	250	CV7208	CV7250
1S6018A	18	19·1	16·9	100	5·0	250	CV7209	CV7251
1S6020A	20	21·2	18·9	100	5·0	250	CV7210	CV7252
1S6022A	22	23·3	20·8	100	5·0	250	CV7211	CV7253
1S6024A	24	25·9	22·7	100	5·0	250	CV7212	CV7254
1S6027A	27	28·9	25·1	100	5·0	250	CV7213	CV7255
1S6030A	30	32	28	100	8·0	300	CV7214	CV7256
1S6033A	33	35	31	50	8·0	300	CV7215	CV7257
1S6036A	36	38	34	50	8·0	300	CV7216	CV7258
1S6039A	39	41	37	50	8·0	300	CV7217	CV7259
1S6043A	43	45	40	50	10	400	CV7218	CV7260
1S6047A	47	50	44	50	10	400	CV7219	CV7261
1S6051A	51	54	48	50	10	500	CV7220	CV7262
1S6056A	56	60	53	50	10	500	CV7221	CV7263
1S6062A	62	66	58	50	15	600	CV7222	CV7264
1S6068A	68	72	64	20	50	600	CV7223	CV7265
1S6075A	75	79	71	20	50	600	CV7224	CV7266
1S6082A	82	87	77	20	50	700	CV7225	CV7267
1S6091A	91	96	86	20	60	800	CV7226	CV7268
1S6100A	100	106	94	20	60	900	CV7227	CV7269
1S6110A	110	116	104	20	60	1100	CV7228	CV7270
1S6120A	120	126	114	20	80	1200	CV7229	CV7271
1S6130A	130	141	124	20	80	1300	CV7230	CV7272
1S6150A	150	156	139	10	180	1500	CV7231	CV7273
1S6160A	160	171	154	10	200	1600	CV7232	CV7274
1S6180A	180	191	169	10	250	1850	CV7233	CV7275
1S6200A	200	212	189	10	300	2000	CV7234	CV7276

*Measured at 5mA

1S6000 Series (±10% Nominal Tolerance)

Type No.	Breakdown Voltage V_Z at 100 C, 100 mS pulse at I_Z			Test Current I_Z mA	Max. Slope Impedance Z_Z at 25 C	
	Nom. V	Max. V	Min. V		at I_Z ohm	at 1mA ohm
1S6006	6·8	7·6	6·1	200	6·0	250
1S6007	7·5	8·3	6·7	200	4·0	200
1S6008	8·2	9·2	7·4	200	2·5	150
1S6009	9·1	10·1	8·1	200	2·5	250
1S6010	10	11·1	9·0	200	2·5	250
1S6011	11	12·1	9·9	200	2·5	250
1S6012	12	13·1	10·9	200	2·5	250
1S6013	13	15·1	11·9	200	4·0	250
1S6015	15	16·1	12·9	100	5·0	250
1S6016	16	18·5	14·5	100	5·0	250
1S6018	18	20·5	15·5	100	5·0	250
1S6020	20	22·5	17·5	100	5·0	250
1S6022	22	24·5	19·5	100	5·0	250
1S6024	24	27·5	21·5	100	5·0	250
1S6027	27	30·5	23·5	100	8·0	300
1S6030	30	33·5	26·5	100	8·0	300
1S6033	33	37	29	50	8·0	300
1S6036	36	40	32	50	8·0	300
1S6039	39	44	35	50	10	400
1S6043	43	48	38	50	10	400
1S6047	47	52	42	50	10	500
1S6051	51	57	46	50	10	500
1S6056	56	63	50	50	15	600
1S6062	62	69	55	50	25	600
1S6068	68	76	61	20	50	600
1S6075	75	83	67	20	50	700
1S6082	82	92	74	20	60	800
1S6091	91	101	81	20	60	900
1S6100	100	111	90	20	60	1100
1S6110	110	121	99	20	80	1200
1S6120	120	131	109	20	80	1300
1S6130	130	151	119	20	120	1500
1S6150	150	161	129	10	200	1600
1S6160	160	185	145	10	250	1850
1S6180	180	205	155	10	300	2000
1S6200	200	225	175	10	400	2200

1S6000 SERIES
SILICON VOLTAGE REGULATORS

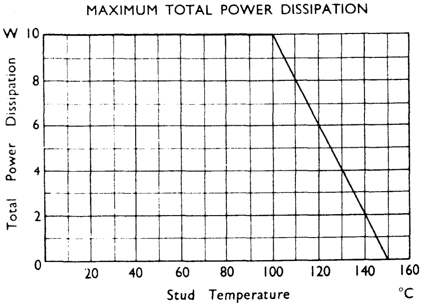
typical electrical characteristics

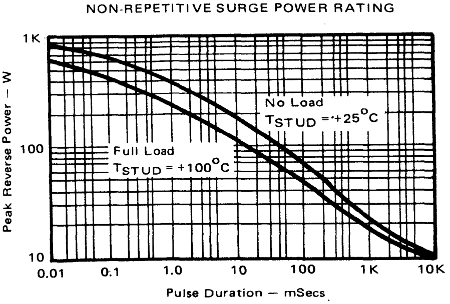
1S6000A Series (±5% Nominal Tolerance)

Type No.	Slope Impedance Z_Z at I_Z at 25 C		Temperature Coefficient over range 25 C to 100 C at I_Z, 100 mS pulse		
	Typ ohm	Min ohm	Typ %/°C	Max. %/ C	Min. %/°C
1S6006A	1·2	0·9	0·03	0·07	−0·01
1S6007A	1·1	0·85	0·04	0·08	0·00
1S6008A	1·0	0·8	0·04	0·08	0·00
1S6009A	1·0	0·8	0·05	0·09	0·01
1S6010A	0·9	0·7	0·05	0·09	0·01
1S6011A	0·9	0·7	0·05	0·09	0·01
1S6012A	0·9	0·7	0·055	0·095	0·015
1S6013A	1·0	0·7	0·055	0·095	0·015
1S6015A	1·1	0·8	0·06	0·10	0·02
1S6016A	1·1	0·8	0·06	0·10	0·02
1S6018A	1·1	0·85	0·06	0·10	0·02
1S6020A	1·3	0·85	0·06	0·10	0·02
1S6022A	1·3	0·9	0·06	0·10	0·02
1S6024A	1·5	1·1	0·06	0·10	0·02
1S6027A	2·0	1·5	0·06	0·10	0·02
1S6030A	2·4	1·6	0·06	0·10	0·02
1S6033A	3·2	1·8	0·06	0·10	0·02
1S6036A	4·0	2·0	0·07	0·11	0·03
1S6039A	4·5	3·5	0·07	0·11	0·03
1S6043A	5·6	4·0	0·07	0·11	0·03
1S6047A	5·8	4·5	0·07	0·12	0·03
1S6051A	7·0	5·0	0·08	0·12	0·04
1S6056A	8·2	5·6	0·08	0·12	0·04
1S6062A	10·0	6·2	0·08	0·12	0·04
1S6068A	18·0	10·0	0·08	0·12	0·04
1S6075A	22·0	12·5	0·09	0·13	0·05
1S6082A	26·0	15·0	0·09	0·13	0·05
1S6091A	31·0	19·0	0·10	0·14	0·06
1S6100A	34·0	23·0	0·10	0·14	0·06
1S6110A	37·0	27·0	0·10	0·14	0·06
1S6120A	41·0	30·0	0·10	0·14	0·06
1S6130A	45·0	34·0	0·10	0·14	0·06
1S6150A	79·0	56·0	0·10	0·14	0·06
1S6160A	84·0	60·0	0·10	0·14	0·06
1S6180A	96·0	68·0	0·10	0·14	0·06
1S6200A	100·0	80·0	0·10	0·14	0·06

1S6000 Series (±10% Nominal Tolerance)

Type No.	Slope Impedance Z_Z at I_Z at 25 C		Temperature Coefficient over range 25 C to 100 C at I_Z, 100 mS pulse		
	Typ ohm	Min ohm	Typ %/ C	Max %/ C	Min. %/ C
1S6006	1·2	0·85	0·03	0·07	−0·01
1S6007	1·1	0·8	0·04	0·08	0·00
1S6008	1·0	0·8	0·04	0·08	0·00
1S6009	1·0	0·7	0·05	0·09	0·01
1S6010	0·9	0·7	0·05	0·09	0·01
1S6011	0·9	0·7	0·05	0·09	0·01
1S6012	0·9	0·7	0·055	0·095	0·015
1S6013	1·0	0·7	0·055	0·095	0·015
1S6015	1·1	0·8	0·06	0·10	0·02
1S6016	1·1	0·8	0·06	0·10	0·02
1S6018	1·1	0·8	0·06	0·10	0·02
1S6020	1·3	0·85	0·06	0·10	0·02
1S6022	1·3	0·85	0·06	0·10	0·02
1S6024	1·5	0·9	0·06	0·10	0·02
1S6027	2·0	1·1	0·06	0·10	0·02
1S6030	2·4	1·5	0·06	0·10	0·02
1S6033	3·2	1·7	0·06	0·10	0·02
1S6036	4·0	1·8	0·07	0·11	0·03
1S6039	4·5	2·0	0·07	0·11	0·03
1S6043	5·6	3·5	0·07	0·11	0·03
1S6047	5·8	4·0	0·07	0·12	0·03
1S6051	7·0	4·5	0·08	0·12	0·04
1S6056	8·2	5·0	0·08	0·12	0·04
1S6062	10·0	5·6	0·08	0·12	0·04
1S6068	18·0	9·0	0·08	0·12	0·04
1S6075	22·0	10·0	0·09	0·13	0·05
1S6082	26·0	12·5	0·09	0·13	0·05
1S6091	31·0	15·0	0·10	0·14	0·06
1S6100	34·0	19·0	0·10	0·14	0·06
1S6110	37·0	23·0	0·10	0·14	0·06
1S6120	41·0	27·0	0·10	0·14	0·06
1S6130	45·0	30·0	0·10	0·14	0·06
1S6150	79·0	50·0	0·10	0·14	0·06
1S6160	84·0	56·0	0·10	0·14	0·06
1S6180	96·0	60·0	0·10	0·14	0·06
1S6200	100·0	68·0	0·10	0·14	0·06

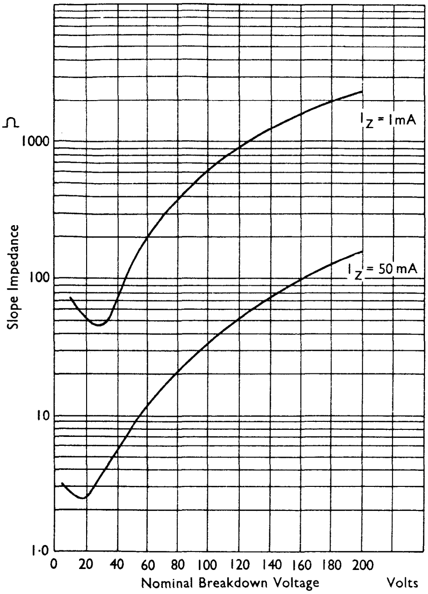




1S6000 SERIES
SILICON VOLTAGE REGULATORS

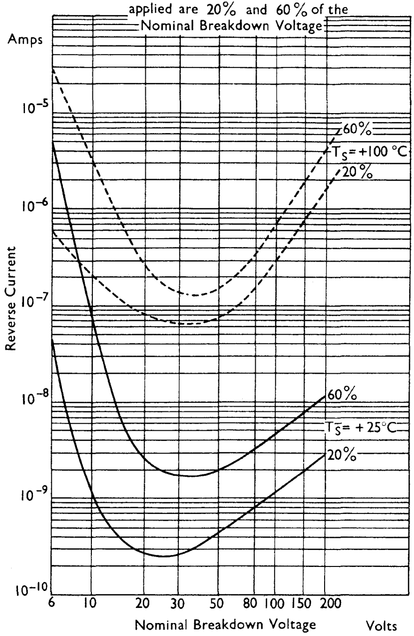
TYPICAL SLOPE IMPEDANCE

$T_{Stud} = +100\ °C$

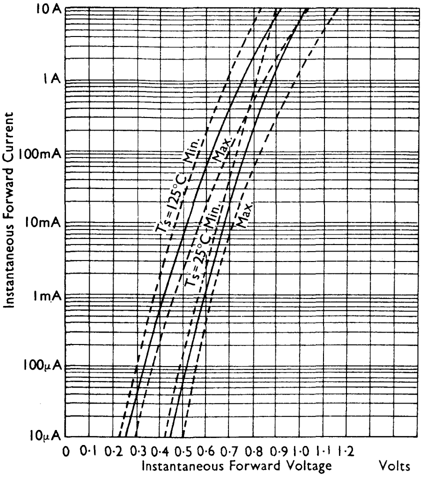


TYPICAL REVERSE CURRENT

at +25°C and +100 °C Stud where the Reverse Voltages applied are 20% and 60% of the Nominal Breakdown Voltage

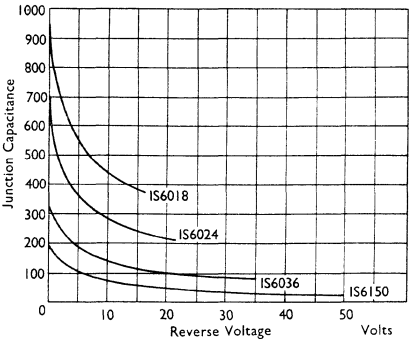


TYPICAL FORWARD CHARACTERISTIC



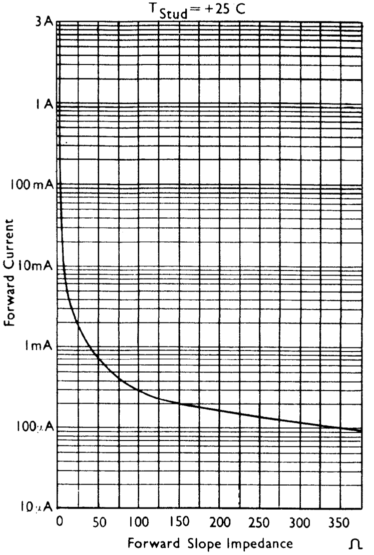
TYPICAL JUNCTION CAPACITANCE

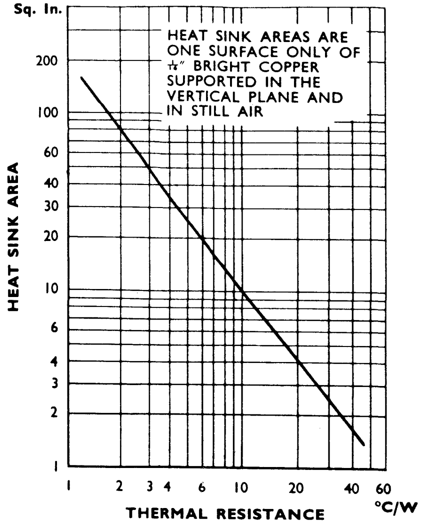
$T_{Stud} = +25°C$



TEXAS INSTRUMENTS

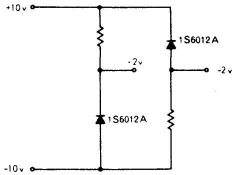
TYPICAL FORWARD SLOPE IMPEDANCE
$T_{Stud} = +25$ C



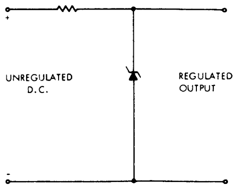


TYPICAL CIRCUITS

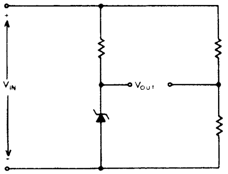
SHORT CIRCUIT PROOF
LOW-VOLTAGE POWER SUPPLY



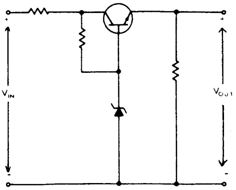
BASIC SUPPLY



IMPEDANCE COMPENSATING CIRCUIT



EMITTER FOLLOWER REGULATOR



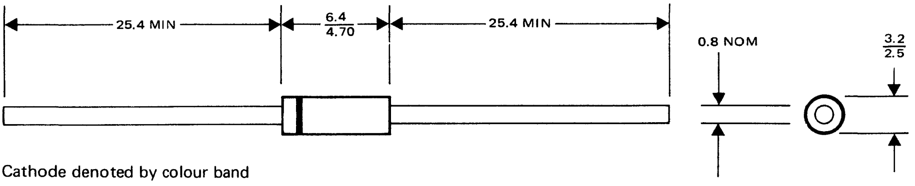
SERIES 1SX170 - 1SX175

HIGH VOLTAGE FAST RECOVERY SILICON RECTIFIERS

REVISED JULY 1975

- V_{RRM} – 60V – 500 V
- T_{rr} – 250nS Typical, 350nSec Max
- $I_{F(AV)}$ – 1.0A
- Exceptional efficiency at high frequency, operates up to 150KHz
- Intended for TV Linescan Applications

Mechanical Data



Cathode denoted by colour band

Dimensions in millimetres

Absolute Maximum Ratings at 25°C ambient (unless otherwise stated)

		1SX170	1SX171	1SX172	1SX173	1SX174	1SX175	Units
V_{RRM}	Repetitive Peak Reverse Voltage 1mSec Duration, -55°C to 175°C	60	100	200	300	400	500	V
V_{RSM}	Non-Repetitive Peak Reverse Voltage, 10mSec Duration, -55°C to +175°C	60	100	200	300	400	500	V
V_{RWM}	Crest Working Reverse Voltage, -55°C to 175°C	50	75	100	200	300	400	V
V_R	Continuous Direct Reverse Voltage, -55°C to 175°C	50	75	100	200	300	400	V
$I_{F(AV)}$	Average Rectified Forward Current, -55°C to +45°C	1.0	1.0	1.0	1.0	1.0	1.0	A
I_F	Continuous D.C. Forward Current, -55°C to +45°C	1.5	1.5	1.5	1.5	1.5	1.5	A
I_{FRM}	Repetitive Peak Forward Current, -55°C to +25°C	5	5	5	5	5	5	A
I_{FSM}	Non-Repetitive Peak Foward Current, 1 Cycle at 50Hz, at 25°C	30	30	30	30	30	30	A
T_{amb}	Ambient Operating Temperature Range	-55°C to 175°C						
T_{stg}	Storage Temperature Range	-55°C to 175°C						
T_j	Junction Temperature Range	-55°C to 175°C						

SERIES 1SX170 - 1SX175

HIGH VOLTAGE FAST RECOVERY SILICON RECTIFIERS

Electrical Characteristics at T amb = 25°C (unless otherwise stated)

I_R	Maximum Reverse Current at Rated V_R	10	μA
I_R	Maximum Reverse Current at Rated V_R and T_{amb} = 100°C	150	μA
V_F	Maximum Forward Voltage Drop at I_F = 1A	1.2	V
t_{rr}	Maximum Reverse Recovery Time at I_F = 0.5A, V_R = 30V, di/dt = 25 A/μS (see Fig. 1 and Note 1)	350	nS
I_{rr}	Maximum Reverse Recovery Current at I_F = 0.5A, V_R = 30V, di/dt = 25 A/μS (see Fig. 1)	3	A

NOTE 1

DETAILS OF t_{rr} AT SPECIFIC OPERATING CONDITIONS, OTHER THAN THOSE QUOTED CAN BE OBTAINED IF REQUISITE INFORMATION IS FORWARDED TO POWER PRODUCT MARKETING, BEDFORD.

Reverse recovery method of measurement

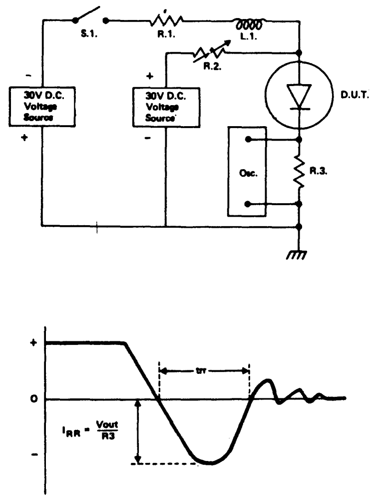


FIG 1

Forward Current Derating Curve

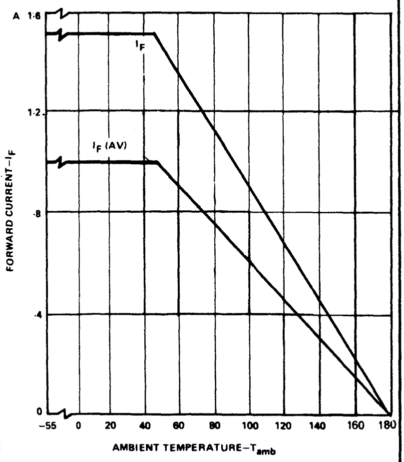


FIG 2

S.1. IS AN ELECTRO MECHANICAL SWITCH.
R.1. AND L.1. ARE ADJUSTED TO GIVE di/dt = 25 A/μS
R.3. IS A NON-INDUCTIVE 1Ω CURRENT SHUNT
R.2. IS ADJUSTED TO GIVE I_F = 0.5A
THE OUTPUT WAVEFORM IS MONITORED ON OSCILLOSCOPE CONNECTED ACROSS R.3.

TYPES 2N3005, 2N3006, 2N3007, 2N3008
P-N-P-N PLANAR SILICON REVERSE-BLOCKING TRIODE THYRISTORS

REVISED JULY 1975

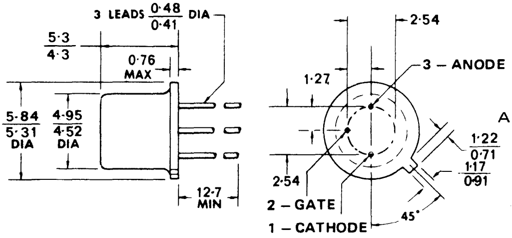
350 mA • 30 to 200 VOLTS • 200 μA GATE SENSITIVITY
ALL PLANAR, OXIDE-PASSIVATED JUNCTIONS—NO SOLDER OR FLUXES

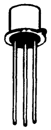
- High Operating Temperature
- High Surge Current Capability
- Fast Switching Speeds
- Low Forward Voltage Drop
- Gate Turn-Off Capability

mechanical data

The devices are in a hermetically sealed welded case with a glass-to-metal seal between case and leads. Approximate weight is 0.35 grams.

*THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE





*ALL JEDEC TO-18 DIMENSIONS AND NOTES ARE APPLICABLE

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

	2N3005	2N3006	2N3007	2N3008	UNIT
*Static Off-State Voltage, V_D (See Note 1)	30	60	100	200	V
*Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	30	60	100	200	V
*Static Reverse Voltage, V_R (See Note 2)	30	60	100	200	V
*Repetitive Peak Reverse Voltage, V_{RRM} (See Note 2)	30	60	100	200	V
*Continuous or RMS On-State Current at (or below) 55°C Free-Air Temperature (See Note 3)	350				mA
*Average On-State Current (180° Conduction Angle) at (or below) 55°C Free-Air Temperature (See Note 4)	250				mA
*Surge On-State Current (See Note 5)	6				A
Peak Negative Gate Voltage	8				V
*Peak Positive Gate Current (Pulse Width ⩽ 8 ms)	250				mA
*Average Gate Power Dissipation	100				mW
*Operating Free-Air Temperature Range	−65 to 200				°C
*Storage Temperature Range	−65 to 175				°C
*Lead Temperature 1.588mm from Case for 10 Seconds	300				°C

NOTES:
1. These values apply when the gate-cathode resistance $R_{GK} \leqslant 1\ k\Omega$.
2. These values apply when the gate-cathode resistance $R_{GK} \leqslant \infty$.
3. This value applies for continuous d-c or single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 55°C, derate according to Figure 13.
4. This value may be applied continuously under single-phase, 60-Hz, half-sine-wave operation with resistive load. Above 55°C, derate according to Figure 13.
5. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_D Static Off-State Current	V_D = Rated V_D, R_{GK} = 1 kΩ			0.1	μA
	V_D = Rated V_D, R_{GK} = 1 kΩ, T_A = 150°C			100	
I_R Static Reverse Current	V_R = Rated V_R, R_{GK} = ∞,			0.1	μA
	V_R = Rated V_R, R_{GK} = ∞, T_A = 150°C			100	
I_G Gate Current	V_G = −5 V, I_A = 0			−5	μA
I_{GT} Gate Trigger Current	V_{AA} = 5 V, R_L = 12 Ω, $t_{p(g)} \geq 10$ μs		90	200	μA
V_{GT} Gate Trigger Voltage	V_{AA} = 5 V, R_L = 12 Ω, $t_{p(g)} \geq 10$ μs, T_A = −65°C			0.9	V
	V_{AA} = 5 V, R_L = 12 Ω, $t_{p(g)} \geq 10$ μs		0.6	0.8	
	V_{AA} = 5 V, R_L = 12 Ω, $t_{p(g)} \geq 10$ μs, T_A = 150°C	0.2			
I_H Holding Current	R_{GK} = 1 kΩ, R_L = 2 kΩ		1.8	5	mA
	R_{GK} = 1 kΩ, R_L = 2 kΩ, T_A = −65°C			8	
V_T On-State Voltage	I_T = 350 mA, $R_{GK} \geq 1$ kΩ, See Note 6			1.2	V
I_{GQ} Static Gate Turn-Off Current	I_T = 200 mA (See Note 7), $V_{AA} \leq 100$ V (Not to exceed rated V_D)		40		mA
V_{GQ} Static Gate Turn-Off Voltage			−4		V
dv/dt Critical Rate of Rise of Off-State Voltage	V_D = 1 V		400		V/μs

NOTES: 6. The initial instantaneous value is measured using pulse techniques. On-state pulse width = 300 μs, PRR = 10 pps.

7. Anode current should not exceed 200 mA for gate turn-off applications.

*JEDEC registered data

switching characteristics at 25° C free-air temperature

PARAMETER	TEST CONDITIONS	2N3008	UNIT
		TYPICAL	
t_{gt} Gate-Controlled Turn-On Time	V_{AA} = 200 V, R_L = 2.2 kΩ, R_G = 100 Ω, V_{in} = 3 V, See Figure 14	0.55	μs
t_q Circuit-Commutated Turn-Off Time	V_{AA} = 50 V, R_L = 140 Ω, 1N645 between gate and cathode, See Figure 15	2.2	

thermal characteristics

PARAMETER	TYPICAL	UNIT
$R_{\theta JC}$ Junction-to-Case Thermal Resistance	75	°C/W
$R_{\theta JA}$ Junction-to-Free-Air Thermal Resistance	275	

ANODE CHARACTERISTICS

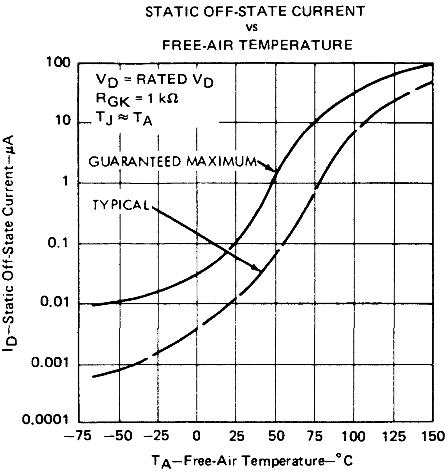

STATIC OFF-STATE CURRENT
vs
FREE-AIR TEMPERATURE

FIGURE 1

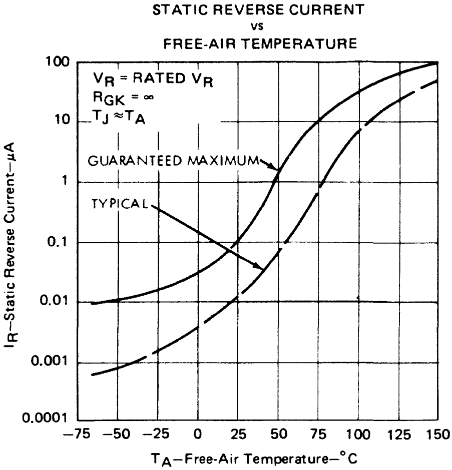

STATIC REVERSE CURRENT
vs
FREE-AIR TEMPERATURE

FIGURE 2

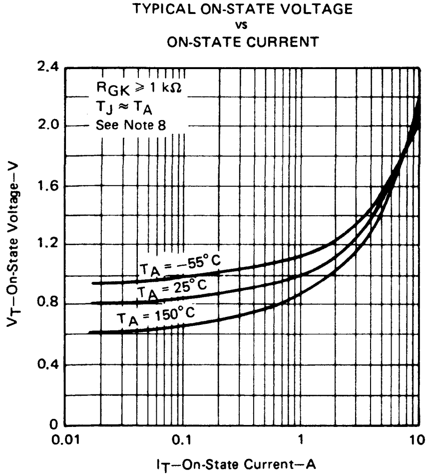

TYPICAL ON-STATE VOLTAGE
vs
ON-STATE CURRENT

FIGURE 3

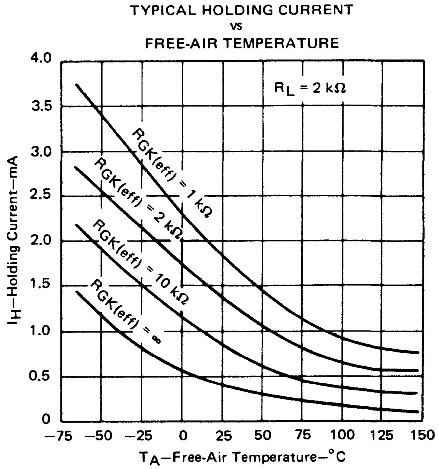

TYPICAL HOLDING CURRENT
vs
FREE-AIR TEMPERATURE

FIGURE 4

NOTE 8: **These parameters were measured using pulse techniques. t_w = 300 μs, PRR = 10 pps.**

GATE CHARACTERISTICS

GATE TRIGGER CURRENT
vs
FREE-AIR TEMPERATURE

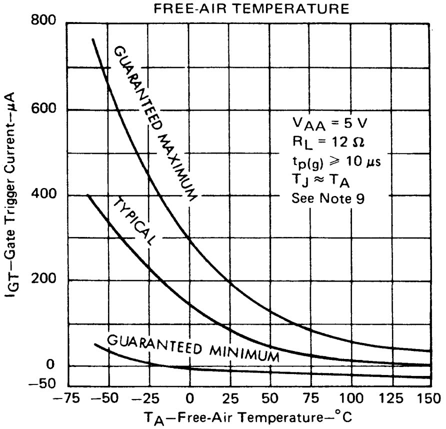


FIGURE 5

GATE TRIGGER VOLTAGE
vs
FREE-AIR TEMPERATURE

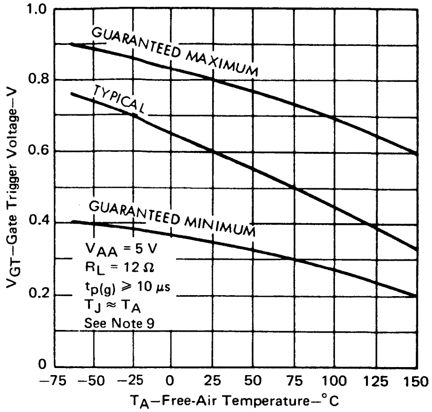


FIGURE 6

TYPICAL GATE VOLTAGE
vs
POSITIVE GATE CURRENT

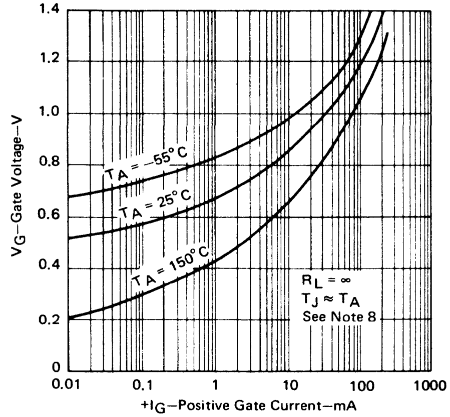


FIGURE 7

TYPICAL GATE TRIGGER VOLTAGE
vs
GATE PULSE WIDTH

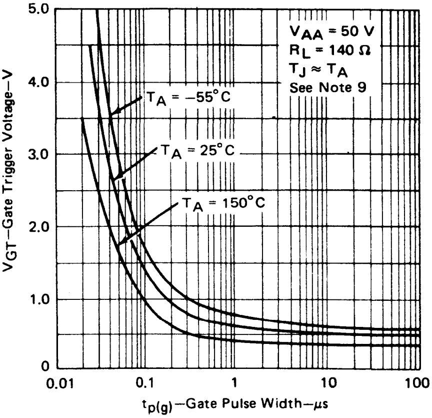


FIGURE 8

NOTES: 8. These parameters were measured using pulse techniques. t_w = 300 μs, PRR = 10 pps.
9. These parameters were measured using single-pulse techniques. t_w = 300 μs, duty cycle = 0.

TYPICAL SWITCHING CHARACTERISTICS, $T_A = 25°C$

2N3008
GATE-CONTROLLED TURN-ON TIME
vs
GATE INPUT PULSE AMPLITUDE

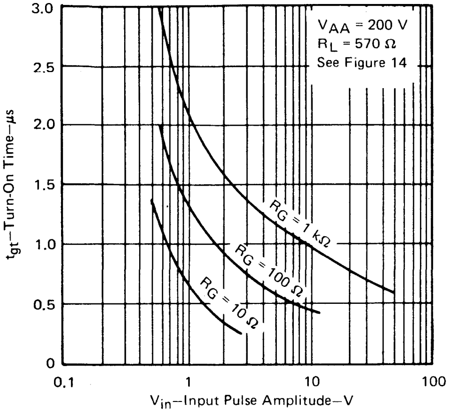


FIGURE 9

2N3008
GATE-CONTROLLED TURN-ON TIME
vs
ANODE SUPPLY VOLTAGE

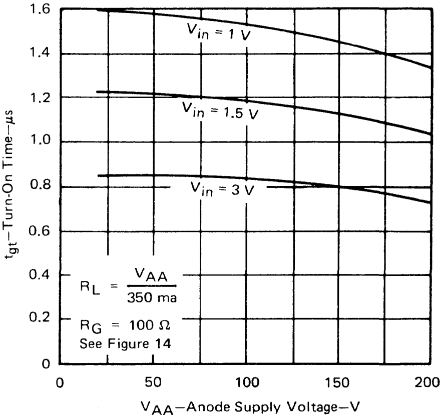


FIGURE 10

2N3008
GATE-CONTROLLED TURN-ON TIME
vs
ON-STATE CURRENT

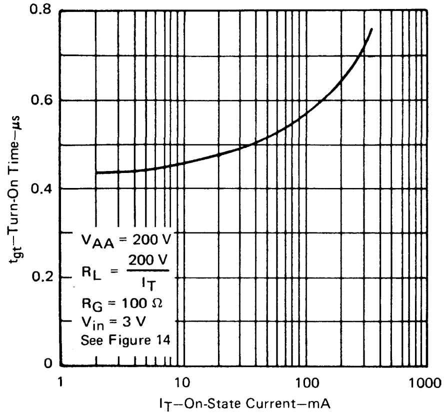


FIGURE 11

2N3008
CIRCUIT COMMUTATED TURN-OFF TIME
vs
ON-STATE CURRENT

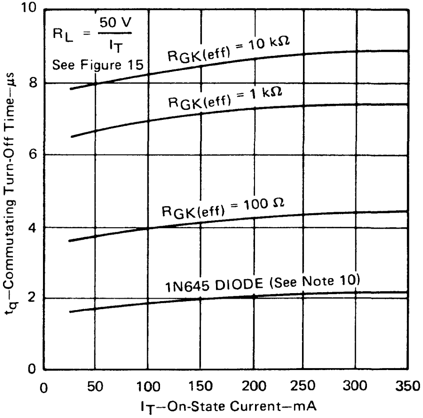


FIGURE 12

NOTE 10: The commutating turn-off time of the 2N3005 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Figure 12. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Figure 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

ANODE FORWARD CURRENT DERATING CURVES

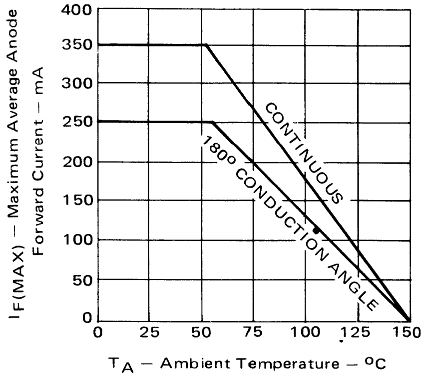
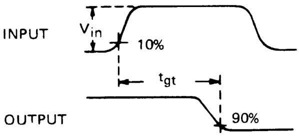
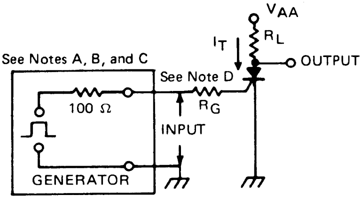


FIGURE 13

PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS

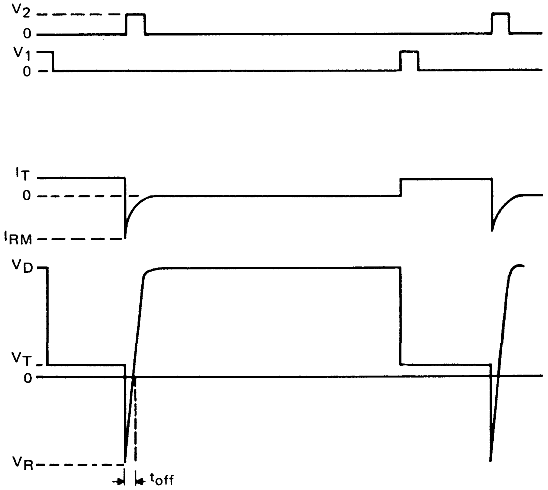


TEST CIRCUIT

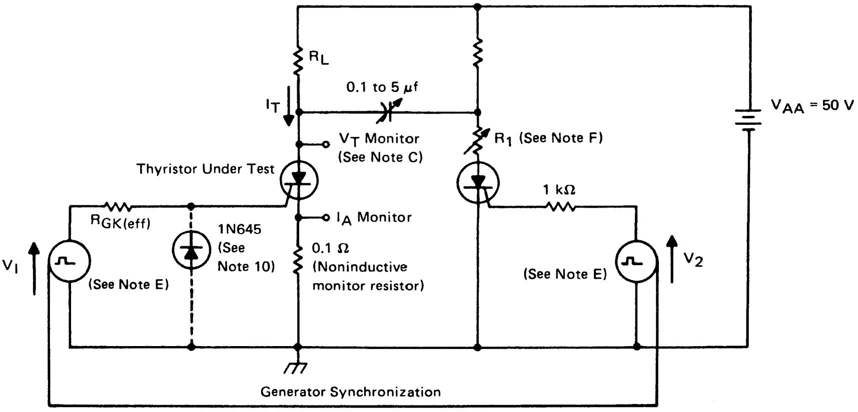
FIGURE 14—TURN-ON TIME

NOTES:
A. V_{in} is measured with gate and cathode terminals connected as shown and anode terminal open.
B. The input waveform of Figure 14 has the following characteristics: $t_r \leqslant 40$ ns, $t_w \geqslant$ device turn-on time at the operating point.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 12$ pF.
D. R_G includes the total resistance of the generator and the external resistor.

PARAMETER MEASUREMENT INFORMATION



WAVEFORMS



TEST CIRCUIT

NOTES: E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: t_w = 50 to 300 µs, duty cycle = 1%. The pulse widths of V_1 and V_2 are ⩾ 10 µs.

F. Resistor R_1 is adjusted for I_{RM} = 1 A.

FIGURE 15—CIRCUIT COMMUTATED TURN-OFF TIME

NOTE 10: The commutating turn-off time of the 2N3005 series thyristor is significantly affected by the source impedance of the gate firing circuit as shown in Figure 12. Faster turn-off times are achieved when this impedance is low. However, some circuits require the use of a high source impedance, even though fast turn-off is desired. In these applications, a diode may be used to by-pass the gate-cathode junction, as shown in the circuit in Figure 15. This diode improves commutating turn-off time by eliminating the effect of the gate-cathode recovery time.

TYPICAL GATE TURN-OFF CHARACTERISTICS

The 2N3005 series thyristors exhibit gate-turn-off gain, in addition to the standard controlled switch characteristics. Figure 16 shows the typical gate-turn-off gain as a function of on-state current. This characteristic offers increased flexibility in the design of pulse-width modulators, pulse-forming networks, static switches, choppers, bistable circuits, and inverters.

TYPICAL GATE-TURN-OFF GAIN
vs
ON-STATE CURRENT

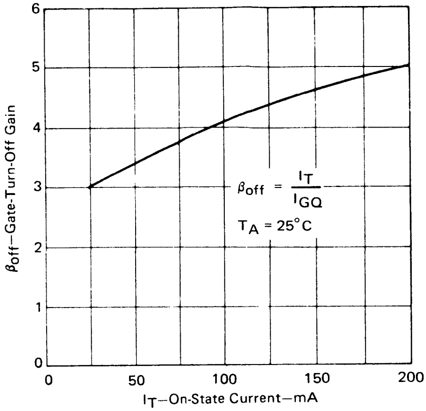
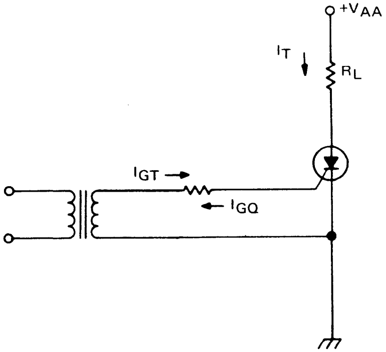
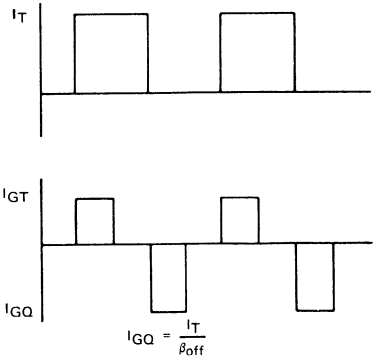


FIGURE 16



TYPICAL GATE-TURN-OFF CIRCUIT



TYPICAL WAVEFORMS

Improved turn-off time may be realized using the gate-turn-off method. A combination of gate-turn-off and standard commutating turn-off will further improve the turn-off time. For applications requiring a guaranteed β_{off}, contact your nearest TI Sales Office for information on special types.

TYPE 2N3055
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

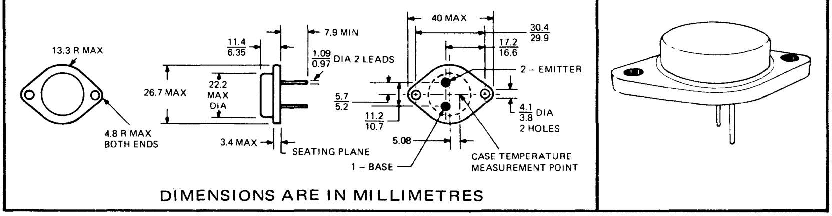
REVISED AUGUST 1975

FOR POWER-AMPLIFIER APPLICATIONS

- **115 W at 25°C Case Temperature**
- **Max I_C of 15 A**
- **Min f_{hfe} of 20 kHz**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	70 V
Emitter-Base Voltage	7 V
Continuous Collector Current	15 A
Continuous Base Current	7 A
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	115 W
Operating Case Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Lead Temperature 0.8mm from Case for 10 Seconds	235°C

NOTES: 1. This value applies when the base-emitter resistance $R_{BE} = 100\ \Omega$.

2. Derate linearly to 200°C case temperature at the rate of 0.66 W/deg.

*Indicates JEDEC registered data

TYPE 2N3055
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 4	60		V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $R_{BE} = 100\ \Omega$	70		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		0.7	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 100$ V, $V_{BE} = -1.5$ V		5	mA
		$V_{CE} = 100$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$		30	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 7$ V, $I_C = 0$		5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 3 and 4	20	70	
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 3 and 4	5		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 4$ A, See Notes 3 and 4		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 400$ mA, $I_C = 4$ A, See Notes 3 and 4		1.1	V
		$I_B = 3.3$ A, $I_C = 10$ A, See Notes 3 and 4		8	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	15	60	
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	$V_{CE} = 4$ V, $I_C = 1$ A, See Note 5	10		kHz

NOTES: 3. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

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

5. f_{hfe} is the frequency at which the magnitude of the small-signal forward current transfer ratio is 0.707 of its low-frequency value. For this device, the reference measurement is made at 1 kHz.

*Indicates JEDEC registered data

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.52	deg/W

2N3418, 2N3419, 2N3420, 2N3421
NPN EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

REVISED JUNE 1975

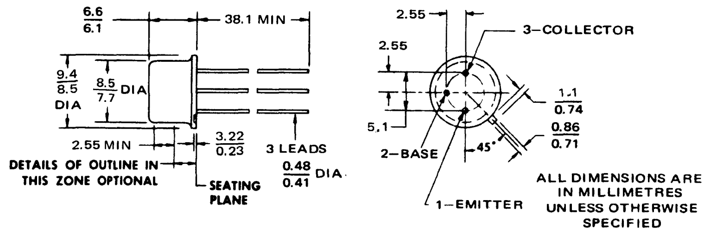
High-Frequency Medium-Power Transistors
Formerly TIX3033/34/35/36

- ✱ **High-Power Dissipation in TO-5 Package: 15 watts at $T_C = 100°C$**
- ✱ **Low-Leakage Current: 0.5 μa at max voltage**
- ✱ **Low-Saturation Voltage: $V_{CE(sat)} = 0.25$ v max at $I_C = 1$ a**
- ✱ **High f_T: 40 Mc min at 10 v, 100 ma**

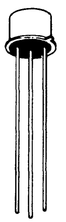
mechanical data

These transistors are in precision welded, hermetically sealed enclosures. Extreme cleanliness during the assembly process prevents sealed-in contamination. The approximate unit weight is 1.8 grams.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3418 2N3420	2N3419 2N3421
Collector-Base Voltage	85 v	125 v
Collector-Emitter Voltage (See Note 1)	60 v	80 v
Emitter-Base Voltage	← 8 v →	
Collector Current, Continuous	← 3 a →	
Collector Current, Peak (See Note 2)	← 5 a →	
Base Current	← 1 a →	
Safe Operating Region	See Figures 8 and 9	
Total Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 15 w →	
Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 1 w →	
Operating Case Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Lead Temperature 1.60mm from Case for 10 Seconds	← 230°C →	

NOTES:

1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for PW ≤ 1 msec, Duty Cycle ≤ 50%.
3. Derate linearly to 200°C case temperature at the rate of 0.15 w/C°.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mw/C°.

*Indicates JEDEC registered data.

2N3418, 2N3419, 2N3420, 2N3421
NPN EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3418		2N3419		2N3420		2N3421		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 50$ ma, $I_B = 0$, See Note 5	60		80		60		80		v
I_{CEX}	Collector Cutoff Current	$V_{CE} = 80$ v, $V_{BE} = -0.5$ v		0.5				0.5			μa
		$V_{CE} = 120$ v, $V_{BE} = -0.5$ v				0.5				0.5	
		$V_{CE} = 80$ v, $V_{BE} = -0.5$ v, $T_C = 150°C$		50				50			μa
		$V_{CE} = 120$ v, $V_{BE} = -0.5$ v, $T_C = 150°C$				50				50	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 6$ v, $I_C = 0$		500		500		500		500	na
		$V_{EB} = 8$ v, $I_C = 0$		10		10		10		10	μa
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ v, $I_C = 100$ ma, See Notes 5 and 6	20		20		40		40		
		$V_{CE} = 2$ v, $I_C = 1$ a, See Notes 5 and 6	20	60	20	60	40	120	40	120	
		$V_{CE} = 2$ v, $I_C = 2$ a, See Notes 5 and 6	15		15		30		30		
		$V_{CE} = 5$ v, $I_C = 5$ a, See Notes 5 and 6	10		10		15		15		
		$V_{CE} = 2$ v, $I_C = 1$ a, $T_C = -55°C$ See Notes 5 and 6	10		10		10		10		
V_{BE}	Base-Emitter Voltage	$I_B = 100$ ma, $I_C = 1$ a, See Notes 5 and 6	0.6	1.2	0.6	1.2	0.6	1.2	0.6	1.2	v
		$I_B = 200$ ma, $I_C = 2$ a, See Notes 5 and 6	0.7	1.4	0.7	1.4	0.7	1.4	0.7	1.4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ ma, $I_C = 1$ a, See Notes 5 and 6		0.25		0.25		0.25		0.25	v
		$I_B = 200$ ma, $I_C = 2$ a, See Notes 5 and 6		0.5		0.5		0.5		0.5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ v, $I_C = 100$ ma, f = 20 Mc	2		2		2		2		
C_{ob}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ v, $I_E = 0$, f = 1 Mc		150		150		150		150	pf

NOTES:

5. These parameters must be measured using pulse techniques. PW = 300 μsec, Duty Cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts located 0.25 in. from the header of the transistor. Voltage-sensing contacts are separate from current-carrying contacts.

*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TYP	MAX	UNIT
t_{on}	Turn-On Time	$I_C = 1$ a, $I_{B(1)} = 100$ ma, $I_{B(2)} = -100$ ma, $V_{BE(off)} = -3.7$ v, $R_L = 20\ \Omega$, See Figure 10	165	300	nsec
t_{off}	Turn-Off Time		540	1200	
t_{on}	Turn-On Time	$I_C = 2$ a, $I_{B(1)} = 200$ ma, $I_{B(2)} = -200$ ma, $V_{BE(off)} = -4.7$ v, $R_L = 20\ \Omega$, See Figure 10	200		
t_{off}	Turn-Off Time		350		

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data (typical values excluded).

2N3418, 2N3419, 2N3420, 2N3421
NPN EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

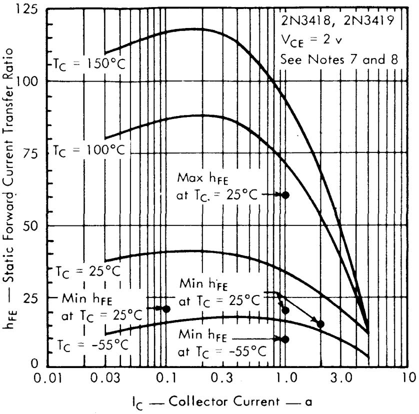


FIGURE 1

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

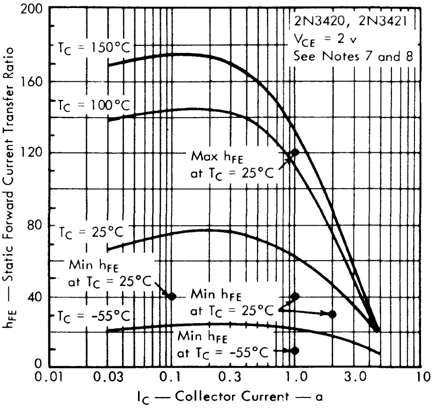


FIGURE 2

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

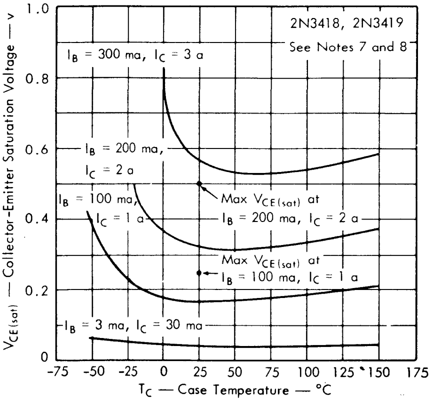


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

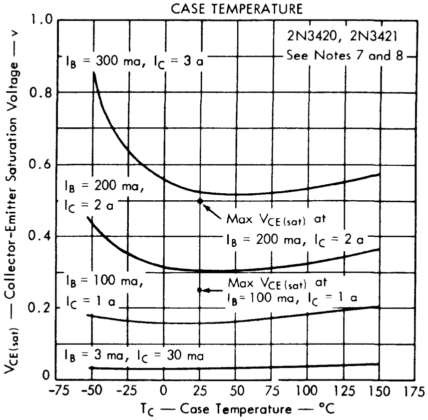


FIGURE 4

NOTES:

7. These parameters were measured using pulse techniques. PW = 300 μsec. Duty Cycle ≤ 2%.

8. Separate voltage-sensing and current-carrying contacts were used.

2N3418, 2N3419, 2N3420, 2N3421
NPN EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

TYPICAL CHARACTERISTICS

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

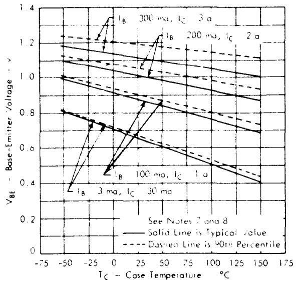


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

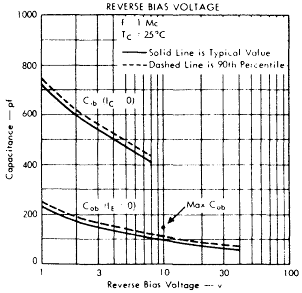


FIGURE 6

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

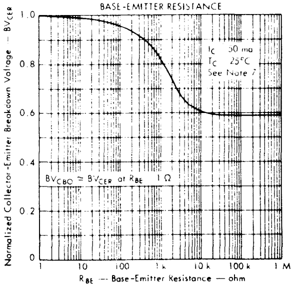


FIGURE 7

MAXIMUM SAFE OPERATING REGION

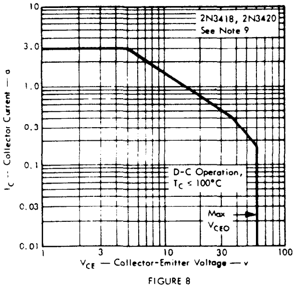


FIGURE 8

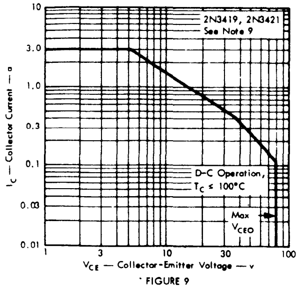
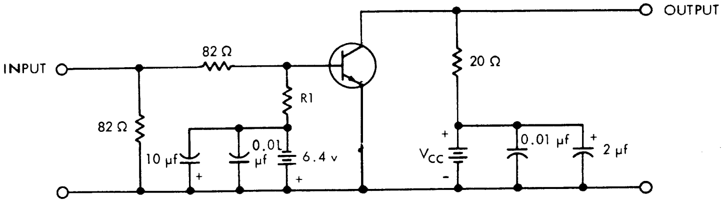


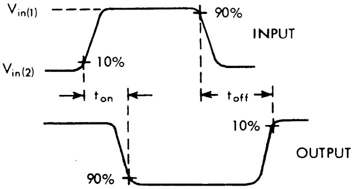
FIGURE 9

NOTE 9: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base voltage rating is not exceeded.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

Nominal I_C	R1	V_{CC}	$V_{in(1)}$	$V_{in(2)}$
1 A	82 Ω	20.3 v	+16.0 v	-1.0 v
2 A	41 Ω	40.5 v	+32.0 v	-1.3 v

CIRCUIT CONDITIONS

FIGURE 10

NOTES:

a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ nsec, $t_f \leq 15$ nsec, $Z_{out} = 50$ Ω, PW = 2 μsec, Duty Cycle ≤ 2%.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ nsec, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pf
c. Resistors must be non-inductive types.

2N3418, 2N3419, 2N3420, 2N3421
NPN EPITAXIAL PLANAR SILICON MEDIUM-POWER TRANSISTORS

THERMAL INFORMATION

CASE TEMPERATURE
and
FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVES

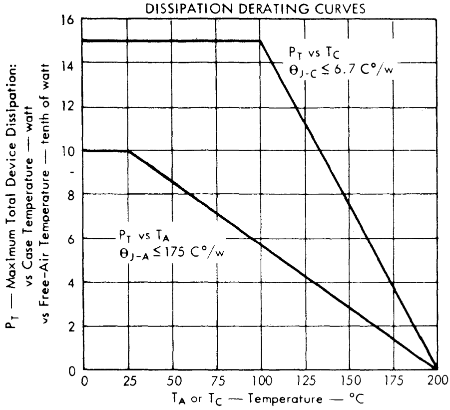


FIGURE 11

PEAK-POWER COEFFICIENT CURVE

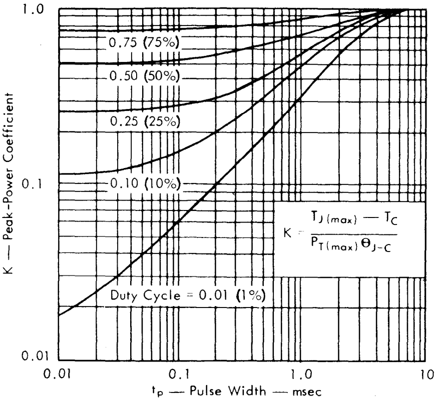


FIGURE 12

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		w
$P_{T(max)}$	Peak Power Dissipation		w
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	175	C°/w
θ_{J-C}	Junction-to-Case Thermal Resistance	6.67	C°/w
θ_{C-A}	Case-to-Free-Air Thermal Resistance	168.33	C°/w
θ_{C-HS}	Case-to-Heat Sink Thermal Resistance		C°/w
θ_{HS-A}	Heat-Sink-to-Free-Air Thermal Resistance		C°/w
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 12	
t_p	Pulse Width		msec
t_x	Pulse Period		msec
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}} \quad \text{for } 100°C \leq T_C \leq 200°C, \text{ as in Figure 11}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J-A}} \quad \text{for } 25°C \leq T_A \leq 200°C, \text{ as in Figure 11}$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C-A} + K\,\theta_{J-C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C-HS} + \theta_{HS-A} = 7$ C°/w (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$
$T_A = 50°C$
$d = 10\%\ (0.1)$
$t_p = 0.1$ msec

Solution:

From Figure 12, Peak-Power Coefficient
K = 0.155 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.155\,(6.67)} = 86 \text{ w}$$

2N3583, 2N3584, 2N3585, 2N4240
NPN SILICON POWER TRANSISTORS

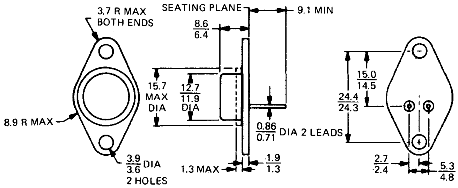
REVISED JUNE 1975

- Min $V_{(BR)CEO}$ of 300 V (2N3585, 2N4240)
- Typ $V_{CE(sat)}$ of 0.25 V at I_B = 125 mA, I_C = 1 A
- Typ t_{on} of 0.2 μs, at 750 mA, 200 V (2N4240)
- Min f_T of 15 MHz at 10 V, 200 mA (2N4240)
- 35 W at 25°C Case Temperature

HIGH-VOLTAGE POWER TRANSISTORS DESIGNED FOR INDUSTRIAL AND MILITARY APPLICATIONS

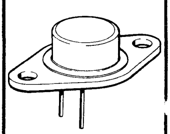
*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES

ALL JEDEC TO-66 DIMENSIONS AND NOTES ARE APPLICABLE



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

<table>
<tr><th></th><th>2N3583</th><th>2N3584</th><th>2N3585</th><th>2N4240</th></tr>
<tr><td>Collector-Base Voltage</td><td>250 V*</td><td>330 V*</td><td>440 V*</td><td>440 V*</td></tr>
<tr><td>Collector-Emitter Voltage (See Note 1)</td><td>175 V*</td><td>250 V*</td><td>300 V*</td><td>300 V*</td></tr>
<tr><td>Emitter-Base Voltage</td><td colspan="4">6 V*</td></tr>
<tr><td>Continuous Collector Current</td><td>1 A*</td><td>2 A*</td><td>2 A*</td><td>2 A*</td></tr>
<tr><td>Peak Collector Current (See Note 2)</td><td>5 A*</td><td>5 A</td><td>5 A</td><td>5 A</td></tr>
<tr><td>Continuous Base Current</td><td colspan="4">1 A*</td></tr>
<tr><td>Safe Operating Area at 100°C Case Temperature</td><td colspan="4">See Figure 5</td></tr>
<tr><td>Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)</td><td colspan="4">35 W*</td></tr>
<tr><td>Continuous Device Dissipation at 100°C Case Temperature (See Note 3)</td><td colspan="4">20 W*</td></tr>
<tr><td>Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)</td><td colspan="4">2 W</td></tr>
<tr><td>Operating Collector Junction Temperature Range</td><td colspan="4">−65°C to 200°C*</td></tr>
<tr><td>Storage Temperature Range</td><td colspan="4">−65°C to 200°C*</td></tr>
<tr><td>Terminal Temperature 0.794mm from Case for 10 Seconds</td><td colspan="4">235°C*</td></tr>
</table>

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.2 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

TEXAS INSTRUMENTS

2N3583, 2N3584, 2N3585, 2N4240
NPN SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3583		2N3584		2N3585		2N4240		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 5	175		250		300		300		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 150 V, I_B = 0		10							mA
I_{CEV}	Collector Cutoff Current	V_{CE} = 225 V, V_{BE} = −1.5 V		1							mA
		V_{CE} = 300 V, V_{BE} = −1.5 V				1					
		V_{CE} = 400 V, V_{BE} = −1.5 V						1		2	
		V_{CE} = 225 V, V_{BE} = −1.5 V, T_C = 150°C		3							
		V_{CE} = 300 V, V_{BE} = −1.5 V, T_C = 150°C				3		3		5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 6 V, I_C = 0		5†		0.5		0.5		0.5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, See Notes 5 and 6	40	200							
		V_{CE} = 10 V, I_C = 1 A	10								
		V_{CE} = 2 V, I_C = 1 A			8	140	8	140			
		V_{CE} = 2 V, I_C = 0.75 A							6	240	
V_{BE}	Base-Emitter Voltage	I_B = 75 mA, I_C = 0.75 A, See Notes 5 and 6								1.8	V
		I_B = 0.1 A, I_C = 1 A				1.4		1.4			
		V_{CE} = 10 V, I_C = 1 A		1.4							
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 75 mA, I_C = 0.75 A, See Notes 5 and 6								1	V
		I_B = 125 mA, I_C = 1 A		5		0.75		0.75			
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 30 V, I_C = 0.1 A, f = 1 kHz	25	350							
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 5 MHz	2		2		2		3		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

*JEDEC registered data

†Proposed addition to JEDEC registered data

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	

2N3583, 2N3584, 2N3585, 2N4240
NPN SILICON POWER TRANSISTORS

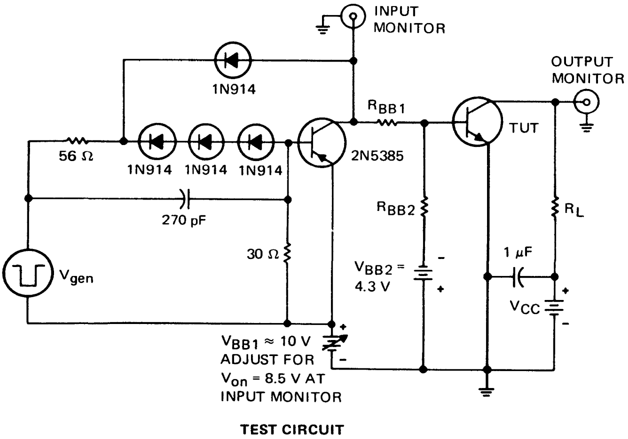
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS‡	2N3584 2N3585		2N4240		UNIT
			TYP	MAX	TYP	MAX	
t_r	Rise Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA, $V_{BE(off)}$ = −4.3 V, R_L = 30 Ω, See Figure 1	1	3			μs
t_s	Storage Time		1.5	4			
t_f	Fall Time		1	3			
t_{on}	Turn-On Time		1.3	3			
t_{off}	Turn-Off Time		2.5	7			
t_r	Rise Time	I_C = 0.75 A, $I_{B(1)}$ = 75 mA, $I_{B(2)}$ = −75 mA, $V_{BE(off)}$ = −4.3 V, R_L = 267 Ω, See Figure 1			0.15	0.5	μs
t_s	Storage Time				2.5	6	
t_f	Fall Time				0.5	3	
t_{on}	Turn-On Time				0.2	0.5	
t_{off}	Turn-Off Time				3	9	

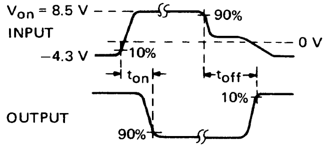
‡Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

CIRCUIT CONDITIONS

NOMINAL I_C	R_{BB1}	R_{BB2}	R_L	V_{CC}
1 A	37 Ω	53 Ω	30 Ω	30 V
0.75 A	50 Ω	70 Ω	267 Ω	200 V

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TYPICAL CHARACTERISTICS

2N3583
STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

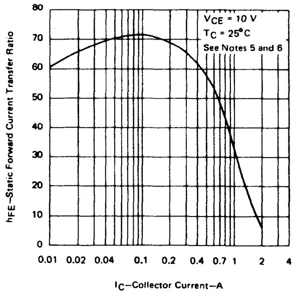


FIGURE 2

BASE-EMITTER VOLTAGE vs COLLECTOR CURRENT

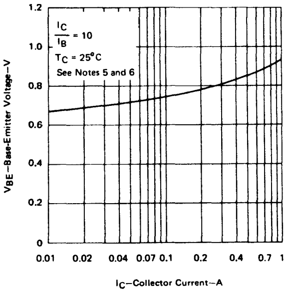


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE vs COLLECTOR CURRENT

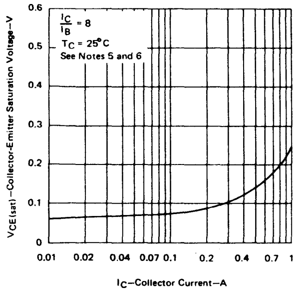


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREA

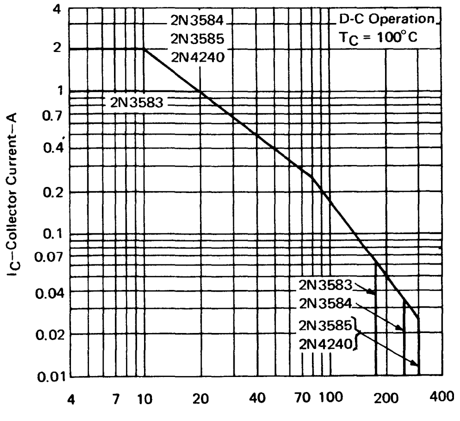


FIGURE 5

THERMAL INFORMATION

DISSIPATION DERATING CURVE

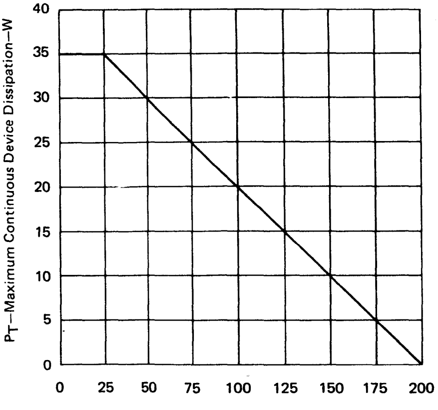


FIGURE 6

TYPES 2N3713, 2N3714, 2N3715, 2N3716
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

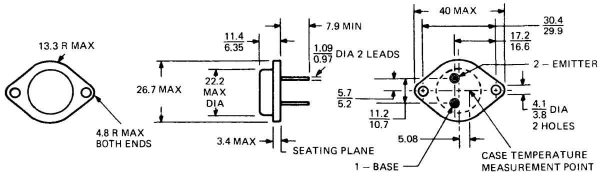
REVISED JULY 1975

FOR POWER-AMPLIFIER AND SWITCHING APPLICATIONS

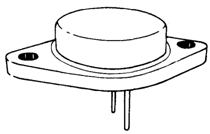
- **150 W at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_{hfe} of 30 kHz**
- **Min f_T of 4 MHz**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3713	2N3714	2N3715	2N3716
*Collector-Base Voltage	80 V	100 V	80 V	100 V
*Collector-Emitter Voltage (See Note 1)	60 V	80 V	60 V	80 V
*Emitter-Base Voltage	← 7 V →			
*Continuous Collector Current	← 10 A →			
Peak Collector Current (See Note 2)	← 15 A →			
*Continuous Base Current	← 4 A →			
*Safe Operating Region at (or below) 25°C Case Temperature	See Figures 8 and 9			
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 150 W →			
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →			
*Operating Collector Junction Temperature Range	← –65°C to 200°C →			
*Storage Temperature Range	← –65°C to 200°C →			
Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C →			

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for t_p = 0.3 ms, duty cycle ≤ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.855 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3713		2N3714		2N3715		2N3716		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 5	60		80		60		80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V, I_B = 0		0.7				0.7			mA
		V_{CE} = 40 V, I_B = 0				0.7				0.7	
I_{CEV}	Collector Cutoff Current	V_{CE} = 80 V, V_{BE} = −1.5 V		1				1			mA
		V_{CE} = 100 V, V_{BE} = −1.5 V				1				1	
		V_{CE} = 60 V, V_{BE} = −1.5 V, T_C = 150°C		10				10			mA
		V_{CE} = 80 V, V_{BE} = −1.5 V, T_C = 150°C				10				10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 7 V, I_C = 0		1		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V, I_C = 1 A, See Notes 5 and 6	25	75	25	75	50	150	50	150	
		V_{CE} = 2 V, I_C = 3 A, See Notes 5 and 6	15		15		30		30		
		V_{CE} = 4 V, I_C = 10 A, See Notes 5 and 6	5		5		5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 2 V, I_C = 5 A, See Notes 5 and 6		2		2		1.8		1.8	V
		V_{CE} = 4 V, I_C = 10 A, See Notes 5 and 6		4		4		4		4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.5 A, I_C = 5 A, See Notes 5 and 6		1		1		0.8		0.8	V
		I_B = 2 A, I_C = 10 A, See Notes 5 and 6		4		4		4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 kHz	25	250	25	250	25	250	25	250	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 MHz	4		4		4		4		
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	V_{CE} = 10 V, I_C = 0.5 A	30		30		30		30		kHz
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V, I_E = 0, f = 100 kHz		250		250		250		250	pF

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1.17	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	

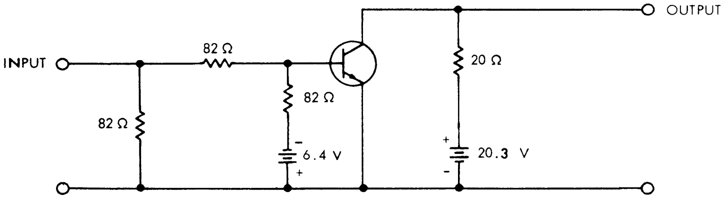
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

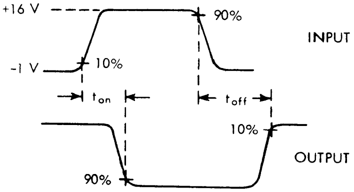
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 1$ A, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA, $V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	450	ns
t_{off}	Turn-Off Time		350	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

2N3713, 2N3714
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

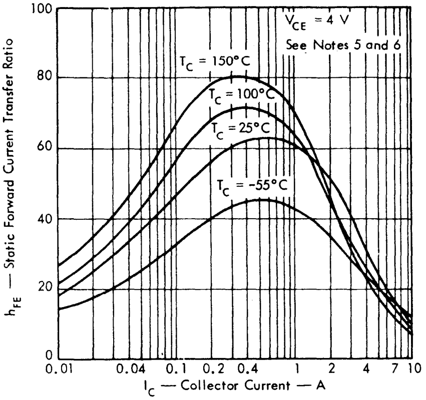


FIGURE 2

2N3715, 2N3716
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

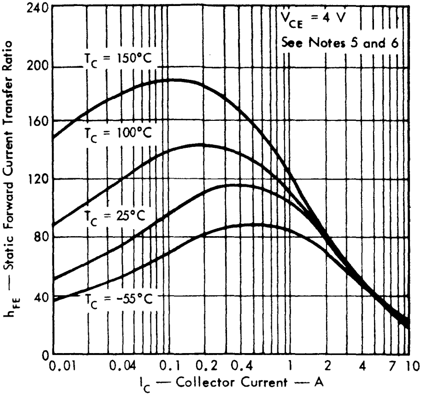


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

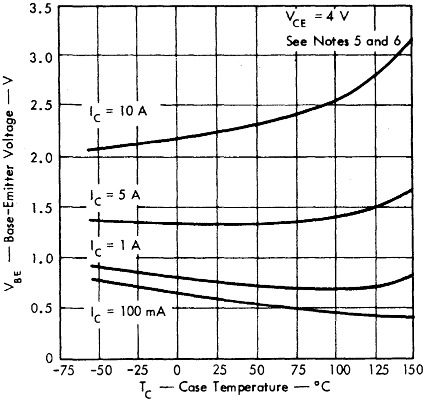


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

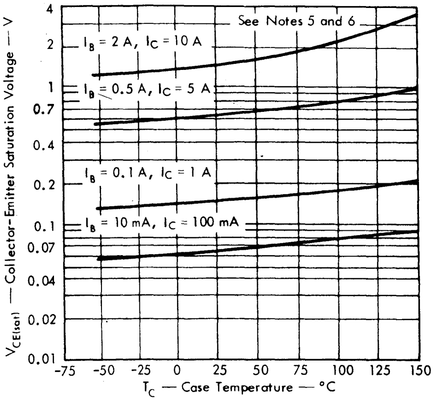


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

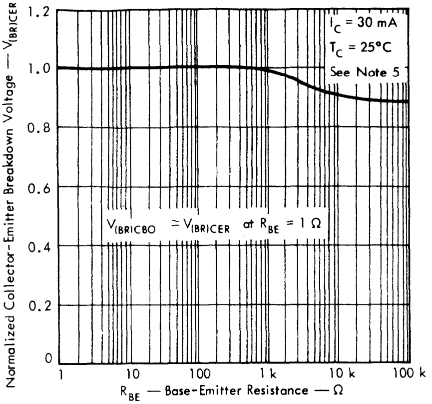


FIGURE 6

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

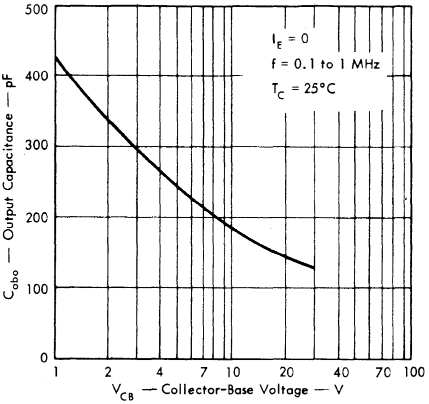


FIGURE 7

MAXIMUM SAFE OPERATING REGIONS

2N3713, 2N3715

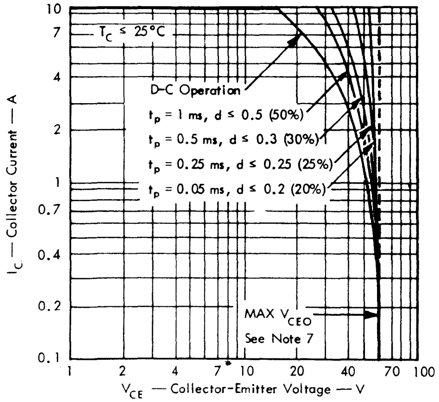


FIGURE 8

2N3714, 2N3716

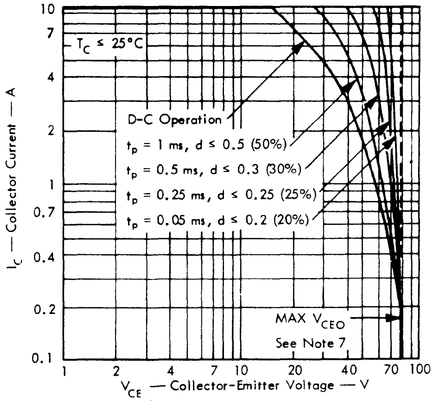


FIGURE 9

NOTES: 5. This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

7. Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL INFORMATION

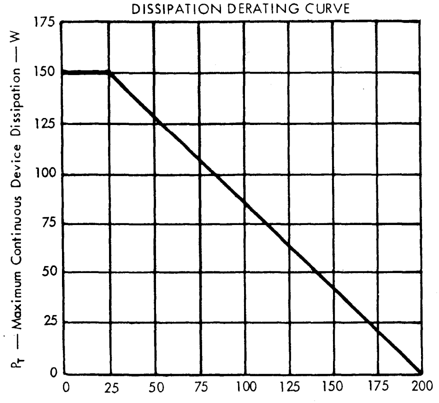


FIGURE 10

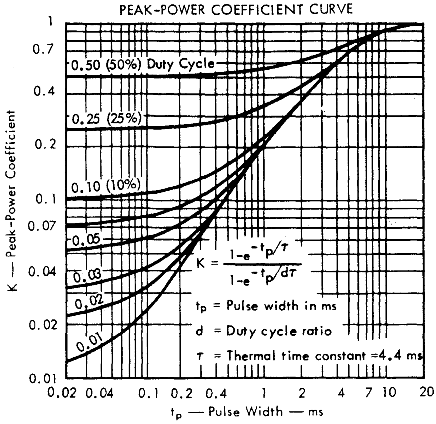


FIGURE 11

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.17	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	42.5	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 11	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 25\,°\text{C} \leq T_C \leq 200°\text{C, as in figure 10.}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \text{ for } 25°\text{C} \leq T_A \leq 200°\text{C}$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \text{ for } 25\,°\text{C} \leq T_C \leq 200°\text{C}$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\theta_{J\text{-}C}} \text{ for } 25°\text{C} \leq T_A \leq 200°\text{C}$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.25$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°$C

$T_A = 50°$C

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From figure 11, Peak-Power Coefficient K = 0.11 and by use of equation No. 3

$$P_{T(max)} \doteq \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.25) + 0.11(1.17)} = 424\text{ W}$$

TYPES 2N3771, 2N3772
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

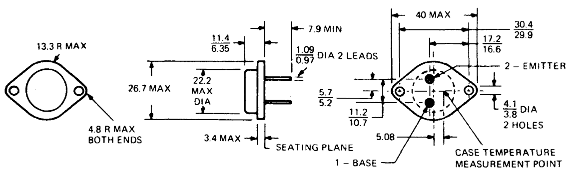
REVISED AUGUST 1975

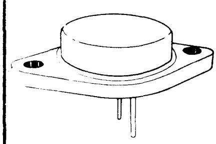
FOR UNTUNED POWER-AMPLIFIER APPLICATIONS

150 W at 25°C Case Temperature
30-A Rated Continuous Collector Current (2N3771)
20-A Rated Continuous Collector Current (2N3772)

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3771	2N3772
Collector-Base Voltage	50 V*	100 V*
Collector-Emitter Voltage (See Note 1)	50 V*	100 V† 80 V*
Collector-Emitter Voltage (See Note 2)	40 V*	60 V*
Emitter-Base Voltage	5 V*	7 V*
Continuous Collector Current	30 A*	20 A*
Peak Collector Current (See Note 3)	← 30 A* →	
Continuous Base Current	7.5 A*	5 A*
Peak Base Current	← 15 A* →	
Safe Operating Region	See Figure 1*	
Continuous Dissipation at (or below) 25°C Case Temperature (See Note 4)	← 150 W* →	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C* →	

NOTES:
1. These values apply when the base-emitter voltage $V_{BE} = -1.5$ V.
2. These values apply when the base-emitter diode is open-circuited.
3. This value applies for a nonrepetitive pulse of any duration for the 2N3771, or of 500-ms maximum duration for the 2N3772.
4. Derate linearly to 200°C case temperature at the rate of 0.855 W/deg see figure 2.

*Indicates JEDEC registered data

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3771		2N3772		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 5	40		60		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$		10			mA
		$V_{CE} = 50$ V, $I_B = 0$				10	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 50$ V, $I_E = 0$		2			mA
		$V_{CB} = 100$ V, $I_E = 0$				5	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 50$ V, $V_{BE} = -1.5$ V		2			mA
		$V_{CE} = 100$ V, $V_{BE} = -1.5$ V				5	
		$V_{CE} = 30$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$		10		10	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		5			mA
		$V_{EB} = 7$ V, $I_C = 0$				5	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6			15	60	
		$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 5 and 6	15	60			
		$V_{CE} = 4$ V, $I_C = 20$ A, See Notes 5 and 6			5		
		$V_{CE} = 4$ V, $I_C = 30$ A, See Notes 5 and 6	5				
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6				2.2	V
		$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 5 and 6		2.7			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 1$ A, $I_C = 10$ A, See Notes 5 and 6				1.4	V
		$I_B = 1.5$ A, $I_C = 15$ A, See Notes 5 and 6		2			
		$I_B = 4$ A, $I_C = 20$ A, See Notes 5 and 6				4	
		$I_B = 6$ A, $I_C = 30$ A, See Notes 5 and 6		4			
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 50$ kHz	4		4		

NOTES: 5. These parameters must be measured using pulse techniques: $t_p = 300$ μs, duty cycle $\leq 2\%$.

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

*Indicates JEDEC registered data

MAXIMUM SAFE OPERATING REGION

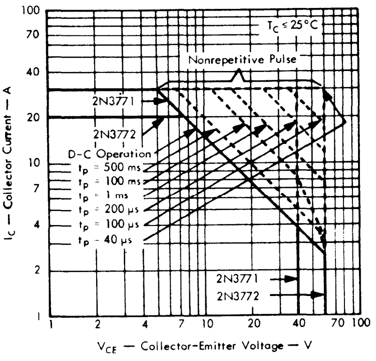


FIGURE 1

THERMAL INFORMATION

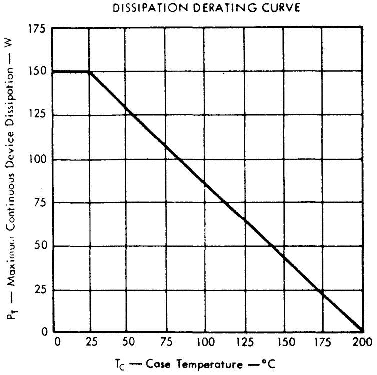


FIGURE 2

TYPES 2N3789, 2N3790, 2N3791, 2N3792
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

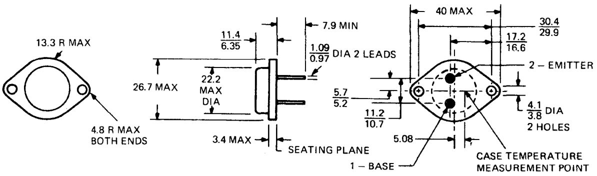
REVISED JULY 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N3713 THRU 2N3716

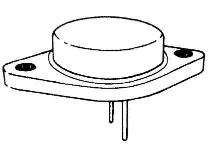
- **150 Watts at 25°C Case Temperature**
- **10 A Rated Collector Current**
- **Min f_T of 4 MHz at 10 V, 500 mA**
- **Min f_{hfe} of 30 kHz at 10 V, 500 mA**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3789 2N3791	2N3790 2N3792
*Collector-Base Voltage	-60 V	-80 V
*Collector-Emitter Voltage (See Note 1)	-60 V	-80 V
*Emitter-Base Voltage	← -7 V →	
*Continuous Collector Current	← -10 A →	
Peak Collector Current (See Note 2)	← -15 A →	
*Continuous Base Current	← -4 A →	
*Safe Operating Region at (or below) 25°C Case Temperature	See Figures 6 and 7	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 150 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →	
*Operating Collector Junction Temperature Range	-65°C to 200°C	
*Storage Temperature Range	-65°C to 200°C	
Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C →	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p = 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.855 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3789		2N3790		2N3791		2N3792		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = -200 mA, I_B = 0, See Note 5	-60		-80		-60		-80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = -30 V, I_B = 0		-10				-10			mA
		V_{CE} = -40 V, I_B = 0				-10				-10	
I_{CEV}	Collector Cutoff Current	V_{CE} = -60 V, V_{BE} = 1.5 V		-1				-1			mA
		V_{CE} = -80 V, V_{BE} = 1.5 V				-1				-1	
		V_{CE} = -60 V, V_{BE} = 1.5 V, T_C = 150°C		-5				-5			
		V_{CE} = -80 V, V_{BE} = 1.5 V, T_C = 150°C				-5				-5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = -7 V, I_C = 0		-5		-5		-5		-5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = -2 V, I_C = -1 A, See Notes 5 and 6	25	90	25	90	50	180	50	180	
		V_{CE} = -2 V, I_C = -3 A, See Notes 5 and 6	15		15		30		30		
		V_{CE} = -4 V, I_C = -10 A, See Notes 5 and 6	4		4		4		4		
V_{BE}	Base-Emitter Voltage	V_{CE} = -2 V, I_C = -5 A, See Notes 5 and 6		-2		-2		-1.8		-1.8	V
		V_{CE} = -4 V, I_C = -10 A, See Notes 5 and 6		-4		-4		-4		-4	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = -0.4 A, I_C = -4 A, See Notes 5 and 6		-1		-1					V
		I_B = -0.5 A, I_C = -5 A, See Notes 5 and 6						-1		-1	
		I_B = -2 A, I_C = -10 A, See Notes 5 and 6		-4		-4		-4		-4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = -10 V, I_C = -0.5 A, f = 1 kHz	25	250	25	250	25	250	25	250	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = -10 V, I_C = -0.5 A, f = 1 MHz	4		4		4		4		
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	V_{CE} = -10 V, I_C = -0.5 A, See Note 7	30		30		30		30		kHz
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = -10 V, I_E = 0, f = 100 kHz		500		500		500		500	pF

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

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

7. f_{hfe} is the frequency at which the magnitude of the small-signal forward current transfer ratio is 0.707 of its low-frequency value. For this device, the reference measurement is made at 1 kHz.

*Indicates JEDEC registered data

thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	1.17	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	

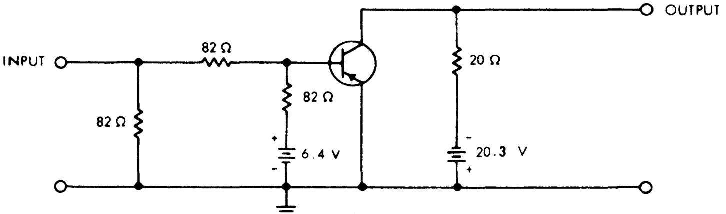
TYPES 2N3789, 2N3790, 2N3791, 2N3792
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

switching characteristics at 25°C case temperature

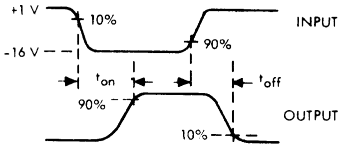
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -100$ mA, $I_{B(2)} = 100$ mA,	0.35	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, **See Figure 1**	0.8	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

2N3789, 2N3790
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

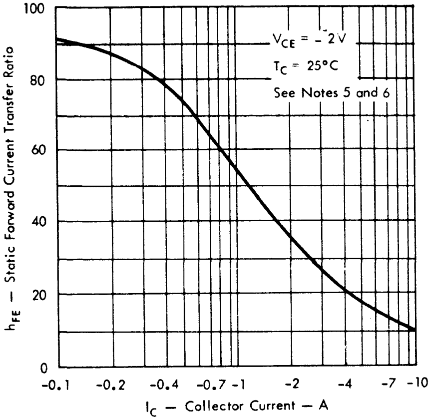


FIGURE 2

2N3791, 2N3792
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

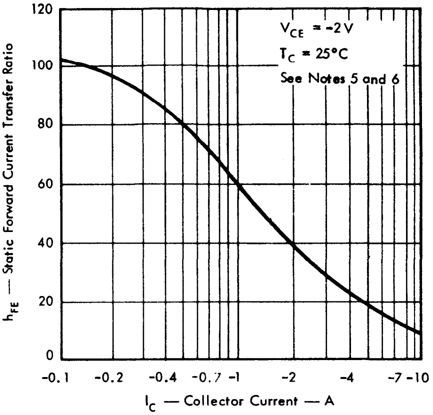


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

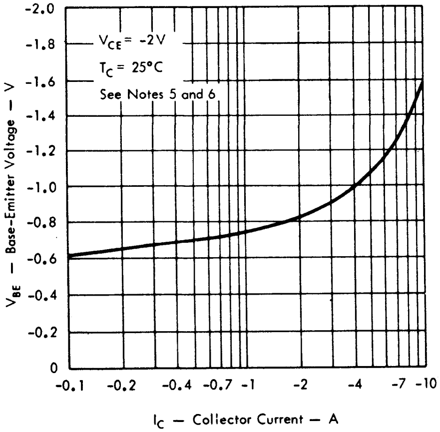


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

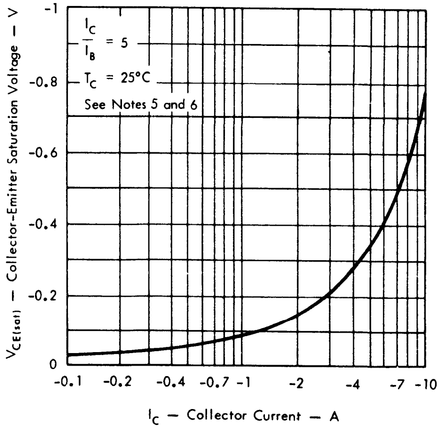


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$ 2%.

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

MAXIMUM SAFE OPERATING REGIONS

2N3789, 2N3791

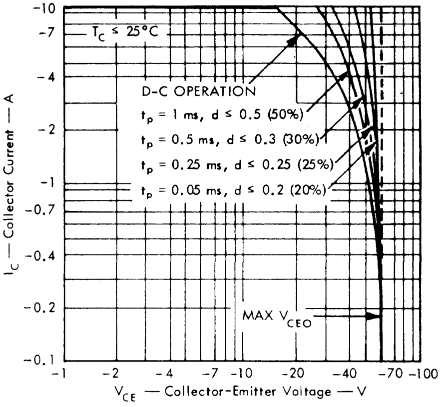


FIGURE 6

2N3790, 2N3792

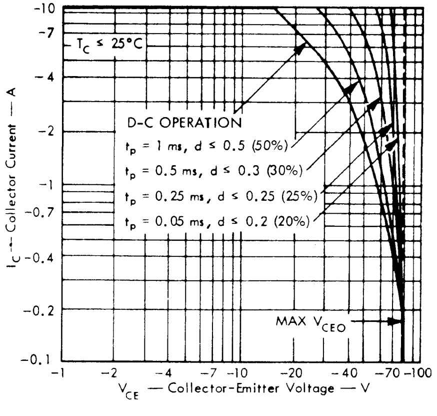


FIGURE 7

TYPES 2N3789, 2N3790, 2N3791, 2N3792
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

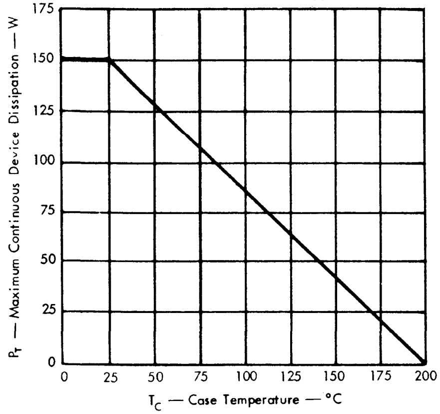


FIGURE 8

PEAK-POWER COEFFICIENT CURVE

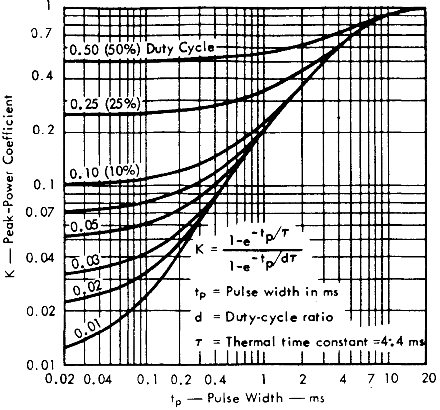


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1.17	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	42.5	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 25\,°C \leq T_C \leq 200°C, \text{ as in Figure 8.}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \text{ for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \text{ for } 25°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\theta_{J\text{-}C}} \text{ for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.25$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient

K = 0.11 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.25) + 0.11(1.17)} = 424 \text{ W}$$

2N3846, 2N3847
NPN TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

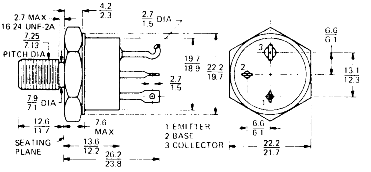
REVISED JUNE 1975

FOR POWER-AMPLIFIER APPLICATIONS

- **150 Watts at 100°C Case Temperature**
- **200 V, 300 V Rated Collector-Emitter Voltages**
- **Max $V_{CE(sat)}$ of 0.75 V at 10 A I_C**
- **Max Thermal Resistance of 0.5 deg/W**
- **Min f_T of 10 MHz at 10 V, 1 A**

*mechanical data

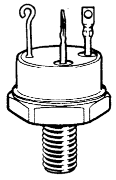
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD

ALL DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N3846	2N3847
Collector-Base Voltage	300 V	400 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V
Emitter-Base Voltage	← 10 V →	
Continuous Collector Current	← 20 A →	
Continuous Base Current	← 10 A →	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 2)	← 150 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 4 W →	
Operating Case Temperature Range	−65°C to 175°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 260°C →	

NOTES: 1. These values apply when the base-emitter diode is open-circuited.

2. Derate linearly to 175°C case temperature at the rate of 2 W/deg.

3. Derate linearly to 175°C free-air temperature at the rate of 26.6 mW/deg.

*Indicates JEDEC registered data

2N3846, 2N3847
NPN TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3846		2N3847		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 4	200		300		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 200 V, I_B = 0		5			mA
		V_{CE} = 300 V, I_B = 0				5	
I_{CES}	Collector Cutoff Current	V_{CE} = 300 V, V_{BE} = 0		2			mA
		V_{CE} = 400 V, V_{BE} = 0				2	
		V_{CE} = 300 V, V_{BE} = 0, T_C = 150°C		10			
		V_{CE} = 400 V, V_{BE} = 0, T_C = 150°C				10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 10 V, I_C = 0		250		250	μA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 3 V, I_C = 5 A, See Notes 4 and 5	40	200	40	200	
		V_{CE} = 3 V, I_C = 10 A, See Notes 4 and 5	10	60	10	60	
		V_{CE} = 3 V, I_C = 10 A, T_C = −55°C, See Notes 4 and 5	10		10		
V_{BE}	Base-Emitter Voltage	V_{CE} = 3 V, I_C = 10 A, See Notes 4 and 5		1.2		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.6 A, I_C = 10 A, See Notes 4 and 5		0.75		0.75	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 5 A, f = 1 kHz	50	250	50	250	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 MHz	10		10		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V, I_E = 0, f = 1 MHz		750		750	pF

NOTES: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	0.5	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	37.5	

*Indicates JEDEC registered data

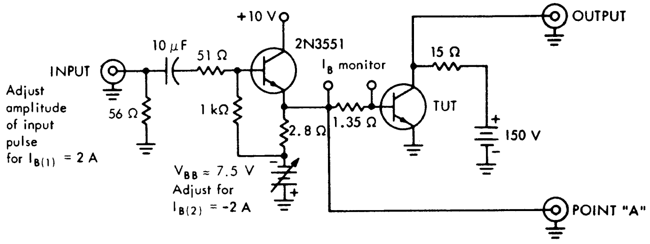
2N3846, 2N3847
NPN TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

*switching characteristics at 25°C case temperature

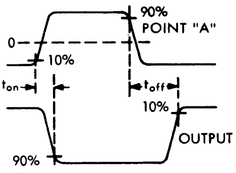
PARAMETER		TEST CONDITIONS†			MAX	UNIT
t_{on}	Turn-On Time	$I_C \simeq 10$ A,	$I_{B(1)} = 2$ A,	$I_{B(2)} = -2$ A,	4	µs
t_{off}	Turn-Off Time	$V_{BE(off)} \simeq -7.5$ V,	$R_L = 15\ \Omega$,	See Figure 1	7	

† Base-emitter voltage and collector current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The waveform at point "A" has the following characteristics: $t_r \leq 100$ ns, $t_f \leq 100$ ns, $t_p = 20$ µs, duty cycle $\leq 0.2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

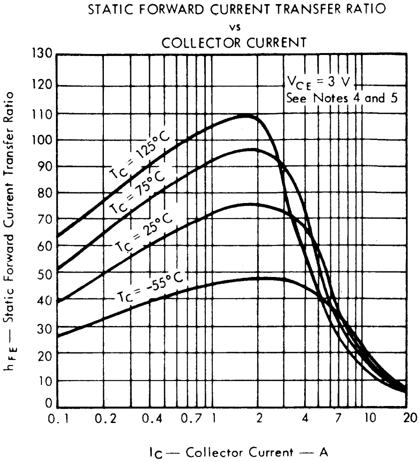


FIGURE 2

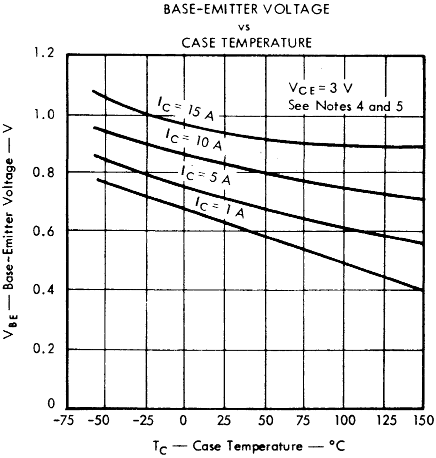


FIGURE 3

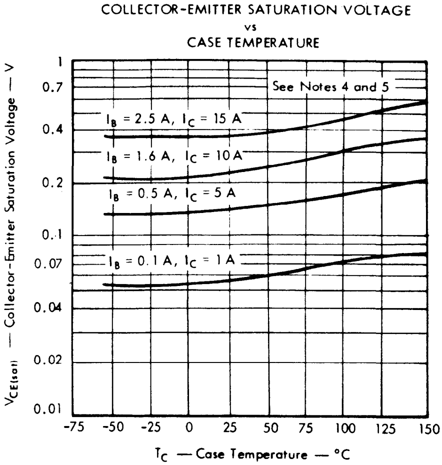


FIGURE 4

NOTES: 4. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.
5. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

2N3846, 2N3847
NPN TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

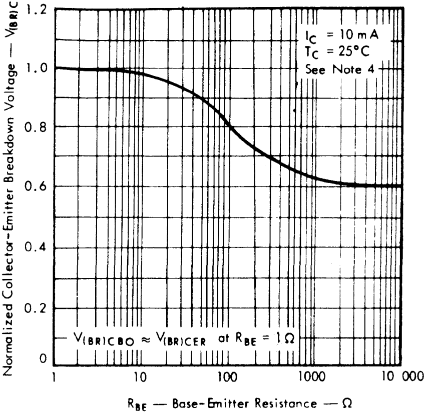


FIGURE 5

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

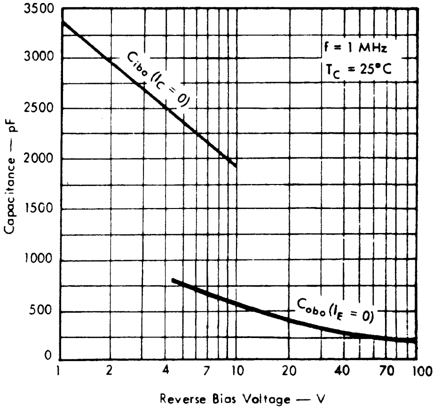


FIGURE 6

MAXIMUM SAFE OPERATING REGION

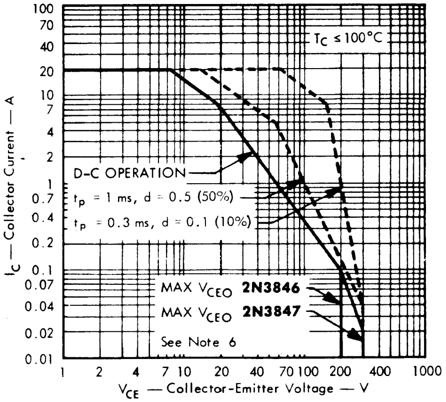


FIGURE 7

NOTES: 4. This parameter must be measured using pulse techniques: t_p = 300 μs, duty cycle ≤ 2%.

6. Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL INFORMATION

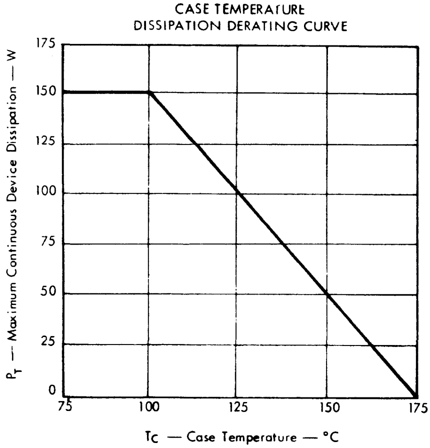


FIGURE 8

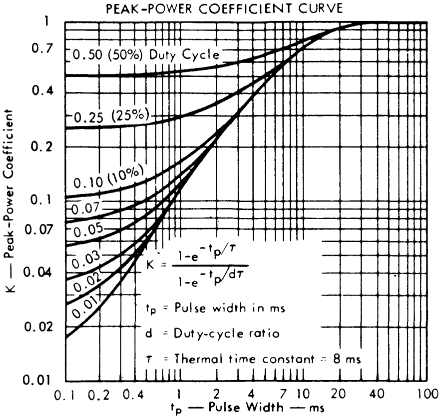


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	37.5	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	0.5	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	37	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 175	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 175	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 175°C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 175°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 175°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 175°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.5$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 175°C$
$T_A = 50°C$
$d = 10\%\ (0.1)$
$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient

K = 0.105 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{175 - 50}{0.1(2.5) + 0.105\,(0.5)} = 413\ \text{W}$$

2N3902
NPN SILICON POWER TRANSISTOR

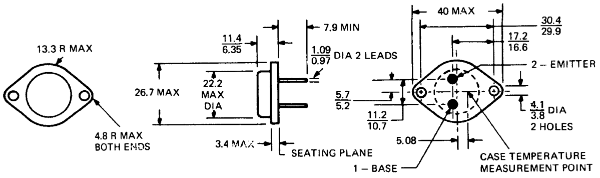
REVISED JULY 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND MILITARY APPLICATIONS

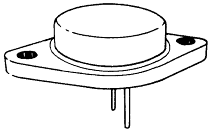
- 100 W at 75°C Case Temperature
- 400 V Collector-Emitter Off-State Voltage
- Min $V_{(BR)CEO}$ of 325 V
- Max t_{off} of 1.7 μs at $I_C = 1$ A
- Typ $V_{CE(sat)}$ of 0.25 V at $I_C = 2.5$ A
- Typ f_T of 5 MHz at 10 V, 0.2 A

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

*Collector-Emitter Voltage (See Note 1)	400 V
*Emitter-Base Voltage	5 V
*Continuous Collector Current	2.5 A
*Continuous Base Current	1 A
Safe Operating Area at (or below) 75°C Case Temperature	See Figure 6
*Continuous Device Dissipation at (or below) 75°C Case Temperature (See Note 2)	100 W
Continuous Device Dissipation at (or below 25°C Free-Air Temperature (See Note 3)	4 W
Unclamped Inductive Load Energy (See Note 4)	180 mJ
*Operating Collector Junction Temperature Range	−65°C to 150°C
*Storage Temperature Range	−65°C to 200°C
*Terminal Temperature 1.588mm from Case for 10 Seconds	300°C

NOTES:
1. This value applies only when the collector-emitter voltage is applied with the transistor in the off-state and the base-emitter diode is open-circuited or reverse-biased. In operation, the limitations of Figure 7 must be observed.
2. Derate linearly to 150°C case temperature at the rate of 1.33 W/°C.
3. Derate linearly to 150°C free-air temperature at the rate of 32 mW/°C.
4. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. L = 40 mH, $R_{BB2} = 3$ kΩ, $V_{BB2} = 1.5$ V, $R_S = 0.1$ Ω, $V_{CC} = 50$ V. Energy ≈ $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

2N3902
NPN SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 mA, I_B = 0, See Note 5	325			V
I_{CEO}	Collector Cutoff Current	V_{CE} = 400 V, I_B = 0			0.25	mA
I_{CEV}	Collector Cutoff Current	V_{CE} = 400 V, V_{BE} = −1.5 V			0.25	mA
		V_{CE} = 400 V, V_{BE} = −1.5 V, T_C = 125°C			0.5	mA
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, See Notes 5 and 6	30		90	
		V_{CE} = 5 V, I_C = 2.5 A, See Notes 5 and 6	10			
V_{BE}	Base-Emitter Voltage	I_B = 0.5 A, I_C = 2.5 A, See Notes 5 and 6		1	2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.1 A, I_C = 1 A, See Notes 5 and 6		0.2	0.8	V
		I_B = 0.5 A, I_C = 2.5 A, See Notes 5 and 6		0.25	2.5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.2 A, f = 1 MHz		5		
f_{hfe}	Small-Signal Common-Emitter Forward Current Transfer Ratio Cutoff Frequency	V_{CE} = 12 V, I_C = 0.2 A, See Note 7	40			kHz

NOTES:
5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.
7. f_{hfe} is the frequency at which the magnitude of the small-signal forward current transfer ratio is 0.707 of its low-frequency value. For this device, the reference measurement is made at 1 kHz.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	0.75	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	31.25	

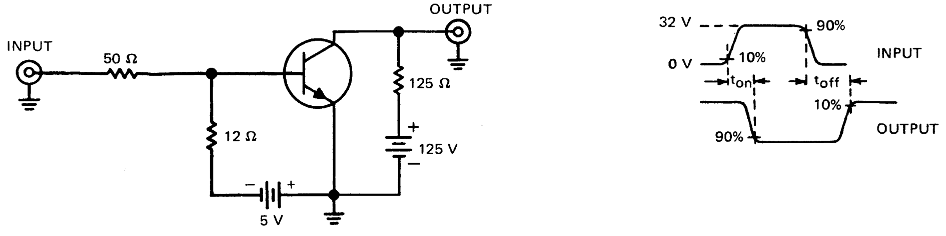
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_r	Rise Time	I_C = 1 A, $I_{B(1)}$ = 0.1 A, $I_{B(2)}$ = −0.1 A, $V_{BE(off)}$ = −5 V, R_L = 125 Ω, See Figure 1	0.8	μs
t_s	Storage Time		0.9	
t_f	Fall Time		0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $t_r \leqslant 20$ ns, $t_f \leqslant 20$ ns, $Z_{out} = 50\ \Omega$, $t_w = 5\ \mu s$, duty cycle ⩽ 5%.

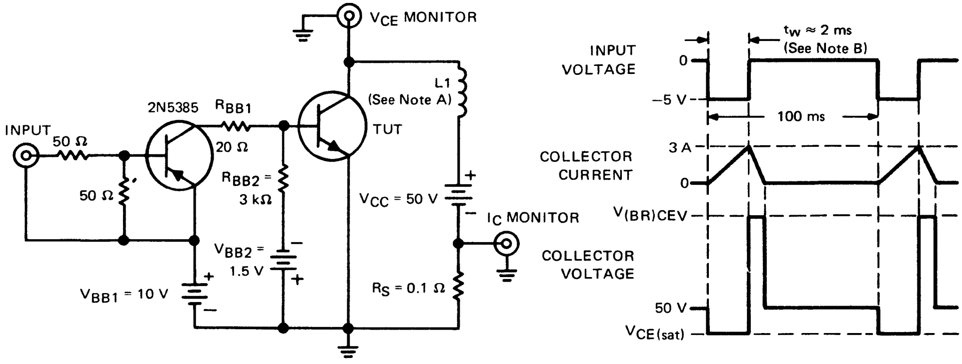
B. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 20$ ns, $R_{in} \geqslant 100\ k\Omega$, $C_{in} \leqslant 50$ pF.

C. Resistors must be noninductive types.

D. The d-c power supply may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTES: A. L1 is a 40-mH inductor.

B. Input pulse width is increased until $I_{CM} = 3$ A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

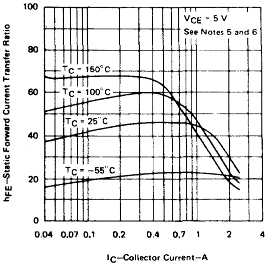


FIGURE 3

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

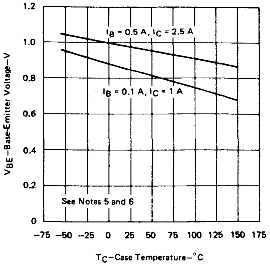


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

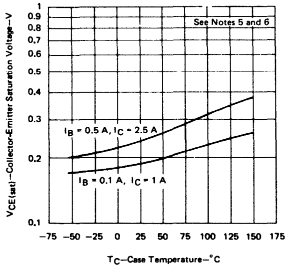


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle $\leqslant$ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREA

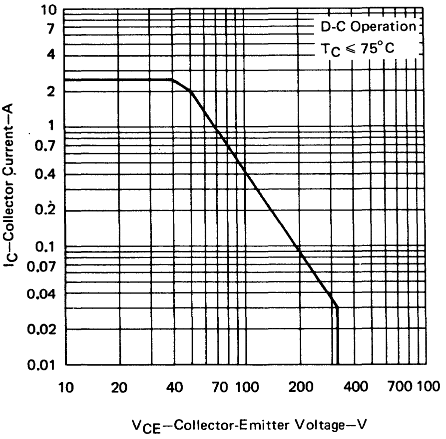


FIGURE 6

THERMAL INFORMATION

DISSIPATION DERATING CURVE

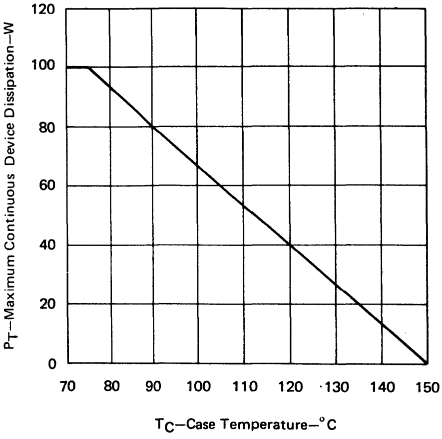


FIGURE 7

TYPES 2N3996, 2N3997, 2N3998, 2N3999
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

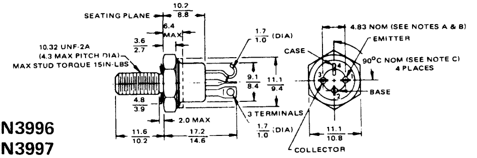
REVISED SEPTEMBER 1975

FOR HIGH-SPEED POWER SWITCHING APPLICATIONS

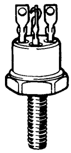
- **30 W at 100°C Case Temperature**
- **Isolated-Stud Package (2N3996, 2N3997)**
- **Max $V_{CE(sat)}$ of 0.25 V at 1 A I_C**
- **Max t_{on} of 300 ns at 1 A I_C**
- **Min f_T of 40 MHz**

*mechanical data

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

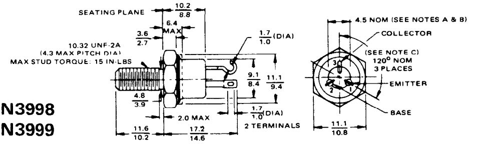


2N3996
2N3997

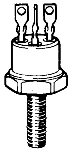


ALL JEDEC TO-111 DIMENSIONS AND NOTES ARE APPLICABLE

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



2N3998
2N3999



ALL JEDEC TO-111 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES: A. Position of terminals with respect to hexagon is not controlled.
B. Terminals located on true position within 0.76mm relative to diameter of can.
C. This dimension applies to the location of the center line of the terminals.
D. The case temperature may be measured anywhere on the seating plane within 3.18mm of the stud.
E. All dimensions are in mm unless otherwise specified.

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	8 V
Continuous Collector Current	5 A
Peak Collector Current (See Note 2)	10 A
Continuous Base Current	1 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 8
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Operating Collector Junction Temperature Range	–65°C to 200°C
Storage Temperature Range	–65°C to 200°C
Lead Temperature 1.588mm from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 1$ ms, duty cycle $\leq$ 50%.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/deg.

*Indicates JEDEC registered data.

TYPES 2N3996, 2N3997, 2N3998, 2N3999
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N3996 2N3998		2N3997 2N3999		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 50$ mA, $I_B = 0$, See Note 5	80		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 60$ V, $I_B = 0$		10		10	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		5		5	μA
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		50		50	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		0.5		0.5	μA
		$V_{EB} = 8$ V, $I_C = 0$		10		10	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 50$ mA	30		60		
		$V_{CE} = 2$ V, $I_C = 1$ A, See Note 5	40	120	80	240	
		$V_{CE} = 5$ V, $I_C = 5$ A, See Note 5	15		20		
		$V_{CE} = 2$ V, $I_C = 1$ A, $T_C = -55°C$, See Note 5	10		20		
V_{BE}	Base-Emitter Voltage	$I_B = 100$ mA, $I_C = 1$ A, See Note 5	0.6	1.2	0.6	1.2	V
		$I_B = 500$ mA, $I_C = 5$ A, See Note 5		1.6		1.6	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ mA, $I_C = 1$ A, See Note 5		0.25		0.25	V
		$I_B = 500$ mA, $I_C = 5$ A See Note 5		2		2	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 10$ MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz		150		150	pF

NOTE 5: This parameter must be measured using pulse techniques: $t_p = 300$ μs, duty cycle $\leq 2\%$.

* thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	3.33	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	87.5	deg/W

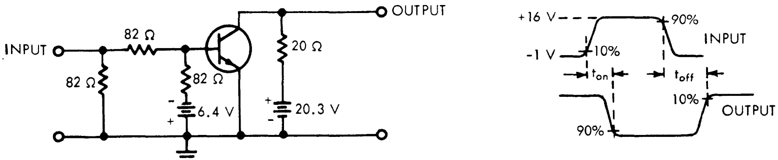
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	2N3996 2N3998	2N3997 2N3999	UNIT
			MAX	MAX	
t_{on}	Turn-On Time	$I_C = 1$ R, $I_{B(1)} = 100$ mA, $I_{B(2)} = -100$ mA, $V_{BE(off)} = -3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.3	0.3	μs
t_{off}	Turn-Off Time		1.5	2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data.

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 2\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

2N3996, 2N3998
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

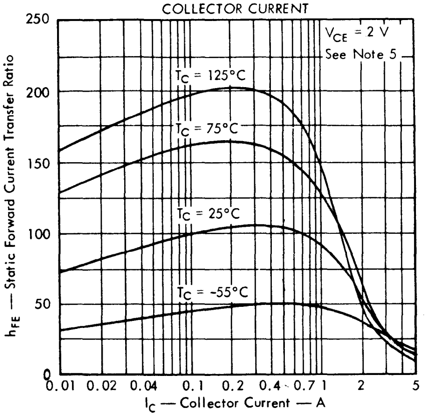


FIGURE 2

2N3997, 2N3999
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

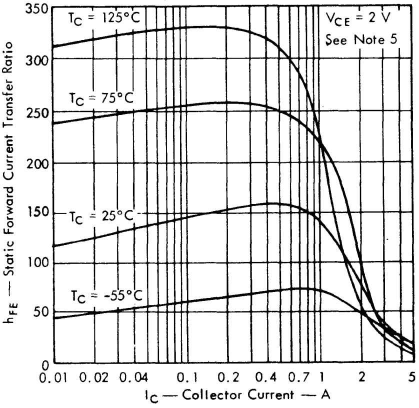


FIGURE 3

NOTE 5: This parameter must be measured using pulse techniques: $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

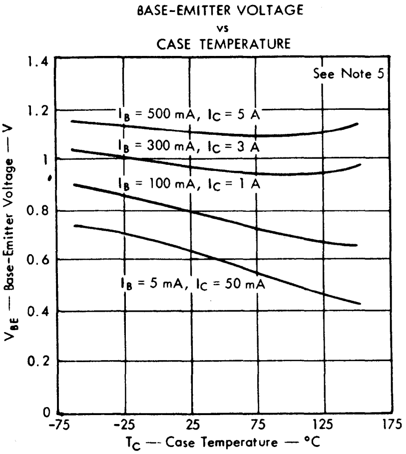

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

FIGURE 4

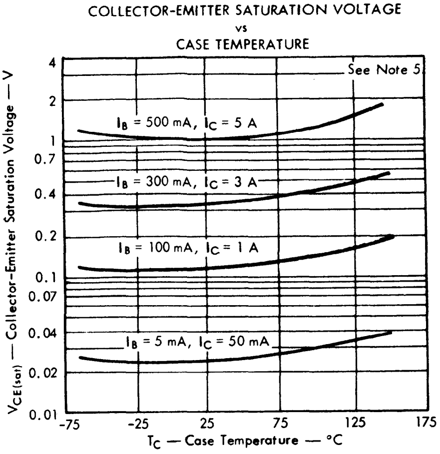

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

FIGURE 5

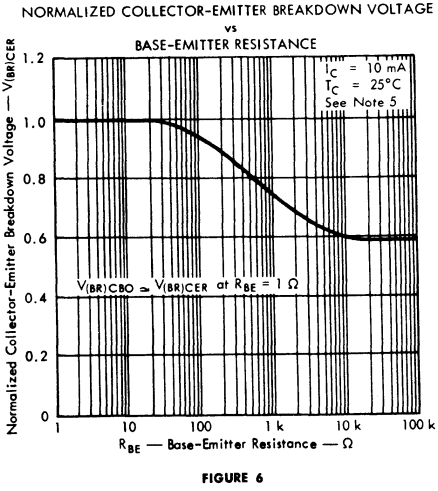

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE vs BASE-EMITTER RESISTANCE

FIGURE 6

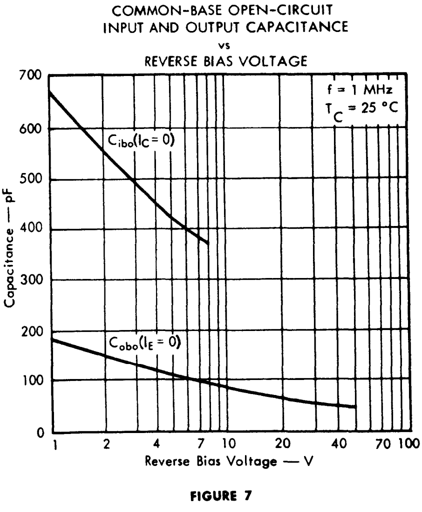

COMMON-BASE OPEN-CIRCUIT INPUT AND OUTPUT CAPACITANCE vs REVERSE BIAS VOLTAGE

FIGURE 7

NOTE 5: This parameter must be measured using pulse techniques: t_p = 300 μs, duty cycle ≤ 2%.

MAXIMUM SAFE OPERATING REGION

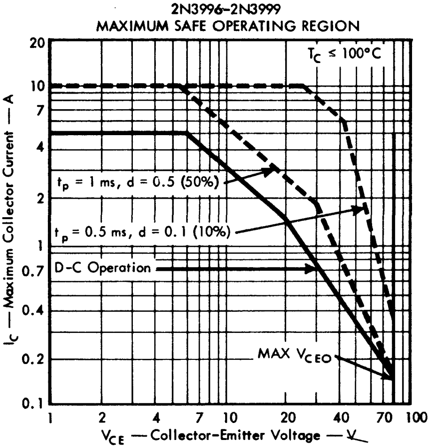


FIGURE 8

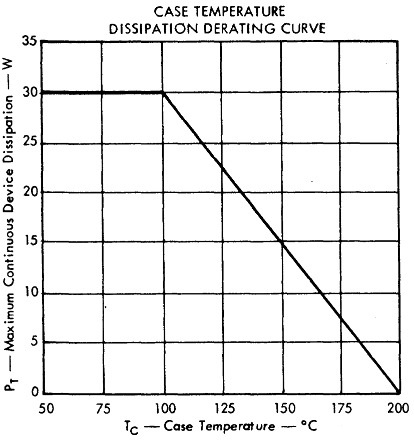


FIGURE 9

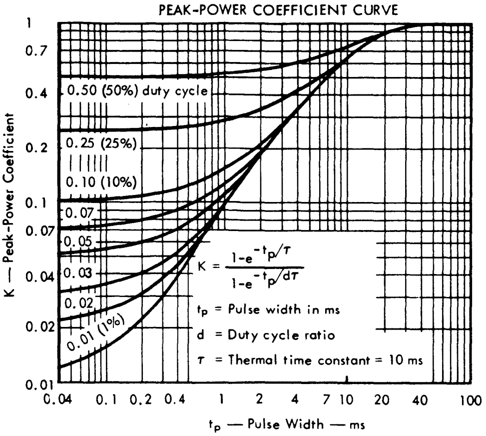


FIGURE 10

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	87.5	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	3.33	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	84.17	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 10	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 9}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C.$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 10, Peak-Power Coefficient

K = 0.103 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + (0.103)\,3.33} = 143\,\text{W}$$

TYPES 2N4002, 2N4003
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

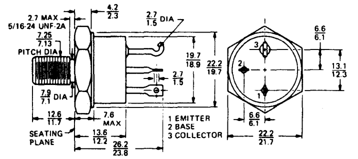
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **30-A Rated Continuous Collector Current**
- **100 Watts at 100°C Case Temperature**
- **Maximum $V_{CE(sat)}$ of 1.2 V at 30 A**
- **Maximum V_{BE} of 1.8 V at 30 A**
- **Maximum t_{on} of 1 μs at 15 A**

*mechanical data

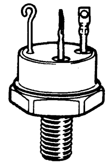
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD

DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4002	2N4003
Collector-Base Voltage	100 V	120 V
Collector-Emitter Voltage (See Note 1)	80 V	100 V
Emitter-Base Voltage	← 8 V →	
Continuous Collector Current	← 30 A →	
Peak Collector Current (See Note 2)	← 40 A →	
Continuous Base Current	← 10 A →	
Continuous Emitter Current	← 30 A →	
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 100 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 230°C →	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 1 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4002		2N4003		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		2			mA
		$V_{CE} = 50$ V, $I_B = 0$				2	
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		1			mA
		$V_{CE} = 110$ V, $V_{BE} = 0$				1	
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		2			
		$V_{CE} = 110$ V, $V_{BE} = 0$, $T_C = 150°C$				2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		100		100	μA
		$V_{EB} = 8$ V, $I_C = 0$		50		50	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 30$ A, See Notes 5 and 6	10		10		
		$V_{CE} = 4$ V, $I_C = 15$ A, See Notes 5 and 6	20	80	20	80	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 30$ A, See Notes 5 and 6		1.8		1.8	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 4$ A, $I_C = 30$ A, See Notes 5 and 6		1.2		1.2	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 1$ A, $f = 1$ kHz	30		30		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 10$ MHz	3		3		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

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

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W

*Indicates JEDEC registered data.

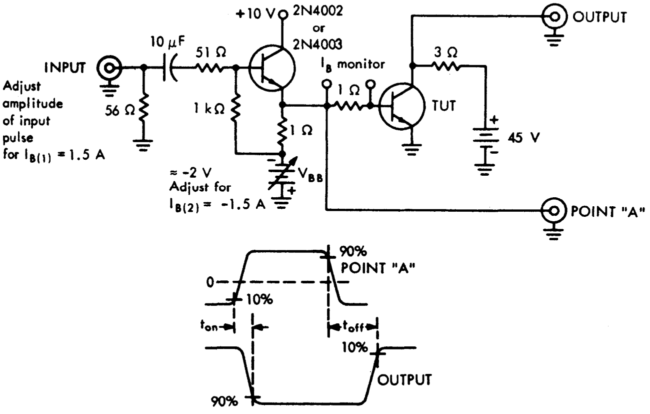
TYPES 2N4002, 2N4003
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTORS

*switching characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS†	MAX	UNIT
t_{on} Turn-On Time	$I_C = 15$ A, $I_{B(1)} = 1.5$ A, $I_{B(2)} = -1.5$ A, $V_{BE(off)} = -2$ V, $R_L = 3\ \Omega$, See Figure 1	1	µs
t_{off} Turn-Off Time		3	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform at point "A" has the following characteristics: $t_r \leq 100$ ns, $t_f \leq 100$ ns, $t_p = 20\ \mu s$, duty cycle $\leq 0.2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 5$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

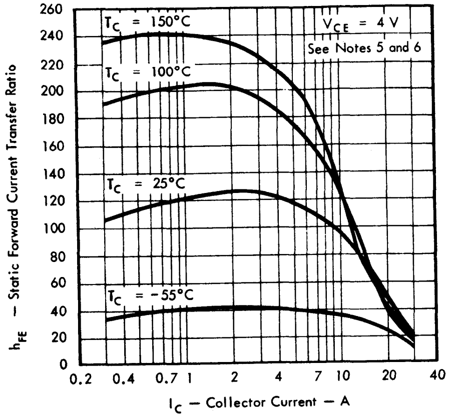


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

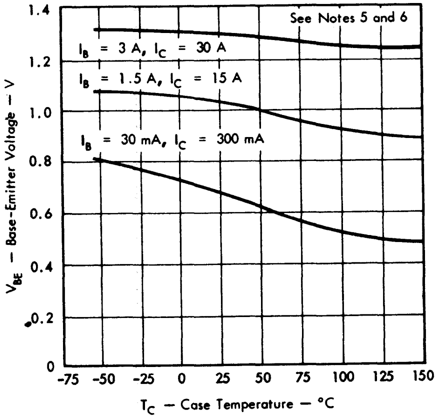


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

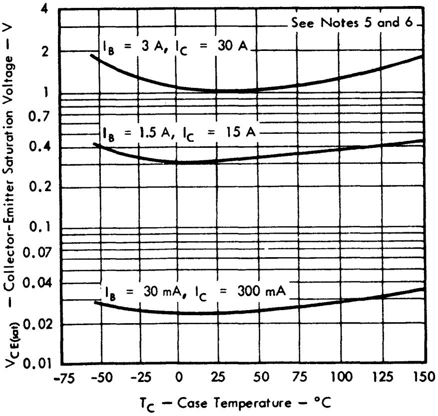


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq$ 2%.

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

TYPICAL CHARACTERISTICS

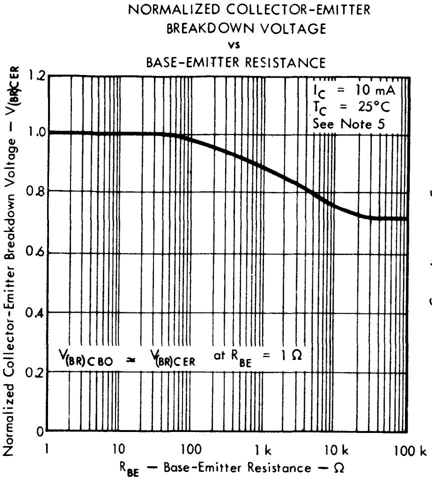


FIGURE 5

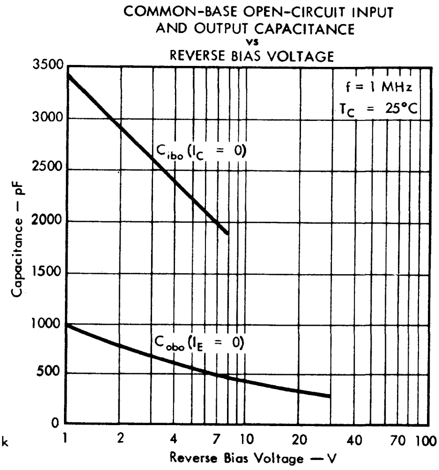


FIGURE 6

NOTE 5: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

MAXIMUM SAFE OPERATING REGION

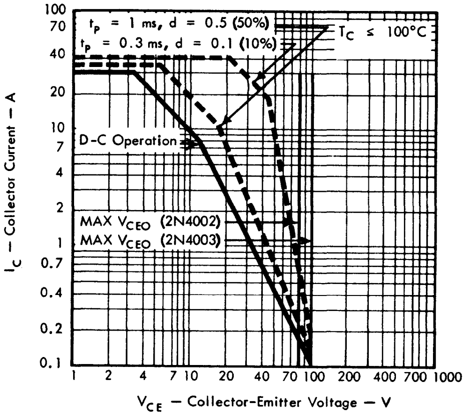


FIGURE 7

THERMAL INFORMATION

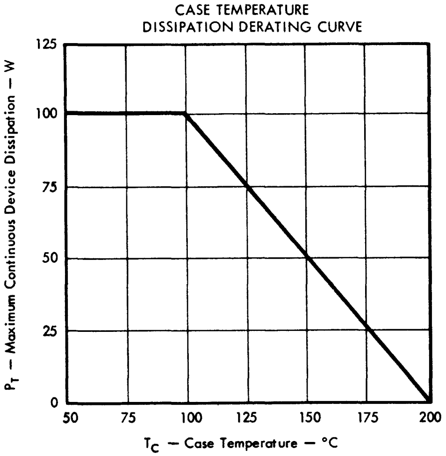


FIGURE 8

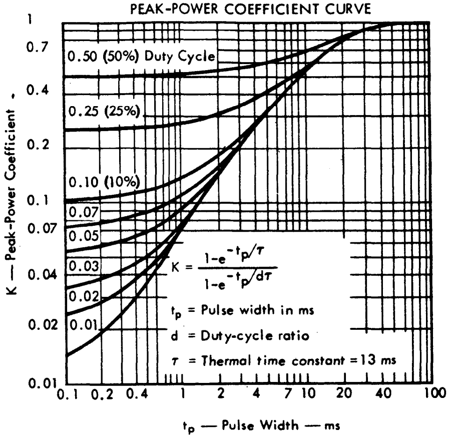


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	42.7	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	$\leq$ 200	°C
$T_{J(max)}$	Peak Junction Temperature	$\leq$ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C, \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.5$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%\ (0.1)$

$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient

K = 0.1 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.5) + 0.1(1)} = 428 \text{ W}$$

TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

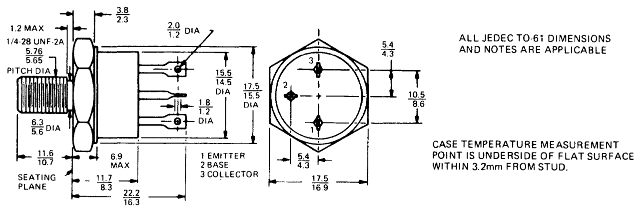
REVISED JULY 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS

- **50 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.4 V at 5 A I_C**
- **Typ t_{on} of 150 ns at 5 A I_C**
- **Min f_T of 40 MHz**

*mechanical data

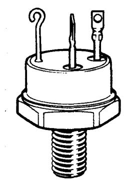
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	100 V
Collector-Emitter Voltage (See Note 1)	80 V
Emitter-Base Voltage	8 V
Continuous Collector Current	10 A
Peak Collector Current (See Note 2)	20 A
Continuous Base Current	4 A
Continuous Emitter Current	10 A
Safe Operating Region at (or below) 100° Case Temperature	See Figure 7
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	50 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1.588mm from Case for 10 Seconds	230°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.

2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.

3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.

4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data.

TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$, See Note 5	80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		10	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 90$ V, $V_{BE} = 0$		10	μA
		$V_{CE} = 90$ V, $V_{BE} = 0$, $T_C = 150°C$		500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		5	μA
		$V_{EB} = 8$ V, $I_C = 0$		50	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 5$ A, See Notes 5 and 6	30	120	
		$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6	15		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 10$ A, See Notes 5 and 6		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A, $I_C = 5$ A, See Notes 5 and 6		0.4	V
		$I_B = 1.3$ A, $I_C = 10$ A, See Notes 5 and 6		1	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 1$ kHz	30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 1$ A, $f = 20$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

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

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

*Indicates JEDEC registered data.

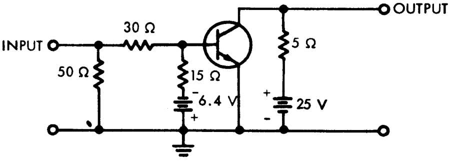
TYPE 2N4301
N-P-N EPITAXIAL PLANAR SILICON POWER TRANSISTOR

switching characteristics at 25°C case temperature

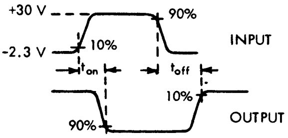
PARAMETER	TEST CONDITIONS†	TYP	UNIT
t_{on} Turn-On Time	$I_C = 5$ A, $I_{B(1)} = 500$ mA, $I_{B(2)} = -500$ mA,	0.15	μs
t_{off} Turn-Off Time	$V_{BE(off)} = -5$ V, $R_L = 5\ \Omega$, See Figure 1	1.5	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

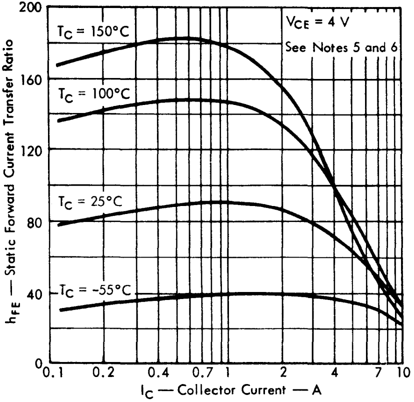


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

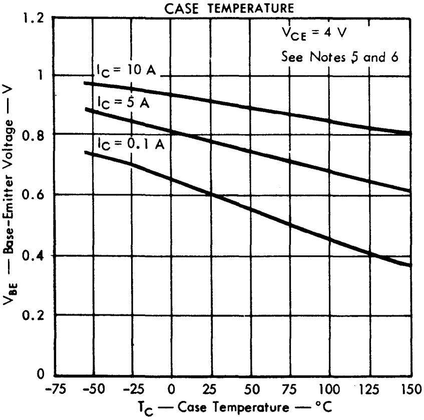


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

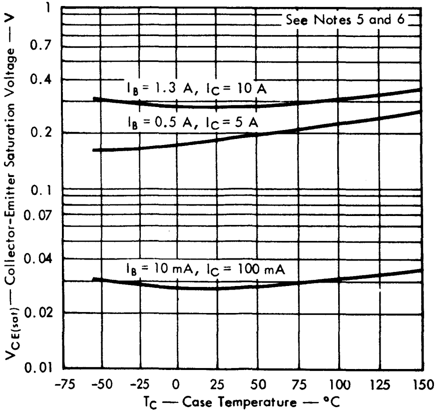


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

TYPICAL CHARACTERISTICS

NORMALIZED COLLECTOR-EMITTER BREAKDOWN VOLTAGE
vs
BASE-EMITTER RESISTANCE

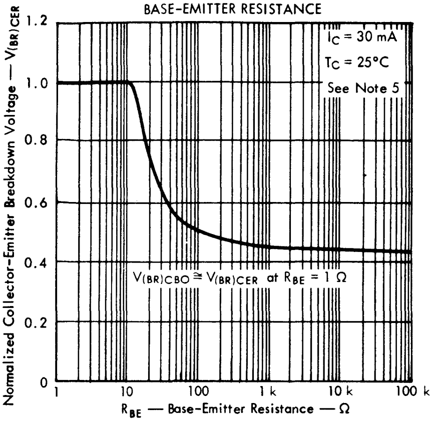


FIGURE 5

COMMON-BASE OPEN-CIRCUIT
INPUT AND OUTPUT CAPACITANCE
vs
REVERSE BIAS VOLTAGE

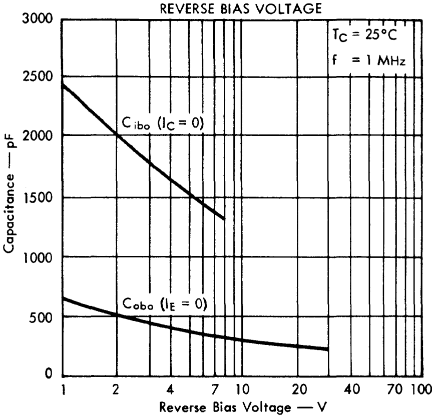


FIGURE 6

MAXIMUM SAFE OPERATING REGION

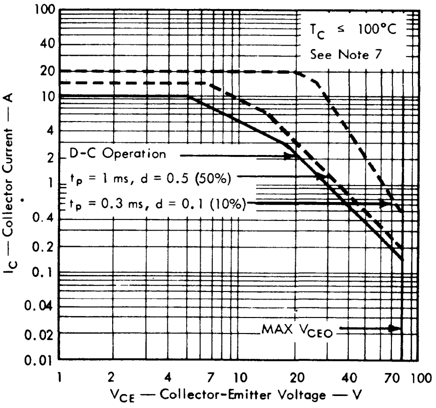


FIGURE 7

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL INFORMATION

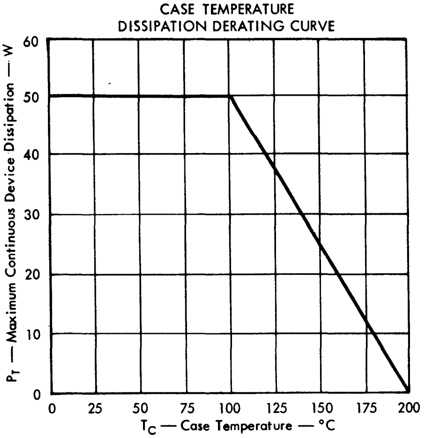


FIGURE 8

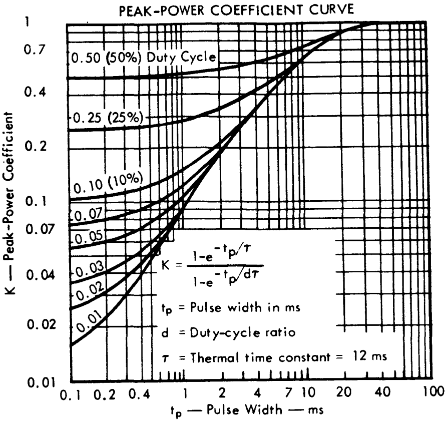


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(avg)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	48	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(avg)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100^\circ C \leq T_C \leq 200^\circ C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(avg)} = \frac{T_{J(avg)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25^\circ C \leq T_A \leq 200^\circ C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100^\circ C \leq T_C \leq 200^\circ C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}A}) + K\,\theta(_{J\text{-}C})} \quad \text{for } 25^\circ C \leq T_A \leq 200^\circ C.$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(avg)}$ (design limit) $= 200^\circ C$

$T_A = 50^\circ C$

$d = 10\%\ (0.1)$

$t_p = 0.1$ ms

Solution:

From Figure 9, Peak-Power Coefficient $K = 0.101$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\ (7) + 0.101\ (2)} = 166\ W$$

TYPES 2N4398, 2N4399
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

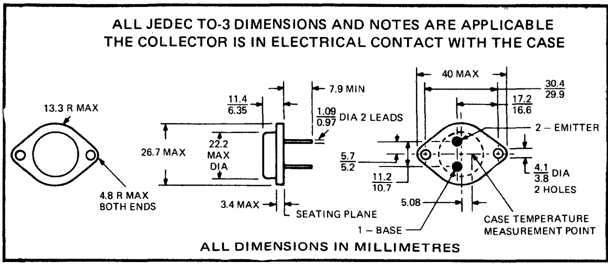
REVISED JULY 1975

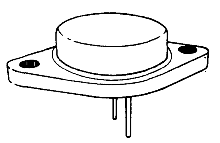
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N5301, 2N5302

- **200 Watts at 25°C Case Temperature**
- **30 A Rated Continuous Collector Current**
- **Min f_T of 4 MHz at 10 V, 1 A**

*mechanical data

The case outline falls within JEDEC TO-3 except for lead diameter.





absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4398	2N4399
*Collector-Base Voltage	-40 V	-60 V
*Collector-Emitter Voltage (See Note 1)	-40 V	-60 V
*Collector-Emitter Voltage (See Note 2)	-40 V	-60 V
*Emitter-Base Voltage	← -5 V →	
*Continuous Collector Current	← -30 A →	
*Peak Collector Current (See Note 3)	← -50 A →	
*Continuous Base Current	← -7.5 A →	
*Peak Base Current (See Note 3)	← -15 A →	
Safe Operating Region at (or below) 25°C Case Temperature	See Figure 2	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 4)	← 200 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 5)	← 5 W →	
*Operating Collector Junction Temperature Range	-65°C to 200°C	
*Storage Temperature Range	-65°C to 200°C	
*Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C →	

NOTES:
1. These values apply when the base-emitter voltage V_{BE} = 1.5 V.
2. These values apply when the base-emitter diode is open-circuited.
3. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
4. Derate linearly to 200°C case temperature at the rate of 1.15 W/deg.
5. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/deg.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N4398		2N4399		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = -200 mA, I_B = 0	See Note 6	-40		-60		V
I_{CBO}	Collector Cutoff Current	V_{CB} = -40 V, I_E = 0			-1			mA
		V_{CB} = -60 V, I_E = 0					-1	
I_{CEO}	Collector Cutoff Current	V_{CE} = -40 V, I_B = 0			-5			mA
		V_{CE} = -60 V, I_B = 0					-5	
I_{CEV}	Collector Cutoff Current	V_{CE} = -40 V, V_{BE} = 1.5 V			-5			mA
		V_{CE} = -60 V, V_{BE} = 1.5 V					-5	
		V_{CE} = -30 V, V_{BE} = 1.5 V, T_C = 150°C			-10		-10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = -5 V, I_C = 0			-5		-5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = -2 V, I_C = -1 A	See Notes 6 and 7	40		40		
		V_{CE} = -4 V, I_C = -15 A		15	60	15	60	
		V_{CE} = -4 V, I_C = -30 A		5		5		
V_{BE}	Base-Emitter Voltage	I_B = -1.5 A, I_C = -15 A	See Notes 6 and 7		-1.85		-1.85	V
		V_{CE} = -2 V, I_C = -15 A			-1.7		-1.7	
		V_{CE} = -4 V, I_C = -30 A			-3		-3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = -1 A, I_C = -10 A	See Notes 6 and 7		-0.75		-0.75	V
		I_B = -1.5 A, I_C = -15 A			-1		-1	
		I_B = -6 A, I_C = -30 A			-4		-4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = -10 V, I_C = -1 A,	f = 1 kHz	40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = -10 V, I_C = -1 A,	f = 1 MHz	4		4		

NOTES: 6. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤2%.

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

thermal characteristics

PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	0.875	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	35	

*switching characteristics at 25°C case temperature

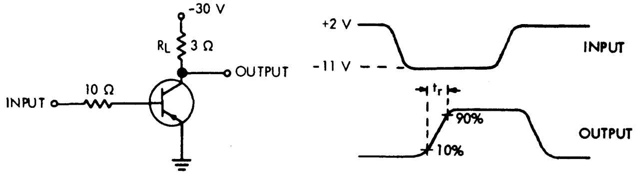
PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_r	Rise Time	I_C = -10 A, $I_{B(1)}$ = -1 A, $V_{BE(off)}$ = 2 V, R_L = 3 Ω, See Figure 1	0.4	μs
t_s	Storage Time	I_C = -10 A, $I_{B(1)}$ = -1 A, $I_{B(2)}$ = 1 A,	1.5	
t_f	Fall Time	R_L = 3 Ω, See Figure 2	0.6	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*Indicates JEDEC registered data

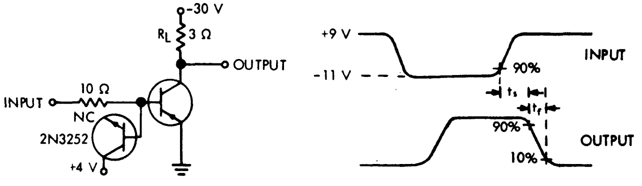
TYPES 2N4398, 2N4399
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 1 – RISE TIME



TEST CIRCUIT VOLTAGE WAVEFORMS

FIGURE 2 – STORAGE AND FALL TIMES

NOTES: a. The input waveforms have the following characteristics: $t_r \leq 20$ ns, $t_f \leq 20$ ns, t_p = 10 μs to 100 μs, duty cycle ≤ 2%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 20$ ns, $R_{in} \geq 10$ kΩ, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data

MAXIMUM SAFE OPERATING REGION

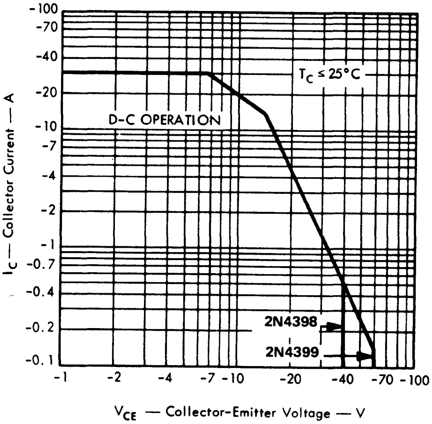


FIGURE 3

TEXAS INSTRUMENTS

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

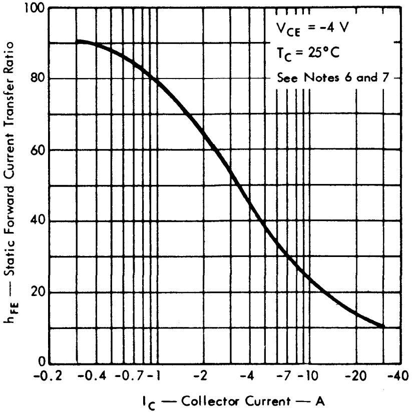


FIGURE 4

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

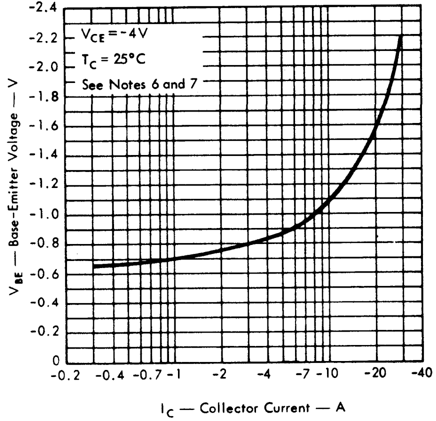


FIGURE 5

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

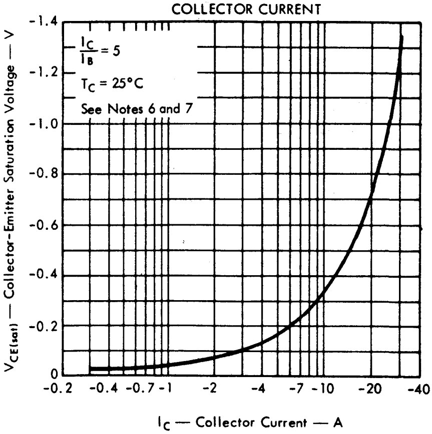


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$2%.

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

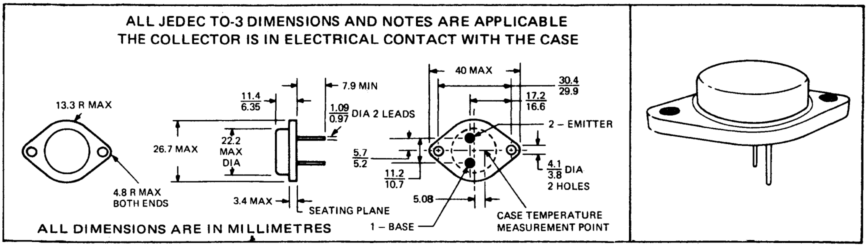
TYPES 2N4901, 2N4902, 2N4903
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND SWITCHING APPLICATIONS

- **87.5 W at 25°C Case Temperature**
- **5 A Rated Collector Current**
- **Min f_T of 4 MHz at 10 V, 1 A**

*mechanical data


ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4901	2N4902	2N4903
*Collector-Base Voltage	-40 V	-60 V	-80 V
*Collector-Emitter Voltage (See Note 1)	-40 V	-60 V	-80 V
*Emitter-Base Voltage	← -5 V →		
*Continuous Collector Current	← -5 A →		
Peak Collector Current (See Note 2)	← -15 A →		
*Continuous Base Current	← -1 A →		
Safe Operating Region at (or below) 25°C Case Temperature	← See Figure 2 →		
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 87.5 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →		
*Operating Collector Junction Temperature Range	← -65°C to 200°C →		
*Storage Temperature Range	← -65°C to 200°C →		
*Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C →		

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4901		2N4902		2N4903		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 5	-40		-60		-80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		-1					mA
		$V_{CE} = -60$ V, $I_B = 0$				-1			
		$V_{CE} = -80$ V, $I_B = 0$						-1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 1.5$ V		-0.1					mA
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V				-0.1			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V						-0.1	
		$V_{CE} = -40$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$		-2					
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$				-2			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$						-2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		-1		-1		-1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V, $I_C = -1$ A, See Notes 5 and 6	20	80	20	80	20	80	
		$V_{CE} = -2$ V, $I_C = -5$ A, See Notes 5 and 6	7		7		7		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V, $I_C = -1$ A, See Notes 5 and 6		-1.2		-1.2		-1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.1$ A, $I_C = -1$ A, See Notes 5 and 6		-0.4		-0.4		-0.4	V
		$I_B = -1$ A, $I_C = -5$ A, See Notes 5 and 6		-1.5		-1.5		-1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 MHz	4		4		4		

NOTES: 5. These parameters must be measured using pulse techniques: $t_p = 300$ µs, duty cycle $\leq 2\%$.

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

*Indicates JEDEC registered data

thermal characteristics

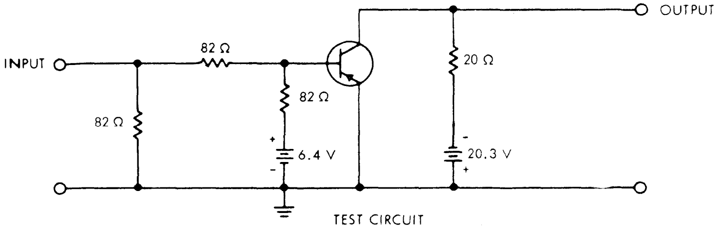
PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	2	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	

switching characteristics at 25°C case temperature

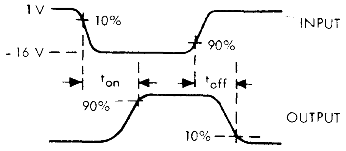
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -0.1$ A, $I_{B(2)} = 0.1$ A,	0.35	µs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, See Figure 1	0.8	

†Voltage and current values shown are nominal; exact values vary slightly with device parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES:
a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\,\Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

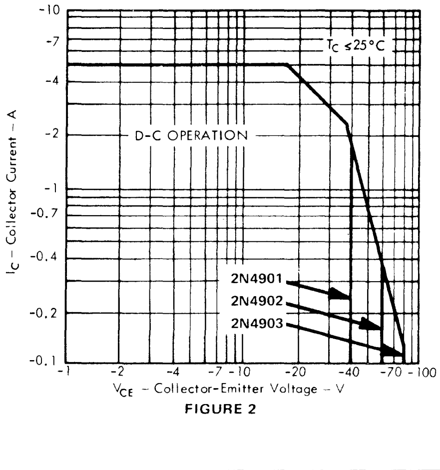


FIGURE 2

TYPICAL CHARACTERISTICS

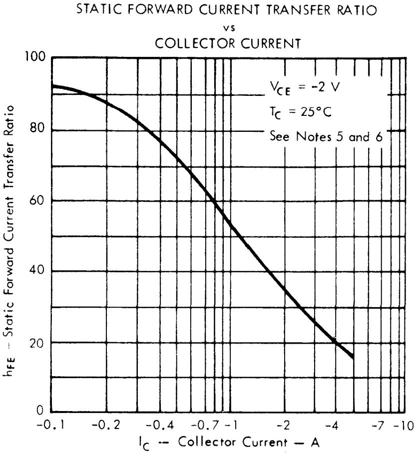


FIGURE 3

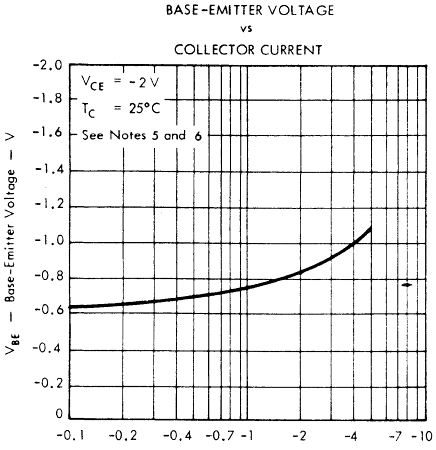


FIGURE 4

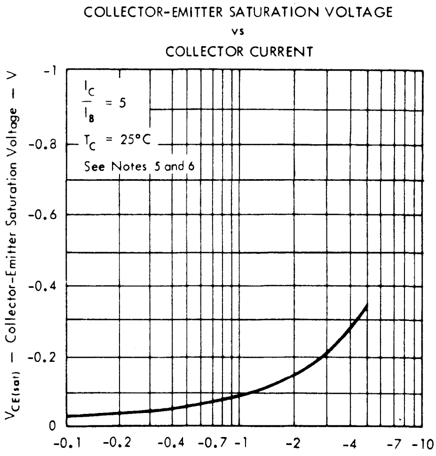


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤2%.

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

TYPES 2N4904, 2N4905, 2N4906
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

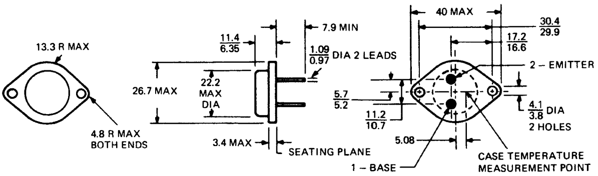
REVISED JULY 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4913, 2N4914, 2N4915

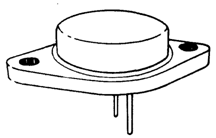
- **87.5 W at 25°C Case Temperature**
- **5 A Rated Collector Current**
- **Min f_T of 4 MHz at 10 V, 500 mA**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4904	2N4905	2N4906
*Collector-Base Voltage	-40 V	-60 V	-80 V
*Collector-Emitter Voltage (See Note 1)	-40 V	-80 V	-80 V
*Emitter-Base Voltage	←	-5 V	→
*Continuous Collector Current	←	-5 A	→
Peak Collector Current (See Note 2)	←	-15 A	→
*Continuous Base Current	←	-1 A	→
Safe Operating Region at (or below) 25°C Case Temperature	←	See Figure 2	→
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←	87.5 W	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←	4 W	→
*Operating Collector Junction Temperature Range	←	-65°C to 200°C	→
*Storage Temperature Range	←	-65°C to 200°C	→
*Lead Temperature 1.588mm from Case for 10 Seconds	←	235°C	→

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4904		2N4905		2N4906		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 5	-40		-60		-80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		-1					mA
		$V_{CE} = -60$ V, $I_B = 0$				-1			
		$V_{CE} = -80$ V, $I_B = 0$						-1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -40$ V, $V_{BE} = 1.5$ V		-0.1					mA
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V				-0.1			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V						-0.1	
		$V_{CE} = -40$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$		-2					
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$				-2			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$						-2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		-1		-1		-1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V, $I_C = -2.5$ A, See Notes 5 and 6	25	100	25	100	25	100	
		$V_{CE} = -2$ V, $I_C = -5$ A, See Notes 5 and 6	7		7		7		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -2$ V, $I_C = -2.5$ A, See Notes 5 and 6		-1.4		-1.4		-1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.25$ A, $I_C = -2.5$ A, See Notes 5 and 6		-1		-1		-1	V
		$I_B = -1$ A, $I_C = -5$ A, See Notes 5 and 6		-1.5		-1.5		-1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 kHz	40		40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.5$ A, f = 1 MHz	4		4		4		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

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

*Indicates JEDEC registered data

thermal characteristics

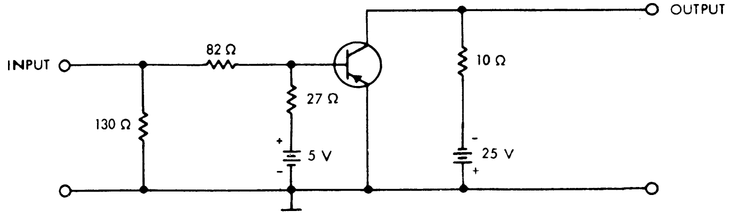
PARAMETER		MAX	UNIT
θ_{J-C}	Junction-to-Case Thermal Resistance	2	deg/W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	43.7	

switching characteristics at 25°C case temperature

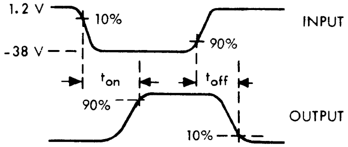
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -2.5$ A, $I_{B(1)} = -250$ mA, $I_{B(2)} = 250$ mA, $V_{BE(off)} = 4.1$ V, $R_L = 10\ \Omega$, See Figure 1	0.4	μs
t_{off}	Turn-Off Time		0.7	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES:
a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

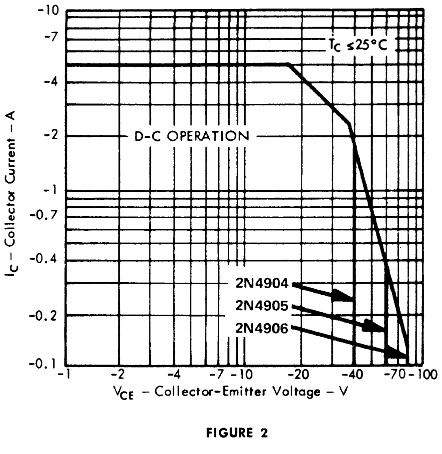


FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

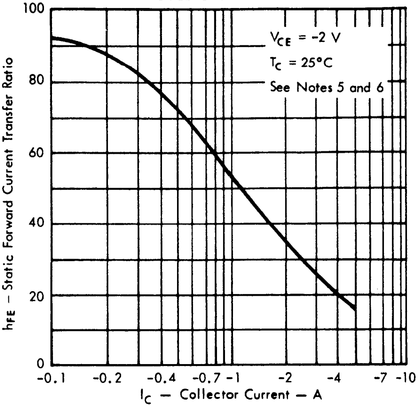


FIGURE 3

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

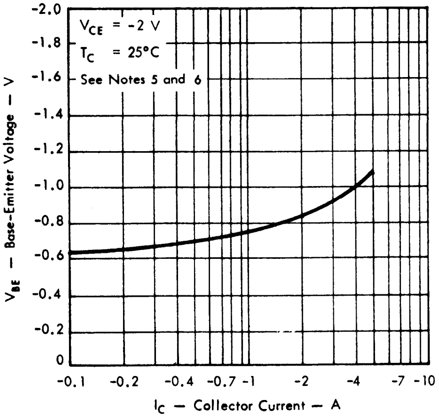


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

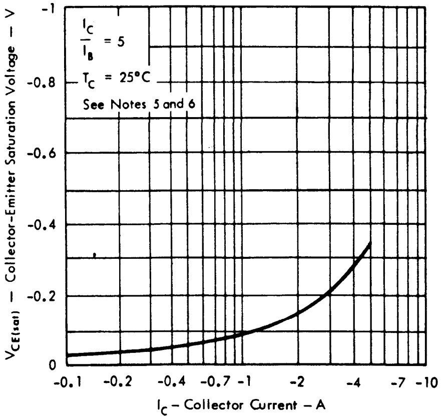


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle $\leq$2%.

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

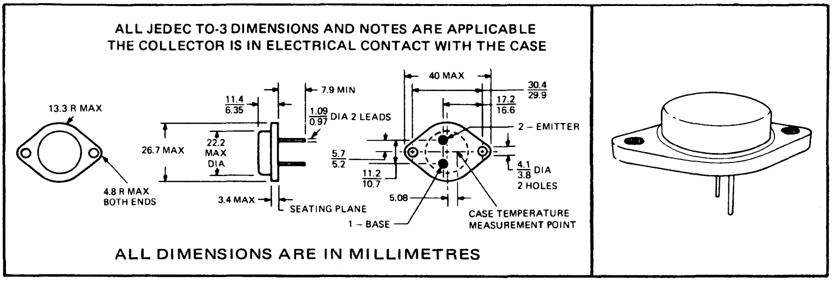
TYPES 2N4913, 2N4914, 2N4915
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4904 THRU 2N4906

- **87.5 W at 25°C Case Temperature**
- **5 A Rated Collector Current**
- **Min f_T of 4 MHz at 10 V, 1 A**

*mechanical data


ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4913	2N4914	2N4915
*Collector-Base Voltage	40 V	60 V	80 V
*Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V
*Emitter-Base Voltage	← 5 V →		
*Continuous Collector Current	← 5 A →		
Peak Collector Current (See Note 2)	← 15 A →		
*Continuous Base Current	← 1 A →		
Safe Operating Region at (or below) 25°C Case Temperature	← See Figure 6 →		
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 87.5 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 4 W →		
*Operating Collector Junction Temperature Range	← −65°C to 200°C →		
*Storage Temperature Range	← −65°C to 200°C →		
*Lead Temperature 1.588mm from Case for 10 Seconds	← 235°C →		

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p = 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N4913		2N4914		2N4915		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 200$ mA, $I_B = 0$, See Note 5	40		60		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$		1					mA
		$V_{CE} = 60$ V, $I_B = 0$				1			
		$V_{CE} = 80$ V, $I_B = 0$						1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 40$ V, $V_{BE} = -1.5$ V		0.1					mA
		$V_{CE} = 60$ V, $V_{BE} = -1.5$ V				0.1			
		$V_{CE} = 80$ V, $V_{BE} = -1.5$ V						0.1	
		$V_{CE} = 40$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$		2					
		$V_{CE} = 60$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$				2			
		$V_{CE} = 80$ V, $V_{BE} = -1.5$ V, $T_C = 150°C$						2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 2$ V, $I_C = 2.5$ A, See Notes 5 and 6	25	100	25	100	25	100	
		$V_{CE} = 2$ V, $I_C = 5$ A, See Notes 5 and 6	7		7		7		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 2$ V, $I_C = 2.5$ A, See Notes 5 and 6		1.4		1.4		1.4	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.25$ A, $I_C = 2.5$ A, See Notes 5 and 6		0.75		0.75		0.75	V
		$I_B = 1$ A, $I_C = 5$ A, See Notes 5 and 6		1.5		1.5		1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 0.5$ A, $f = 1$ kHz	20		20		20		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A, $f = 1$ MHz	4		4		4		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

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

thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	

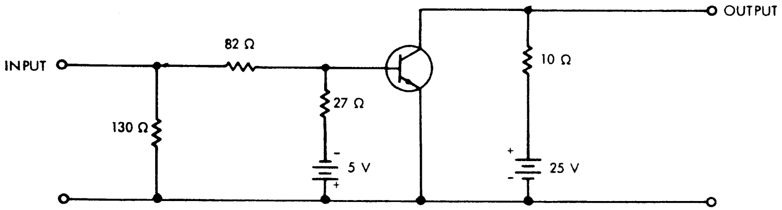
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

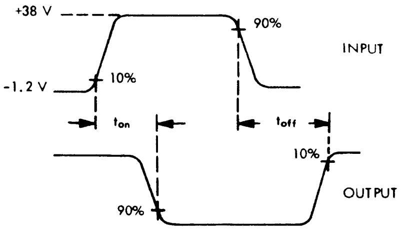
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = 2.5$ A, $I_{B(1)} = 250$ mA, $I_{B(2)} = -250$ mA, $V_{BE(off)} = -4.1$ V, $R_L = 10\ \Omega$, See Figure 1	0.6	µs
t_{off}	Turn-Off Time		1.2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

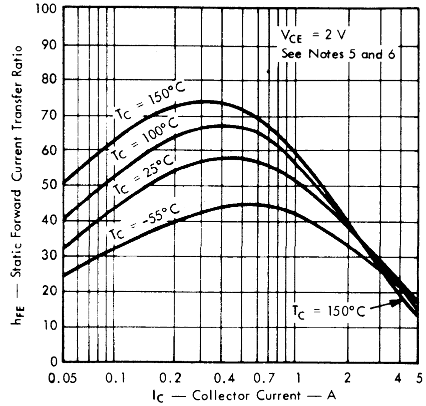


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

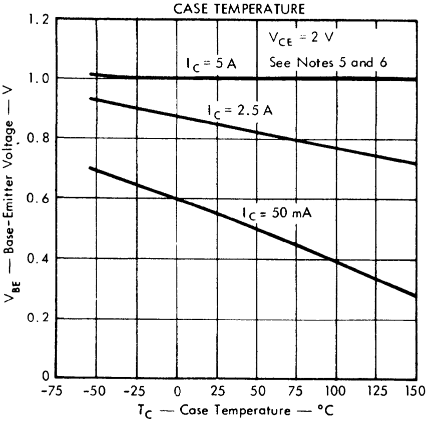


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

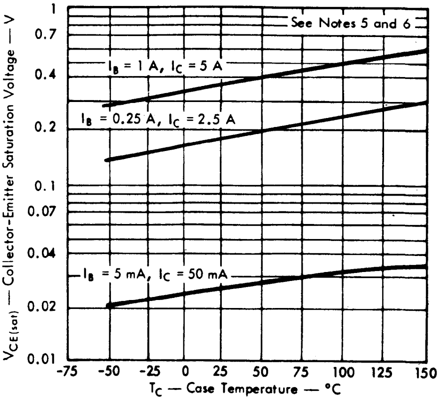


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

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

TYPICAL CHARACTERISTICS

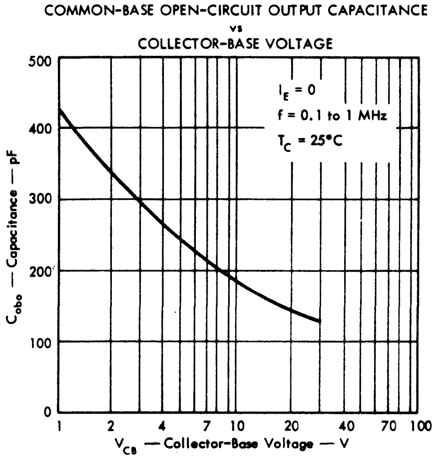


FIGURE 5

MAXIMUM SAFE OPERATING REGION

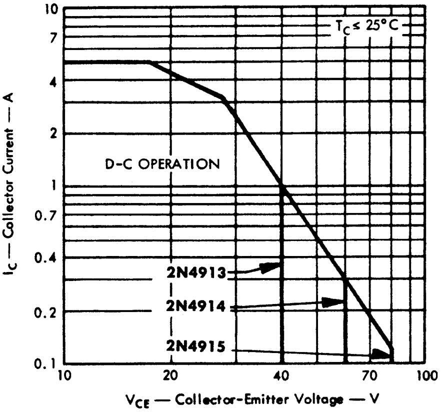


FIGURE 6

THERMAL INFORMATION

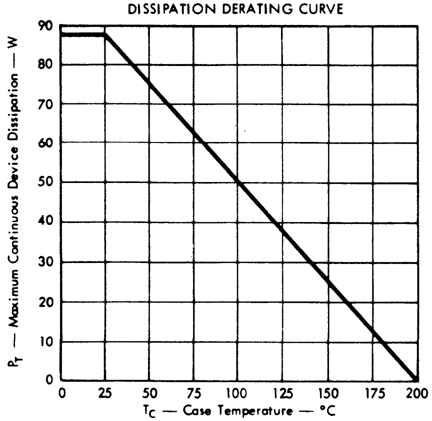


FIGURE 7

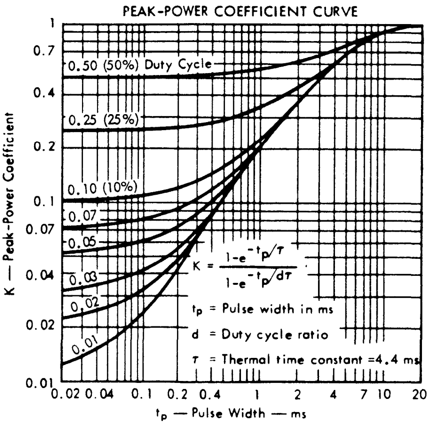


FIGURE 8

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	43.7	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	41.7	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 8	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 25\,°C \leq T_C \leq 200°C, \text{ as in figure 7.}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 25\,°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 2.25$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From figure 8, Peak-Power Coefficient $K = 0.11$ and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1(2.25) + 0.11(2)} = 337 \text{ W}$$

2N4998, 2N5000, 2N5148, 2N5150
NPN SILICON POWER TRANSISTORS

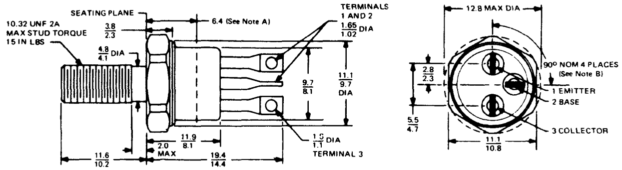
REVISED JUNE 1975

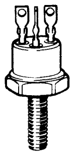
HIGH-FREQUENCY POWER TRANSISTORS WITH COMPUTER-DESIGNED ISOTHERMAL GEOMETRY

- For Complementary Use With 2N4999, 2N5001, 2N5147 and 2N5149
- Isolated Stud Package; 30 W at 40 V, T_C = 50°C (2N4998, 2N5000)
- Min f_T of 50 and 60 MHz at 5 V, 200 mA

*mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

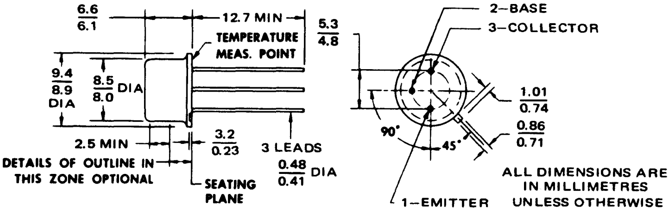


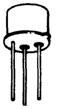


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in mm unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE SPECIFIED

ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4998 2N5000	2N5148 2N5150
Collector-Base Voltage	100 V*	
Collector-Emitter Voltage (See Note 1)	80 V*	
Emitter-Base Voltage	6 V*	
Continuous Collector Current	2 A*	2 A*
Peak Collector Current (See Note 2)	5 A*	5 A
Continuous Base Current	1 A*	1 A*
Safe Operating Area at (or below) 25°C Case Temperature	See Figures 7 and 8*	
Continuous Device Dissipation at 50°C Case Temperature (See Note 3)	30 W*	6 W*
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	20 W*	4 W*
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	1 W*
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Lead or Terminal Temperature 3.2mm from Case for 10 Seconds	300°C*	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 8.3$ ms, duty cycle $\leqslant 1\%$.
3. For operation above (or below) 50°C case temperature, refer to Dissipation Derating Curves, Figures 9 and 10.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C for 2N4998 and 2N5000, 5.7 mW/°C for 2N5148 and 2N5150.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N4998 2N5148		2N5000 2N5150		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100$ mA, $I_B = 0$,	See Note 5	80		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$			50		50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 60$ V, $V_{BE} = 0$			1		1	μA
		$V_{CE} = 100$ V, $V_{BE} = 0$			1		1	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 60$ V, $V_{BE} = -2$ V, $T_C = 150°C$			500		500	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$			1		1	μA
		$V_{EB} = 6$ V, $I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 50$ mA	See Notes 5 and 6	20		50		
		$V_{CE} = 5$ V, $I_C = 1$ A		30	90	70	200	
		$V_{CE} = 5$ V, $I_C = 2$ A		15		30		
		$V_{CE} = 5$ V, $I_C = 3$ A		5		15		
		$V_{CE} = 5$ V, $I_C = 1$ A, $T_C = -55°C$		15		35		
V_{BE}	Base-Emitter Voltage	$I_B = 100$ mA, $I_C = 1$ A	See Notes 5 and 6		1.2		1.2	V
		$I_B = 200$ mA, $I_C = 2$ A			1.5		1.5	
		$V_{CE} = 5$ V, $I_C = 2$ A			1.5		1.5	
		$V_{CE} = 5$ V, $I_C = 3$ A			3		3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 100$ mA, $I_C = 1$ A	See Notes 5 and 6		0.46		0.46	V
		$I_B = 200$ mA, $I_C = 2$ A			0.85		0.85	
		$I_B = 600$ mA, $I_C = 3$ A			5		5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.1$ A, $f = 1$ kHz		20		50		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.2$ A, $f = 20$ MHz		2.5		3		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_E = 0$, $f = 1$ MHz			70		70	pF

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 1%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

thermal characteristics

PARAMETER		2N4998 2N5000	2N5148 2N5150	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	25	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	175	

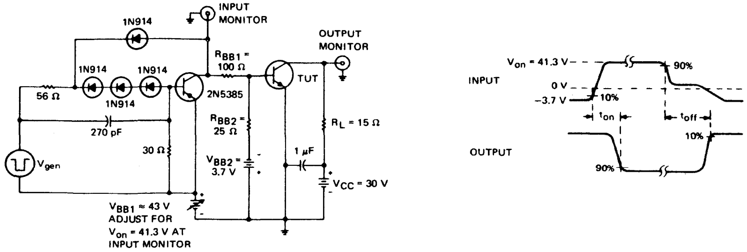
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			ALL TYPES	UNIT
					TYP	
t_{on}	Turn-On Time	$I_C = 2$ A,	$I_{B(1)} = 200$ mA,	$I_{B(2)} = -200$ mA,	0.1	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V,	$R_L = 15\ \Omega$,	See Figure 1	1.1	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.
*JEDEC registered data

2N4998, 2N5000, 2N5148, 2N5150
NPN SILICON POWER TRANSISTORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.

C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TYPICAL CHARACTERISTICS

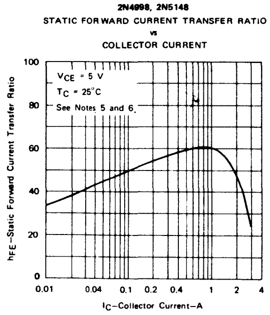


FIGURE 2

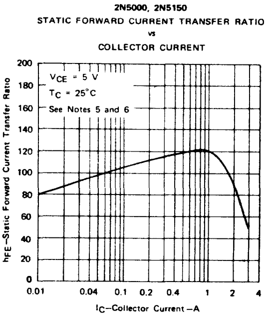


FIGURE 3

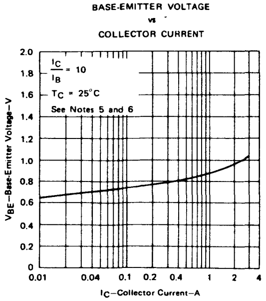


FIGURE 4

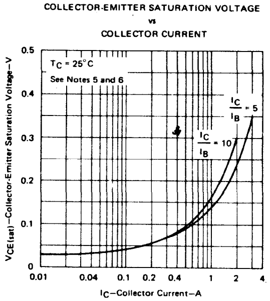


FIGURE 5

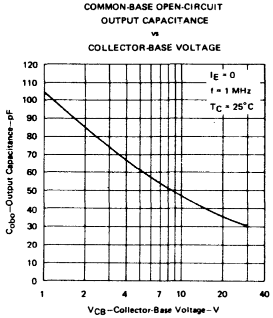


FIGURE 6

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle ⩽ 1%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREA

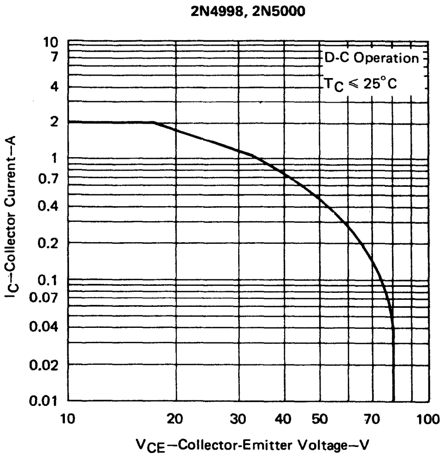


FIGURE 7

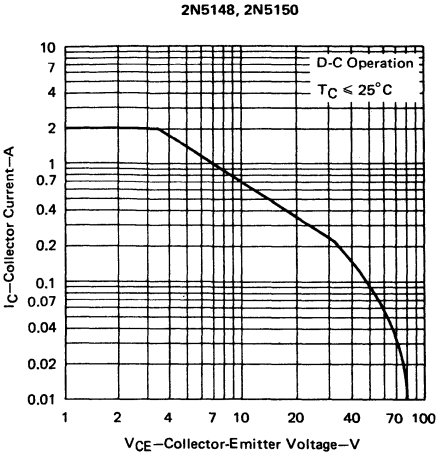


FIGURE 8

THERMAL CHARACTERISTICS

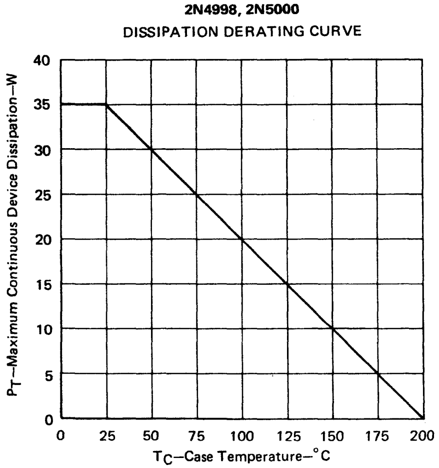


FIGURE 9

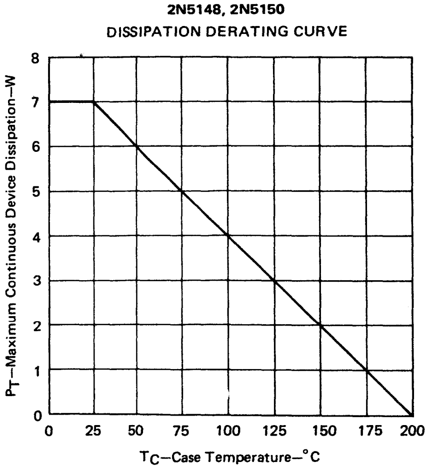


FIGURE 10

TYPES 2N4999, 2N5001, 2N5147, 2N5149
P-N-P SILICON POWER TRANSISTORS

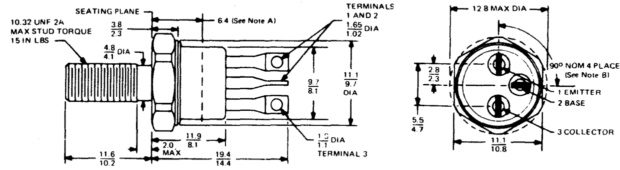
REVISED JUNE 1975

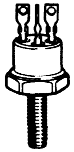
HIGH-FREQUENCY POWER TRANSISTORS WITH COMPUTER-DESIGNED ISOTHERMAL GEOMETRY

- For Complementary Use With 2N4998, 2N5000, 2N5148 and 2N5150
- Isolated Stud Package; 30 W at 40 V, T_C = 50°C (2N4999, 2N5001)
- Min f_T of 50 and 60 MHz at 5 V, 200 mA

*mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

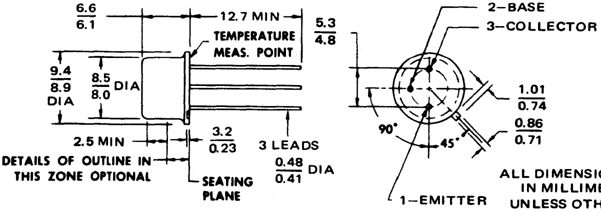


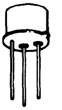


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in mm unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE SPECIFIED

ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N4999 2N5001	2N5147 2N5149
Collector-Base Voltage	−100 V*	
Collector-Emitter Voltage (See Note 1)	−80 V*	
Emitter-Base Voltage	−5.5 V*	
Continuous Collector Current	−2 A*	−2 A*
Peak Collector Current (See Note 2)	−5 A*	−5 A
Continuous Base Current	−1 A*	−1 A*
Safe Operating Area at (or below) 25°C Case Temperature	See Figures 7 and 8*	
Continuous Device Dissipation at 50°C Case Temperature (See Note 3)	30 W*	6 W*
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	20 W	4 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W	1 W*
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Lead or Terminal Temperature 3.2mm from Case for 10 Seconds	300°C*	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 8.3$ ms, duty cycle ⩽ 1%.
3. For operation above (or below) 50°C case temperature, refer to Dissipation Derating Curves Figures 9 and 10.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/°C for 2N4999 and 2N5001, 5.7 mW/°C for 2N5147 and 2N5149.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N4999 2N5147		2N5001 2N5149		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -100$ mA, $I_B = 0$,	See Note 5	−80		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$			−50		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 0$			−1		−1	μA
		$V_{CE} = -100$ V, $V_{BE} = 0$			−1		−1	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 2$ V, $T_C = 150°C$			−500		−500	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$			−1		−1	μA
		$V_{EB} = -5.5$ V, $I_C = 0$			−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -50$ mA	See Notes 5 and 6	20		50		
		$V_{CE} = -5$ V, $I_C = -1$ A		30	90	70	200	
		$V_{CE} = -5$ V, $I_C = -2$ A		15		30		
		$V_{CE} = -5$ V, $I_C = -3$ A		5		15		
		$V_{CE} = -5$ V, $I_C = -1$ A, $T_C = -55°C$		15		35		
V_{BE}	Base-Emitter Voltage	$I_B = -100$ mA, $I_C = -1$ A	See Notes 5 and 6		−1.2		−1.2	V
		$I_B = -200$ mA, $I_C = -2$ A			−1.5		−1.5	
		$V_{CE} = -5$ V, $I_C = -2$ A			−1.5		−1.5	
		$V_{CE} = -5$ V, $I_C = -3$ A			−3		−3	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -100$ mA, $I_C = -1$ A	See Notes 5 and 6		−0.46		−0.46	V
		$I_B = -200$ mA, $I_C = -2$ A			−0.85		−0.85	
		$I_B = -600$ mA, $I_C = -3$ A			−5		−5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.1$ A, f = 1 kHz		20		50		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.2$ A, f = 20 MHz		2.5		3		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, f = 1 MHz			120		120	pF

NOTES: 5. This parameter must be measured using pulse techniques: $t_w = 300$ μs, duty cycle ⩽ 1%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

thermal characteristics

PARAMETER		2N4999 2N5001	2N5147 2N5149	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	5	25	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	87.5	175	

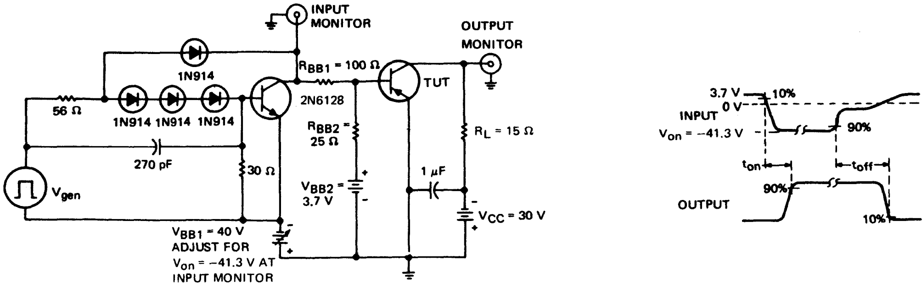
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			ALL TYPES	UNIT
					TYP	
t_{on}	Turn-On Time	$I_C = -2$ A,	$I_{B(1)} = -200$ mA,	$I_{B(2)} = 200$ mA,	0.2	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V,	$R_L = 15\ \Omega$,	See Figure 1	0.4	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ≤ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TYPICAL CHARACTERISTICS

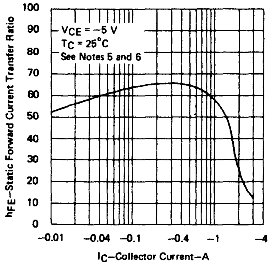

2N4999, 2N5147
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

FIGURE 2

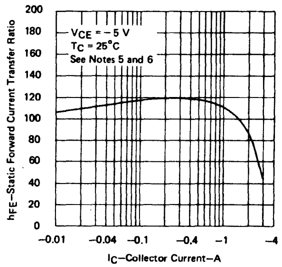

2N5001, 2N5149
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

FIGURE 3

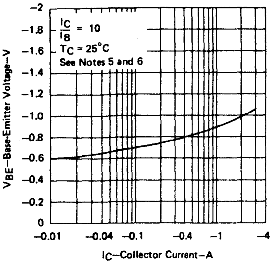

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

FIGURE 4

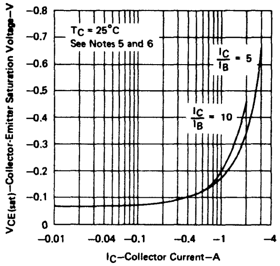

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

FIGURE 5

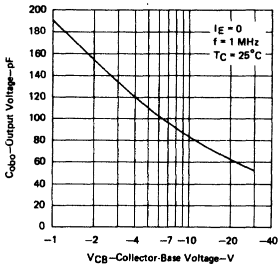

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

FIGURE 6

NOTES:
- 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 1%.
- 6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREA

2N4999, 2N5001

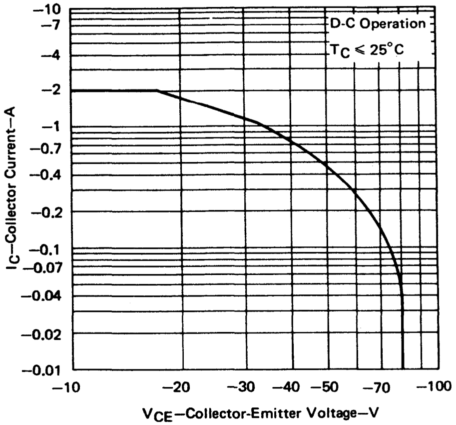


FIGURE 7

2N5147, 2N5149

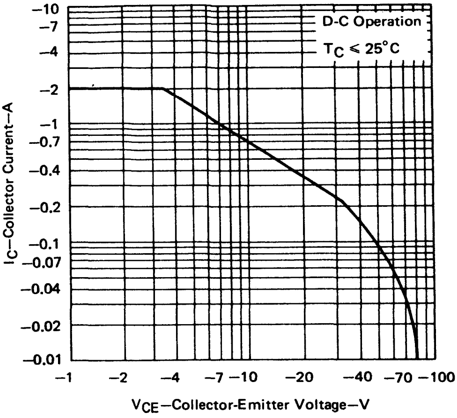


FIGURE 8

THERMAL CHARACTERISTICS

2N4999, 2N5001

DISSIPATION DERATING CURVE

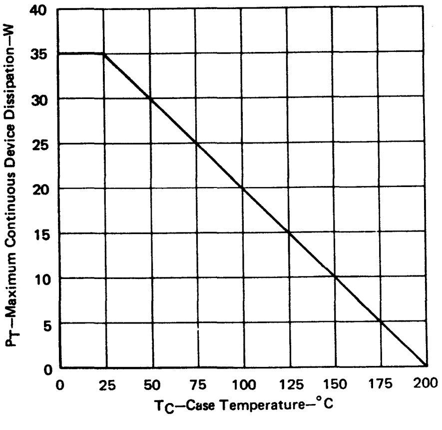


FIGURE 9

2N5147, 2N5149

DISSIPATION DERATING CURVE

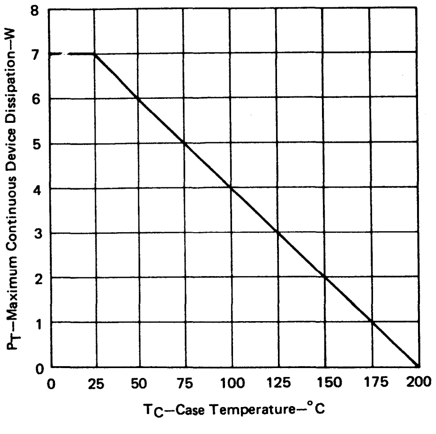


FIGURE 10

2N5002, 2N5004, 2N5152, 2N5154
NPN SILICON POWER TRANSISTORS

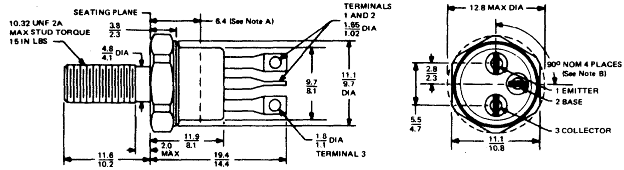
REVISED JUNE 1975

HIGH-FREQUENCY POWER TRANSISTORS WITH COMPUTER-DESIGNED ISOTHERMAL GEOMETRY

- For Complementary Use with 2N5003, 2N5005, 2N5151, and 2N5153
- Isolated Stud Package; 50 W at 40 V, T_C = 50°C (2N5002, 2N5004)
- Min f_T of 60 and 70 MHz at 5 V, 500 mA

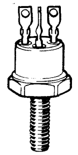
*mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

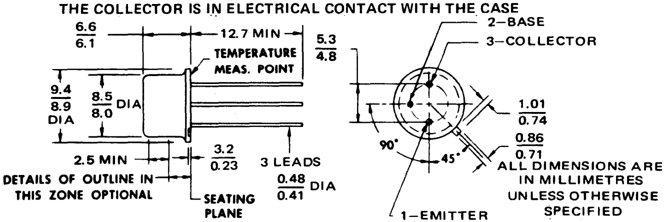


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

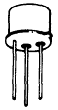
NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to hexagon is not controlled.
C. The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in mm unless otherwise specified.



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5002 2N5004	2N5152 2N5154
Collector-Base Voltage	←100 V*→	
Collector-Emitter Voltage (See Note 1)	←80 V*→	
Emitter-Base Voltage	←6 V*→	
Continuous Collector Current	5 A*	2 A*
Peak Collector Current (See Note 2)	10 A*	10 A
Continuous Base Current	2 A*	1 A*
Safe Operating Area at (or below) 25°C Case Temperature	See Figures 7 and 8*	
Continuous Device Dissipation at 50°C Case Temperature (See Note 3)	50 W*	10 W*
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	33.3 W	6.7 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)		1 W*
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Lead or Terminal Temperature 3.2mm from Case for 10 Seconds	←300°C*→	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 8.3$ ms, duty cycle ≤ 1%.
3. For operation above (or below) 50°C case temperature, refer to Dissipation Derating Curves, Figures 9 and 10.
4. Derate linearly to 200°C free-air temperature at the rate of 5.7 mW/°C.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

2N5002, 2N5004, 2N5152, 2N5154
NPN SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N5002 2N5152		2N5004 2N5154		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100$ mA, $I_B = 0$,	See Note 5	80		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 40$ V, $I_B = 0$			50		50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = 60$ V, $V_{BE} = 0$			1		1	μA
		$V_{CE} = 100$ V, $V_{BE} = 0$			1		1	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = 60$ V, $V_{BE} = -2$ V, $T_C = 150°C$			500		500	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$			1		1	μA
		$V_{EB} = 6$ V, $I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 50$ mA	See Notes 5 and 6	20		50		
		$V_{CE} = 5$ V, $I_C = 2.5$ A		30	90	70	200	
		$V_{CE} = 5$ V, $I_C = 5$ A		20		40		
		$V_{CE} = 5$ V, $I_C = 2.5$ A, $T_C = -55°C$		15		35		
V_{BE}	Base-Emitter Voltage	$I_B = 250$ mA, $I_C = 2.5$ A	See Notes 5 and 6		1.45		1.45	V
		$I_B = 500$ mA, $I_C = 5$ A			2.2		2.2	
		$V_{CE} = 5$ V, $I_C = 2.5$ A			1.45		1.45	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 250$ mA, $I_C = 2.5$ A	See Notes 5 and 6		0.75		0.75	V
		$I_B = 500$ mA, $I_C = 5$ A			1.5		1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.1$ A, $f = 1$ kHz		20		50		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 5$ V, $I_C = 0.5$ A, $f = 20$ MHz		3		3.5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V, $I_B = 0$, $f = 1$ MHz			250		250	pF

NOTES: 5. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 1%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		2N5002 2N5004	2N5152 2N5154	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3	15	°C/W

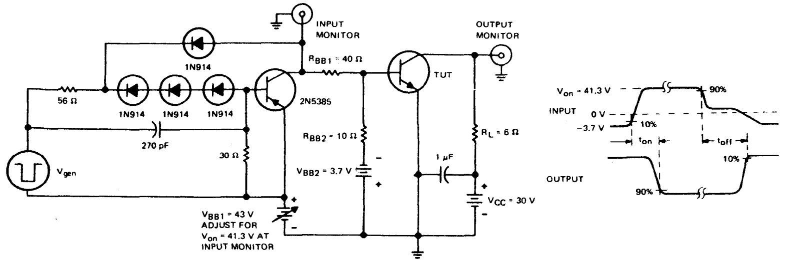
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	All TYPES	UNIT
			TYP	
t_{on}	Turn-On Time	$I_C = 5$ A, $I_{B(1)} = 500$ mA, $I_{B(2)} = -500$ mA,	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3.7$ V, $R_L = 6\ \Omega$, See Figure 1	1.3	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30 V pulse (from 0 V) into a 50 Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, Z_{out} = 50 Ω, t_w = 20 µs, duty cycle ⩽ 2%.

C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TYPICAL CHARACTERISTICS

2N5002, 2N5152
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

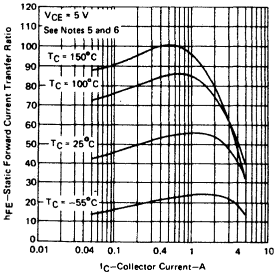


FIGURE 2

2N5004, 2N5154
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

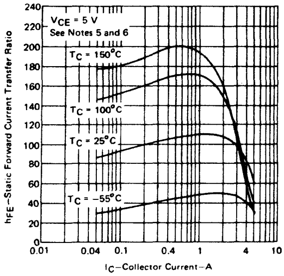


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

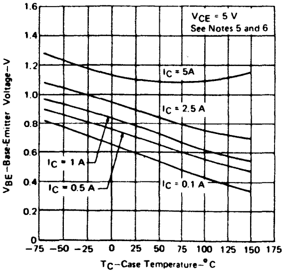


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

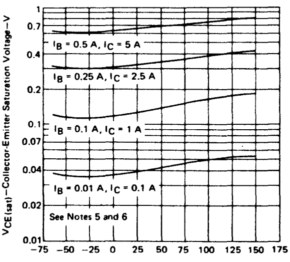


FIGURE 5

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

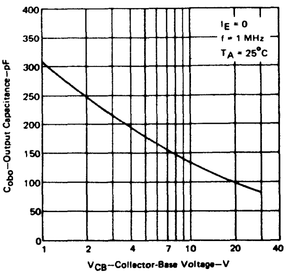


FIGURE 6

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 1%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREA

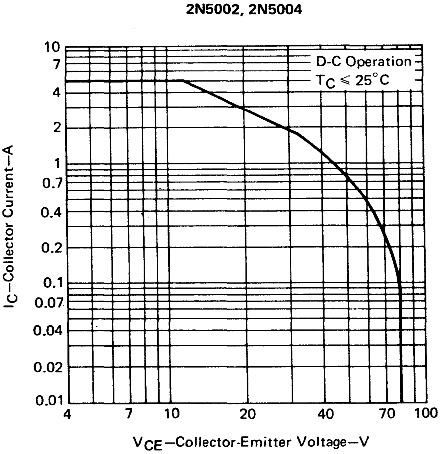


FIGURE 7

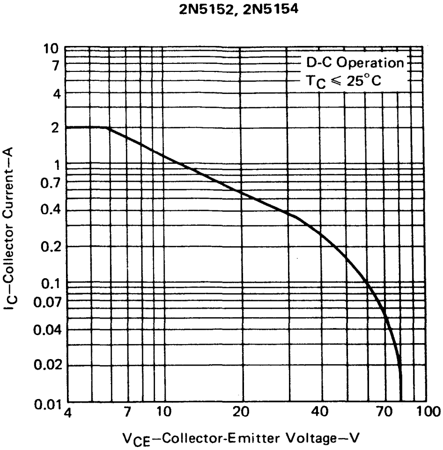


FIGURE 8

THERMAL CHARACTERISTICS

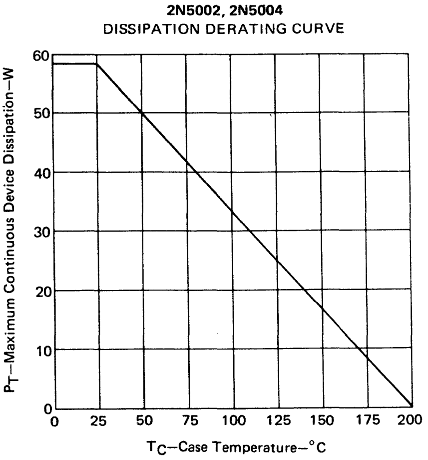


FIGURE 9

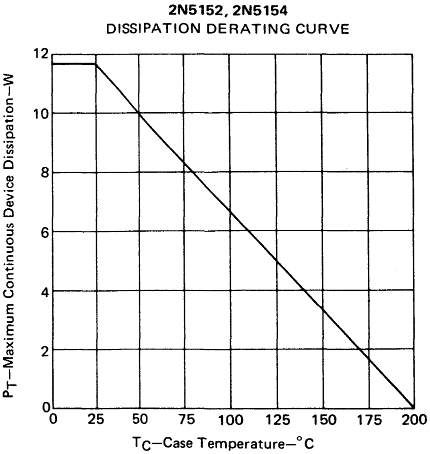


FIGURE 10

TYPES 2N5003, 2N5005, 2N5151, 2N5153
P-N-P SILICON POWER TRANSISTORS

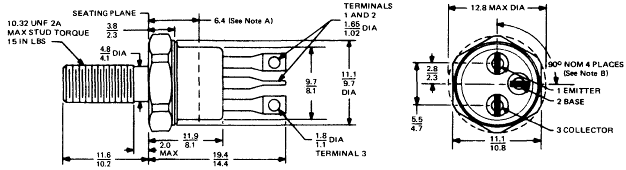
REVISED JUNE 1975

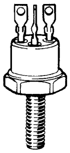
HIGH-FREQUENCY POWER TRANSISTORS WITH COMPUTER-DESIGNED ISOTHERMAL GEOMETRY

- For Complementary Use With 2N5002, 2N5004, 2N5152, 2N5154
- 15 mJ Reverse Energy Rating with I_C = 10 A and 4 V Reverse Bias

*mechanical data

ALL TERMINALS ARE INSULATED FROM THE CASE

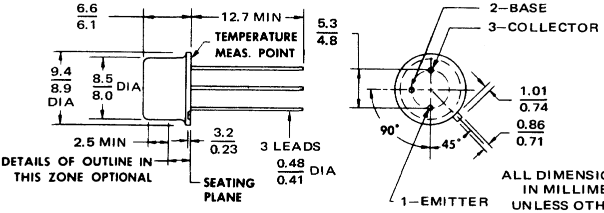


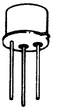


ALL JEDEC TO-59 DIMENSIONS AND NOTES ARE APPLICABLE

NOTES:
A. Within this dimension, case diameter may vary.
B. Position of terminals with respect to the hexagon is not controlled.
C, The case temperature may be measured anywhere on the seating plane within 3.2mm of the stud.
D. All dimensions are in millimetres unless otherwise specified.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE SPECIFIED

ALL JEDEC TO-39 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5003 2N5005	2N5151 2N5153
Collector-Base Voltage	←—100 V*—→	
Collector-Emitter Voltage (See Note 1)	←—80 V*—→	
Emitter-Base Voltage	←—5.5 V*—→	
Continuous Collector Current	−5 A*	−5 A*
Peak Collector Current (See Note 2)	−10 A*	−10 A
Continuous Base Current	−2 A*	−2.5 A*
Safe Operating Areas	See Figures 7* and 8	
Continuous Device Dissipation at 50°C Case Temperature (See Note 3)	50 W*	10 W*
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	33.3 W	6.7 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)		1 W*
Unclamped Inductive Load Energy (See Note 5)	←—15 mJ—→	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Lead or Terminal Temperature 3.2mm from Case for 60 Seconds	←—300°C*—→	

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 8.3$ ms, duty cycle $\leqslant 1\%$.
3. For operation above (or below) 50°C case temperature, refer to Dissipation Derating Curves, Figures 9 and 10.
4. Derate linearly to 200°C free-air temperature at the rate of 5.7 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors*†. $L = 0.3$ mH, $R_{BB1} = 10\ \Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 4$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = 10$ A. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

TYPES 2N5003, 2N5005, 2N5151, 2N5153
P-N-P SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N5003 2N5151		2N5005 2N5153		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -100$ mA, $I_B = 0$,	See Note 6	−80		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$			−50		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 0$			−1		−1	μA
		$V_{CE} = -100$ V, $V_{BE} = 0$			−1		−1	mA
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 2$ V, $T_C = 150°C$			−500		−500	μA
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$			−1		−1	μA
		$V_{EB} = -5.5$ V, $I_C = 0$			−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -50$ mA	See Notes 6 and 7	20		50		
		$V_{CE} = -5$ V, $I_C = -2.5$ A		30	90	70	200	
		$V_{CE} = -5$ V, $I_C = -5$ A		20		40		
		$V_{CE} = -5$ V, $I_C = -2.5$ A, $T_C = -55°C$		15		35		
V_{BE}	Base-Emitter Voltage	$I_B = -250$ mA, $I_C = -2.5$ A	See Notes 6 and 7		−1.45		−1.45	V
		$I_B = -500$ mA, $I_C = -5$ A			−2.2		−2.2	
		$V_{CE} = -5$ V, $I_C = -2.5$ A			−1.45		−1.45	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -250$ mA, $I_C = -2.5$ A	See Notes 6 and 7		−0.75		−0.75	V
		$I_B = -500$ mA, $I_C = -5$ A			−1.5		−1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.1$ A, f = 1 kHz		20		50		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -0.5$ A, f = 20 MHz		3		3.5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, f = 1 MHz			250		250	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 1%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*JEDEC registered data

thermal characteristics

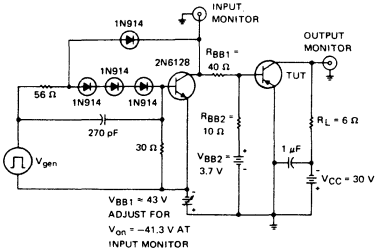
PARAMETER		2N5003 2N5005	2N5151 2N5153	UNIT
		MAX	MAX	
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	3	15	°C/W

switching characteristics at 25°C case temperature

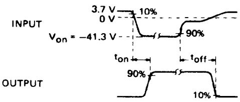
PARAMETER		TEST CONDITIONS†	ALL TYPES	UNIT
			TYP	
t_{on}	Turn-On Time	$I_C = -5$ A, $I_{B(1)} = -500$ mA, $I_{B(2)} = 500$ mA,	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 6\ \Omega$, See Figure 1	1.3	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.

C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

TYPICAL CHARACTERISTICS

2N5003, 2N5151
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

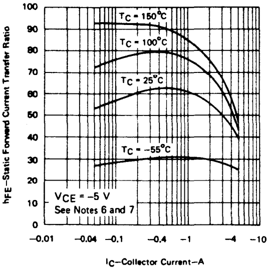


FIGURE 2

2N5005 and 2N5153
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

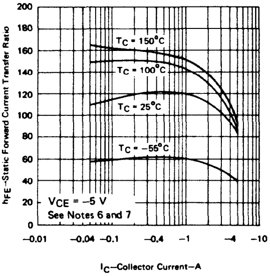


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

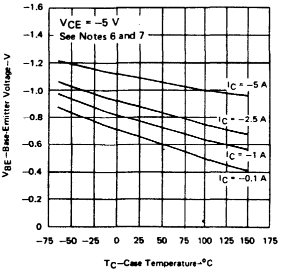


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

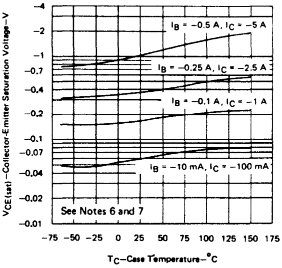


FIGURE 5

COMMON-BASE OPEN-CIRCUIT OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

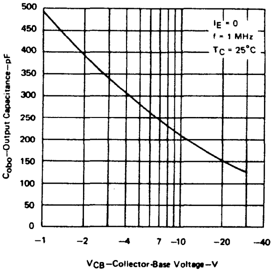


FIGURE 6

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 1%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

MAXIMUM SAFE OPERATING AREAS

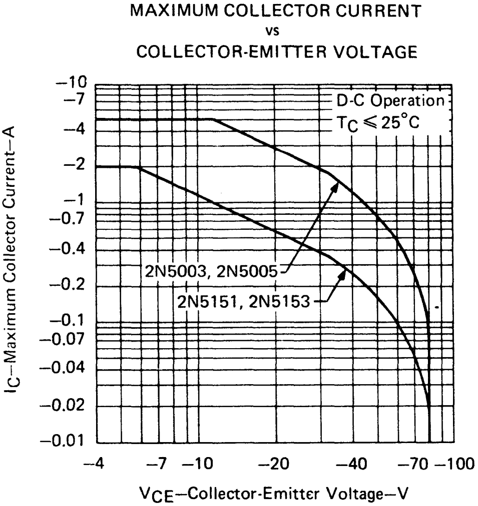


FIGURE 7

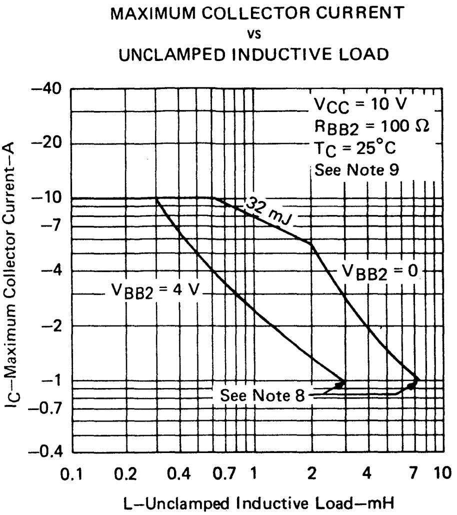


FIGURE 8

NOTES: 8. Above these points the safe operating areas have not been defined.

9. These curves are based on the capability of the transistors to operate safely in the unclamped inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*† $R_{BB1} = 10 \cdot V_{BB1}/I_C$, $V_{BB1} = 10$ V, $R_L = 0.1$ Ω. Energy $\approx I_C{}^2L/2$.

†This circuit appears on page 5-1 of this data book.

THERMAL INFORMATION

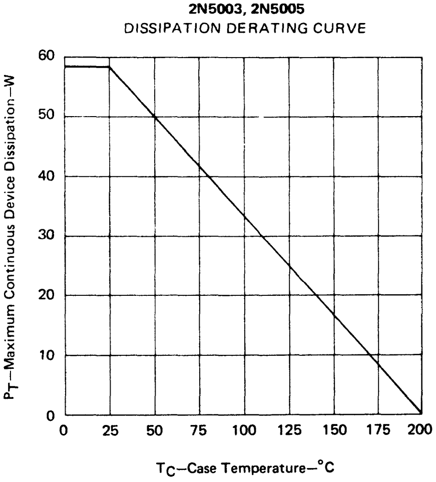


FIGURE 9

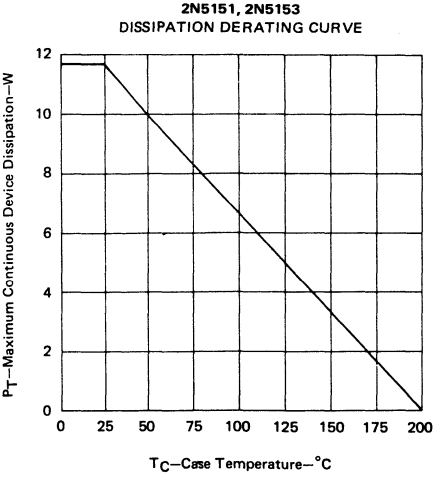


FIGURE 10

2N5038, 2N5039
N-P-N SILICON POWER TRANSISTORS

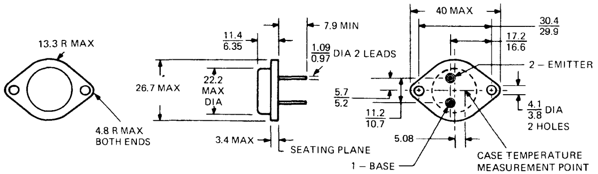
REVISED JULY 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED SWITCHING APPLICATIONS

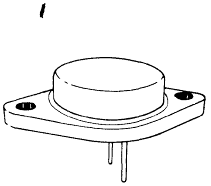
- Min $V_{(BR)CEO}$ of 90 V (2N5038)
- Min f_T of 60 MHz at 10 V, 2 A
- 20-A Rated Continuous Collector Current

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5038	2N5039
*Collector-Emitter Voltage (V_{BE} = −1.5 V, See Note 1)	150 V	120 V
Collector-Emitter Voltage (Base Open, See Note 1)	90 V	75 V
*Emitter-Base Voltage	←— 7 V —→	
*Continuous Collector Current	←— 20 A —→	
*Peak Collector Current (See Note 2)	←— 30 A —→	
*Continuous Base Current	←— 5 A —→	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←— 140 W —→	
*Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	←— 80 W —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←— 5 W —→	
*Operating Collector Junction Temperature Range	−65°C to 200°C	
*Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 0.8mm from Case for 10 Seconds	←— 230°C —→	

NOTES:
1. These values apply only when the collector-emitter voltage is applied with the transistor in the off-state with the base-emitter diode reverse-biased or open-circuited, as specified.
2. This value applies for $t_w \leqslant 10$ ms, duty cycle $\leqslant 50\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.8 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5038		2N5039		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 5	90		75		V
I_{CEV}	Collector Cutoff Current	V_{CE} = 140 V, V_{BE} = −1.5 V		50			mA
		V_{CE} = 110 V, V_{BE} = −1.5 V				50	
		V_{CE} = 85 V, V_{BE} = −1.5 V, T_C = 150°C				10	
		V_{CE} = 100 V, V_{BE} = −1.5 V, T_C = 150°C		10			
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		5		15	mA
		V_{EB} = 7 V, I_C = 0		50		50	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 10 A, See Notes 5 and 6			20	100	
		V_{CE} = 5 V, I_C = 12 A, See Notes 5 and 6	20	100			
V_{BE}	Base-Emitter Voltage	I_B = 5 A, I_C = 20 A, See Notes 5 and 6		3.3		3.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 5 A, I_C = 20 A, See Notes 5 and 6		2.5		2.5	V
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 2 A, f = 5 MHz	12		12		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

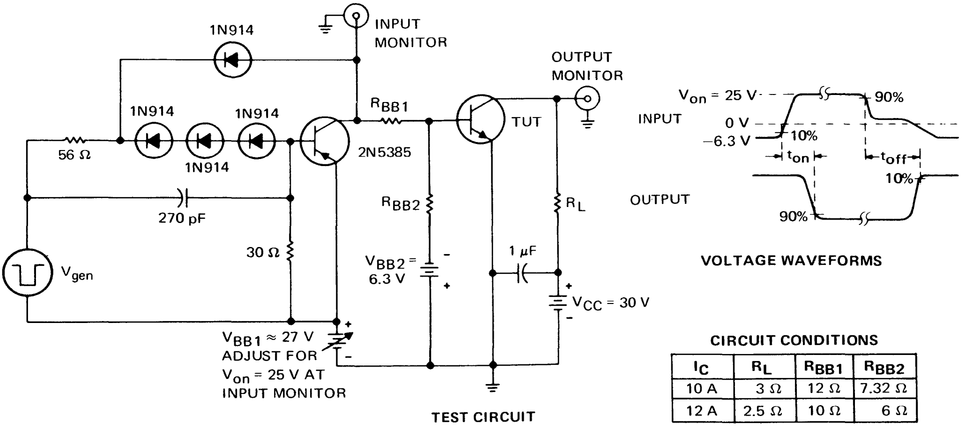
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_r	Rise Time	**2N5038** I_C = 12 A, $I_{B(1)}$ = 1.2 A, $I_{B(2)}$ = −1.2 A, $V_{BE(off)}$ = −6.3 V, R_L = 2.5 Ω, See Figure 1 **2N5039** I_C = 10 A, $I_{B(1)}$ = 1 A, $I_{B(2)}$ = −1 A, $V_{BE(off)}$ = −6.3 V, R_L = 3 Ω, See Figure 1	0.5	µs
t_s	Storage Time		1.5	
t_f	Fall Time		0.5	
t_{on}	Turn-On Time		0.5	
t_{off}	Turn-Off Time		2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

CIRCUIT CONDITIONS

I_C	R_L	R_{BB1}	R_{BB2}
10 A	3 Ω	12 Ω	7.32 Ω
12 A	2.5 Ω	10 Ω	6 Ω

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: t_r ⩽ 15 ns, t_f ⩽ 15 ns, Z_{out} = 50 Ω, t_w = 20 µs, duty cycle ⩽ 2%.

C. Waveforms are monitored on an oscilliscope with the following characteristics: t_r ⩽ 15 ns, R_{in} ⩾ 10 MΩ, C_{in} ⩽ 11.5 pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

2N5060 to 2N5064
PNPN SILICON REVERSE-BLOCKING TRIODE THYRISTORS

REVISED SEPTEMBER 1975

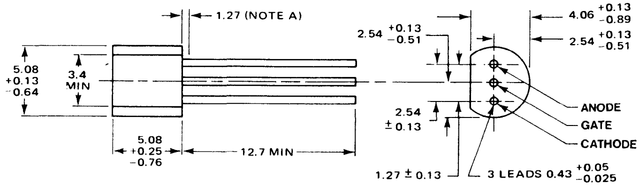
SILECT† THYRISTORS‡
800 mA DC • 30 thru 200 VOLTS

mechanical data

These thyristors are encapsulated in a plastic compound specifically designed for this purpose, using a highly mechanized process developed by Texas Instruments. The case will withstand soldering temperatures without deformation. These devices exhibit stable characteristics under high-humidity conditions and are capable of meeting MIL-STD-202C method 106B. The thyristors are insensitive to light.

THE GATE LEAD IS CONNECTED A P REGION

*ALL JEDEC TO-92 DIMENSIONS AND NOTES ARE APPLICABLE



NOTES: A. Lead diameter is not controlled in this area.
B. All dimensions are in millimetres.

absolute maximum ratings at specified case temperature

		2N5060	2N5061	2N5062	2N5063	2N5064	UNIT
*Repetitive Peak Off-State Voltage, V_{DRM} (See Note 1)	−65°C to 125°C	30	60	100	150	200	V
*Repetitive Peak Reverse Voltage, V_{RRM}	−65°C to 125°C	30	60	100	150	200	V
*Nonrepetitive Peak Reverse Voltage, V_{RSM} (Pulse Width ≤ 5 ms)	−65°C to 125°C	45	80	125	180	230	V
Continuous On-State Current (See Note 2)	−65°C to 50°C			800			mA
*Average On-State Current (180° Conduction Angle, See Note 3)	−65°C to 67°C			510			mA
*Surge On-State Current (See Note 4)	25°C			6			A
*Peak Positive Gate Current (Pulse Width ≤ 300 μs, f ≤ 120 pps)	25°C			1			A
*Peak Gate Reverse Voltage	−65°C to 125°C			5			V
*Average Gate Power Dissipation (See Note 5)	25°C			10			mW
*Peak Gate Power Dissipation (Pulse Width ≤ 300 μs)	25°C			100			mW
*Operating Case Temperature Range				−65 to 125			°C
*Storage Temperature Range				−65 to 150			°C
*Lead Temperature 1.588mm from Case for 10 Seconds				230			°C

NOTES:
1. These values apply when the gate-cathode resistance R_{GK} = 1 kΩ.
2. These values apply for continuous d-c operation with resistive load. Above 50°C derate according to Figure 1.
3. This value may be applied continuously under single-phase 60-Hz half-sine-wave operation with resistive load. Above 67°C derate according to Figure 1.
4. This value applies for one 60-Hz half sine wave when the device is operating at (or below) rated values of peak reverse voltage and on-state current. Surge may be repeated after the device has returned to original thermal equilibrium.
5. This value applies for a maximum averaging time of 16.6 ms.

*JEDEC registered data.

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† Trademark of Texas Instruments

‡U.S. Patent No. 3,439,238

2N5060 to 2N5064
PNPN SILICON REVERSE-BLOCKING TRIODE THYRISTORS

electrical characteristics at specified case temperature

PARAMETER	TEST CONDITIONS		2N5060 THRU 2N5064		UNIT
			MIN	MAX	
I_{DRM} Repetitive Peak Off-State Current	V_D = Rated V_{DRM}, R_{GK} = 1 kΩ	125°C		50*	μA
I_{RRM} Repetitive Peak Reverse Current	V_R = Rated V_{RRM}, R_{GK} = 1 kΩ	125°C		50*	μA
I_{GT} Gate Trigger Current	V_{AA} = 7 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geq 1$ ms	−65°C		350*	μA
		25°C		200	
V_{GT} Gate Trigger Voltage	V_{AA} = 7 V, R_L = 100 Ω, R_{GK} = 1 kΩ, $t_{p(g)} \geq 1$ ms	−65°C		1.2*	V
		25°C		0.8	
	V_D = Rated V_{DRM}, R_L = 100 Ω, R_{GK} = 1 kΩ; $t_{p(g)} \geq 1$ ms	125°C	0.1*		
I_H Holding Current	V_{AA} = 7 V, R_{GK} = 1 kΩ, Initiating I_T = 20 mA	−65°C		10*	mA
		25°C		5	
V_{TM} Peak On-State Voltage	I_{TM} = 1.2 A, See Note 6	25°C		1.7*	V

*thermal characteristics

PARAMETER	MAX	UNIT
$R_{\theta JC}$ Junction-to-Case Thermal Resistance	75	°C/W

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 1%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2mm from the device body.

*JEDEC registered data

THERMAL INFORMATION

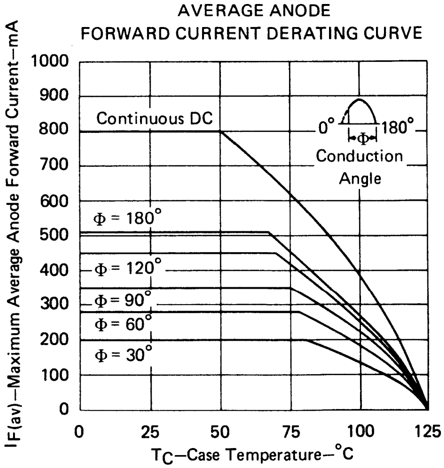
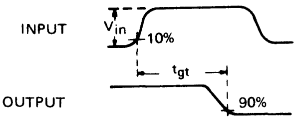


FIGURE 1

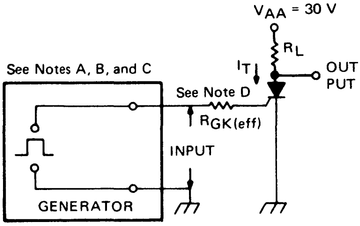
switching characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	TYP	UNIT
t_{gt} Gate-Controlled Turn-On-Time	V_{AA} = 30 V, R_L = 39 Ω, $R_{GK(eff)}$ = 20 kΩ, V_{in} = 20 V, See Figure 2	3	μs
t_q Circuit-Commutated Turn-Off Time	V_{AA} = 30 V, R_L = 30 Ω, I_{RM} ≈ 7 A, See Figure 3	7	μs

PARAMETER MEASUREMENT INFORMATION

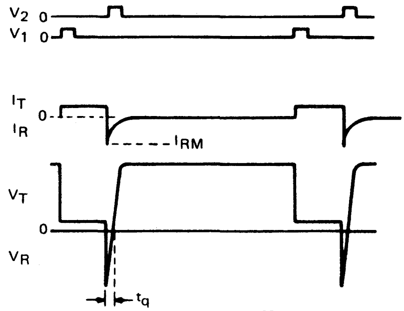


VOLTAGE WAVEFORMS

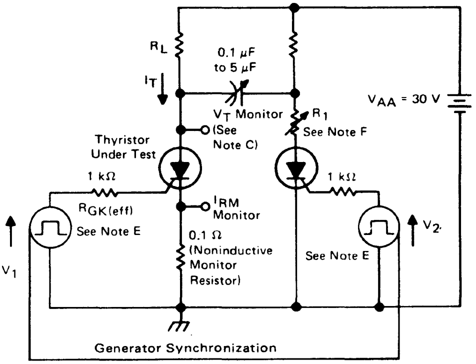


TEST CIRCUIT

FIGURE 2–GATE-CONTROLLED TURN-ON TIME



WAVEFORMS



TEST CIRCUIT

FIGURE 3–CIRCUIT-COMMUTATED TURN-OFF TIME

NOTES:
- A. V_{in} is measured with gate and cathode terminals open.
- B. The input waveform of Figure 2 has the following characteristics: $t_r \leqslant 40$ ns, $t_w \geqslant 20$ μs.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 14$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 12$ pF.
- D. $R_{GK(eff)}$ includes the total resistance of the generator and the external resistor.
- E. Pulse generators for V_1 and V_2 are synchronized to provide an anode current waveform with the following characteristics: t_w = 50 to 300 μs, duty cycle = 1%. The pulse widths of V_1 and V_2 are ⩾ 10 μs.
- F. Resistor R_1 is adjusted for I_{RM} ≈ 7 A.

TYPICAL CHARACTERISTICS

GATE TRIGGER CURRENT
vs
CASE TEMPERATURE

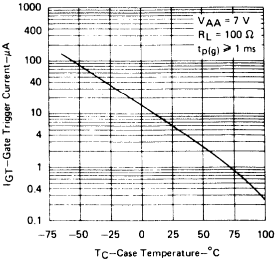


FIGURE 4

GATE TRIGGER VOLTAGE
vs
CASE TEMPERATURE

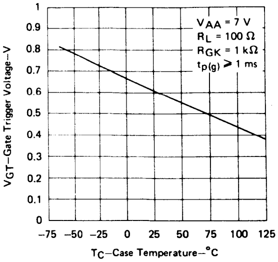


FIGURE 5

HOLDING CURRENT
vs
CASE TEMPERATURE

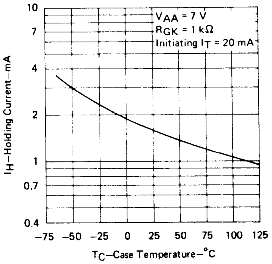
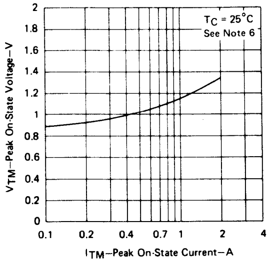


FIGURE 6

PEAK ON-STATE VOLTAGE
vs
PEAK ON-STATE CURRENT



GATE-CONTROLLED TURN-ON TIME
vs
GATE CURRENT

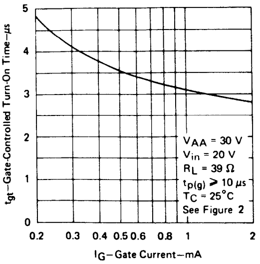


FIGURE 7

FIGURE 8

NOTE 6: This parameter must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%. Voltage-sensing contacts, separate from the current-carrying contacts, are located within 3.2 mm from the device body.

TYPES 2N5067, 2N5068, 2N5069
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

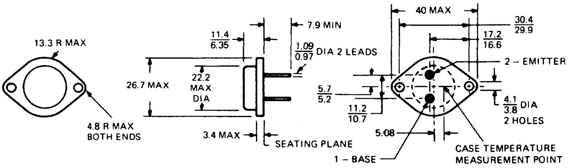
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4901 THRU 2N4903

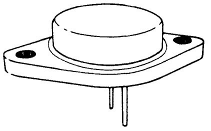
- **87.5 W at 25°C Case Temperature**
- **5-A Rated Collector Current**
- **Min f_T of 4 MHz at 10 V, 1 A**
- **62.5 mJ Reverse Energy Rating**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5067	2N5068	2N5069
*Collector-Base Voltage	40 V	60 V	80 V
*Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V
*Emitter-Base Voltage	5 V	5 V	5 V
*Continuous Collector Current	◄— 5 A —►		
Peak Collector Current (See Note 2)	◄— 15 A —►		
*Continuous Base Current	◄— 1 A —►		
Safe Operating Areas at (or below) 25°C Case Temperature	◄ See Figures 6 and 7 ►		
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄— 87.5 W —►		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 4 W —►		
Unclamped Inductive Load Energy (See Note 5)	◄— 62.5 mJ —►		
*Operating Collector Junction Temperature Range	◄— −65°C to 200°C —►		
*Storage Temperature Range	◄— −65°C to 200°C —►		
*Terminal Temperature 1.588mm from Case for 10 Seconds	◄— 235°C —►		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/°C or refer to Dissipation Derating Curve, Figure 8.
4. Derate linearly to 200°C free-air temperature at the rate of 22.9 mW/°C or refer to Dissipation Derating Curve, Figure 9.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 5. $L = 20$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

TYPES 2N5067, 2N5068, 2N5069
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5067		2N5068		2N5069		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 6	40		60		80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 40 V, I_B = 0		1					mA
		V_{CE} = 60 V, I_B = 0				1			
		V_{CE} = 80 V, I_B = 0						1	
I_{CEV}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = −1.5 V		1					mA
		V_{CE} = 60 V, V_{BE} = −1.5 V				1			
		V_{CE} = 80 V, V_{BE} = −1.5 V						1	
		V_{CE} = 40 V, V_{BE} = −1.5 V, T_C = 150°C		2					
		V_{CE} = 60 V, V_{BE} = −1.5 V, T_C = 150°C				2			
		V_{CE} = 80 V, V_{BE} = −1.5 V, T_C = 150°C						2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0		1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V, I_C = 1 A, See Notes 6 and 7	20	80	20	80	20	80	
		V_{CE} = 2 V, I_C = 5 A, See Notes 6 and 7	7		7		7		
V_{BE}	Base-Emitter Voltage	V_{CE} = 2 V, I_C = 1 A, See Notes 6 and 7		1.2		1.2		1.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.1 A, I_C = 1 A, See Notes 6 and 7		0.4		0.4		0.4	V
		I_B = 1 A, I_C = 5 A, See Notes 6 and 7		1.5		1.5		1.5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 0.5 A, f = 1 kHz	20		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 MHz	4		4		4		

*JEDEC registered data

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 100 mA, $I_{B(2)}$ = −100 mA,	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.3 V, R_L = 30 Ω, See Figure 4	2	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

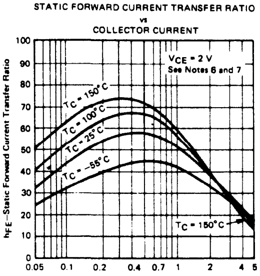


FIGURE 1

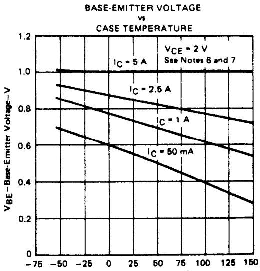


FIGURE 2

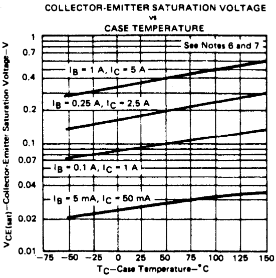
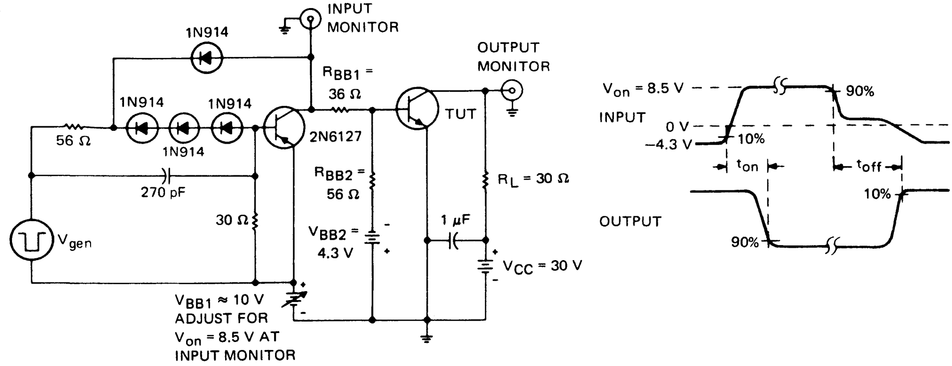


FIGURE 3

NOTES:
6. These parameters must be measured using pulse techniques. t_W = 300 μs, duty cycle ≤ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

PARAMETER MEASUREMENT INFORMATION

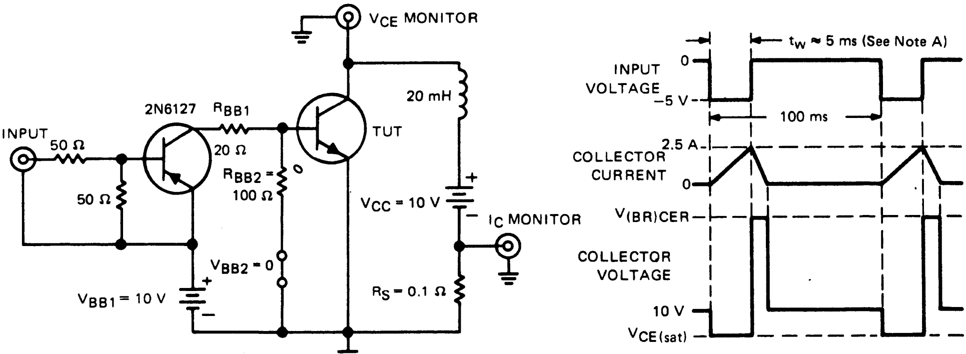


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle $\leqslant 2\%$.
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
D. Resistors must be noninductive types.
E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE: A. Input pulse width is increased until I_{CM} = 2.5 A.

FIGURE 5

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

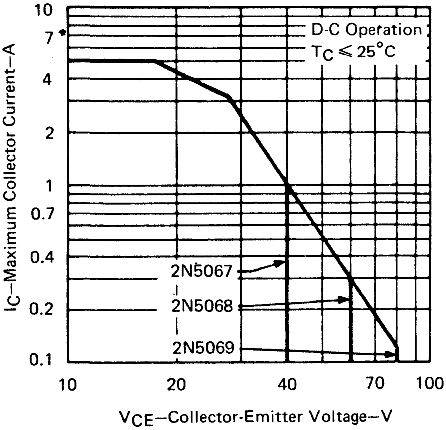


FIGURE 6

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

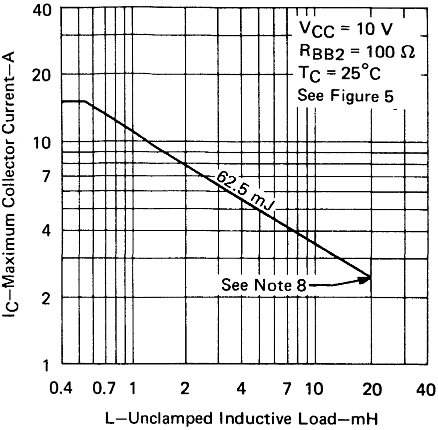


FIGURE 7

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

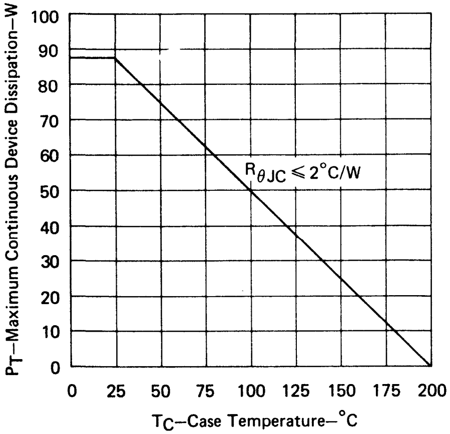


FIGURE 8

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

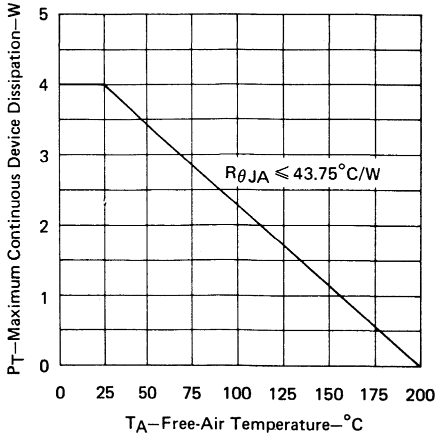


FIGURE 9

2N5157
NPN SILICON POWER TRANSISTOR

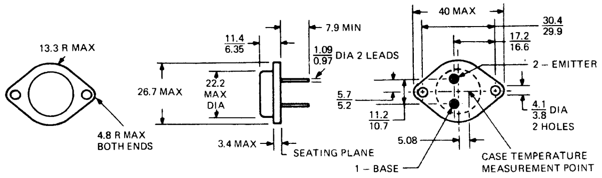
REVISED JUNE 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND MILITARY APPLICATIONS

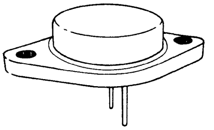
- 100 W at 75°C Case Temperature
- 700 V Collector-Emitter Off-State Voltage
- Min $V_{(BR)CEO}$ of 400 V
- Max t_{off} of 1.7 μs at $I_C = 1$ A
- Typ $V_{CE(sat)}$ of 0.3 V at $I_C = 3.5$ A
- Typ f_T of 5 MHz at 12 V, 0.2 A

*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

*Collector-Emitter Voltage ($V_{BE} = -1.5$ V, See Note 1)	700 V
*Collector-Emitter Voltage (Base Open, See Note 1)	500 V
*Emitter-Base Voltage	6 V
*Continuous Collector Current	3.5 A
*Continuous Base Current	2 A
Safe Operating Area at (or below) 75°C Case Temperature	See Figure 6
*Continuous Device Dissipation at (or below) 75°C Case Temperature (See Note 2)	100 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	4 W
Unclamped Inductive Load Energy (See Note 4)	180 mJ
*Operating Collector Junction Temperature Range	−65°C to 150°C
*Storage Temperature Range	−65°C to 200°C
*Terminal Temperature 1.588mm from Case for 10 Seconds	300°C

NOTES:
1. These values apply only when the collector-emitter voltage is applied with the transistor in the off-state with the base-emitter diode reverse-biased or open-circuited, as specified. In operation, the limitations of Figure 6 must be observed.
2. Derate linearly to 150°C case temperature at the rate of 1.33 W/°C.
3. Derate linearly to 150°C free-air temperature at the rate of 32 mW/°C.
4. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2, condition 1. L = 40 mH, $R_{BB2} = 3$ kΩ, $V_{BB2} = 1.5$ V, $R_S = 0.1$ Ω, $V_{CC} = 50$ V. Energy ≈ $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

2N5157
NPN SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 mA, I_B = 0, See Note 5	400			V
$V_{(BR)CER}$	Collector-Emitter Breakdown Voltage	I_{CM} = 3.5 A, R_{BE} = 10 Ω, See Figure 2 (Condition 2)	500			V
I_{CEO}	Collector Cutoff Current	V_{CE} = 500 V, I_B = 0			0.25	mA
I_{CEV}	Collector Cutoff Current	V_{CE} = 700 V, V_{BE} = −1.5 V			0.5	mA
		V_{CE} = 400 V, V_{BE} = −1.5 V, T_C = 125°C			0.5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 6 V, I_C = 0			5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 1 A, See Notes 5 and 6	30		90	
		V_{CE} = 5 V, I_C = 2.5 A	10			
		V_{CE} = 5 V, I_C = 1 A, T_C = −55°C	10			
V_{BE}	Base-Emitter Voltage	I_B = 0.7 A, I_C = 3.5 A, See Notes 5 and 6		1.1	2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.1 A, I_C = 1 A, See Notes 5 and 6		0.2	0.8	V
		I_B = 0.7 A, I_C = 3.5 A		0.3	2.5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 12 V, I_C = 0.2 A, f = 1 MHz	2.8	5		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 20 V, I_E = 0, f = 1 MHz		100	150	pF

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Junction-to-Case Thermal Resistance	0.75	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	31.25	

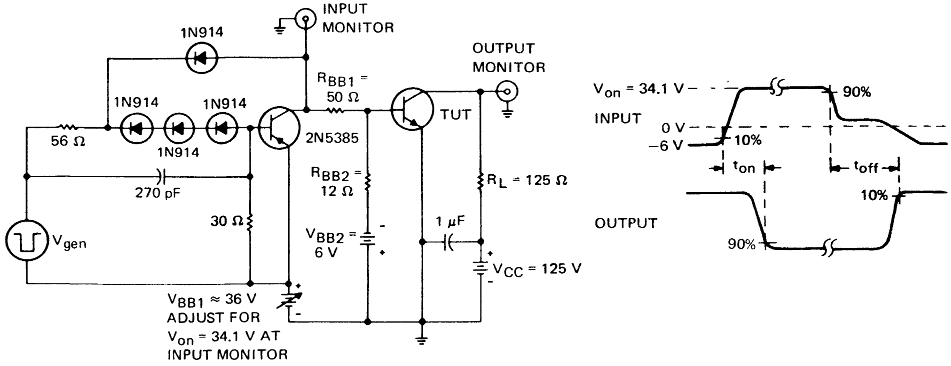
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	I_C = 1 A, $I_{B(1)}$ = 0.1 A, $I_{B(2)}$ = −0.5 A,	0.8	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −6 V, R_L = 125 Ω, See Figure 1	1.7	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



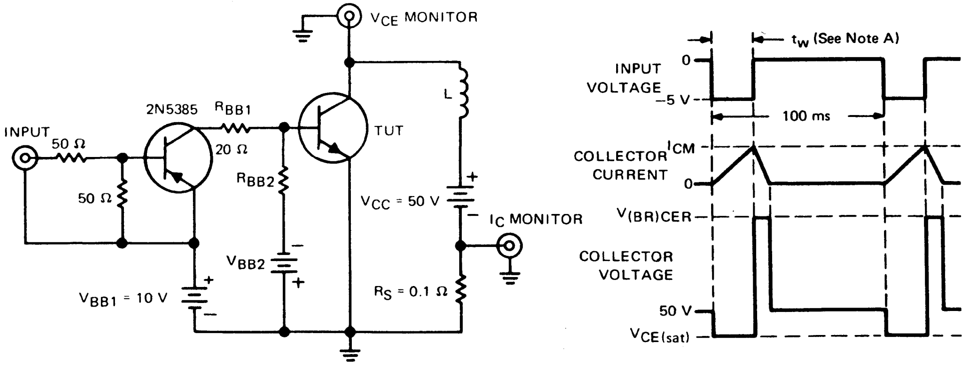
TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$ $t_w = 5\ \mu s$, duty cycle ⩽ 5%.
- C. Waveforms are monitored on an ocsilloscope with the following characteristics: $t_r \leqslant 10$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



CONDITION	R_{BB2}	V_{BB2}	L	I_{CM}	t_w
1	3 kΩ	1.5 V	40 mH	3 A	≈ 2.4 ms
2	10 Ω	0 V	10 mH	3.5 A	≈ 0.7 ms

TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until the peak collector current reaches the specified value of I_{CM}.

FIGURE 2

2N5157
NPN SILICON POWER TRANSISTOR

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT
TRANSFER RATIO
vs
COLLECTOR CURRENT

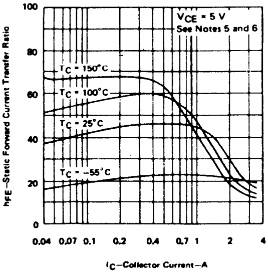


FIGURE 3

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

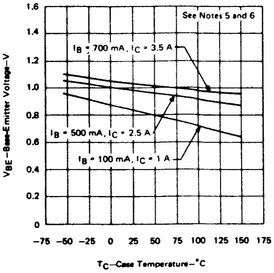


FIGURE 4

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
CASE TEMPERATURE

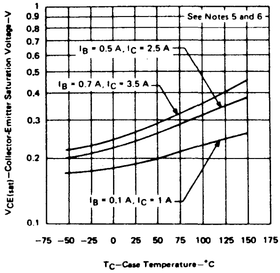


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREA

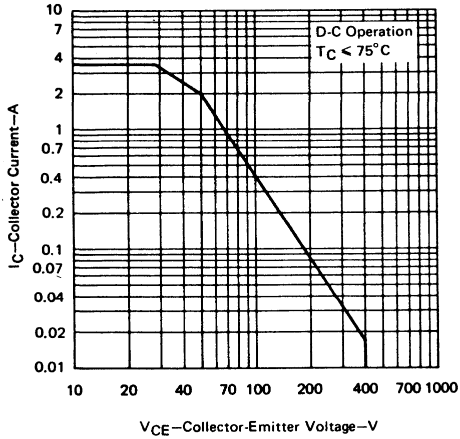


FIGURE 6

THERMAL INFORMATION

DISSIPATION DERATING CURVE

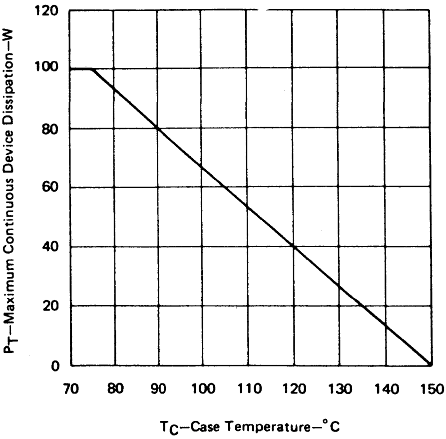


FIGURE 7

2N5241
NPN SILICON POWER TRANSISTOR

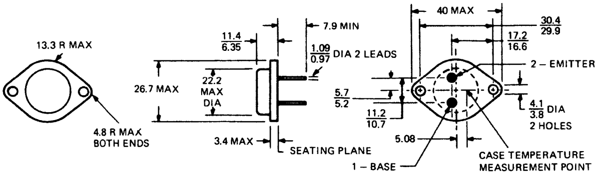
REVISED JUNE 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND MILITARY APPLICATIONS

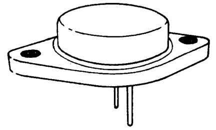
- **125 W at 62.5°C Case Temperature**
- **400 V Collector-Emitter Off-State Voltage**
- **Min $V_{(BR)CEO}$ of 325 V**
- **Max t_{off} of 1.7 μs at $I_C = 2.5$ A**
- **Typ $V_{CE(sat)}$ of 0.35 V at $I_C = 5$ A**
- **Typ f_T of 5 MHz at 12 V, 0.2 A**

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

*Collector-Emitter Voltage (See Note 1)	400 V
*Emitter-Base Voltage	5 V
*Continuous Collector Current	5 A
*Continuous Base Current	2 A
Safe Operating Area at (or below) 62.5°C Case Temperature	See Figure 6
*Continuous Device Dissipation at (or below) 62.5°C Case Temperature (See Note 2)	125 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	4 W
Unclamped Inductive Load Energy (See Note 4)	180 mJ
*Operating Collector Junction Temperature Range	–65°C to 150°C
*Storage Temperature Range	–65°C to 200°C
*Terminal Temperature 1.588mm from Case for 1.0 Seconds	300°C

NOTES:
1. This value applies only when the collector-emitter voltage is applied with the transistor in the off-state with the base-emitter diode reverse-biased or open-circuited. In operation, the limitations of Figure 6 must be observed.
2. Derate linearly to 150°C case temperature at the rate 1.43 W/°C.
3. Derate linearly to 150°C free-air temperature at the rate 32 mW/°C.
4. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 2. $L = 40$ mH, $R_{BB2} = 3$ kΩ, $V_{BB2} = 1.5$ V, $R_S = 0.1$ Ω, $V_{CC} = 50$ V. Energy $\approx I_C{}^2 L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

2N5241
NPN SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 mA, I_B = 0,	See Note 5	325			V
I_{CEO}	Collector Cutoff Current	V_{CE} = 400 V, I_B = 0				2.5	mA
I_{CEV}	Collector Cutoff Current	V_{CE} = 400 V, V_{BE} = −1.5 V				0.5	mA
		V_{CE} = 400 V, V_{BE} = −1.5 V, T_C = 125°C				5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0				2	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 2.5 A	See Notes 5 and 6	15		35	
		V_{CE} = 5 V, I_C = 3.5 A		10			
V_{BE}	Base-Emitter Voltage	I_B = 0.5 A, I_C = 2.5 A	See Notes 5 and 6		1	1.5	V
		I_B = 1 A, I_C = 5 A			1.2	2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.5 A, I_C = 2.5 A	See Notes 5 and 6		0.25	0.7	V
		I_B = 1 A, I_C = 5 A			0.35	2.5	
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 12 V, I_C = 0.2 A, f = 1 MHz		2.5	5		

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 µs, duty cycle ⩽ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

thermal characteristics

PARAMETER		MAX	UNIT
$R_{\theta JC}$	Jucntion-to-Case Thermal Resistance	0.7	°C/W
$R_{\theta JA}$	Junction-to-Free-Air Thermal Resistance	31.25	

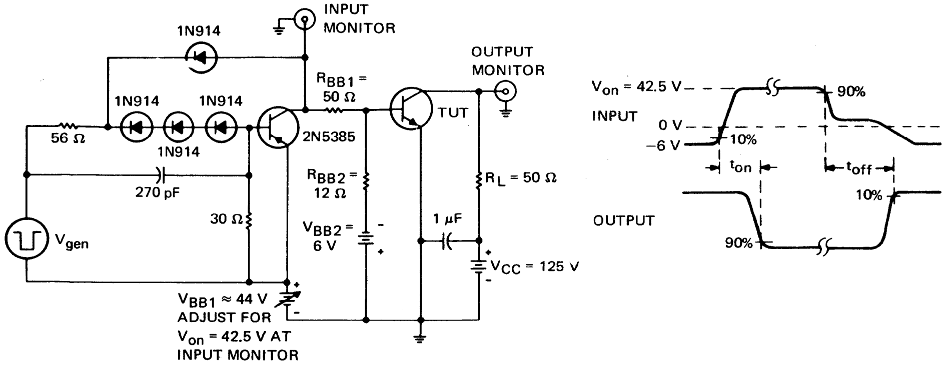
*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_{on}	Turn-On Time	I_C = 2.5 A, $I_{B(1)}$ = 0.25 A, $I_{B(2)}$ = −0.5 A,	0.8	µs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −6 V, R_L = 50 Ω, See Figure 1	1.7	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data

PARAMETER MEASUREMENT INFORMATION



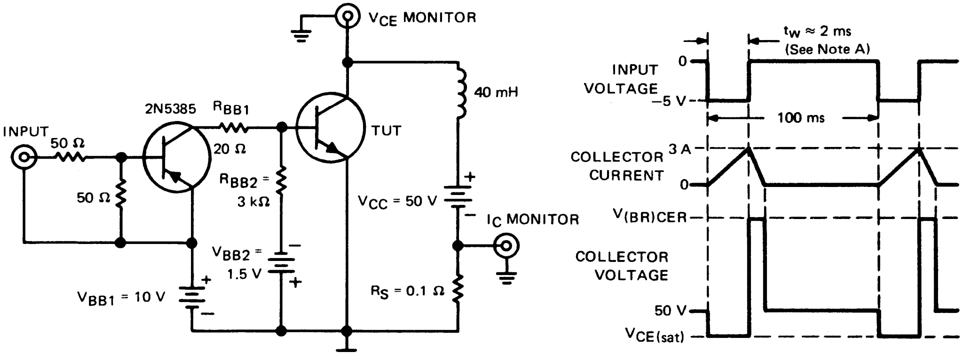
TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50$ Ω, $t_w = 5$ μs, duty cycle ⩽ 5%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 10$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

VOLTAGE AND CURRENT WAVEFORMS

NOTE A: Input pulse width is increased until I_{CM} = 3 A.

FIGURE 2

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

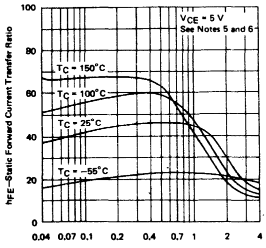


FIGURE 3

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

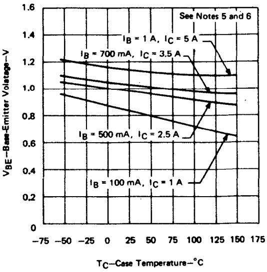


FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

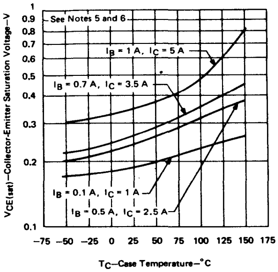


FIGURE 5

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

MAXIMUM SAFE OPERATING AREA

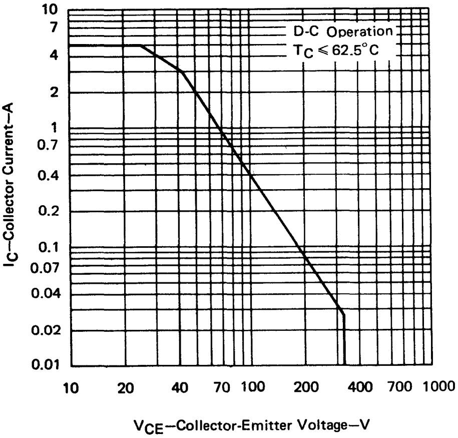


FIGURE 6

THERMAL INFORMATION

DISSIPATION DERATING CURVE

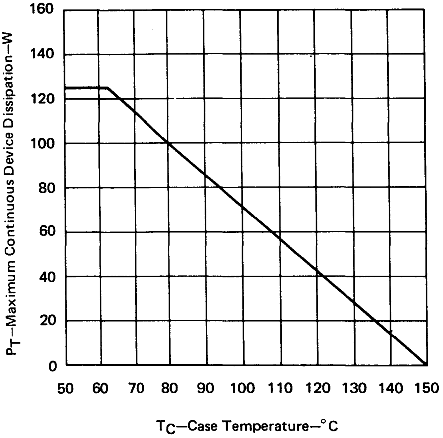


FIGURE 7

TYPES 2N5301, 2N5302, 2N5303
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

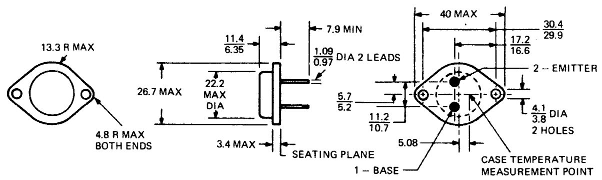
REVISED JUNE 1975

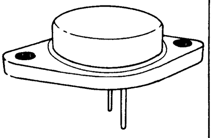
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
2N5301, 2N5302 DESIGNED FOR COMPLEMENTARY USE WITH 2N4398, 2N4399

200 W at 25°C Case Temperature
30-A Rated Continuous Collector Current (2N5301, 2N5302)
20-A Rated Continuous Collector Current (2N5303)
Min f_T of 2 MHz at 10 V, 1 A

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5301	2N5302	2N5303
*Collector-Base Voltage	40 V	60 V	80 V
*Collector-Emitter Voltage (See Note 1)	40 V	60 V	80 V
*Emitter-Base Voltage	5 V	5 V	5 V
*Continuous Collector Current	30 A	30 A	20 A
*Peak Collector Current (See Note 2)	← 50 A →		
*Continuous Base Current	← 7.5 A →		
Safe Operating Region at (or below) 25°C Case Temperature	See Figures 7 and 8		
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 200 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 5 W →		
*Operating Collector Junction Temperature Range	-65°C to 200°C		
*Storage Temperature Range	-65°C to 200°C		

NOTES: 1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1.14 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N5301		2N5302		2N5303		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0,	See Note 5	40		60		80		V
I_{CBO}	Collector Cutoff Current	V_{CB} = 40 V, I_E = 0			1					mA
		V_{CB} = 60 V, I_E = 0					1			
		V_{CB} = 80 V, I_E = 0							1	
I_{CEO}	Collector Cutoff Current	V_{CE} = 40 V, I_B = 0			5					mA
		V_{CE} = 60 V, I_B = 0					5			
		V_{CE} = 80 V, I_B = 0							5	
I_{CEV}	Collector Cutoff Current	V_{CE} = 40 V, V_{BE} = -1.5 V			1					mA
		V_{CE} = 60 V, V_{BE} = -1.5 V					1			
		V_{CE} = 80 V, V_{BE} = -1.5 V							1	
		V_{CE} = 40 V, V_{BE} = -1.5 V, T_C = 150°C			10					
		V_{CE} = 60 V, V_{BE} = -1.5 V, T_C = 150°C					10			
		V_{CE} = 80 V, V_{BE} = -1.5 V, T_C = 150°C							10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V, I_C = 0			5		5		5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V, I_C = 1 A	See Notes 5 and 6	40		40		40		
		V_{CE} = 2 V, I_C = 10 A						15	60	
		V_{CE} = 2 V, I_C = 15 A		15	60	15	60			
		V_{CE} = 2 V, I_C = 20 A						5		
		V_{CE} = 2 V, I_C = 30 A		5		5				
V_{BE}	Base-Emitter Voltage	I_B = 1 A, I_C = 10 A	See Notes 5 and 6		1.7		1.7		1.7	V
		I_B = 1.5 A, I_C = 15 A			1.8		1.8		2	
		I_B = 2 A, I_C = 20 A			2.5		2.5			
		I_B = 4 A, I_C = 20 A							2.5	
		V_{CE} = 2 V, I_C = 10 A							1.5	
		V_{CE} = 2 V, I_C = 15 A			1.7		1.7			
		V_{CE} = 4 V, I_C = 20 A							2.5	
		V_{CE} = 4 V, I_C = 30 A			3		3			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1 A, I_C = 10 A	See Notes 5 and 6		0.75		0.75		1	V
		I_B = 1.5 A, I_C = 15 A							1.5	
		I_B = 2 A, I_C = 20 A			2		2			
		I_B = 4 A, I_C = 20 A							2	
		I_B = 6 A, I_C = 30 A			3		3			
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A,	f = 1 kHz	40		40		40		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A,	f = 1 MHz	2		2		2		

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤2%.

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

*Indicates JEDEC registered data

thermal characteristics

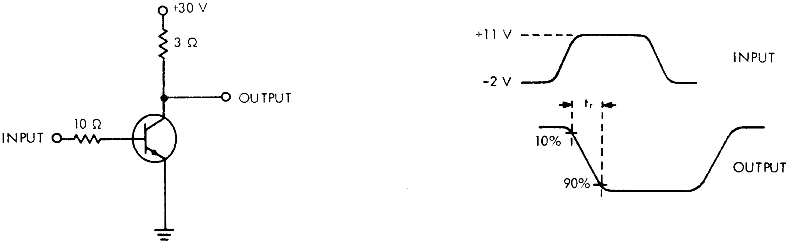
PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	0.875	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	35	

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MAX	UNIT
t_r	Rise Time	$I_C = 10$ A, $I_{B(1)} = 1$ A, $V_{BE(off)} = -2$ V, $R_L = 3\ \Omega$, See Figure 1	1	µs
t_s	Storage Time	$I_C = 10$ A, $I_{B(1)} = 1$ A, $I_{B(2)} = -1$ A,	2	
t_f	Fall Time	$R_L = 3\ \Omega$, See Figure 2	1	

†Voltage and current values shown are nominal, exact values vary slightly with transistor parameters.

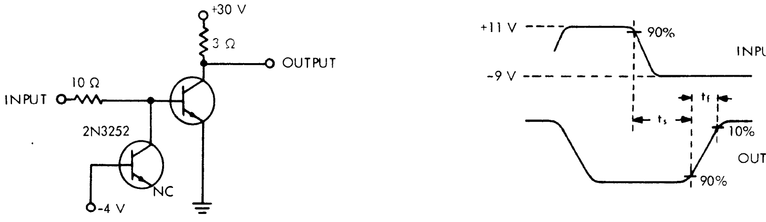
*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 1 – RISE TIME



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 2 – STORAGE AND FALL TIMES

NOTES: a. The input waveforms are supplied by a generator with the following characteristics: $t_r \leq 20$ ns, $t_f \leq 20$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$ to $100\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 20$ ns, $R_{in} \geq 10\ k\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

*Indicates JEDEC registered data

TYPICAL CHARACTERISTICS

2N5301, 2N5302
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

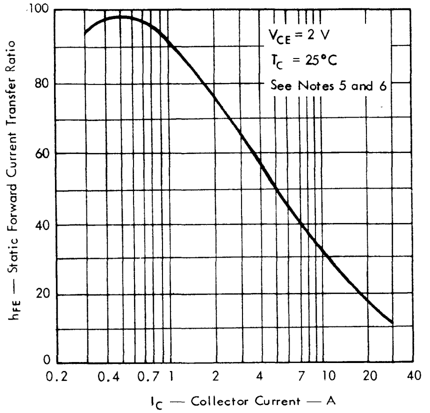


FIGURE 3

2N5303
STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

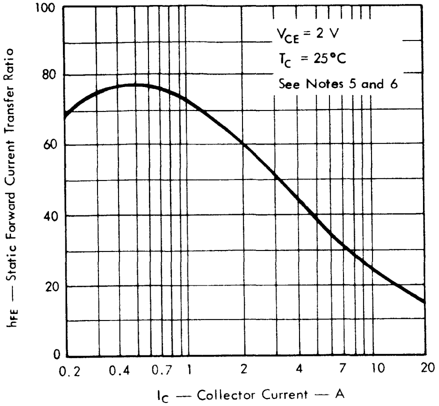


FIGURE 4

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

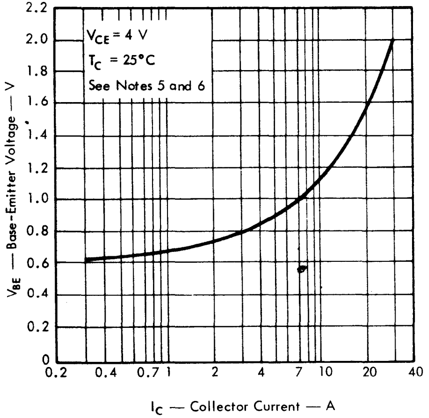


FIGURE 5

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

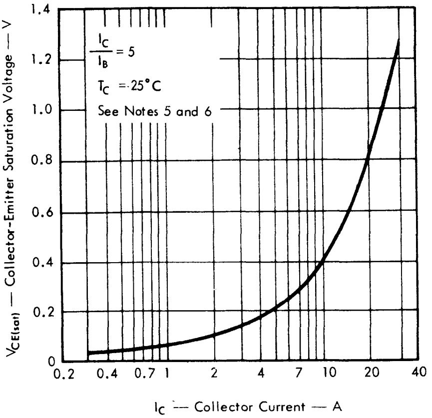


FIGURE 6

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

MAXIMUM SAFE OPERATING REGIONS

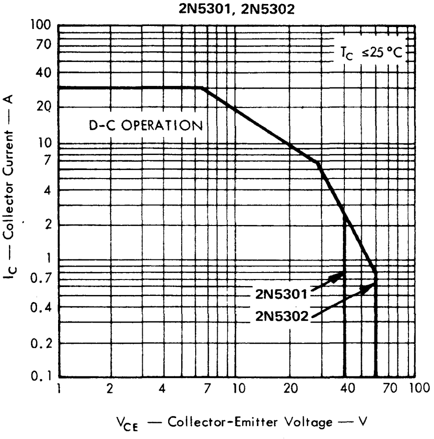


FIGURE 7

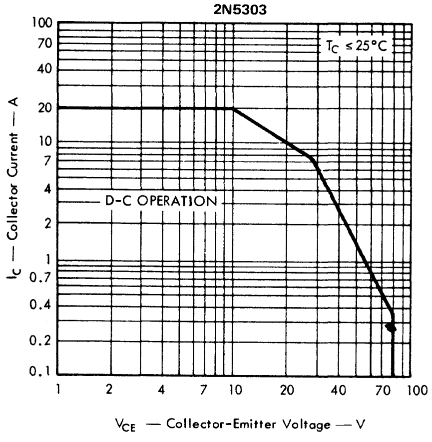


FIGURE 8

THERMAL INFORMATION

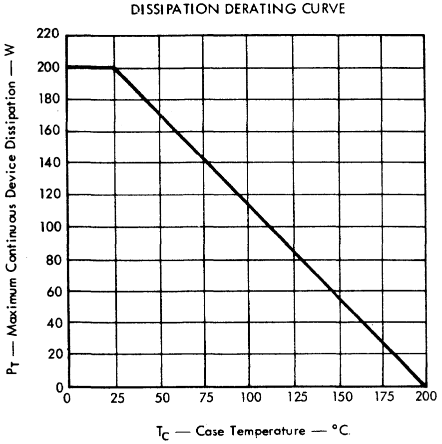


FIGURE 9

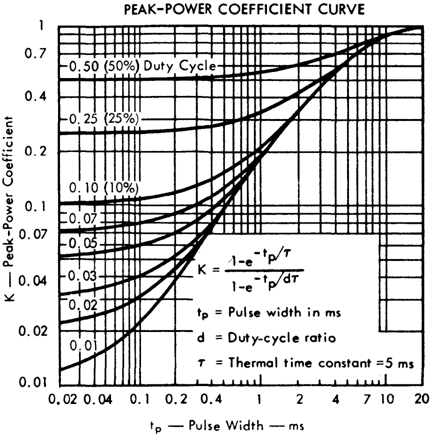


FIGURE 10

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	**Average Power Dissipation**		W
$P_{T(max)}$	**Peak Power Dissipation**		W
θ_{J-A}	**Junction-to-Free-Air Thermal Resistance**	35	deg/W
θ_{J-C}	**Junction-to-Case Thermal Resistance**	0.875	deg/W
θ_{C-A}	**Case-to-Free-Air Thermal Resistance**	34.125	deg/W
θ_{C-HS}	**Case-to-Heat-Sink Thermal Resistance**		deg/W
θ_{HS-A}	**Heat-Sink-to-Free-Air Thermal Resistance**		deg/W
T_A	**Free-Air Temperature**		°C
T_C	**Case Temperature**		°C
$T_{J(av)}$	**Average Junction Temperature**	≤200	°C
$T_{J(max)}$	**Peak Junction Temperature**	≤200	°C
K	**Peak-Power Coefficient**	See Figure 10	
t_p	**Pulse Width**		ms
t_x	**Pulse Period**		ms
d	**Duty-Cycle Ratio (t_p/t_x)**		

Equation No. 1 – Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}} \quad \text{for } 100^\circ C \leq T_C \leq 200^\circ C \text{ as in Figure 9}$$

Equation No. 2 – Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J-A}} \quad \text{for } 25^\circ C \leq T_A \leq 200^\circ C$$

Equation No. 3 – Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\theta_{J-C}} \quad \text{for } 100^\circ C \leq T_C \leq 200^\circ C$$

Equation No. 4 – Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\theta_{C-A} + K\theta_{J-C}} \quad \text{for } 25^\circ C \leq T_A \leq 200^\circ C.$$

Example – Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C-HS} + \theta_{HS-A} = 2.25$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) = 200°C

$T_A = 50^\circ C$

d = 10% (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 10, Peak-Power Coefficient K = 0.109 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\theta_{J-C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(2.25) + 0.109\,(0.875)} = 469 \text{ W}$$

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

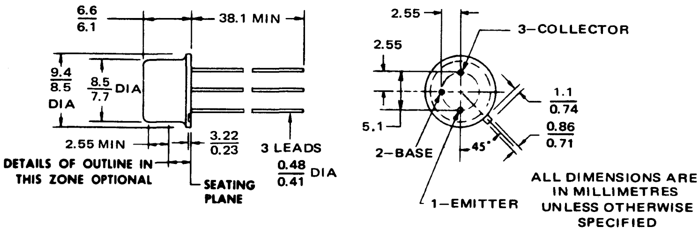
REVISED JUNE 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4300

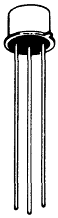
- **15 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.45 V at 1 A I_C**
- **Typ t_{on} of 150 ns at 1 A I_C**
- **Min f_T of 30 MHz**

*mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-5 DIMENSIONS AND NOTES ARE APPLICABLE



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−2 A
Peak Collector Current (See Note 2)	−5 A
Continuous Base Current	−1 A
Continuous Emitter Current	−3 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 7
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	15 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	1 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Lead Temperature 1.588mm from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.15 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 5.72 mW/deg.

*Indicates JEDEC registered data

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	µA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	µA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−1	µA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -1$ A, See Notes 5 and 6	30	120	
		$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.1$ A, $I_C = -1$ A, See Notes 5 and 6		−0.45	V
		$I_B = -0.4$ A, $I_C = -2$ A, See Notes 5 and 6		−1	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 1$ kHz	30		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, $f = 15$ MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ µs, duty cycle $\leq 2\%$.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.66	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	

*Indicates JEDEC registered data

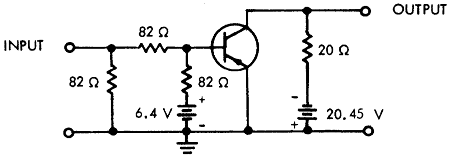
TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

switching characteristics at 25°C case temperature

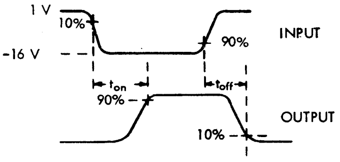
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -1$ A, $I_{B(1)} = -0.1$ A, $I_{B(2)} = 0.1$ A,	150	ns
t_{off}	Turn-Off Time	$V_{BE(off)} = 3.7$ V, $R_L = 20\ \Omega$, See Figure 1	450	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES:
a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 2\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

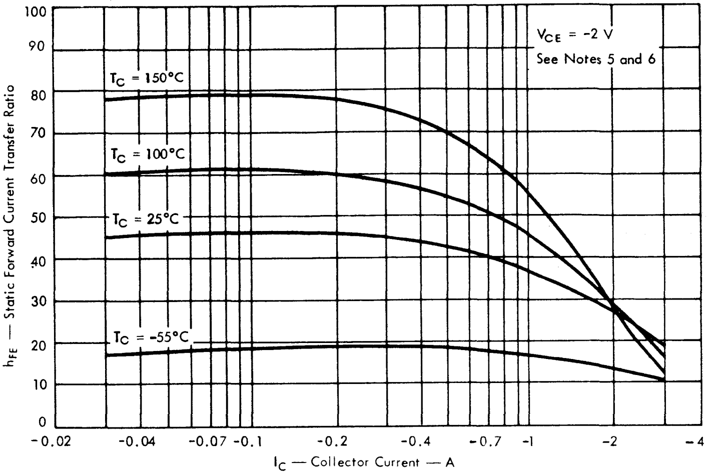


FIGURE 2

BASE-EMITTER VOLTAGE
vs
CASE TEMPERATURE

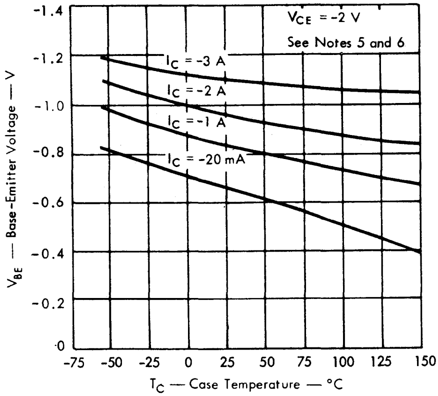


FIGURE 3

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
CASE TEMPERATURE

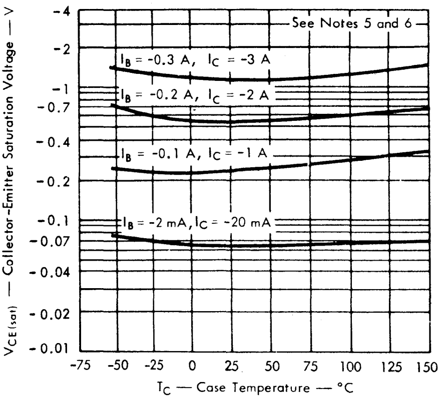


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts.

TYPE 2N5333
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

TYPICAL CHARACTERISTICS

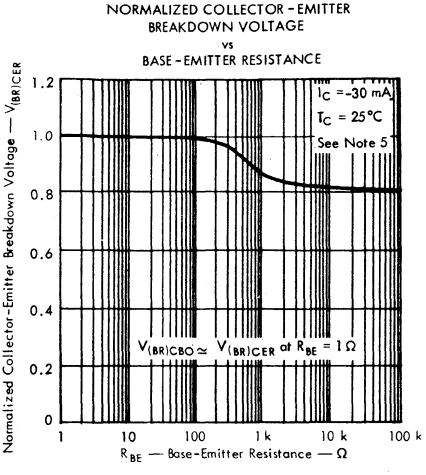


FIGURE 5

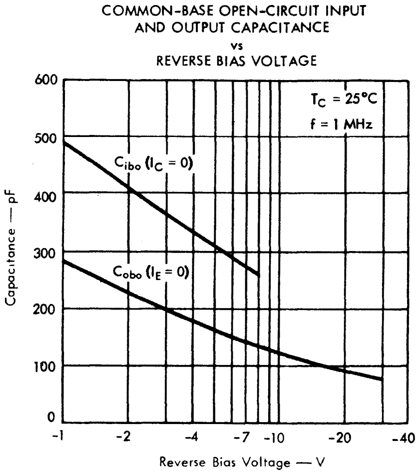


FIGURE 6

NOTE 6: These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

MAXIMUM SAFE OPERATING REGION

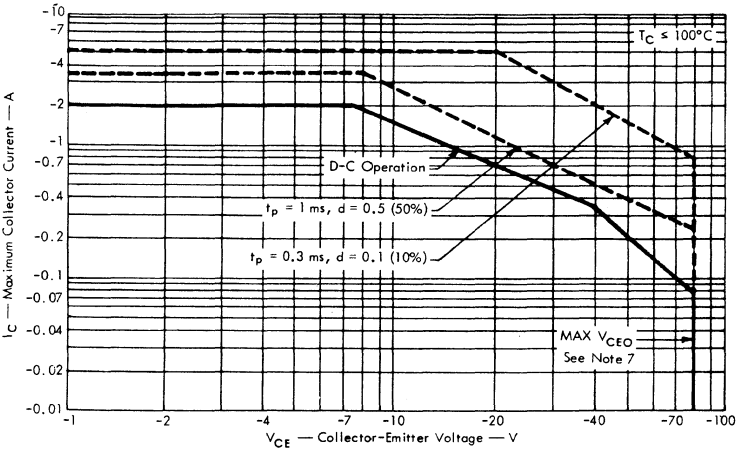


FIGURE 7

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

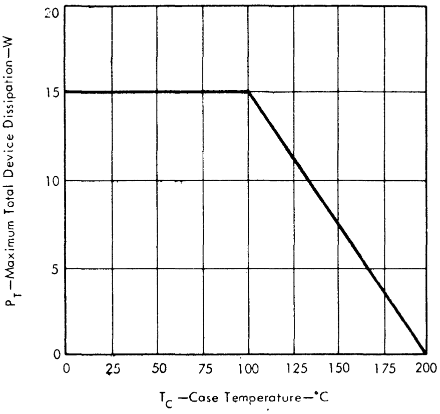


FIGURE 8

PEAK-POWER COEFFICIENT CURVE

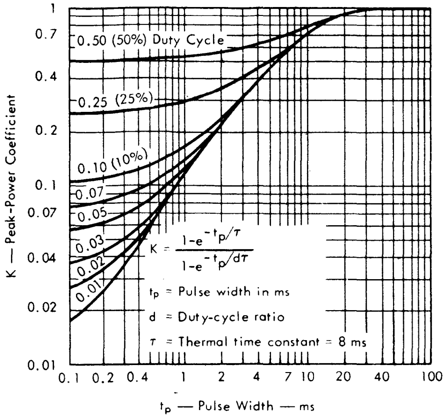


FIGURE 9

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	175	deg/W
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	6.66	deg/W
$\theta_{C\text{-}A}$	Case-to-Free-Air Thermal Resistance	168	deg/W
$\theta_{C\text{-}HS}$	Case-to-Heat-Sink Thermal Resistance		deg/W
$\theta_{HS\text{-}A}$	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 9	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}} \quad \text{for } 100°C \leq T_C \leq 200°C \text{ as in Figure 8}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J\text{-}A}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}} \quad \text{for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C\text{-}A} + K\,\theta_{J\text{-}C}} \quad \text{for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)
OPERATING CONDITIONS:

$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = 7$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) = 200°C
T_A = 50°C
d = 10% (0.1)
t_p = 0.1 ms

Solution:

From Figure 9, Peak-Power Coefficient

K = 0.105 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C\text{-}HS} + \theta_{HS\text{-}A}) + K\,\theta_{J\text{-}C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(7) + 0.105\,(6.66)} = 107 \text{ W}$$

TYPES 2N5384, 2N5385
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTORS

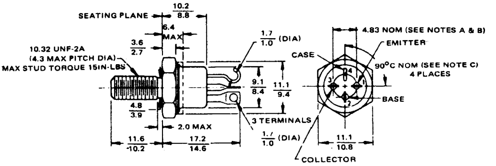
REVISED SEPTEMBER 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N3996 AND 2N3998

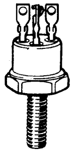
- **30 W at 100°C Case Temperature**
- **Typ t_{on} of 160 ns at 2 A I_C**
- **Max $V_{CE(sat)}$ of 0.6 V at 2 A I_C**
- **Min f_T of 30 MHz**

*mechanical data

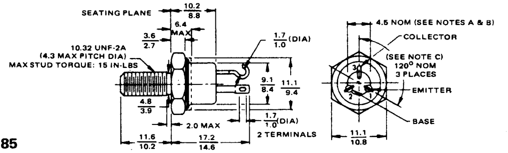
THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE



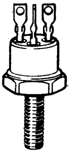
2N5384



THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



2N5385



NOTES:
A. Position of terminals with respect to hexagon is not controlled.
B. Terminals located on true position within 0.76 mm relative to diameter of can.
C. This dimension applies to the location of the center line of the terminals.
D. The case temperature may be measured anywhere on the seating plane within 3.18 mm of the stud.
E. All dimensions are in mm unless otherwise specified.

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−5 A
Peak Collector Current (See Note 2)	−12 A
Continuous Base Current	−1 A
Continuous Emitter Current	−6 A
Safe Operating Region at (or below) 100° C Case Temperature	See Figure 2
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	30 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	2 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1.588mm from Case for 10 Seconds	260°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.3 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 11.4 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	μA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−1	μA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -2$ A, See Notes 5 and 6	20	80	
		$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -5$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.2$ A, $I_C = -2$ A, See Notes 5 and 6		−0.6	V
		$I_B = -1$ A, $I_C = -5$ A, See Notes 5 and 6		−1.4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 15 MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle $\leq 2\%$.

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

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	3.33	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	87.5	

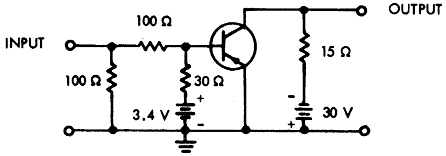
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

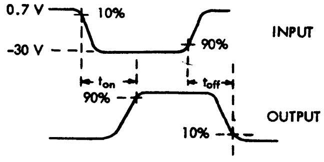
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -2$ A, $I_{B(1)} = -150$ mA, $I_{B(2)} = 150$ mA,	160	ns
t_{off}	Turn-Off Time	$V_{BE(off)} = 2.8$ V, $R_L = 15\ \Omega$, See Figure 1	550	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES:
a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 5\ \mu s$, duty cycle $\leq 2\%$.
b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.
c. Resistors must be noninductive types.
d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

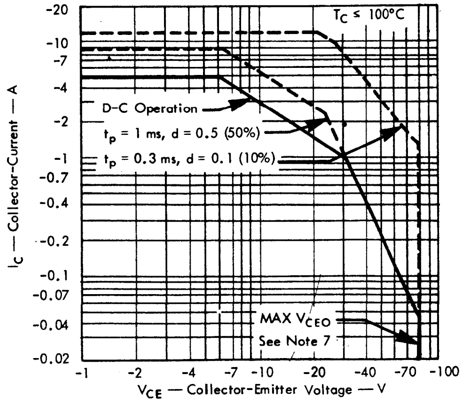


FIGURE 2

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL CHARACTERISTICS

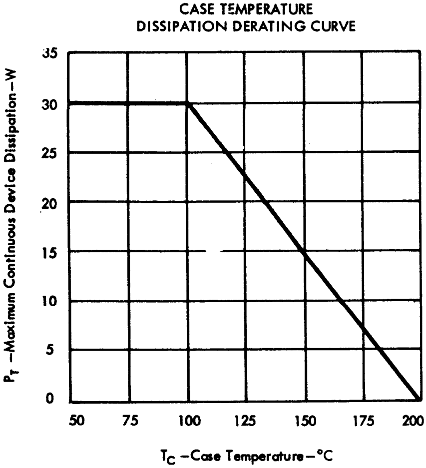

CASE TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 3

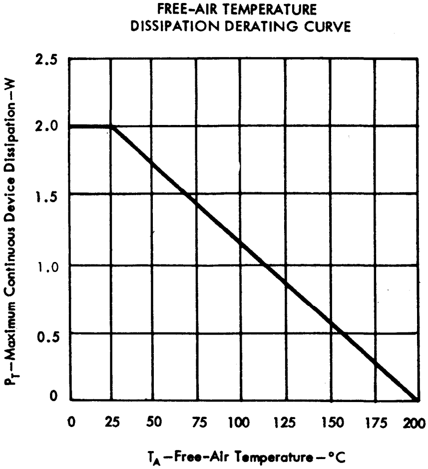

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 4

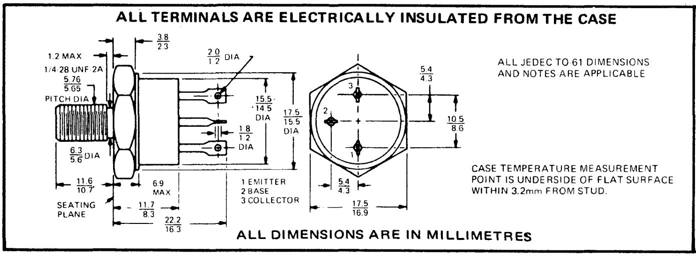
TYPE 2N5386
P-N-P EPITAXIAL PLANAR SILICON POWER TRANSISTOR

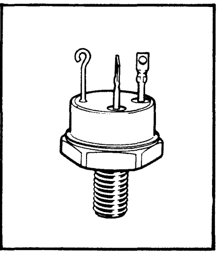
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N4301

- **50 W at 100°C Case Temperature**
- **Max $V_{CE(sat)}$ of 0.6 V at 6 A I_C**
- **Typ t_{on} of 230 ns at 6 A I_C**
- **Min f_T of 30 MHz at 10 V, 1 A**

***mechanical data**





***absolute maximum ratings at 25°C case temperature (unless otherwise noted)**

Collector-Base Voltage	−100 V
Collector-Emitter Voltage (See Note 1)	−80 V
Emitter-Base Voltage	−6 V
Continuous Collector Current	−12 A
Peak Collector Current (See Note 2)	−25 A
Continuous Base Current	−4 A
Continuous Emitter Current	−13 A
Safe Operating Region at (or below) 100°C Case Temperature	See Figure 2
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	50 W
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	3.5 W
Operating Collector Junction Temperature Range	−65°C to 200°C
Storage Temperature Range	−65°C to 200°C
Terminal Temperature 1.588mm from Case for 10 Seconds	260°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -30$ mA, $I_B = 0$, See Note 5	−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -40$ V, $I_B = 0$		−50	μA
I_{CES}	Collector Cutoff Current	$V_{CE} = -90$ V, $V_{BE} = 0$		−10	μA
		$V_{CE} = -50$ V, $V_{BE} = 0$, $T_C = 150°C$		−500	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -4$ V, $I_C = 0$		−5	μA
		$V_{EB} = -6$ V, $I_C = 0$		−100	
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -6$ A, See Notes 5 and 6	20	80	
		$V_{CE} = -4$ V, $I_C = -12$ A, See Notes 5 and 6	10		
V_{BE}	Base-Emitter Voltage	$V_{CE} = -4$ V, $I_C = -12$ A, See Notes 5 and 6		−1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.6$ A, $I_C = -6$ A, See Notes 5 and 6		−0.6	V
		$I_B = -2.4$ A, $I_C = -12$ A, See Notes 5 and 6		−1.4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 1 kHz	20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -1$ A, f = 15 MHz	2		

NOTES: 5. These parameters must be measured using pulse techniques. $t_p = 300$ μs, duty cycle ≤ 2%.

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

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	2	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

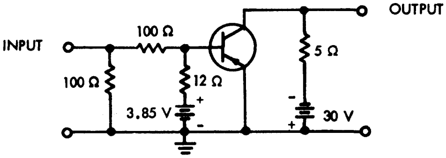
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

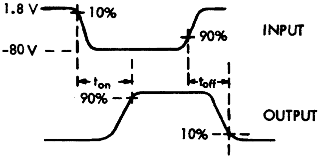
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	$I_C = -6$ A, $I_{B(1)} = -400$ mA, $I_{B(2)} = 400$ mA, $V_{BE(off)} = 3.6$ V, $R_L = 5\ \Omega$, See Figure 1	230	ns
t_{off}	Turn-Off Time		750	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES:
- a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 1.5$ kΩ, $t_p = 5$ μs, duty cycle $\leq 2\%$.
- b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
- c. Resistors must be noninductive types.
- d. The d-c power supplies may require additional bypassing in order to minimize ringing.

MAXIMUM SAFE OPERATING REGION

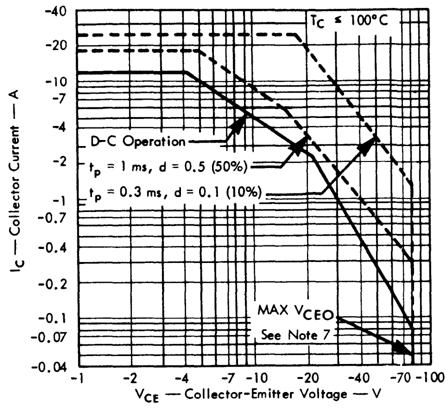


FIGURE 2

NOTE 7: Operation above maximum V_{CEO} is permissible if the base is reverse-voltage-biased with respect to the emitter and the collector-base-voltage rating is not exceeded.

THERMAL CHARACTERISTICS

CASE TEMPERATURE
DISSIPATION DERATING CURVE

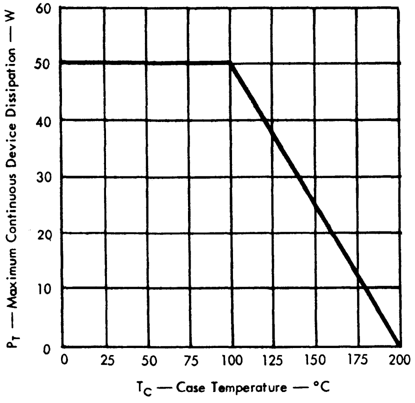


FIGURE 3

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

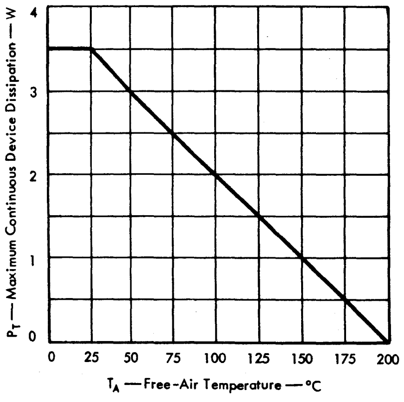


FIGURE 4

TYPES 2N5387, 2N5388, 2N5389
N-P-N TRIPLE-DIFFUSED MESA SILICON POWER TRANSISTORS

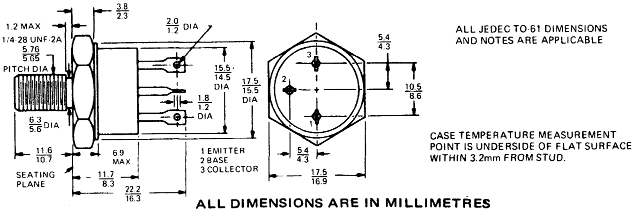
REVISED AUGUST 1975

FOR POWER-AMPLIFIER APPLICATIONS

- **200 V, 250 V, 300 V Rated Collector-Emitter Voltages**
- **100 Watts at 100°C Case Temperature**
- **Typ t_{on} of 300 ns at 2 A I_C**
- **Min f_T of 15 MHz at 10 V, 1 A**

*mechanical data

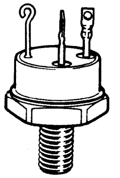
ALL TERMINALS ARE ELECTRICALLY INSULATED FROM THE CASE



ALL JEDEC TO-61 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD.

ALL DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5387	2N5388	2N5389
Collector-Base Voltage	200 V	250 V	300 V
Collector-Emitter Voltage (See Note 1)	200 V	250 V	300 V
Emitter-Base Voltage	← 10 V →		
Continuous Collector Current	← 7.5 A →		
Peak Collector Current (See Note 2)	← 10 A →		
Continuous Base Current	← 3 A →		
Continuous Emitter Current	← 8 A →		
Safe Operating Region at (or below) 100°C Case Temperature	← See Figure 6 →		
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 3)	← 100 W →		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 3.5 W →		
Operating Collector Junction Temperature Range	← −65°C to 200°C →		
Storage Temperature Range	← −65°C to 200°C →		
Terminal Temperature 1.588mm from Case for 10 Seconds	← 260°C →		

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_p \leq 0.3$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1 W/deg.
4. Derate linearly to 200°C free-air temperature at the rate of 20 mW/deg.

*Indicates JEDEC registered data

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5387		2N5388		2N5389		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0, See Note 5	200		250		300		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 180 V, I_B = 0		30					mA
		V_{CE} = 225 V, I_B = 0				30			
		V_{CE} = 270 V, I_B = 0						30	
I_{CES}	Collector Cutoff Current	V_{CE} = 180 V, V_{BE} = 0		1					mA
		V_{CE} = 225 V, V_{BE} = 0				1			
		V_{CE} = 270 V, V_{BE} = 0						1	
		V_{CE} = 100 V, V_{BE} = 0, T_C = 150°C		10					
		V_{CE} = 125 V, V_{BE} = 0, T_C = 150°C				10			
		V_{CE} = 150 V, V_{BE} = 0, T_C = 150°C						10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 8 V, I_C = 0		0.1		0.1		0.1	mA
		V_{EB} = 10 V, I_C = 0		1		1		1	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 5 V, I_C = 2 A, See Notes 5 and 6	25	100	25	100	25	100	
		V_{CE} = 5 V, I_C = 5 A, See Notes 5 and 6	15		15		15		
		V_{CE} = 5 V, I_C = 7 A, See Notes 5 and 6	5		5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 5 V, I_C = 7 A, See Notes 5 and 6		2.5		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1 A, I_C = 5 A, See Notes 5 and 6		2		2		2	V
		I_B = 1.4 A, I_C = 7 A, See Notes 5 and 6		2.2		2.2		2.2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 1 kHz	20		20		20		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 1 A, f = 10 MHz	1.5		1.5		1.5		

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

*thermal characteristics

PARAMETER		MAX	UNIT
$\theta_{J\text{-}C}$	Junction-to-Case Thermal Resistance	1	deg/W
$\theta_{J\text{-}A}$	Junction-to-Free-Air Thermal Resistance	50	

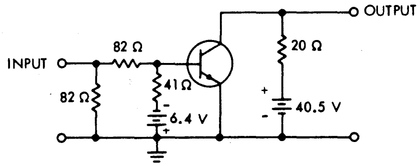
*Indicates JEDEC registered data

switching characteristics at 25°C case temperature

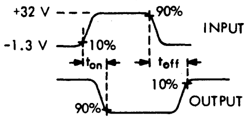
PARAMETER		TEST CONDITIONS†	TYP	UNIT
t_{on}	Turn-On Time	I_C = 2 A, $I_{B(1)}$ = 200 mA, $I_{B(2)}$ = −200 mA,	0.3	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −4.7 V, R_L = 20 Ω, See Figure 1	1	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50\ \Omega$, $t_p = 10\ \mu s$, duty cycle $\leq 2\%$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10\ M\Omega$, $C_{in} \leq 11.5$ pF.

c. Resistors must be noninductive types.

d. The d-c power supplies may require additional bypassing in order to minimize ringing.

TYPICAL CHARACTERISTICS

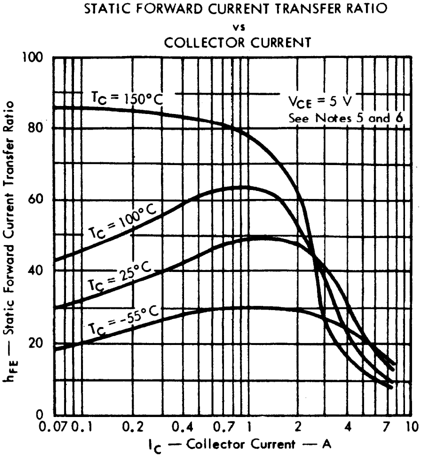


FIGURE 2

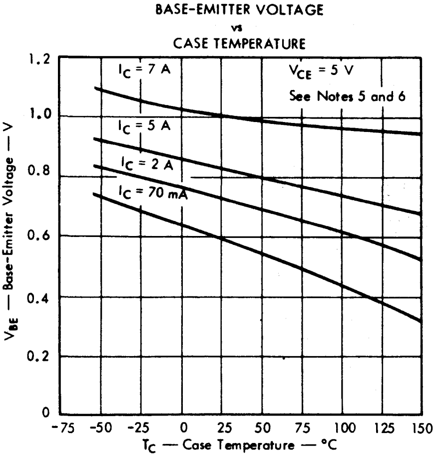


FIGURE 3

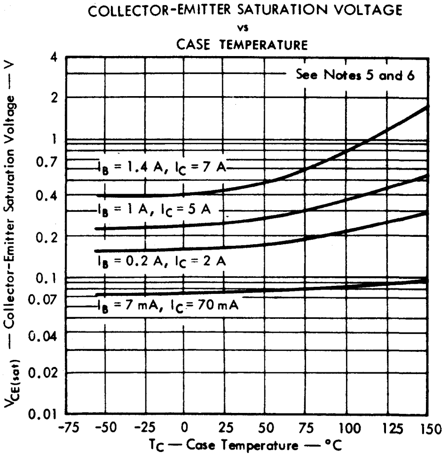


FIGURE 4

NOTES: 5. These parameters must be measured using pulse techniques. t_p = 300 μs, duty cycle ≤ 2%.

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

TYPICAL CHARACTERISTICS

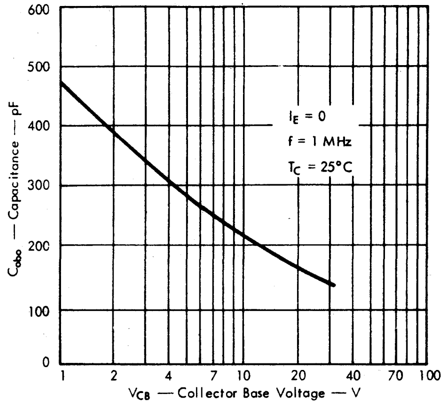

COMMON-BASE OPEN-CIRCUIT
OUTPUT CAPACITANCE
vs
COLLECTOR-BASE VOLTAGE

FIGURE 5

MAXIMUM SAFE OPERATING REGION

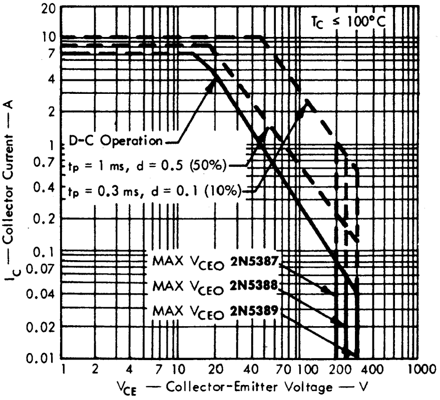


FIGURE 6

NOTE 5: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle $\leq 2\%$.

THERMAL INFORMATION

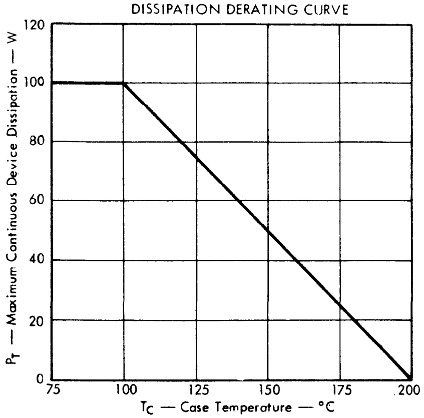


FIGURE 7

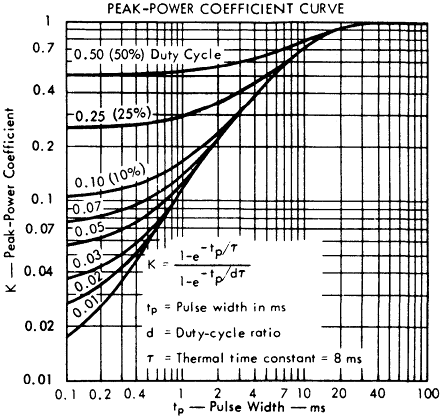


FIGURE 8

SYMBOL DEFINITION

SYMBOL	DEFINITION	VALUE	UNIT
$P_{T(av)}$	Average Power Dissipation		W
$P_{T(max)}$	Peak Power Dissipation		W
θ_{J-A}	Junction-to-Free-Air Thermal Resistance	50	deg/W
θ_{J-C}	Junction-to-Case Thermal Resistance	1	deg/W
θ_{C-A}	Case-to-Free-Air Thermal Resistance	49	deg/W
θ_{C-HS}	Case-to-Heat-Sink Thermal Resistance		deg/W
θ_{HS-A}	Heat-Sink-to-Free-Air Thermal Resistance		deg/W
T_A	Free-Air Temperature		°C
T_C	Case Temperature		°C
$T_{J(av)}$	Average Junction Temperature	≤ 200	°C
$T_{J(max)}$	Peak Junction Temperature	≤ 200	°C
K	Peak-Power Coefficient	See Figure 8	
t_p	Pulse Width		ms
t_x	Pulse Period		ms
d	Duty-Cycle Ratio (t_p/t_x)		

Equation No. 1 — Application: d-c power dissipation, heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}} \text{ for } 100°C \leq T_C \leq 200°C \text{ as in Figure 7}$$

Equation No. 2 — Application: d-c power dissipation, no heat sink used.

$$P_{T(av)} = \frac{T_{J(av)} - T_A}{\theta_{J-A}} \text{ for } 25°C \leq T_A \leq 200°C$$

Equation No. 3 — Application: Peak power dissipation, heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}} \text{ for } 100°C \leq T_C \leq 200°C$$

Equation No. 4 — Application: Peak power dissipation, no heat sink used.

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,\theta_{C-A} + K\,\theta_{J-C}} \text{ for } 25°C \leq T_A \leq 200°C$$

Example — Find $P_{T(max)}$ (design limit)

OPERATING CONDITIONS:

$\theta_{C-HS} + \theta_{HS-A} = 4$ deg/W (From information supplied with heat sink.)

$T_{J(av)}$ (design limit) $= 200°C$

$T_A = 50°C$

$d = 10\%$ (0.1)

$t_p = 0.1$ ms

Solution:

From Figure 8, Peak-Power Coefficient

K = 0.105 and by use of equation No. 3

$$P_{T(max)} = \frac{T_{J(max)} - T_A}{d\,(\theta_{C-HS} + \theta_{HS-A}) + K\,\theta_{J-C}}$$

$$P_{T(max)} = \frac{200 - 50}{0.1\,(4) + 0.106\,(1)} = 296 \text{ W}$$

TYPES 2N5671, 2N5672
N-P-N SILICON POWER TRANSISTORS

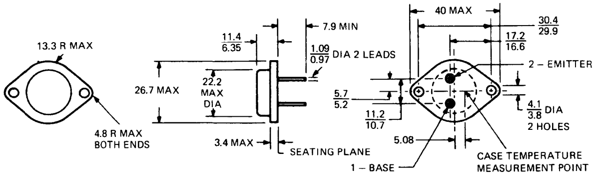
REVISED JULY 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED SWITCHING APPLICATIONS

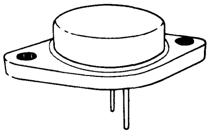
- 20 mJ Reverse Energy Rating
- Min $V_{(BR)CEO}$ of 120 V (2N5672)
- Min f_T of 50 MHz at 10 V, 2 A
- 30-A Rated Continuous Collector Current

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5671	2N5672
Collector-Emitter Voltage (V_{BE} = −1.5 V, See Note 1)	120 V*	150 V*
Collector-Emitter Voltage (Base Open, See Note 1)	90 V	120 V
Emitter-Base Voltage	7 V*	7 V*
Continuous Collector Current	← 30 A* →	
Continuous Base Current	← 10 A* →	
Safe Operating Area at Specified Temperatures	See Figure 6	
Continuous Device Dissipation at (or below) 25°C Case Temperature (see Note 3)	← 140 W* →	
Continuous Device Dissipation at 100°C Case Temperature (see Note 3)	← 80 W* →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (see Note 4)	← 5 W →	
Unclamped Inductive Load Energy (see Note 5)	← 20 mJ* →	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 0.8mm from Case for 10 Seconds	← 230°C* →	

NOTES:
1. These values apply only when the collector-emitter voltage is applied with the transistor in the off-state with the base-emitter diode reverse-biased or open-circuited, as specified. In operation, the limitations of Figure 6 must be observed.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.8 W/°C or refer to Dissipation Derating Curve, Figure 7.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 8.
5. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5, condition 1. $L = 180\ \mu H$, $R_{BB2} = 20\ \Omega$, $V_{BB2} = 4$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 10$ V, Energy = $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5671 MIN	2N5671 MAX	2N5672 MIN	2N5672 MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0, See Note 6	90		120		V
$V_{(BR)CEV}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, See Figure 5 (Condition 2)	120		150		V
I_{CEV}	Collector Cutoff Current	V_{CE} = 110 V, V_{BE} = −1.5 V		12			mA
		V_{CE} = 135 V, V_{BE} = −1.5 V				10	
		V_{CE} = 100 V, V_{BE} = −1.5 V, T_C = 150°C		15		10	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 7 V, I_C = 0		10		10	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V, I_C = 15 A, See Notes 6 and 7	20	100	20	100	
V_{BE}	Base-Emitter Voltage	I_B = 1.2 A, I_C = 15 A, See Notes 6 and 7		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.2 A, I_C = 15 A, See Notes 6 and 7		0.75		0.75	V
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 2 A, f = 5 MHz	10		10		

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MAX	UNIT
t_r	Rise Time	I_C ≈ 15 A, $I_{B(1)}$ = 1.2 A, $I_{B(2)}$ ≈ −1.2 A, $V_{BE(off)}$ = −6 V, R_L = 2 Ω, See Figure 4	0.5	μs
t_s	Storage Time		1.5	
t_f	Fall Time		0.5	

*JEDEC registered data

TYPICAL CHARACTERISTICS

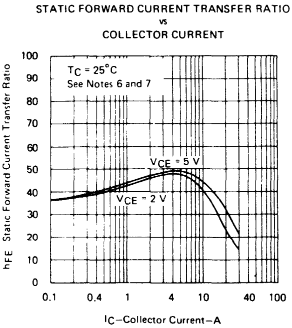


FIGURE 1

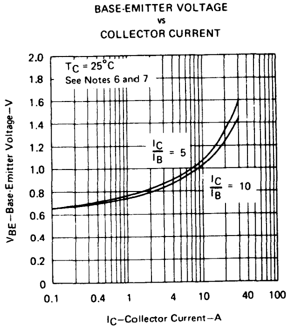


FIGURE 2

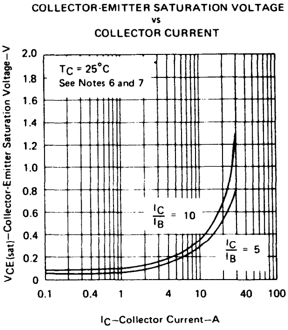
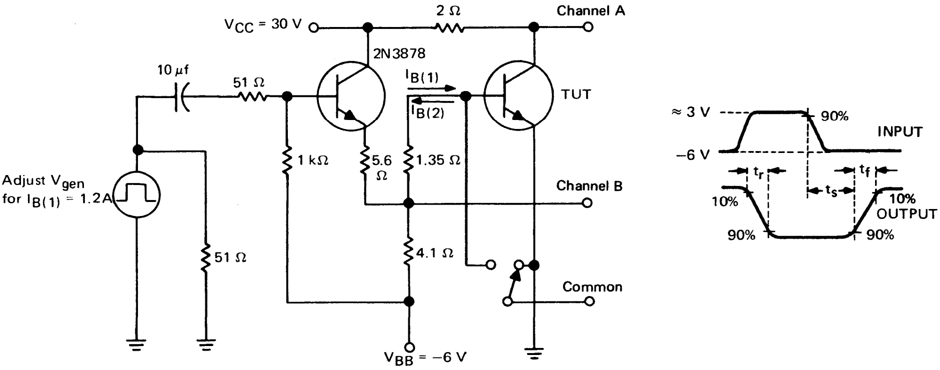


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

NOTES: A. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 20$ ns, $t_f \leqslant 20$ ns, $t_w = 5$ µs, duty cycle = 0.2%.

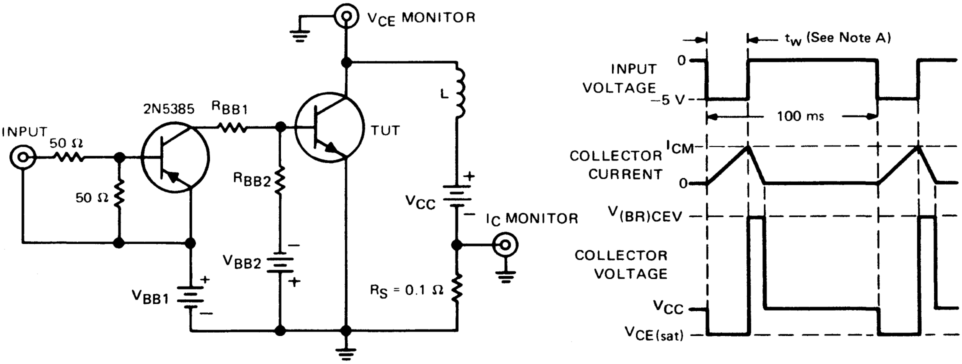
B. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.

C. Resistor must be noninductive types.

D. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT

FIGURE 5

VOLTAGE WAVEFORMS

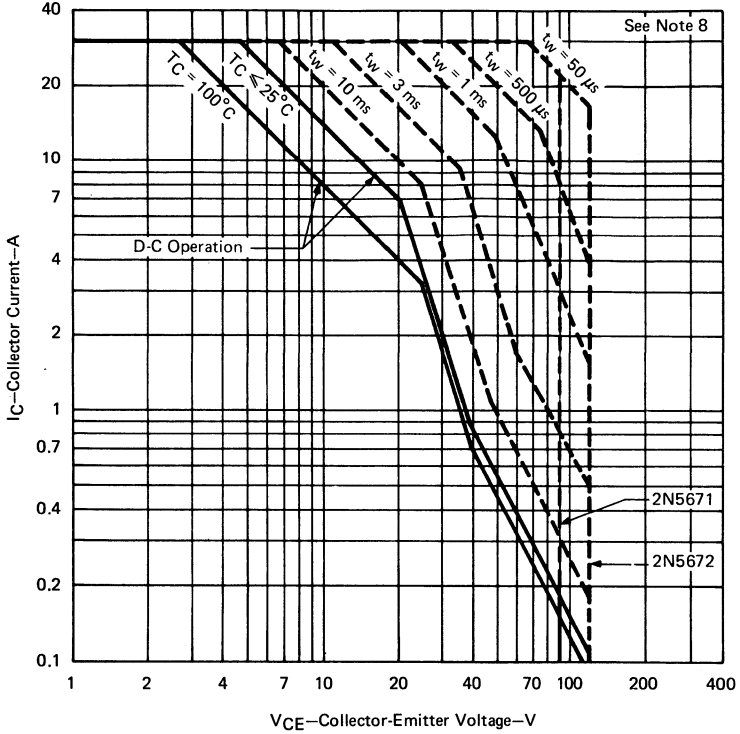
CIRCUIT CONDITIONS

CONDITION	R_{BB1}	R_{BB2}	V_{BB1}	V_{BB2}	V_{CC}	I_{CM}	L	t_w	DUTY CYCLE
1	8.2 Ω	20 Ω	10 V	4 V	10 V	15 A	0.18 mH†	0.3 ms	5%
2	110 Ω	50 Ω	6 V	1.5 V	50 V	0.2 A	2 mH	8 ms	50%

NOTE A: Input pulse width is increased until $I_C = I_{CM}$

†Q = 86 at 1.4 MHz.

MAXIMUM SAFE OPERATING AREA



NOTE 8: Areas defined by dashed lines apply for nonrepetitive-pulse operation at $T_C \leq 25°C$. The pulse may be repeated after the device has regained thermal equilibrium.

FIGURE 6

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

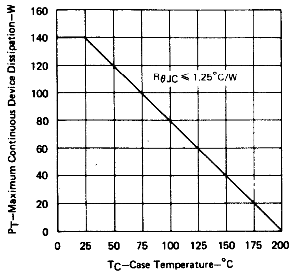


FIGURE 7

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

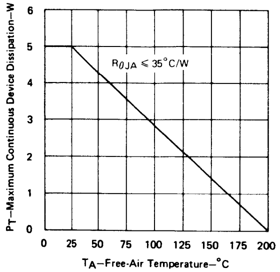


FIGURE 8

TYPES 2N5683, 2N5684
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED JUNE 1975

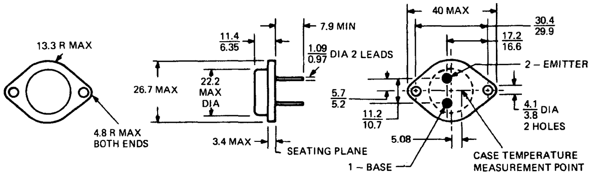
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5685, 2N5686

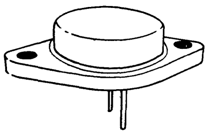
- 300 Watts at 25°C Case Temperature
- 50-A Rated Continuous Collector Current
- Min f_T of 2 MHz at 10 V, 5 A

*mechanical data

The case outline falls within JEDEC-TO-3 except for lead diameter.

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5683	2N5684
*Collector-Base Voltage	–60 V	–80 V
*Collector-Emitter Voltage (See Note 1)	–60 V	–80 V
*Emitter-Base Voltage	–5 V	–5 V
*Continuous Collector Current	← –50 A →	
*Continuous Base Current	← –15 A →	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	← 300 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	← 5 W →	
*Operating Collector Junction Temperature Range	–65°C to 200°C	
*Storage Temperature Range	–65°C to 200°C	
*Terminal Temperature 1.588mm from Case for 10 Seconds	← 235°C →	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C case temperature at the rate of 1.715 W/°C or refer to Dissipation Derating Curve, Figure 1.
3. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 2.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5683		2N5684		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -200$ mA, $I_B = 0$, See Note 6	−60		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$		−1			mA
		$V_{CE} = -40$ V, $I_B = 0$				−1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 1.5$ V		−2			mA
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V				−2	
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$		−10			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$				−10	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$		−2			mA
		$V_{CB} = -80$ V, $I_E = 0$				−2	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$		−5		−5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -2$ V, $I_C = -25$ A, See Notes 6 and 7	15	60	15	60	
		$V_{CE} = -5$ V, $I_C = -50$ A	5		5		
V_{BE}	Base-Emitter Voltage	$I_B = -2.5$ A, $I_C = -25$ A, See Notes 6 and 7		−2		−2	V
		$V_{CE} = -2$ V, $I_C = -25$ A		−2		−2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -2.5$ A, $I_C = -25$ A, See Notes 6 and 7		−1		−1	V
		$I_B = -10$ A, $I_C = -50$ A		−5		−5	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -5$ V, $I_C = -10$ A, f = 1 kHz	15		15		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -5$ A, f = 1 MHz	2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$, f = 0.1 MHz		2000		2000	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

THERMAL INFORMATION

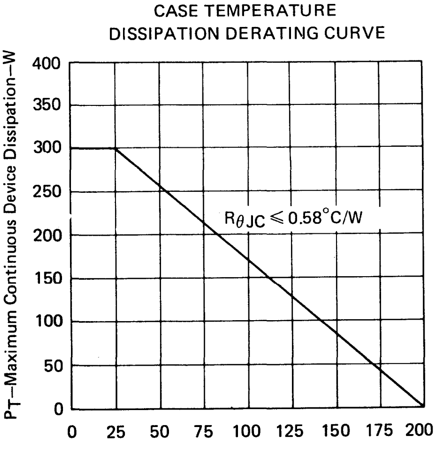


FIGURE 1

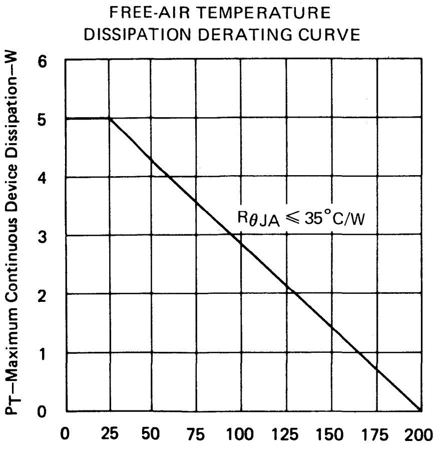


FIGURE 2

TYPES 2N5685, 2N5686
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED AUGUST 1975

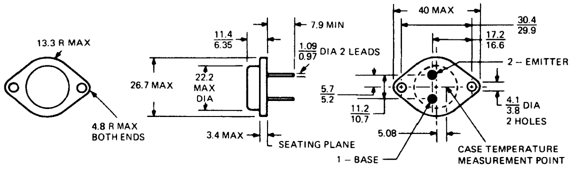
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5683, 2N5684

- 300 Watts at 25°C Case Temperature
- 50-A Rated Continuous Collector Current
- Min f_T of 2 MHz at 10 V, 5 A

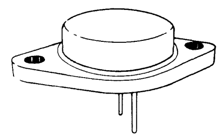
*mechanical data

The case outline falls within JEDEC-TO-3 except for lead diameter.

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5685	2N5686
*Collector-Base Voltage	60 V	80 V
*Collector-Emitter Voltage (See Note 1)	60 V	80 V
*Emitter-Base Voltage	5 V	5 V
*Continuous Collector Current	50 A	
*Continuous Base Current	15 A	
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 2)	300 W	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	5 W	
*Operating Collector Junction Temperature Range	−65°C to 200°C	
*Storage Temperature Range	−65°C to 200°C	
*Terminal Temperature 1.588mm from Case for 10 Seconds	235°C	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. Derate linearly to 200°C case temperature at the rate of 1.715 W/°C or refer to Dissipation Derating Curve, Figure 1.
3. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 2.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

TYPES 2N5685, 2N5686
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5685		2N5686		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA,	I_B = 0,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V,	I_B = 0			1			mA
		V_{CE} = 40 V,	I_B = 0					1	
I_{CEV}	Collector Cutoff Current	V_{CE} = 60 V,	V_{BE} = −1.5 V			2			mA
		V_{CE} = 80 V,	V_{BE} = −1.5 V					2	
		V_{CE} = 60 V,	V_{BE} = −1.5 V,	T_C = 150°C		10			
		V_{CE} = 80 V,	V_{BE} = −1.5 V,	T_C = 150°C				10	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V,	I_E = 0			2			mA
		V_{CB} = 80 V,	I_E = 0					2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			5		5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V,	I_C = 25 A	See Notes 6 and 7	15	60	15	60	
		V_{CE} = 5 V,	I_C = 50 A		5		5		
V_{BE}	Base-Emitter Voltage	I_B = 2.5 A,	I_C = 25 A	See Notes 6 and 7		2		2	V
		V_{CE} = 2 V,	I_C = 25 A			2		2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 2.5 A,	I_C = 25 A	See Notes 6 and 7		1		1	V
		I_B = 10 A,	I_C = 50 A			5		5	
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 5 V,	I_C = 10 A,	f = 1 kHz	15		15		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 5 A,	f = 1 MHz	2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V,	I_E = 0,	f = 0.1 MHz		1200		1200	pF

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

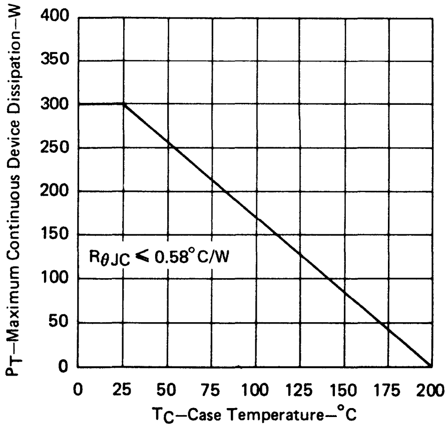


FIGURE 1

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

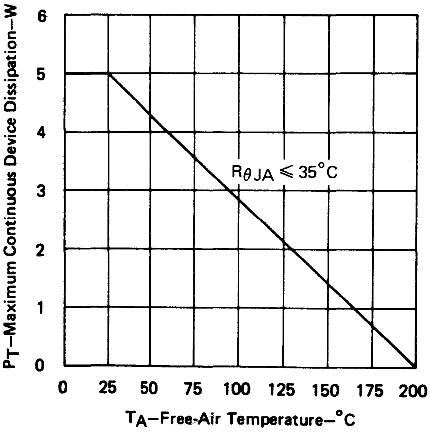


FIGURE 2

TYPES 2N5758, 2N5759, 2N5760
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

REVISED JUNE 1975

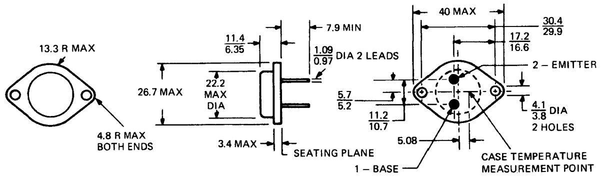
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS RECOMMENDED FOR COMPLEMENTARY USE WITH TIP544, TIP545, TIP546

- **150 W at 25°C Case Temperature**
- **6-A Rated Continuous Collector Current**
- **Min f_T of 1 MHz at 20 V, 0.5 A**

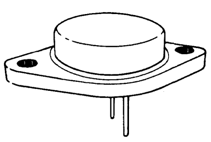
*mechanical data

The case outline falls within JEDEC TO-3.

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5758	2N5759	2N5760
*Collector-Base Voltage	100 V	120 V	140 V
*Collector-Emitter Voltage (See Note 1)	100 V	120 V	140 V
*Emitter-Base Voltage	7 V	7 V	7 V
*Continuous Collector Current	←	6 A	→
*Peak Collector Current (See Note 2)	←	10 A	→
*Continuous Base Current	←	4 A	→
*Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←	150 W	→
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←	5 W	→
*Operating Collector Junction Temperature Range		−65°C to 200°C	
*Storage Temperature Range		−65°C to 200°C	
*Terminal Temperature 1.588mm from Case for 10 Seconds	←	235°C	→

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 0.3$ ms, duty cycle $\leq$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.857 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N5758		2N5759		2N5760		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 200 mA, I_B = 0,	See Note 5	100		120		140		V
I_{CBO}	Collector Cutoff Current	V_{CB} = 100 V, I_E = 0			1					mA
		V_{CB} = 120 V, I_E = 0					1			
		V_{CB} = 140 V, I_E = 0							1	
I_{CEO}	Collector Cutoff Current	V_{CE} = 50 V, I_B = 0			1					mA
		V_{CE} = 60 V, I_B = 0					1			
		V_{CE} = 70 V, I_B = 0							1	
I_{CEV}	Collector Cutoff Current	V_{CE} = 100 V, V_{BE} = −1.5 V			1					mA
		V_{CE} = 120 V, V_{BE} = −1.5 V					1			
		V_{CE} = 140 V, V_{BE} = −1.5 V							1	
		V_{CE} = 100 V, V_{BE} = −1.5 V, T_C = 150°C			5					
		V_{CE} = 120 V, V_{BE} = −1.5 V, T_C = 150°C					5			
		V_{CE} = 140 V, V_{BE} = −1.5 V, T_C = 150°C							5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 7 V, I_C = 0			1		1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 2 V, I_C = 3 A	See Notes 5 and 6	25	100	20	80	15	60	
		V_{CE} = 2 V, I_C = 6 A		5		5		5		
V_{BE}	Base-Emitter Voltage	V_{CE} = 2 V, I_C = 3 A,	See Notes 5 and 6		1.5		1.5		1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 0.3 A, I_C = 3 A	See Notes 5 and 6		1		1		1	V
		I_B = 1.2 A, I_C = 6 A			2		2		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V, I_C = 2 A,	f = 1 kHz	15		15		15		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 20 V, I_C = 0.5 A,	f = 0.5 MHz	2		2		2		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V, I_E = 0,	f = 0.1 MHz		300		300		300	pF

NOTES: 5. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.
6. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

*JEDEC registered data

TYPES 2N5867, 2N5868
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

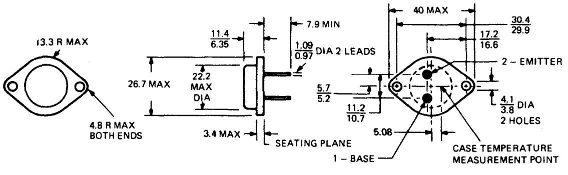
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5869, 2N5870

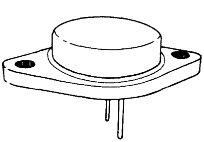
- 87.5 Watts at 25°C Case Temperature
- 5-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.25 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5867	2N5868
Collector-Base Voltage	−60 V*	−80 V*
Collector-Emitter Voltage (See Note 1)	−60 V*	−80 V*
Emitter-Base Voltage	−5 V*	−5 V*
Continuous Collector Current	← −5 A† −3 A* →	
Peak Collector Current (See Note 2)	← −7 A →	
Continuous Base Current	← −1 A* →	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 87.5 W* →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 5 W →	
Unclamped Inductive Load Energy (See Note 5)	← 62.5 mJ →	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 250°C* →	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 mW/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = -2.5$ A, Energy $\approx I_C{}^2L/2$.

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*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

‡This circuit appears on the first page of the data section of this book.

TYPES 2N5867, 2N5868
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

* electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N5867		2N5868		UNIT
				MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -100$ mA, $I_B = 0$,	See Note 6	−60		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V, $I_B = 0$			−0.5			mA
		$V_{CE} = -40$ V, $I_B = 0$					−0.5	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V, $V_{BE} = 1.5$ V			−0.1			mA
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V					−0.1	
		$V_{CE} = -60$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$			−2			
		$V_{CE} = -80$ V, $V_{BE} = 1.5$ V, $T_C = 150°C$					−2	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V, $I_E = 0$			−0.1			mA
		$V_{CB} = -80$ V, $I_E = 0$					−0.1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V, $I_C = 0$			−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -300$ mA	See Notes 6 and 7	35		35		
		$V_{CE} = -4$ V, $I_C = -1.5$ A		20	100	20	100	
		$V_{CE} = -4$ V, $I_C = -3$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = -200$ mA, $I_C = -2$ A	See Notes 6 and 7		−1.6		−1.6	V
		$V_{CE} = -4$ V, $I_C = -3$ A,			−2		−2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -200$ mA, $I_C = -2$ A	See Notes 6 and 7		−1		−1	V
		$I_B = -0.6$ A, $I_C = -3$ A			−2		−2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -4$ V, $I_C = -0.25$ A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V, $I_C = -0.25$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V, $I_E = 0$,	f = 1 MHz		200		200	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	$I_C = -1.5$ A, $I_{B(1)} = -0.15$ A, $I_{B(2)} = 0.15$ A, $V_{BE(off)} = 5$ V, $R_L = 20\,\Omega$, See Note 8		0.7	μs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $V_{BB1} = 25$ V, $V_{BB2} = 5$ V, $V_{CC} = 30$ V, $V_{on} = -23$ V, $R_{BB1} = 73\,\Omega$, $R_{BB2} = 39\,\Omega$.

‡This circuit appears on the first page of the data section of this book

MAXIMUM SAFE OPERATING AREA

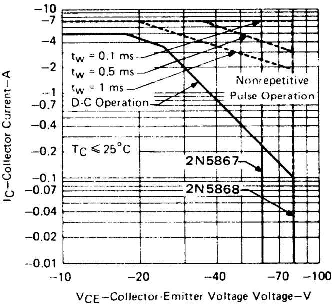


FIGURE 1

THERMAL CHARACTERISTICS

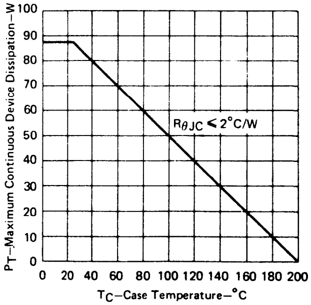


FIGURE 2

TYPES 2N5869, 2N5870
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

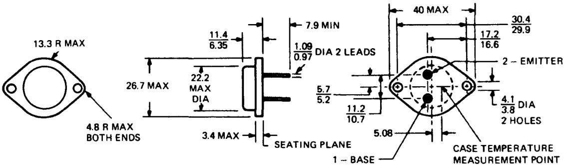
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5867, 2N5868

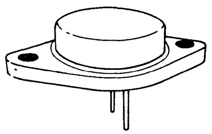
- 87.5 Watts at 25°C Case Temperature
- 5-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.25 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5869	2N5870
Collector-Base Voltage	60 V*	80 V*
Collector-Emitter Voltage (See Note 1)	60 V*	80 V*
Emitter-Base Voltage	5 V*	5 V*
Continuous Collector Current	5 A† 3 A*	
Peak Collector Current (See Note 2)	7 A	
Continuous Base Current	1 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	87.5 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.5 mW/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = 2.5$ A. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

‡ This circuit appears on the first page of the data section

TYPES 2N5869, 2N5870
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5869		2N5870		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 mA,	I_B = 0,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V,	I_B = 0			0.5			mA
		V_{CE} = 40 V,	I_B = 0					0.5	
I_{CEV}	Collector Cutoff Current	V_{CE} = 60 V,	V_{BE} = −1.5 V			0.1			mA
		V_{CE} = 80 V,	V_{BE} = −1.5 V					0.1	
		V_{CE} = 60 V,	V_{BE} = −1.5 V,	T_C = 150°C		2			
		V_{CE} = 80 V,	V_{BE} = −1.5 V,	T_C = 150°C				2	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V,	I_E = 0			0.1			mA
		V_{CB} = 80 V,	I_E = 0					0.1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 300 mA	See Notes 6 and 7	35		35		
		V_{CE} = 4 V,	I_C = 1.5 A		20	100	20	100	
		V_{CE} = 4 V,	I_C = 3 A		5		5		
V_{BE}	Base-Emitter Voltage	I_B = 200 mA,	I_C = 2 A	See Notes 6 and 7		1.6		1.6	V
		V_{CE} = 4 V,	I_C = 3 A			2		2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 200 mA,	I_C = 2 A	See Notes 6 and 7		1		1	V
		I_B = 0.6 A,	I_C = 3 A			2		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 0.25 A,	f = 1 kHz	20		20		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 0.25 A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V,	I_E = 0,	f = 1 MHz		150		150	pF

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3,2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	I_C = 1.5 A, $I_{B(1)}$ = 0.15 A, $I_{B(2)}$ = −0.15 A, $V_{BE(off)}$ = −5 V, R_L = 20 Ω, See Note 8		0.7	μs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.* ‡ V_{BB1} = 25 V, V_{BB2} = 5 V, V_{CC} = 30 V, V_{on} = 23 V, R_{BB1} = 73 Ω, R_{BB2} = 39 Ω.

‡ This circuit appears on the first page of the data section

MAXIMUM SAFE OPERATING AREA

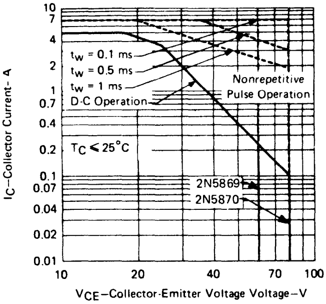


FIGURE 1

THERMAL CHARACTERISTICS

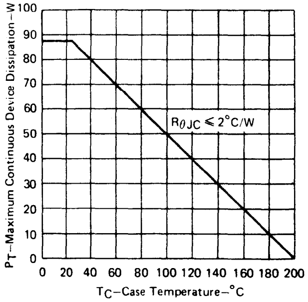


FIGURE 2

TYPES 2N5871, 2N5872
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

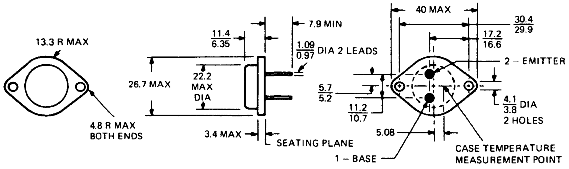
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5873, 2N5874

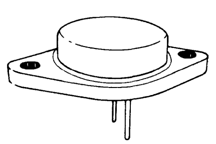
- 115 Watts at 25°C Case Temperature
- 7-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.25 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5871	2N5872
Collector-Base Voltage	−60 V*	−80 V*
Collector-Emitter Voltage (See Note 1)	−60 V*	−80 V*
Emitter-Base Voltage	−5 V*	−5 V*
Continuous Collector Current	−7 A† −5 A*	
Peak Collector Current (See Note 2)	−10 A	
Continuous Base Current	−1.5 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	115 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.66 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = -2.5$ A. Energy $\approx I_C{}^2L/2$.

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*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

‡This circuit appears on the first page of the data section of this book.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	2N5871		2N5872		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = −0.1 A, I_B = 0, See Note 6	−60		−80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = −30 V, I_B = 0		−0.5			mA
		V_{CE} = −40 V, I_B = 0				−0.5	
I_{CEV}	Collector Cutoff Current	V_{CE} = −60 V, V_{BE} = 1.5 V		−0.25			mA
		V_{CE} = −80 V, V_{BE} = 1.5 V				−0.25	
		V_{CE} = −60 V, V_{BE} = 1.5 V, T_C = 150°C		−2			
		V_{CE} = −80 V, V_{BE} = 1.5 V, T_C = 150°C				−2	
I_{CBO}	Collector Cutoff Current	V_{CB} = −60 V, I_E = 0		−0.25			mA
		V_{CB} = −80 V, I_E = 0				−0.25	
I_{EBO}	Emitter Cutoff Current	V_{EB} = −5 V, I_C = 0		−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = −4 V, I_C = −0.5 A, See Notes 6 and 7	35		35		
		V_{CE} = −4 V, I_C = −2.5 A	20	100	20	100	
		V_{CE} = −4 V, I_C = −5 A	5		5		
V_{BE}	Base-Emitter Voltage	I_B = −0.4 A, I_C = −4 A, See Notes 6 and 7		−1.6		−1.6	V
		V_{CE} = −4 V, I_C = −5 A		−2		−2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = −0.4 A, I_C = −4 A, See Notes 6 and 7		−1		−1	V
		I_B = −1 A, I_C = −5 A		−2		−2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −4 V, I_C = −0.5 A, f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −10 V, I_C = −0.25 A, f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = −10 V, I_E = 0, f = 1 MHz		300		300	pF

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	I_C = −2.5 A, $I_{B(1)}$ = −0.25 A, $I_{B(2)}$ = 0.25 A, $V_{BE(off)}$ = 4.6 V, R_L = 12 Ω, See Note 8		0.7	μs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ V_{BB1} = 24 V, V_{BB2} = 4.6 V, V_{CC} = 30 V, V_{on} = 22.5 V, R_{BB1} = 43 Ω, R_{BB2} = 22 Ω.

‡This circuit appears on the first page of the data section of this book.

MAXIMUM SAFE OPERATING AREA

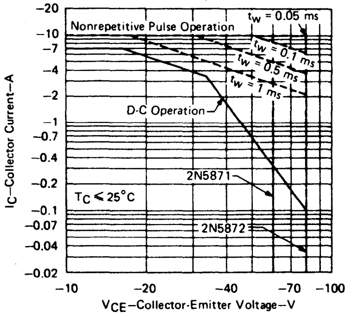


FIGURE 1

THERMAL CHARACTERISTICS

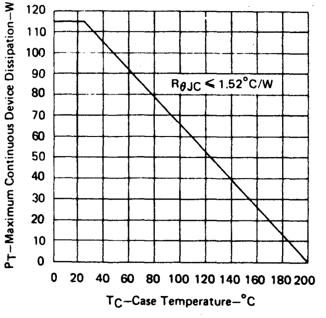


FIGURE 2

TYPES 2N5873, 2N5874
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

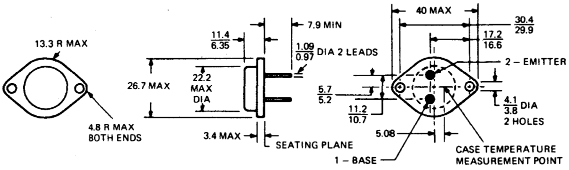
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N5871, 2N5872

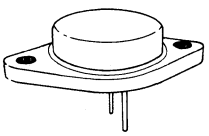
- 115 Watts at 25°C Case Temperature
- 7-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.25 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5873	2N5874
Collector-Base Voltage	60 V*	80 V*
Collector-Emitter Voltage (See Note 1)	60 V*	80 V*
Emitter-Base Voltage	5 V*	5 V*
Continuous Collector Current	7 A† 5 A*	
Peak Collector Current (See Note 2)	10 A	
Continuous Base Current	1.5 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	115 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.66 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = 2.5$ A. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.
†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.
‡This circuit appears on the first page of the data section of this book

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5873		2N5874		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 0.1$ A,	$I_B = 0$,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V,	$I_B = 0$			0.5			mA
		$V_{CE} = 40$ V,	$I_B = 0$					0.5	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V			0.25			mA
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V					0.25	
		$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$		2			
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$				2	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ V,	$I_E = 0$			0.25			mA
		$V_{CB} = 80$ V,	$I_E = 0$					0.25	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 0.5$ A	See Notes 6 and 7	35		35		
		$V_{CE} = 4$ V,	$I_C = 2.5$ A		20	100	20	100	
		$V_{CE} = 4$ V,	$I_C = 5$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = 0.4$ A	$I_C = 4$ A	See Notes 6 and 7		1.6		1.6	V
		$V_{CE} = 4$ V,	$I_C = 5$ A			2		2	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.4$ A,	$I_C = 4$ A	See Notes 6 and 7		1		1	V
		$I_B = 1$ A,	$I_C = 5$ A			2		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 0.5$ A,	f = 1 kHz	20		20		
$\lvert h_{fe} \rvert$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 0.25$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V,	$I_E = 0$,	f = 1 MHz		200		200	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leq 2\%$.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	$I_C = 2.5$ A, $I_{B(1)} = 0.25$ A, $I_{B(2)} = -0.25$ A, $V_{BE(off)} = -4.6$ V, $R_L = 12\ \Omega$, See Note 8		0.7	µs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors*‡. $V_{BB1} = 24$ V, $V_{BB2} = 4.6$ V, $V_{CC} = 30$ V, $V_{on} = 22.5$ V, $R_{BB1} = 43\ \Omega$, $R_{BB2} = 22\ \Omega$.

‡This circuit appears on the first page of the data section of this book

MAXIMUM SAFE OPERATING AREA

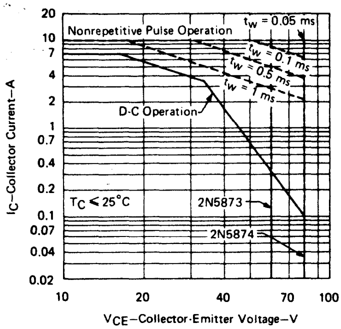


FIGURE 1

THERMAL CHARACTERISTICS

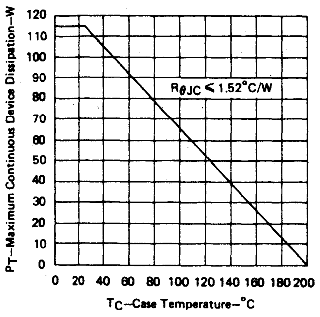


FIGURE 2

TYPES 2N5875, 2N5876
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

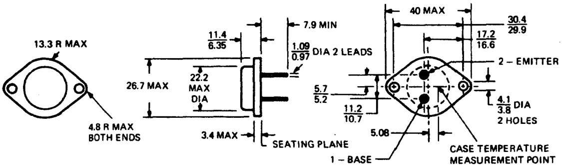
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N5877, 2N5878

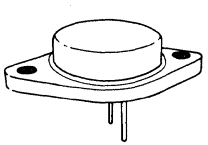
- 150 Watts at 25°C Case Temperature
- 10-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.5 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5875	2N5876
Collector-Base Voltage	−60 V*	−80 V*
Collector-Emitter Voltage (See Note 1)	−60 V*	−80 V*
Emitter-Base Voltage	−5 V*	−5 V*
Continuous Collector Current	−10 A† −8 A*	
Peak Collector Current (See Note 2)	−15 A	
Continuous Base Current	−2 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	150 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	62.5 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.857 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = -2.5$ A. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

‡This circuit appears on the first page of the data section

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5875		2N5876		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -0.2$ A,	$I_B = 0$,	See Note 6	−60		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V,	$I_B = 0$			−1			mA
		$V_{CE} = -40$ V,	$I_B = 0$					−1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V			−0.5			mA
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V					−0.5	
		$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$		−5			
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$				−5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V,	$I_E = 0$			−0.5			mA
		$V_{CB} = -80$ V,	$I_E = 0$					−0.5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V,	$I_C = 0$			−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -1$ A	See Notes 6 and 7	35		35		
		$V_{CE} = -4$ V,	$I_C = -4$ A		20	100	20	100	
		$V_{CE} = -4$ V,	$I_C = -8$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = -0.5$ A,	$I_C = -5$ A	See Notes 6 and 7		−1.6		−1.6	V
		$V_{CE} = -4$ V,	$I_C = -8$ A			−2.5		−2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.5$ A,	$I_C = -5$ A	See Notes 6 and 7		−1		−1	V
		$I_B = -1.6$ A,	$I_C = -8$ A			−3		−3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -1$ A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V,	$I_C = -0.5$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V,	$I_E = 0$,	f = 1 MHz		500		500	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			MIN	MAX	UNIT
t_r	Rise Time	$I_C = -4$ A,	$I_{B(1)} = -0.4$ A,	$I_{B(2)} = 0.4$ A,		0.7	μs
t_s	Storage Time	$V_{BE(off)} = 5$ V,	$R_L = 7.5\ \Omega$,	See Note 8		1	
t_f	Fall Time					0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.* ‡$V_{BB1} = 24$ V, $V_{BB2} = 5$ V, $V_{CC} = 30$ V, $V_{on} = -22$ V, $R_{BB1} = 26\ \Omega$, $R_{BB2} = 15\ \Omega$.

‡This circuit appears on the first page of the data section

MAXIMUM SAFE OPERATION AREAS

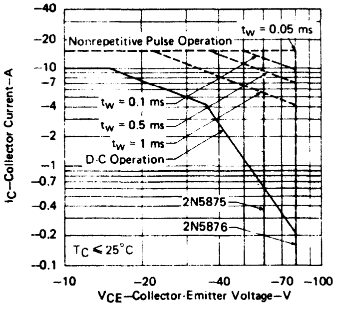


FIGURE 1

THERMAL CHARACTERISTICS

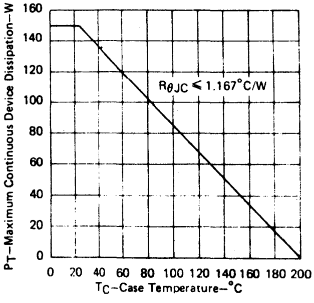


FIGURE 2

TYPES 2N5877, 2N5878
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

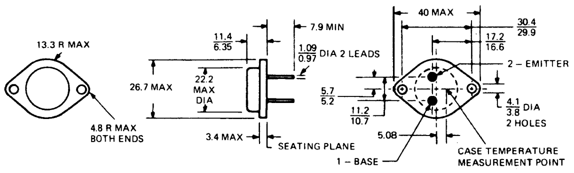
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5875, 2N5876

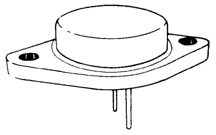
- 150 Watts at 25°C Case Temperature
- 10-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 0.5 A
- 62.5-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5877	2N5878
Collector-Base Voltage	60 V*	80 V*
Collector-Emitter Voltage (See Note 1)	60 V*	80 V*
Emitter-Base Voltage	5 V*	5 V*
Continuous Collector Current	← 10 A† 8 A* →	
Peak Collector Current (See Note 2)	← 15 A →	
Continuous Base Current	← 2 A* →	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	← 150 W* →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	← 5 W →	
Unclamped Inductive Load Energy (See Note 5)	← 62.5 mJ →	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 250°C* →	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 0.857 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.* $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = 2.5$ A. Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.
†Texas Instruments guarantees this value in addition to the JEDEC registered value which-is also shown.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5877		2N5878		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 0.2$ A,	$I_B = 0$,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V,	$I_B = 0$			1			mA
		$V_{CE} = 40$ V,	$I_B = 0$					1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V			0.5			mA
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V					0.5	
		$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$		5			
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$				5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ V,	$I_E = 0$			0.5			mA
		$V_{CB} = 80$ V,	$I_E = 0$					0.5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 1$ A	See Notes 6 and 7	35		35		
		$V_{CE} = 4$ V,	$I_C = 4$ A		20	100	20	100	
		$V_{CE} = 4$ V,	$I_C = 8$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = 0.5$ A,	$I_C = 5$ A	See Notes 6 and 7		1.6		1.6	V
		$V_{CE} = 4$ V,	$I_C = 8$ A			2.5		2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A,	$I_C = 5$ A	See Notes 6 and 7		1		1	V
		$I_B = 1.6$ A,	$I_C = 8$ A			3		3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 1$ A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 0.5$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V,	$I_E = 0$,	f = 1 MHz		300		300	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3 2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	$I_C = 4$ A, $I_{B(1)} = 0.4$ A, $I_{B(2)} = -0.4$ A, $V_{BE(off)} = -5$ V, $R_L = 7.5\ \Omega$,		0.7	µs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

MAXIMUM SAFE OPERATING AREA

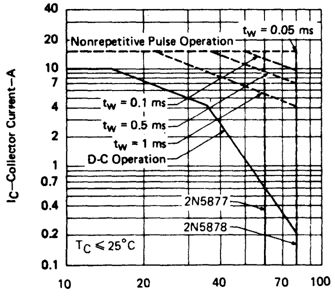


FIGURE 1

THERMAL CHARACTERISTICS

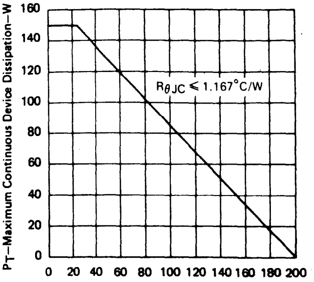


FIGURE 2

TYPES 2N5879, 2N5880
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

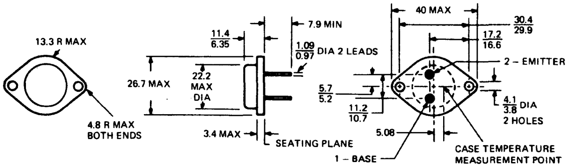
REVISED AUGUST 1975

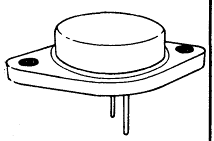
FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5881, 2N5882

- 160 Watts at 25°C Case Temperature
- 15-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 1 A
- 90 mJ-Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





DIMENSIONS ARE IN MILLIMETRES

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5879	2N5880
Collector-Base Voltage	−60 V*	−80 V*
Collector-Emitter Voltage (See Note 1)	−60 V*	−80 V*
Emitter-Base Voltage	−5 V*	−5 V*
Continuous Collector Current	−15 A† −12 A*	
Peak Collector Current (See Note 2)	−20 A	
Continuous Base Current	−4 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	160 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	90 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.915 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = -3$ A. Energy $\approx I_C{}^2L/2$.

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*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.

‡This circuit appears on the first page of the data section of this book.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5875		2N5876		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -0.2$ A,	$I_B = 0$,	See Note 6	−60		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V,	$I_B = 0$			−1			mA
		$V_{CE} = -40$ V,	$I_B = 0$					−1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V			−0.5			mA
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V					−0.5	
		$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$		−5			
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$				−5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V,	$I_E = 0$			−0.5			mA
		$V_{CB} = -80$ V,	$I_E = 0$					−0.5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V,	$I_C = 0$			−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -2$ A	See Notes 6 and 7	35		35		
		$V_{CE} = -4$ V,	$I_C = -6$ A		20	100	20	100	
		$V_{CE} = -4$ V,	$I_C = -12$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = -0.7$ A,	$I_C = -7$ A	See Notes 6 and 7		−1.6		−1.6	V
		$V_{CE} = -4$ V,	$I_C = -12$ A			−2.5		−2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -0.7$ A,	$I_C = -7$ A	See Notes 6 and 7		−1		−1	V
		$I_B = -2.4$ A,	$I_C = -12$ A			−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -2$ A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V,	$I_C = -1$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V,	$I_E = 0$,	f = 1 MHz		600		600	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	$I_C = -6$ A, $I_{B(1)} = -0.6$ A, $I_{B(2)} = 0.6$ A, $V_{BE(off)} = 5$ V, $R_L = 5\ \Omega$, See Note 8		0.7	μs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $V_{BB1} = 23$ V, $V_{BB2} = 5$ V, $V_{CC} = 30$ V, $V_{on} = -20.5$ V, $R_{BB1} = 16\ \Omega$, $R_{BB2} = 10\ \Omega$.

‡This circuit appears on the first page of the data section of this book.

MAXIMUM SAFE OPERATING AREA

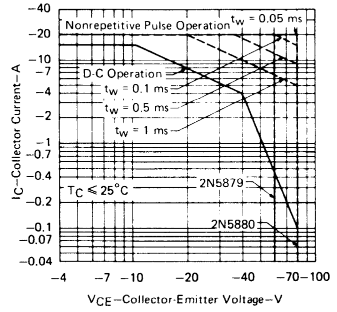


FIGURE 1

THERMAL CHARACTERISTICS

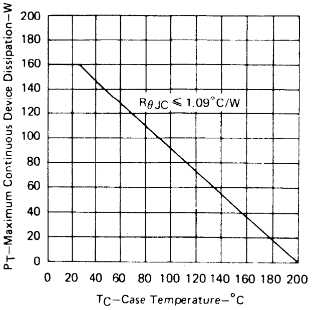


FIGURE 2

TYPES 2N5881, 2N5882
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

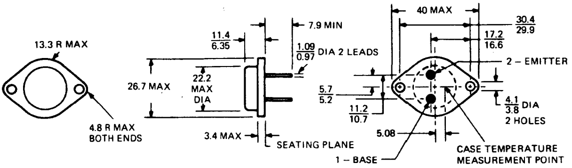
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS
DESIGNED FOR COMPLEMENTARY USE WITH 2N5879, 2N5880

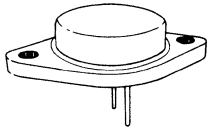
- 160 Watts at 25°C Case Temperature
- 15-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 1 A
- 90-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5881	2N5882
Collector-Base Voltage	60 V*	80 V*
Collector-Emitter Voltage (See Note 1)	60 V*	80 V*
Emitter-Base Voltage	5 V*	5 V*
Continuous Collector Current	◄— 15 A† 12 A* —►	
Peak Collector Current (See Note 2)	◄— 20 A —►	
Continuous Base Current	◄— 4 A* —►	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	◄— 160 W* —►	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	◄— 5 W —►	
Unclamped Inductive Load Energy (See Note 5)	◄— 90 mJ —►	
Operating Collector Junction Temperature Range	–65°C to 200°C*	
Storage Temperature Range	–65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	◄— 250°C* —►	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 0.915 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ L = 20 mH, R_{BB1} = 20 Ω, R_{BB2} = 100 Ω, V_{BB1} = 10 V, V_{BB2} = 0 V, R_L = 0.1 Ω, V_{CC} = 10 V, I_{CM} = 3 A. Energy ≈ $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.
†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.
‡This circuit appears on the first page of the data section of this book.

TYPES 2N5881, 2N5882
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5881		2N5882		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 0.2$ A,	$I_B = 0$,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V,	$I_B = 0$			1			mA
		$V_{CE} = 40$ V,	$I_B = 0$					1	
I_{CEV}	Collector Cutoff Current	$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V			0.5			mA
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V					0.5	
		$V_{CE} = 60$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$		5			
		$V_{CE} = 80$ V,	$V_{BE} = -1.5$ V,	$T_C = 150°C$				5	
I_{CBO}	Collector Cutoff Current	$V_{CB} = 60$ V,	$I_E = 0$			0.5			mA
		$V_{CB} = 80$ V,	$I_E = 0$					0.5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 2$ A	See Notes 6 and 7	35		35		
		$V_{CE} = 4$ V,	$I_C = 6$ A		20	100	20	100	
		$V_{CE} = 4$ V,	$I_C = 12$ A		5		5		
V_{BE}	Base-Emitter Voltage	$I_B = 0.7$ A,	$I_C = 7$ A	See Notes 6 and 7		1.6		1.6	V
		$V_{CE} = 4$ V,	$I_C = 12$ A			2.5		2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.7$ A,	$I_C = 7$ A	See Notes 6 and 7		1		1	V
		$I_B = 2.4$ A,	$I_C = 12$ A			4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 4$ V,	$I_C = 2$ A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 1$ A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = 10$ V,	$I_E = 0$,	f = 1 MHz		400		400	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ µs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	$I_C = 6$ A, $I_{B(1)} = 0.6$ A, $I_{B(2)} = -0.6$ A, $V_{BE(off)} = -5$ V, $R_L = 5\ \Omega$, See Note 8		0.7	µs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

† Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistor.*‡ $V_{BB1} = 23$ V, $V_{BB2} = 5$ V, $V_{CC} = 30$ V, $V_{on} = 20.5$ V, $R_{BB1} = 16\ \Omega$, $R_{BB2} = 10\ \Omega$.

‡This circuit appears on the first page of the data section of this book.

MAXIMUM SAFE OPERATING AREA

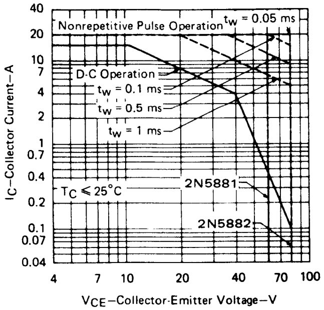


FIGURE 1

THERMAL CHARACTERISTICS

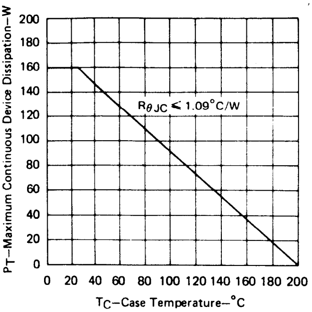


FIGURE 2

TYPES 2N5883, 2N5884
P-N-P SINGLE-DIFFUSED SILICON POWER TRANSISTORS

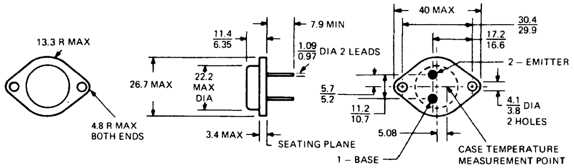
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5885, 2N5886

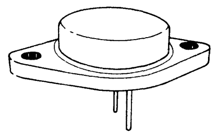
- 200 Watts at 25°C Case Temperature
- 25-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 1 A
- 90-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5883	2N5884
Collector-Base Voltage	−60 V*	−80 V*
Collector-Emitter Voltage (See Note 1)	−60 V*	−80 V*
Emitter-Base Voltage	−5 V*	−5 V*
Continuous Collector Current	−25 A† −20 A*	
Peak Collector Current (See Note 2)	−30 A	
Continuous Base Current	−6 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	200 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	90 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1.14 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = -3$ A, Energy $\approx I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.
†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.
‡This circuit appears on the first page of the data section of this book.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS				2N5883		2N5884		UNIT
						MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = -0.2$ A,	$I_B = 0$,	See Note 6		−60		−80		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = -30$ V,	$I_B = 0$				−2			mA
		$V_{CE} = -40$ V,	$I_B = 0$						−2	
I_{CEV}	Collector Cutoff Current	$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V				−1			mA
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V						−1	
		$V_{CE} = -60$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$			−10			
		$V_{CE} = -80$ V,	$V_{BE} = 1.5$ V,	$T_C = 150°C$					−10	
I_{CBO}	Collector Cutoff Current	$V_{CB} = -60$ V,	$I_E = 0$				−1			mA
		$V_{CB} = -80$ V,	$I_E = 0$						−1	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = -5$ V,	$I_C = 0$				−1		−1	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -3$ A	See Notes 6 and 7		35		35		
		$V_{CE} = -4$ V,	$I_C = -10$ A			20	100	20	100	
		$V_{CE} = -4$ V,	$I_C = -20$ A			5		5		
V_{BE}	Base-Emitter Voltage	$I_B = -1.5$ A,	$I_C = -15$ A	See Notes 6 and 7			−1.8		−1.8	V
		$V_{CE} = -4$ V,	$I_C = -20$ A				−2.5		−2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = -1.5$ A,	$I_C = -15$ A	See Notes 6 and 7			−1		−1	V
		$I_B = -4$ A,	$I_C = -20$ A				−4		−4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -4$ V,	$I_C = -3$ A,	f = 1 kHz		20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = -10$ V,	$I_C = -1$ A,	f = 1 MHz		4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	$V_{CB} = -10$ V,	$I_E = 0$,	f = 1 MHz			800		800	pF

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300$ μs, duty cycle ≤ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			MIN	MAX	UNIT
t_r	Rise Time	$I_C = -10$ A, $V_{BE(off)} = 4$ V,	$I_{B(1)} = -1$ A, $R_L = 3\ \Omega$,	$I_{B(2)} = 1$ A See Note 8		0.7	μs
t_s	Storage Time					1	
t_f	Fall Time					0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.
*JEDEC registered data
NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors*.‡ $V_{BB1} = 25$ V, $V_{BB2} = 4$ V, $V_{CC} = 30$ V, $V_{on} = -23$ V, $R_{BB1} = 11\ \Omega$, $R_{BB2} = 5\ \Omega$.

‡This circuit appears on the first page of the data section of this book.

MAXIMUM SAFE OPERATING AREA

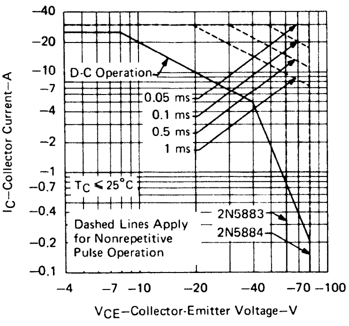


FIGURE 1

THERMAL CHARACTERISTICS

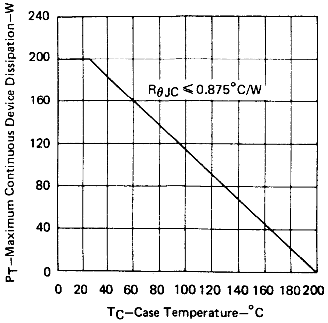


FIGURE 2

TYPES 2N5885, 2N5886
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

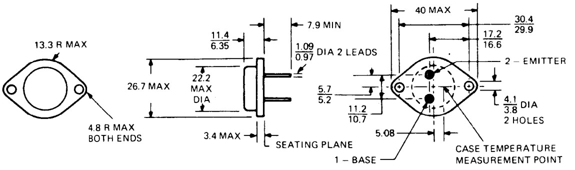
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N5883, 2N5884

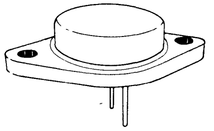
- 200 Watts at 25°C Case Temperature
- 25-A Rated Continuous Collector Current
- Min f_T of 4 MHz at 10 V, 1 A
- 90-mJ Reverse Energy Rating

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N5885	2N5886
Collector-Base Voltage	60 V*	80 V*
Collector-Emitter Voltage (See Note 1)	60 V*	80 V*
Emitter-Base Voltage	5 V*	5 V*
Continuous Collector Current	25 A† 20 A*	
Peak Collector Current (See Note 2)	30 A	
Continuous Base Current	6 A*	
Safe Operating Area at (or below) 25°C Case Temperature	See Figure 1	
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	200 W*	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W	
Unclamped Inductive Load Energy (See Note 5)	90 mJ	
Operating Collector Junction Temperature Range	−65°C to 200°C*	
Storage Temperature Range	−65°C to 200°C*	
Terminal Temperature 1.588mm from Case for 10 Seconds	250°C*	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leq 1$ ms, duty cycle $\leq 10\%$.
3. Derate linearly to 200°C case temperature at the rate of 1.14 W/°C.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C.
5. This rating is based on the capability of the transistors to operate safely in the unclamped-inductive load circuit of Section 3.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.*‡ $L = 20$ mH, $R_{BB1} = 20\ \Omega$, $R_{BB2} = 100\ \Omega$, $V_{BB1} = 10$ V, $V_{BB2} = 0$ V, $R_L = 0.1\ \Omega$, $V_{CC} = 10$ V, $I_{CM} = 3$ A. Energy $\approx I_C{}^2L/2$.

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†Texas Instruments guarantees this value in addition to the JEDEC registered value which is also shown.
‡This circuit appears on the first page of the data section of this book.

TYPES 2N5885, 2N5886
N-P-N SINGLE-DIFFUSED SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N5885		2N5886		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 0.2 A,	I_B = 0,	See Note 6	60		80		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 30 V,	I_B = 0			2			mA
		V_{CE} = 40 V,	I_B = 0					2	
I_{CEV}	Collector Cutoff Current	V_{CE} = 60 V,	V_{BE} = −1.5 V			1			mA
		V_{CE} = 80 V,	V_{BE} = −1.5 V					1	
		V_{CE} = 60 V,	V_{BE} = −1.5 V,	T_C = 150°C		10			
		V_{CE} = 80 V,	V_{BE} = −1.5 V,	T_C = 150°C				10	
I_{CBO}	Collector Cutoff Current	V_{CB} = 60 V,	I_E = 0			1			mA
		V_{CB} = 80 V,	I_E = 0					1	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			1		1	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 3 A	See Notes 6 and 7	35		35		
		V_{CE} = 4 V,	I_C = 10 A		20	100	20	100	
		V_{CE} = 4 V,	I_C = 20 A		5		5		
V_{BE}	Base-Emitter Voltage	I_B = 1.5 A,	I_C = 15 A	See Notes 6 and 7		1.8		1.8	V
		V_{CE} = 4 V,	I_C = 20 A			2.5		2.5	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.5 A,	I_C = 15 A	See Notes 6 and 7		1		1	V
		I_B = 4 A,	I_C = 20 A			4		4	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 3 A,	f = 1 kHz	20		20		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 1 A,	f = 1 MHz	4		4		
C_{obo}	Common-Base Open-Circuit Output Capacitance	V_{CB} = 10 V,	I_E = 0,	f = 1 MHz		500		500	pF

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

*switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†	MIN	MAX	UNIT
t_r	Rise Time	I_C = 10 A, $I_{B(1)}$ = 1 A, $I_{B(2)}$ = −1 A, $V_{BE(off)}$ = −4 V, R_L = 3 Ω, See Note 8		0.7	μs
t_s	Storage Time			1	
t_f	Fall Time			0.8	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

*JEDEC registered data.

NOTE 8: These characteristics are measured in the circuit of clause 3.3.13.2 of the forthcoming JEDEC publication *Suggested Standards on Power Transistors.* ‡ V_{BB1} = 25 V, V_{BB2} = 4 V, V_{CC} = 30 V, V_{on} = 23 V, R_{BB1} = 11 Ω, R_{BB2} = 5 Ω.

‡This circuit appears on the first page of the data section of this book.

MAXIMUM SAFE OPERATING AREA

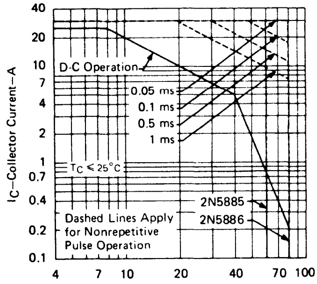


FIGURE 1

THERMAL CHARACTERISTICS

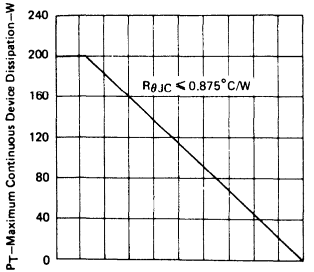


FIGURE 2

2N6270, 2N6271, 2N6272, 2N6273
NPN SILICON POWER TRANSISTORS

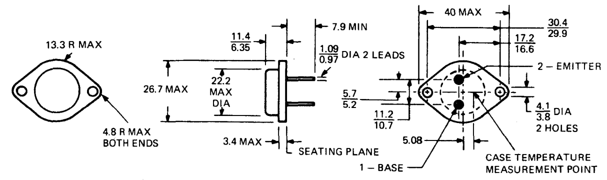
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED SWITCHING APPLICATIONS

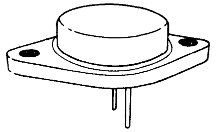
- 100-mJ Reverse-Energy Rating
- 30-A Rated Continuous Collector Current
- 150 Watts at 100°C Case Temperature
- Min f_T of 75 MHz at 10 V, 1 A

*mechanical data

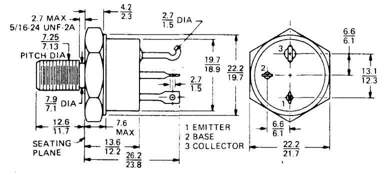
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



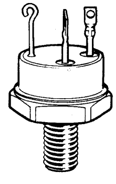
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD

ALL DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N6270 2N6272	2N6271 2N6273
Collector-Base Voltage	100 V	120 V
Collector-Emitter Voltage (See Note 1)	80 V	100 V
Emitter-Base Voltage	8 V	8 V
Continuous Collector Current	← 30 A →	
Peak Collector Current (See Note 2)	← 40 A →	
Continuous Base Current	← 10 A →	
Safe Operating Areas	See Figures 6 and 7	
Unclamped Inductive Load Energy (See Note 3 and Figure 7)	← 100 mJ →	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 4)	← 150 W →	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 5)	← 5 W →	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	← 300°C →	

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. L = 1 mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V, Energy $\approx I_C{}^2L/2$.
4. For operation above 100°C case temperature, refer to Dissipation Derating Curve, Figure 8.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve, Figure 9.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication..

2N6270, 2N6271, 2N6272, 2N6273
NPN SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N6270 2N6272		2N6271 2N6273		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 30 mA,	I_B = 0,	See Note 6	80		100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = 40 V,	I_B = 0			1			mA
		V_{CE} = 50 V,	I_B = 0					1	
I_{CES}	Collector Cutoff Current	V_{CE} = 100 V,	V_{BE} = 0			1			mA
		V_{CE} = 120 V,	V_{BE} = 0					1	
		V_{CE} = 60 V,	V_{BE} = 0,	T_C = 150°C		2		2	
I_{EBO}	Emitter Cutoff Current	V_{EB} = 5 V,	I_C = 0			0.1		0.1	mA
		V_{EB} = 8 V,	I_C = 0			1		1	
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = 4 V,	I_C = 15 A,	See Notes 6 and 7	20	100	20	100	
		V_{CE} = 4 V,	I_C = 30 A,	See Notes 6 and 7	10		10		
V_{BE}	Base-Emitter Voltage	V_{CE} = 4 V,	I_C = 30 A,	See Notes 6 and 7		2.2		2.2	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_B = 1.5 A,	I_C = 15 A,	See Notes 6 and 7		1		1	V
		I_B = 6 A,	I_C = 30 A,	See Notes 6 and 7		2		2	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 1 A,	f = 1 kHz	30		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = 10 V,	I_C = 1 A,	f = 5 MHz	15		15		

*JEDEC registered data

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			2N6270 2N6272	2N6271 2N6273	UNIT
					TYP	TYP	
t_{on}	Turn-On Time	I_C = 15 A,	$I_{B(1)}$ = 1.2 A,	$I_{B(2)}$ = −1.2 A,	0.5	0.5	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = −6.3 V,	R_L = 2 Ω,	See Figure 1	1.3	1.3	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

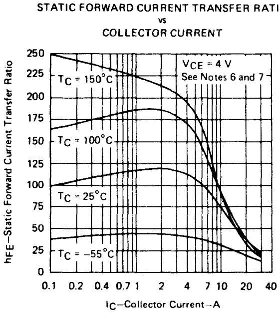

STATIC FORWARD CURRENT TRANSFER RATIO vs COLLECTOR CURRENT

FIGURE 1

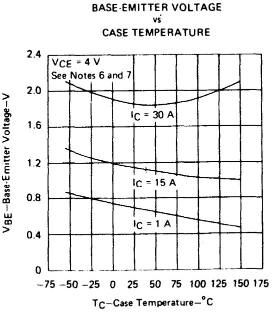

BASE-EMITTER VOLTAGE vs CASE TEMPERATURE

FIGURE 2

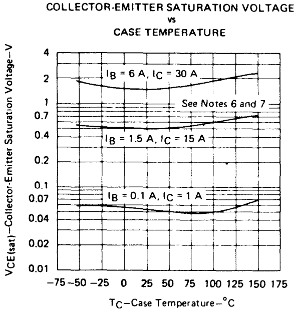

COLLECTOR-EMITTER SATURATION VOLTAGE vs CASE TEMPERATURE

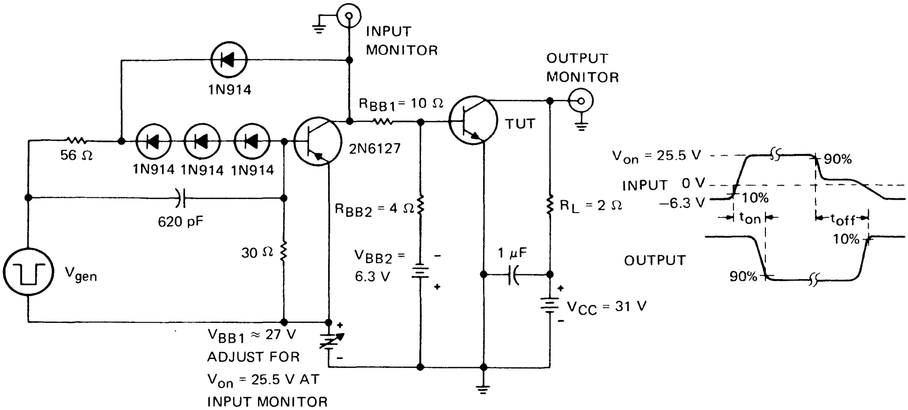
FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. t_W = 300 μs, duty cycle ⩽ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

2N6270, 2N6271, 2N6272, 2N6273
NPN SILICON POWER TRANSISTORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, Z_{out} = 50 Ω, t_w = 20 μs, duty cycle ⩽ 2%.

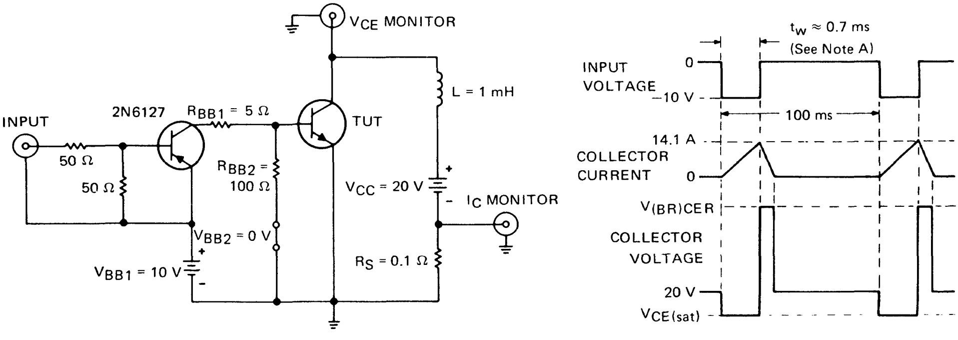
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until I_{CM} = 14.1 A.

FIGURE 5

MAXIMUM SAFE OPERATING AREAS

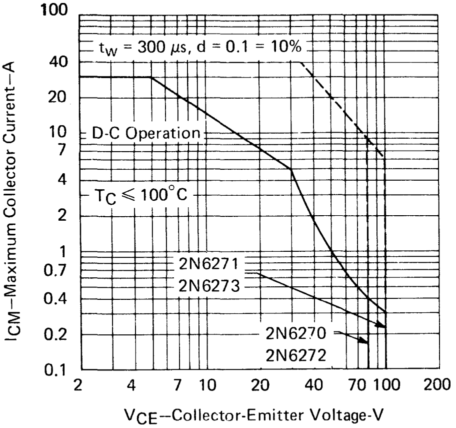

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

FIGURE 6

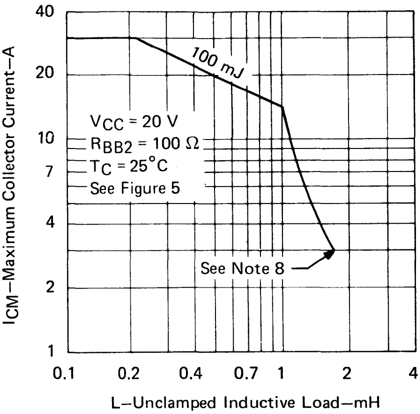

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

FIGURE 7

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

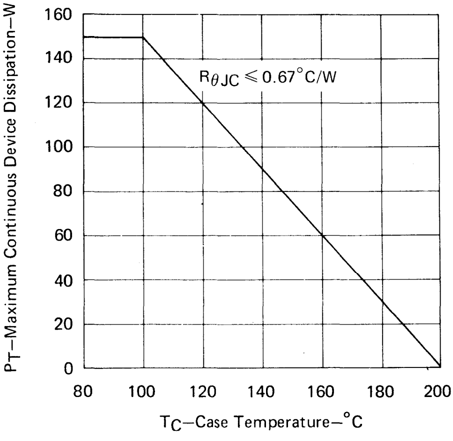

CASE TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 8

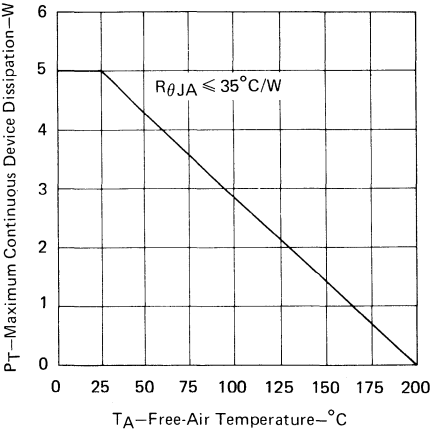

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 9

2N6322, 2N6323, 2N6324, 2N6325
NPN SILICON POWER TRANSISTORS

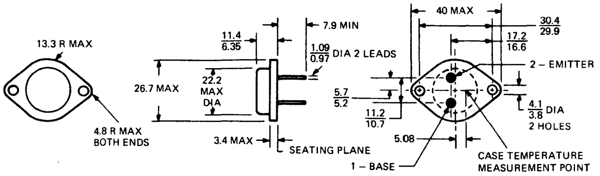
REVISED JULY 1975

HIGH VOLTAGE, HIGH FORWARD AND REVERSE ENERGY DESIGNED FOR INDUSTRIAL AND MILITARY APPLICATIONS

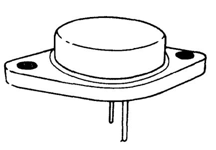
- **100-mJ Reverse-Energy Rating**
- **30-A Rated Continuous Collector Current**
- **200 Watts at 100°C Case Temperature**
- **Min $V_{(BR)CEO}$ of 300 V (2N6323, 2N6325)**

*mechanical data

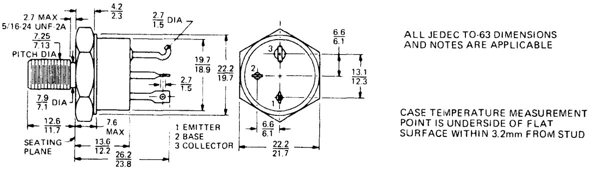
ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES

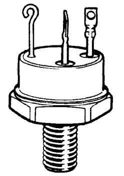


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL JEDEC TO-63 DIMENSIONS AND NOTES ARE APPLICABLE

CASE TEMPERATURE MEASUREMENT POINT IS UNDERSIDE OF FLAT SURFACE WITHIN 3.2mm FROM STUD



ALL DIMENSIONS ARE IN MILLIMETRES

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N6322 2N6324	2N6323 2N6325
Collector-Base Voltage	300 V	400 V
Collector-Emitter Voltage (See Note 1)	200 V	300 V
Emitter-Base Voltage	5 V	5 V
Continuous Collector Current	←— 30 A —→	
Peak Collector Current (See Note 2)	←— 40 A —→	
Continuous Base Current	←— 10 A —→	
Safe Operating Areas	See Figures 6 and 7	
Unclamped Inductive Load Energy (See Note 3 and Figure 7)	←— 100 mJ —→	
Continuous Device Dissipation at (or below) 100°C Case Temperature (See Note 4)	←— 200 W —→	
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 5)	←— 5 W —→	
Operating Collector Junction Temperature Range	−65°C to 200°C	
Storage Temperature Range	−65°C to 200°C	
Terminal Temperature 1.588mm from Case for 10 Seconds	←— 230°C —→	

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 0.3$ ms, duty cycle $\leqslant 10\%$.
3. This rating is based on the capability of the transistor to operate safely in the circuit of Figure 5. $L = 30$ mH, $R_{BB2} = 100\ \Omega$, $V_{BB2} = 0$ V, $R_S = 0.1\ \Omega$, $V_{CC} = 20$ V, Energy $\approx I_C{}^2L/2$.
4. For operation above 100°C case temperature, refer to Dissipation Derating Curve, Figure 8.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curve, Figure 9.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication..

2N6322, 2N6323, 2N6324, 2N6325
NPN SILICON POWER TRANSISTORS

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS			2N6322 2N6324		2N6323 2N6325		UNIT
					MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA,	$I_B = 0$,	See Note 6	200		300		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 100$ V,	$I_B = 0$			5			mA
		$V_{CE} = 150$ V,	$I_B = 0$					5	
I_{CES}	Collector Cutoff Current	$V_{CE} = 300$ V,	$V_{BE} = 0$			2			mA
		$V_{CE} = 400$ V,	$V_{BE} = 0$					2	
		$V_{CE} = 200$ V,	$V_{BE} = 0$,	$T_C = 150°C$		10		10	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V,	$I_C = 0$			5		5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 5$ V,	$I_C = 5$ A	See Notes 6 and 7	40	150	30	150	
		$V_{CE} = 5$ V,	$I_C = 20$ A		12		12		
		$V_{CE} = 5$ V,	$I_C = 30$ A		6		6		
V_{BE}	Base-Emitter Voltage	$V_{CE} = 5$ V,	$I_C = 30$ A,	See Notes 6 and 7		2.5		2.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_B = 0.5$ A,	$I_C = 5$ A	See Notes 6 and 7		0.5		0.5	V
		$I_B = 2$ A,	$I_C = 20$ A			1.5		1.5	
		$I_B = 6$ A,	$I_C = 30$ A			3		3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 1$ A,	f = 1 kHz	35		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V,	$I_C = 1$ A,	f = 5 MHz	2		2		

*JEDEC registered data

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = 20$ A,	$I_{B(1)} = 2$ A,	$I_{B(2)} = -2$ A,	0.8	µs
t_{off}	Turn-Off Time	$V_{BE(off)} = -3$ V,	$R_L = 2\,\Omega$,	See Figure 4	3	

†Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

TYPICAL CHARACTERISTICS

STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

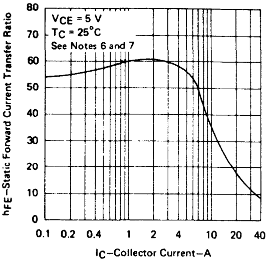


FIGURE 1

BASE-EMITTER VOLTAGE
vs
COLLECTOR CURRENT

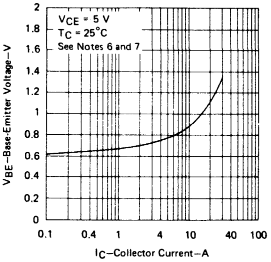


FIGURE 2

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
COLLECTOR CURRENT

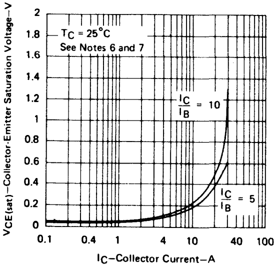
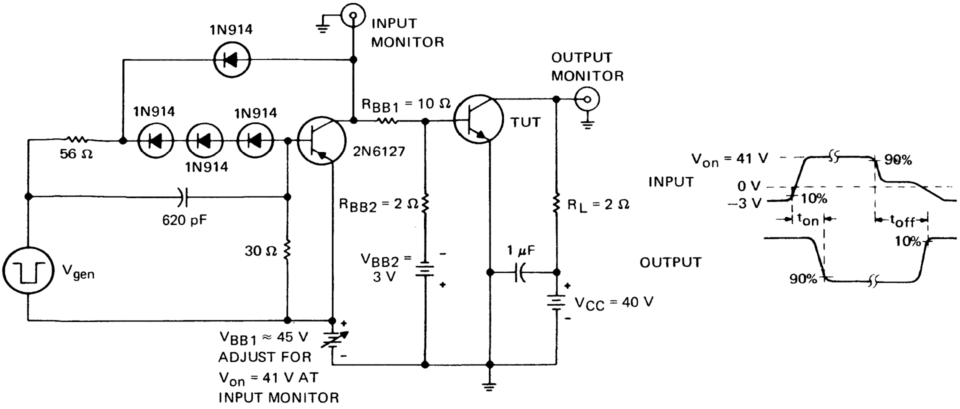


FIGURE 3

NOTES: 6. These parameters must be measured using pulse techniques. $t_W = 300$ µs, duty cycle ⩽ 2%.
7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2mm from the device body.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES: A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.

B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50\ \Omega$, $t_w = 20\ \mu s$, duty cycle ⩽ 2%.

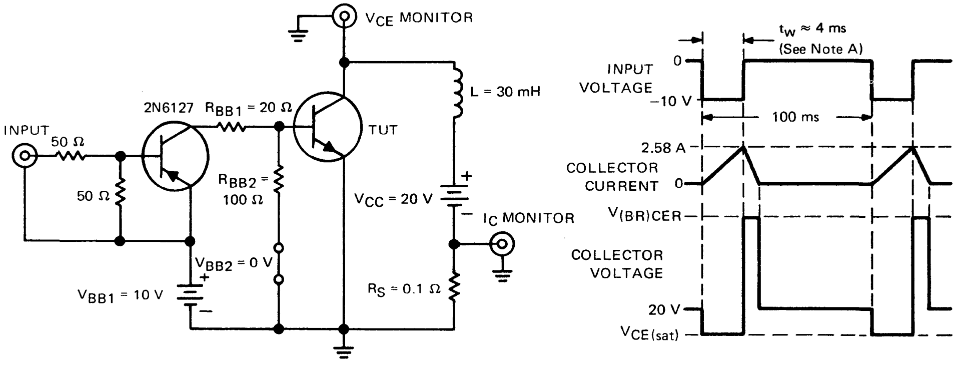
C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10\ M\Omega$, $C_{in} \leqslant 11.5$ pF.

D. Resistors must be noninductive types.

E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 4

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until $I_{CM} = 2.58$ A.

FIGURE 5

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

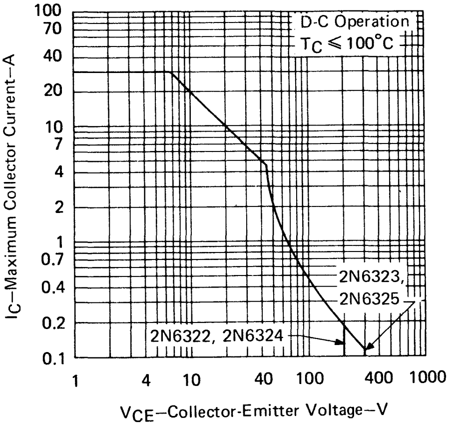


FIGURE 6

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

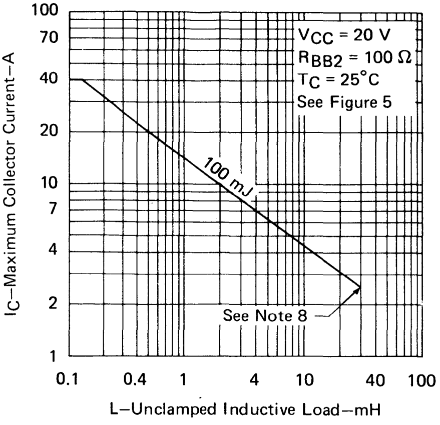


FIGURE 7

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

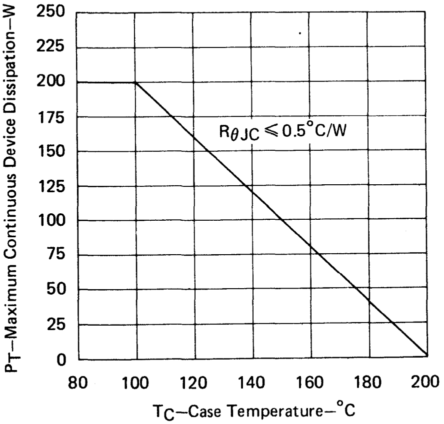


FIGURE 8

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

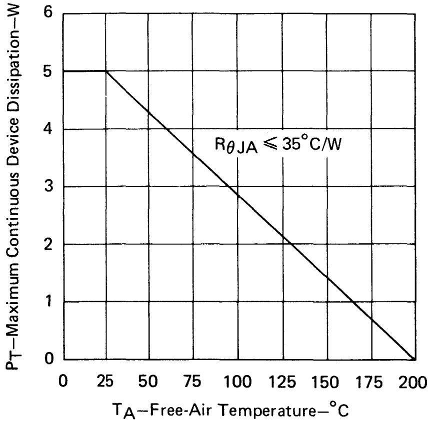


FIGURE 9

TYPES 2N6326, 2N6327, 2N6328
N-P-N SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

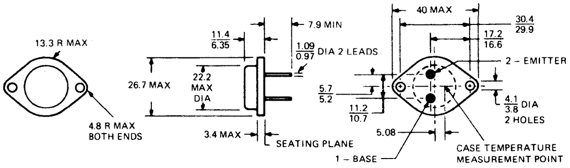
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N6329, 2N6330, 2N6331

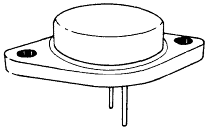
- 200 W at 25°C Case Temperature
- 30-A Rated Collector Current
- 200-mJ Reverse Energy Rating
- High SOA Capability, 20 V and 10 A

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N6326	2N6327	2N6328
Collector-Base Voltage	60 V	80 V	100 V
Collector-Emitter Voltage (See Note 1)	60 V	80 V	100 V
Emitter-Base Voltage	5 V	5 V	5 V
Continuous Collector Current	30 A		
Peak Collector Current (See Note 2)	40 A		
Continuous Base Current	10 A		
Safe Operating Areas at (or below) 25°C Case Temperature	See Figures 3 and 4		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	200 W		
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	114 W		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	5 W		
Unclamped Inductive Load Energy (See Note 5)	200 mJ		
Operating Collector Junction Temperature Range	−65°C to 200°C		
Storage Temperature Range	−65°C to 200°C		
Terminal Temperature 3.2 mm from Case for 10 Seconds	250°C		

NOTES:
1. These values apply when the base-emitter diode is open-circuited.
2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 10%.
3. Derate linearly to 200°C case temperature at the rate of 1.14 W/°C or refer to Dissipation Derating Curve, Figure 5.
4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 6.
5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N6326		2N6327		2N6328		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 30$ mA, $I_B = 0$,	See Note 6	60		80		100		V
I_{CEO}	Collector Cutoff Current	$V_{CE} = 30$ V, $I_B = 0$			1					mA
		$V_{CE} = 40$ V, $I_B = 0$					1			
		$V_{CE} = 50$ V, $I_B = 0$							1	
I_{CES}	Collector Cutoff Current	$V_{CE} = 60$ V, $V_{BE} = 0$			0.5					mA
		$V_{CE} = 80$ V, $V_{BE} = 0$					0.5			
		$V_{CE} = 100$ V, $V_{BE} = 0$							0.5	
		$V_{CE} = 30$ V, $V_{BE} = 0$,	$T_C = 150°C$		5					
		$V_{CE} = 40$ V, $V_{BE} = 0$,	$T_C = 150°C$				5			
		$V_{CE} = 50$ V, $V_{BE} = 0$,	$T_C = 150°C$						5	
I_{EBO}	Emitter Cutoff Current	$V_{EB} = 5$ V, $I_C = 0$,			0.5		0.5		0.5	mA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CE} = 4$ V, $I_C = 5$ A	See Notes 6 and 7	25		25		25		
		$V_{CE} = 4$ V, $I_C = 15$ A		12		12		12		
		$V_{CE} = 4$ V, $I_C = 30$ A		6	30	6	30	6	30	
V_{BE}	Base-Emitter Voltage	$V_{CE} = 4$ V, $I_C = 15$ A	See Notes 6 and 7		2		2		2	V
		$V_{CE} = 4$ V, $I_C = 30$ A			4		4		4	
$V_{CE(sat)}$	Collector-Emitter Voltage	$I_B = 2$ A, $I_C = 15$ A	See Notes 6 and 7		1.5		1.5		1.5	V
		$I_B = 7.5$ A, $I_C = 30$ A			3		3		3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A,	f = 1 kHz	30		30		30		
$\|h_{fe}\|$	Small-Signal Common-Emitter Forward Current Transfer Ratio	$V_{CE} = 10$ V, $I_C = 1$ A,	f = 1 MHz	3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. $t_w = 300\ \mu s$, duty cycle $\leq 2\%$.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

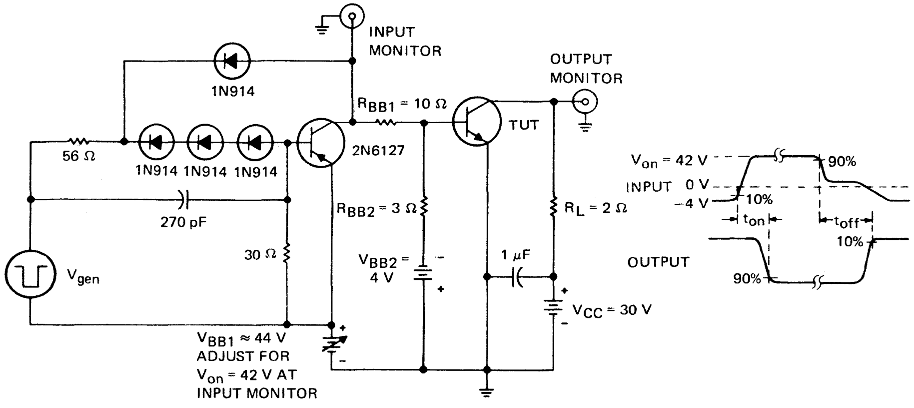
*JEDEC registered data

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	$I_C = 15$ A,	$I_{B(1)} = 2$ A,	$I_{B(2)} = -2$ A,	0.6	μs
t_{off}	Turn-Off Time	$V_{BE(off)} = -4$ V,	$R_L = 2\ \Omega$,	See Figure 1	0.9	

†Voltage and current values shown are nominal, exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

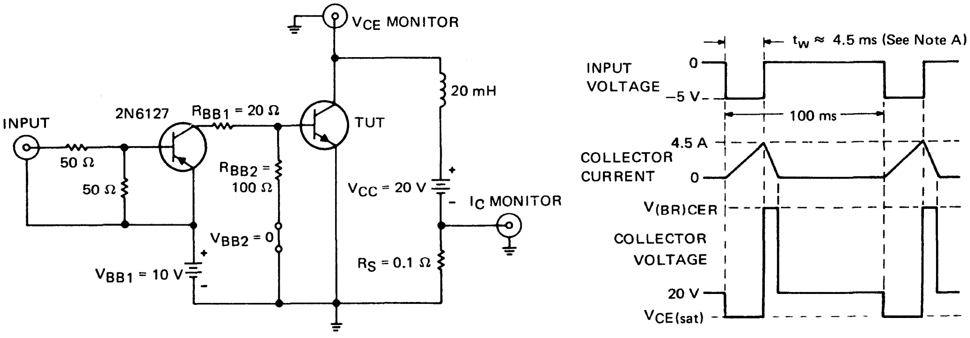


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a −30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leq 15$ ns, $t_f \leq 15$ ns, $Z_{out} = 50$ Ω, $t_w = 20$ µs, duty cycle ≤ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 15$ ns, $R_{in} \geq 10$ MΩ, $C_{in} \leq 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until I_{CM} = 4.5 A.

FIGURE 2

MAXIMUM SAFE OPERATING AREAS

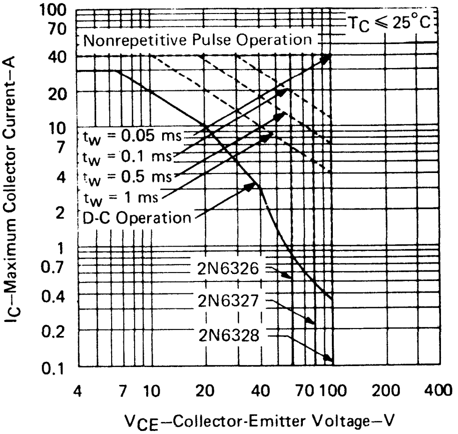

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

FIGURE 3

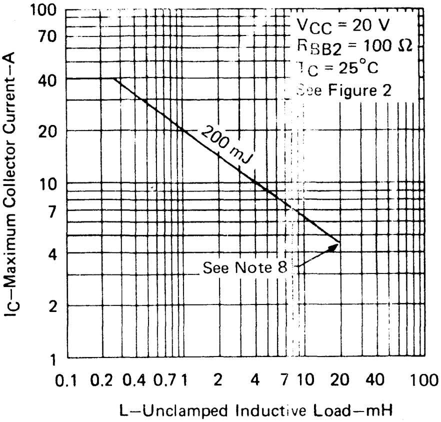

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

FIGURE 4

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

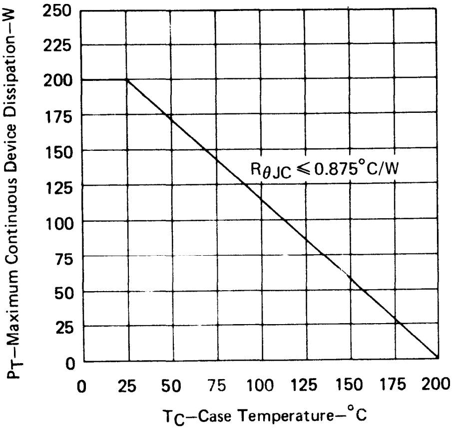

CASE TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 5

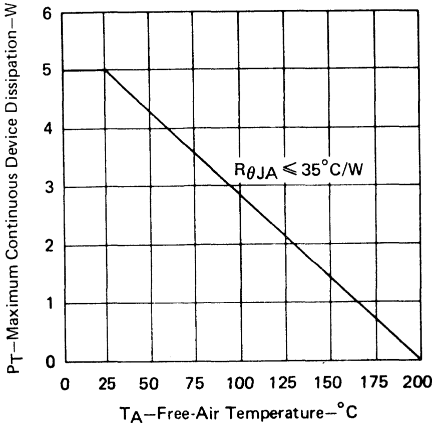

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

FIGURE 6

TYPES 2N6329, 2N6330, 2N6331
P-N-P SINGLE-DIFFUSED MESA SILICON POWER TRANSISTORS

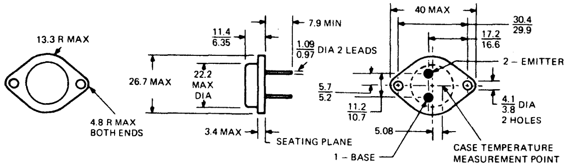
REVISED AUGUST 1975

FOR POWER-AMPLIFIER AND HIGH-SPEED-SWITCHING APPLICATIONS DESIGNED FOR COMPLEMENTARY USE WITH 2N6326, 2N6327, 2N6328

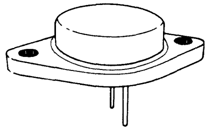
- 200 W at 25°C Case Temperature
- 30-A Rated Collector Current
- 200-mJ Reverse Energy Rating
- High SOA Capability, 20 V and 10 A

*mechanical data

ALL JEDEC TO-3 DIMENSIONS AND NOTES ARE APPLICABLE
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN MILLIMETRES



*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

	2N6329	2N6330	2N6331
Collector-Base Voltage	−60 V	−80 V	−100 V
Collector-Emitter Voltage (See Note 1)	−60 V	−80 V	−100 V
Emitter-Base Voltage	−5 V	−5 V	−5 V
Continuous Collector Current	←——— −30 A ———→		
Peak Collector Current (See Note 2)	←——— −40 A ———→		
Continuous Base Current	←——— −10 A ———→		
Safe Operating Areas at (or below) 25°C Case Temperature	←—See Figures 3 and 4—→		
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 3)	←———200 W———→		
Continuous Device Dissipation at 100°C Case Temperature (See Note 3)	←———114 W———→		
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	←——— 5 W ———→		
Unclamped Inductive Load Energy (See Note 5)	←———200 mJ———→		
Operating Collector Junction Temperature Range	←——−65°C to 200°C——→		
Storage Temperature Range	←——−65°C to 200°C——→		
Terminal Temperature 3.2mm from Case for 10 Seconds	←———250°C ———→		

NOTES: 1. These value apply when the base-emitter diode is open-circuited.

2. This value applies for $t_w \leqslant 1$ ms, duty cycle $\leqslant$ 10%.

3. Derate linearly to 200°C case temperature at the rate of 1.14 W/°C or refer to Dissipation Derating Curve, Figure 5.

4. Derate linearly to 200°C free-air temperature at the rate of 28.6 mW/°C or refer to Dissipation Derating Curve, Figure 6.

5. This rating is based on the capability of the transistors to operate safely in the circuit of Figure 2. L = 20 mH, R_{BB2} = 100 Ω, V_{BB2} = 0 V, R_S = 0.1 Ω, V_{CC} = 20 V. Energy ≈ $I_C{}^2L/2$.

*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

*electrical characteristics at 25° C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		2N6329		2N6330		2N6331		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = −30 mA, I_B = 0,	See Note 6	−60		−80		−100		V
I_{CEO}	Collector Cutoff Current	V_{CE} = −30 V, I_B = 0		−1						mA
		V_{CE} = −40 V, I_B = 0				−1				
		V_{CE} = −50 V, I_B = 0						−1		
I_{CES}	Collector Cutoff Current	V_{CE} = −60 V, V_{BE} = 0			−0.5					mA
		V_{CE} = −80 V, V_{BE} = 0					−0.5			
		V_{CE} = −100 V, V_{BE} = 0							−0.5	
		V_{CE} = −30 V, V_{BE} = 0,	T_C = 150°C		−5					
		V_{CE} = −40 V, V_{BE} = 0,	T_C = 150°C				−5			
		V_{CE} = −50 V, V_{BE} = 0,	T_C = 150°C						−5	
I_{EBO}	Emitter Cutoff Current	V_{EB} = −5 V, I_C = 0,			−0.5		−0.5		−0.5	mA
h_{FE}	Static Forward Current Transfer Ratio	V_{CE} = −4 V, I_C = −5 A	See Notes 6 and 7	25		25		25		
		V_{CE} = −4 V, I_C = −15 A		12		12		12		
		V_{CE} = −4 V, I_C = −30 A		6	30	6	30	6	30	
V_{BE}	Base-Emitter Voltage	V_{CE} = −4 V, I_C = −15 A	See Notes 6 and 7		−2		−2	4	−2	V
		V_{CE} = −4 V, I_C = −30 A			−4		−4		−4	
$V_{CE(sat)}$	Collector-Emitter Voltage	I_B = −2 A, I_C = −15 A	See Notes 6 and 7		−1.5		−1.5		−1.5	V
		I_B = −7.5 A, I_C = −30 A			−3		−3		−3	
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −10 V, I_C = −1 A,	f = 1 kHz	30		30		30		
h_{fe}	Small-Signal Common-Emitter Forward Current Transfer Ratio	V_{CE} = −10 V, I_C = −1 A,	f = 1 MHz	3		3		3		

NOTES: 6. These parameters must be measured using pulse techniques. t_w = 300 μs, duty cycle ≤ 2%.

7. These parameters are measured with voltage-sensing contacts separate from the current-carrying contacts and located within 3.2 mm from the device body.

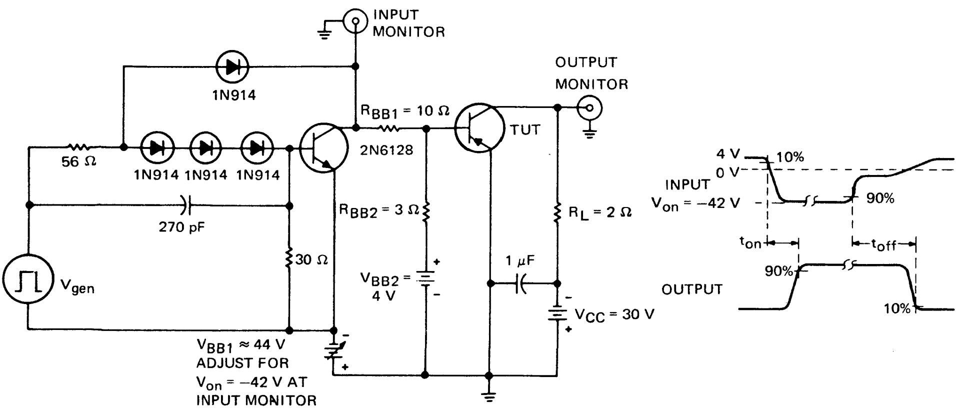
†JEDEC registered data

switching characteristics at 25° C case temperature

PARAMETER		TEST CONDITIONS†			TYP	UNIT
t_{on}	Turn-On Time	I_C = −15 A,	$I_{B(1)}$ = −2 A,	$I_{B(2)}$ = 2 A,	0.6	μs
t_{off}	Turn-Off Time	$V_{BE(off)}$ = 4 V,	R_L = 2 Ω,	See Figure 1	0.9	

†Voltage and current values shown are nominal, exact values vary slightly with transistor parameters.

PARAMETER MEASUREMENT INFORMATION

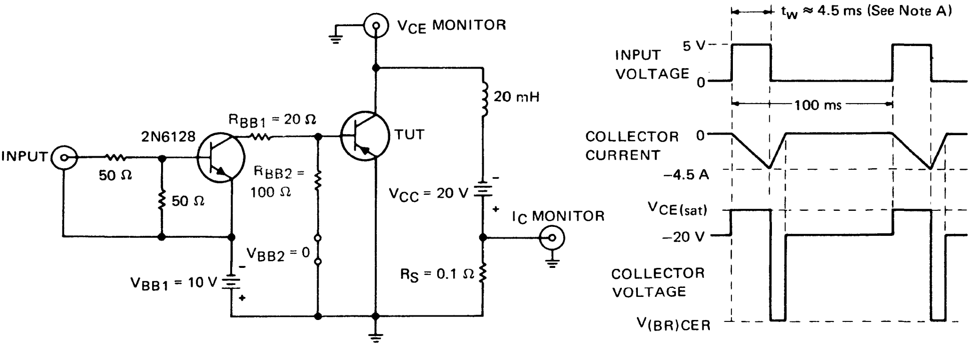


TEST CIRCUIT **VOLTAGE WAVEFORMS**

NOTES:
- A. V_{gen} is a 30-V pulse (from 0 V) into a 50-Ω termination.
- B. The V_{gen} waveform is supplied by a generator with the following characteristics: $t_r \leqslant 15$ ns, $t_f \leqslant 15$ ns, $Z_{out} = 50$ Ω, $t_w = 20$ μs, duty cycle ⩽ 2%.
- C. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 15$ ns, $R_{in} \geqslant 10$ MΩ, $C_{in} \leqslant 11.5$ pF.
- D. Resistors must be noninductive types.
- E. The d-c power supplies may require additional bypassing in order to minimize ringing.

FIGURE 1

INDUCTIVE LOAD SWITCHING



TEST CIRCUIT **VOLTAGE AND CURRENT WAVEFORMS**

NOTE A: Input pulse width is increased until $I_{CM} = -4.5$ A.

FIGURE 2

MAXIMUM SAFE OPERATING AREAS

MAXIMUM COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

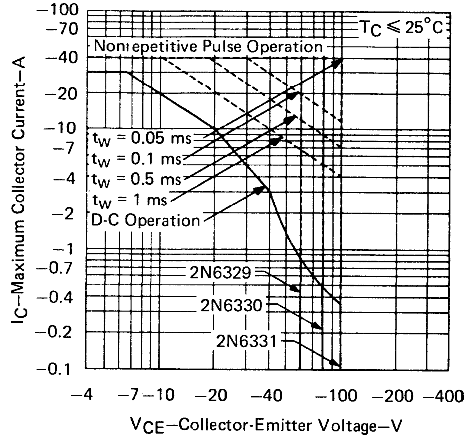


FIGURE 3

MAXIMUM COLLECTOR CURRENT
vs
UNCLAMPED INDUCTIVE LOAD

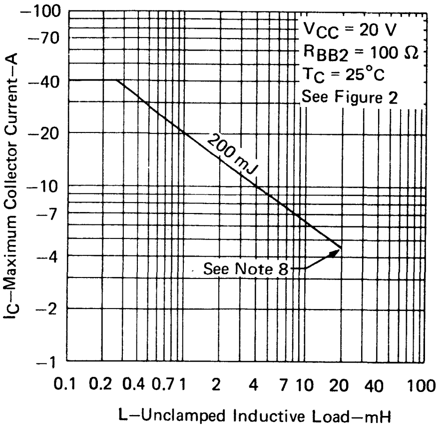


FIGURE 4

NOTE 8: Above this point the safe operating area has not been defined.

THERMAL INFORMATION

CASE TEMPERATURE
DISSIPATION DERATING CURVE

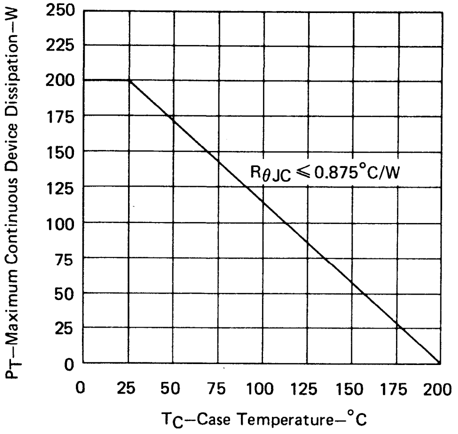


FIGURE 5

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

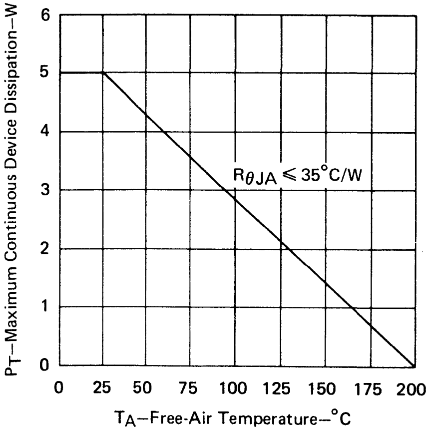


FIGURE 6

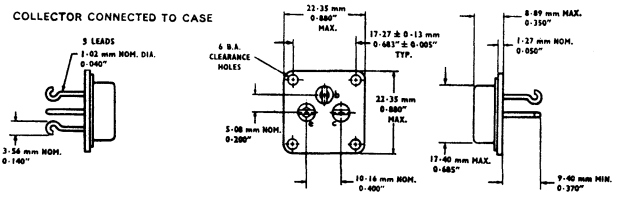
2S024,2S025,2S026
NPN DIFFUSED MESA SILICON POWER TRANSISTORS

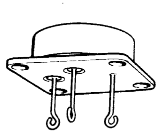
REVISED AUGUST 1975

HIGH FREQUENCY POWER TRANSISTORS

- **50 WATTS AT 100°C CASE TEMPERATURE**
- **MAXIMUM $V_{CE(SAT)}$ 0·8 VOLTS AT 2 AMPERES I_C**
- **MINIMUM f_T OF 10 Mc/s**

mechanical data





absolute maximum ratings

	2S024	2S025	2S026	Units
Collector Base Voltage	100	150	200	V
Collector Emitter Voltage (Note 1)	100	150	200	V
Collector Emitter Voltage (Note 2)	32	60	100	V
Emitter Base Voltage	10	10	10	V
Collector Current	7·5	7·5	7·5	Amps
Device Dissipation at $T_{case} \leq 25°C$ (Note 3)	100	100	100	Watts
Operating Temperature Range		−55°C to +175°C		

notes

1. $R_{BE} \leq 33$ ohms.
2. $I_B = 0$
3. Derate linearly at 1·5°C/Watt to 175°C.

2S024,2S025,2S026
NPN DIFFUSED MESA SILICON POWER TRANSISTORS

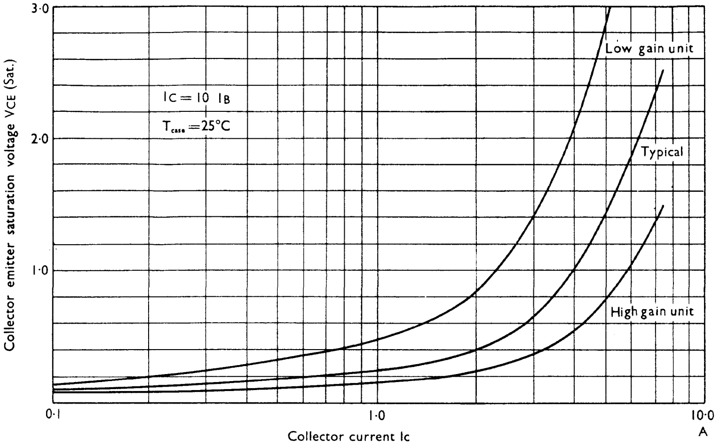
electrical characteristics (at $T_{case} = 25°C$ unless otherwise stated)

Parameter	Test Conditions	Type	Min.	Typ.	Max.	Units
I_{CBO} Collector-Base Leakage Current	$V_{CB} = 100$ V $V_{CB} = 150$ V $V_{CB} = 200$ V	2S024 2S025 2S026	— — —	— — —	10 10 10	mA mA mA
I_{CER} Collector-Emitter Leakage Current	$V_{CE} = 100$ V, $R_{BE} = 33\ \Omega$ $V_{CE} = 150$ V, $R_{BE} = 33\ \Omega$ $V_{CE} = 200$ V, $R_{BE} = 33\ \Omega$	2S024 2S025 2S026	— — —	— — —	10 10 10	mA mA mA
BV_{CEO} Collector-Emitter Breakdown Voltage	$I_C = 10$ mA, $I_B = 0$ (see Note 4)	2S024 2S025 2S026	32 60 100	— — —	— — —	V V V
BV_{EBO} Emitter-Base Breakdown Voltage	$I_C = 0$ $I_E = 10$ mA	ALL	10	—	—	V
I_{CBO} Collector-Base Leakage Current	$I_E = 0$ $V_{CB} = 32$ V (2S024) $V_{CB} = 60$ V (2S025) $V_{CB} = 100$ V (2S026)	ALL	—	—	1	mA
I_{CBO} Collector-Base Leakage Current	$I_E = 0$, $T_{amb} = 150°C$ $V_{CB} = 32$ V (2S024) $V_{CB} = 60$ V (2S025) $V_{CB} = 100$ V (2S026)	ALL	—	—	3	mA
h_{FE} D.C. Current Gain	$V_{CE} = 15$ V (see Note 4) $I_C = 2$ A	ALL	20	30	—	—
h_{FE} D.C. Current Gain	$V_{CE} = 15$ V (see Note 4) $I_C = 2$ A, $T_{case} = -55°C$	ALL	12	—	—	—
$V_{CE(SAT)}$ Collector-Emitter Saturation Voltage	$I_C = 2$ A, $I_C = 0{\cdot}2$ A (see Note 4)	ALL	—	0·4	0·8	V
$V_{BE(SAT)}$ Base-Emitter Saturation Voltage	$I_C = 2$ A, $I_B = 0{\cdot}2$ A (see Note 4)	ALL	—	1·0	1·5	V
f_T Transition Frequency	$V_{CE} = 15$ V, $I_B = 0{\cdot}5$ A $f = 1$ Mc/s	ALL	10	12	—	Mc/s
C_{OB} Collector-Base Capacitance	$V_{CB} = 15$ V, $I_E = 0$ $f = 1$ Mc/s	ALL	—	470	550	pf
$t_{on} + t_{off}$ Total Switching Time	See circuit P.7	ALL	—	2·0	—	μ Sec.
$\theta_{j\text{-}c}$ Thermal Resistance Junction to Case		ALL	—	—	1·5	°C/W
Thermal Time Constant (see Note 5)		ALL	—	8	—	mSec.

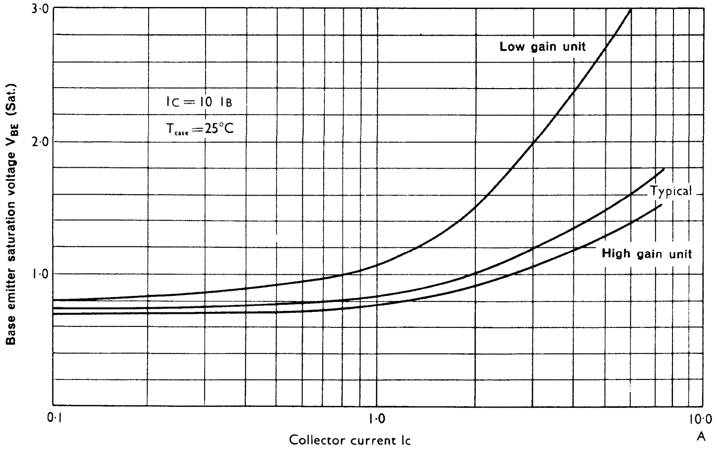
notes

4. These parameters measured using pulse techniques. 300 μsec max. pulse width, 2% duty ratio.
5. This is the time required for the junction temperature to reach 66% of its final value assuming constant stud temperature.

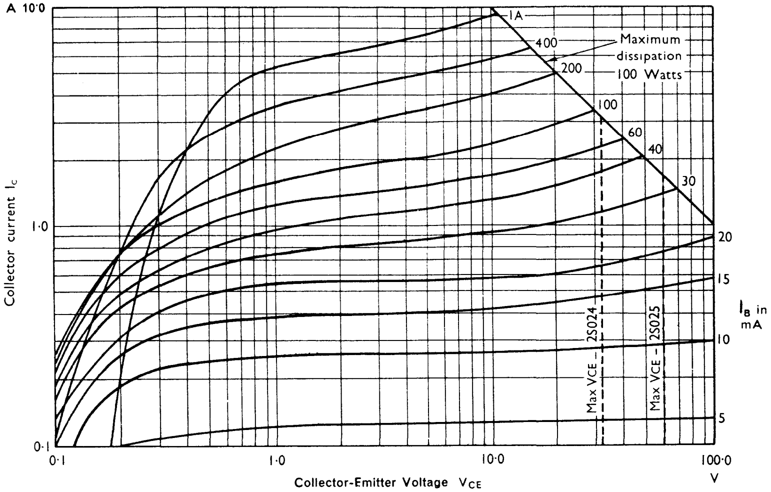
TYPICAL VARIATION OF VCE (Sat.) WITH COLLECTOR CURRENT



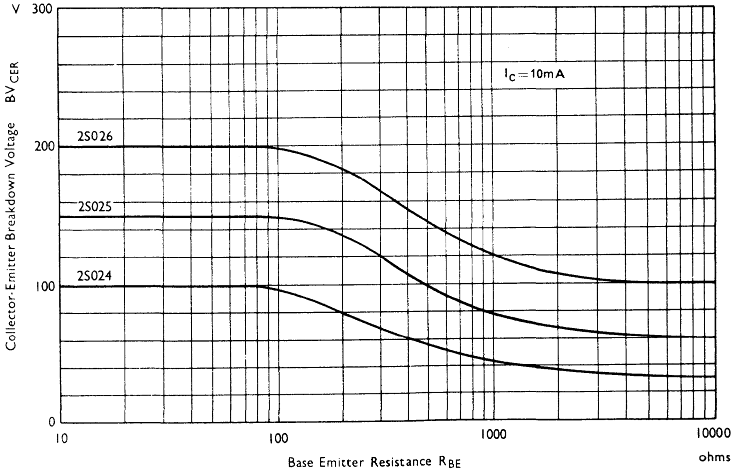
TYPICAL VARIATION OF VBE (Sat.) WITH COLLECTOR CURRENT



TYPICAL COMMON-EMITTER OUTPUT CHARACTERISTICS

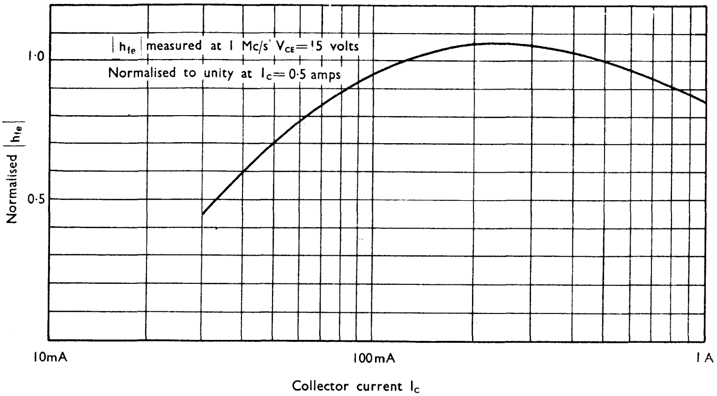


TYPICAL VARIATION OF BV_{CER} WITH BASE-EMITTER RESISTANCE

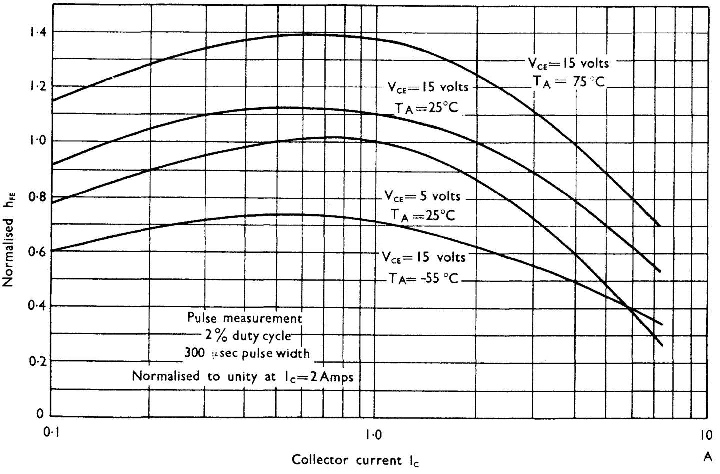


2S024,2S025,2S026
NPN DIFFUSED MESA SILICON POWER TRANSISTORS

TYPICAL VARIATION OF NORMALISED |h_{fe}| WITH COLLECTOR CURRENT

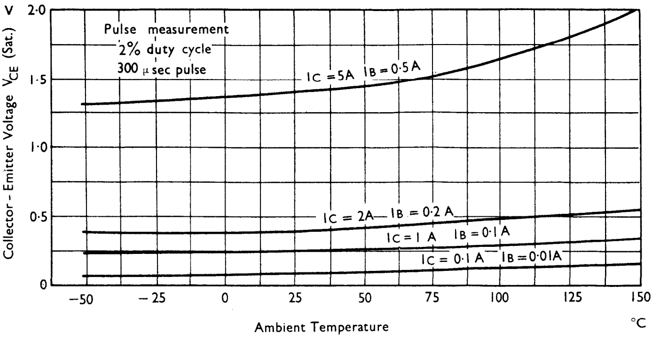


TYPICAL VARIATION OF NORMALISED h_{FE} WITH COLLECTOR CURRENT

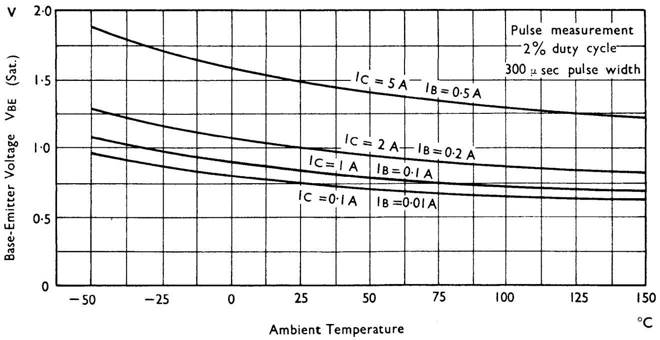


TEXAS INSTRUMENTS

TYPICAL VARIATION OF V_{CE} (Sat.) WITH TEMPERATURE

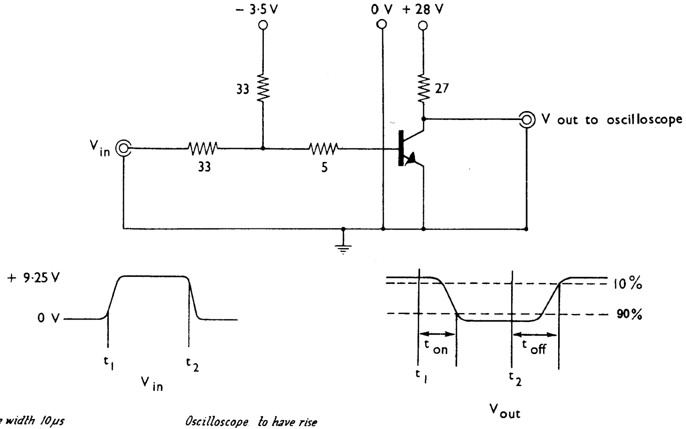


TYPICAL VARIATION OF V_{BE} (Sat.) WITH TEMPERATURE



2S024, 2S025, 2S026
NPN DIFFUSED MESA SILICON POWER TRANSISTORS

SWITCHING TIME CIRCUIT FOR 2S024, 2S025 AND 2S026

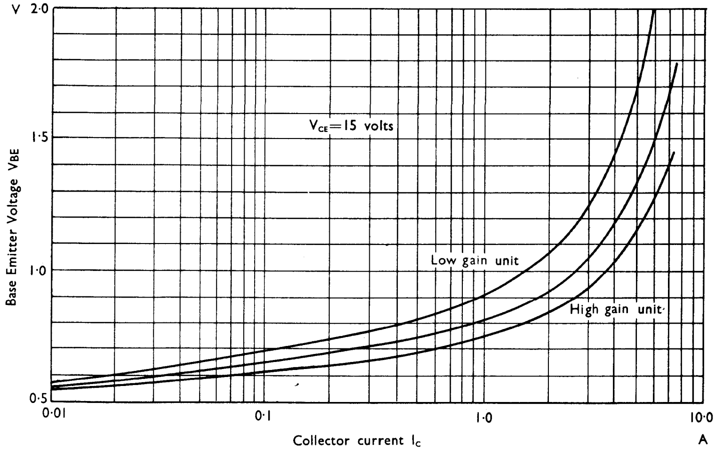


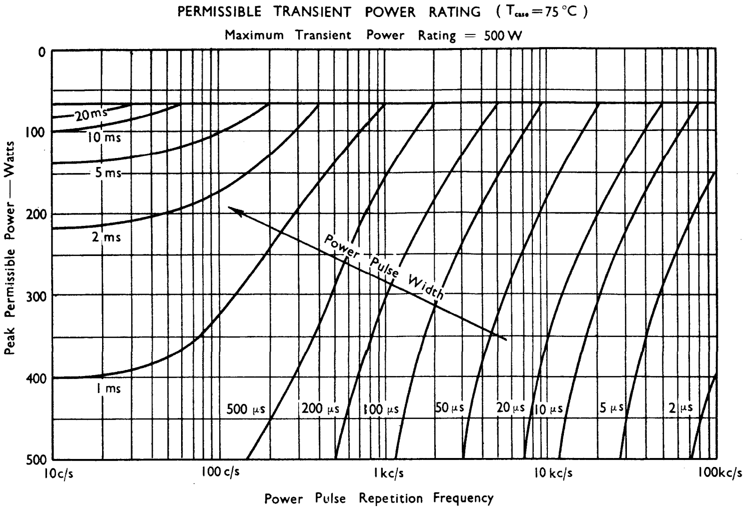
Pulse width 10μs
Pulse repetition rate 200 pps
Resistors ±1% tolerance
Recommended Pulse Generator
Hewlett Packard 214A

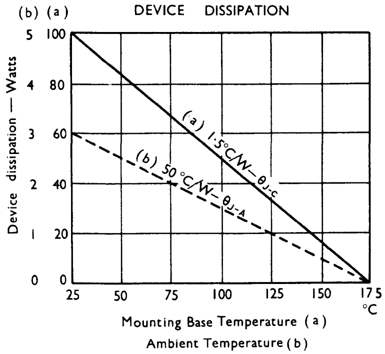
Oscilloscope to have rise time better than 50ns. such as Tektronix 530, 540 or 580 series or Hewlett Packard 140A

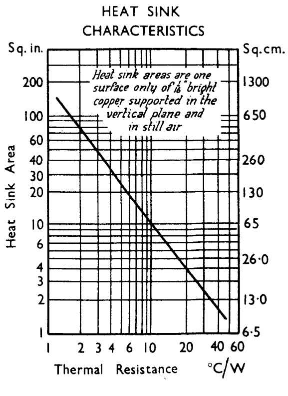
$I_{B1} \doteqdot 100\text{mA}$
$I_{B2} \doteqdot 100\text{mA}$
$I_C \doteqdot 1\text{A}$

TYPICAL TRANSFER CHARACTERISTICS




PERMISSIBLE TRANSIENT POWER RATING (T_case = 75 °C)
Maximum Transient Power Rating = 500 W
Peak Permissible Power — Watts
0
100
200
300
400
500
20 ms
10 ms
5 ms
2 ms
1 ms
500 μs
200 μs
100 μs
50 μs
20 μs
10 μs
5 μs
2 μs
Power Pulse Width
10c/s
100 c/s
1 kc/s
10 kc/s
100kc/s
Power Pulse Repetition Frequency


(b) (a)
DEVICE DISSIPATION
Device dissipation — Watts
5 100
4 80
3 60
2 40
1 20
0 0
(a) 1·5°C/W – θJ-C
(b) 50 °C/W – θJ-A
25
50
75
100
125
150
175
°C
Mounting Base Temperature (a)
Ambient Temperature (b)


HEAT SINK CHARACTERISTICS
Sq. in.
Sq.cm.
Heat sink areas are one surface only of 1/16" bright copper supported in the vertical plane and in still air
Heat Sink Area
200
100
60
40
30
20
10
6
4
3
2
1
1300
650
260
130
65
26·0
13·0
6·5
1
2
3
4
6
10
20
40
60
Thermal Resistance °C/W

TYPES 2S721, 2S722, 2S723, 2S724
N-P-N DIFFUSED SILICON POWER TRANSISTORS

REVISED JUNE 1975

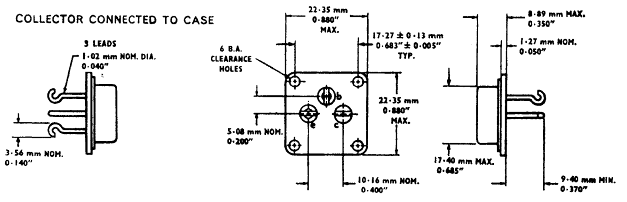
DESIGNED FOR HIGH VOLTAGE, HIGH POWER APPLICATIONS

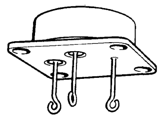
- **85 Watts dissipation at 25°C**
- **Close gain spread at 1 amp collector current**

environmental tests

To ensure maximum reliability each unit undergoes a high temperature stabilisation bake, followed by test of the hermetic seal. In addition production samples are life tested at regular periods to ensure stable performance under extreme operating conditions.

mechanical data





absolute maximum ratings

	2S721	2S722	2S723	2S724	UNIT
Collector-Base Voltage	60	100	60	100	V
Collector-Emitter Voltage (Note 1)	60	100	60	100	V
Collector-Emitter Voltage (Note 2)	30	60	30	60	V
Emitter-Base Voltage	10	10	10	10	V
Collector Current	2	2	2	2	A
Device Dissipation at T_{case} 25°C (Note 3)	85	85	85	85	W
Operating Temperature Range	−55 to +200				C

notes

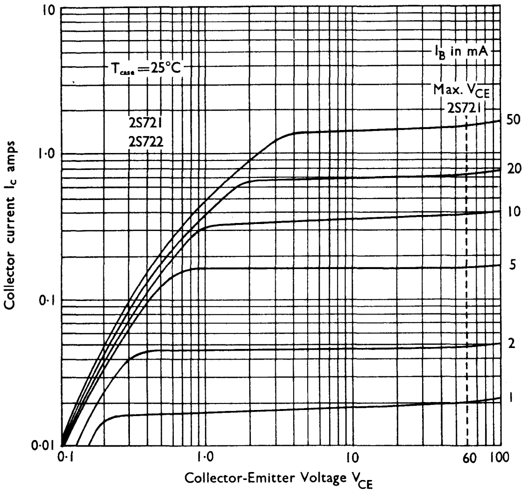
1. $R_{BE} \leqslant 33$ ohms.
2. $I_B = 0$.
3. Derate linearly to 200°C at 0·485 Watts/°C.

TYPES 2S721, 2S722, 2S723, 2S724
N-P-N DIFFUSED SILICON POWER TRANSISTORS

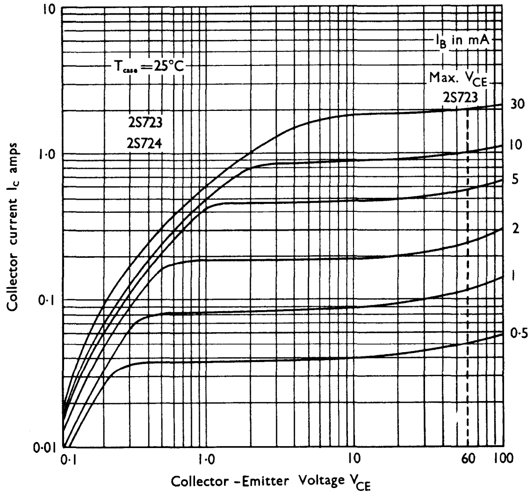
electrical characteristics (at T_{case} = 25°C unless otherwise stated)

Parameter		Test Conditions	Type	Min.	Typ.	Max.	Unit
BV_{CER}	Collector-Emitter Breakdown Voltage	I_C = 10 mA, R_{BE} = 33 Ω	2S721 2S723	60	—	—	V
			2S722 2S724	100	—	—	V
BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 30 mA, I_B = 0	2S721 2S723	30	—	—	V
			2S722 2S724	60	—	—	V
I_{EBO}	Emitter-Base Leakage Current	V_{EB} = 10 V, I_C = 0	ALL	—	0·2	1	mA
I_{CBO}	Collector-Base Leakage Current	V_{CB} = 40 V, T_{amb} = 150°C	2S721 2S723	—	1	10	mA
		V_{CB} = 60 V, T_{amb} = 150°C	2S722 2S724	—	1	10	mA
h_{FE}	D.C. Forward-Current Transfer Ratio	V_{CE} = 15 V, I_C = 1 A	2S721 2S722	20	35	120	—
			2S723 2S724	40	85	200	—
V_{BE}	Base-Emitter Voltage	V_{CE} = 15 V, I_C = 1 A	2S721 2S722	—	5	8	V
			2S723 2S724	—	3	5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 1 A, I_B = 0·2 A	2S721 2S722	—	3	5	V
			2S723 2S724	—	1·5	3	V
f_T	Transition Frequency	V_{CE} = 30 V, I_C = 30 mA	ALL	—	3	—	Mc/s
C_{obo}	Collector-Base Capacitance	V_{CB} = 20 V, I_E = 0	ALL	—	250	—	pF

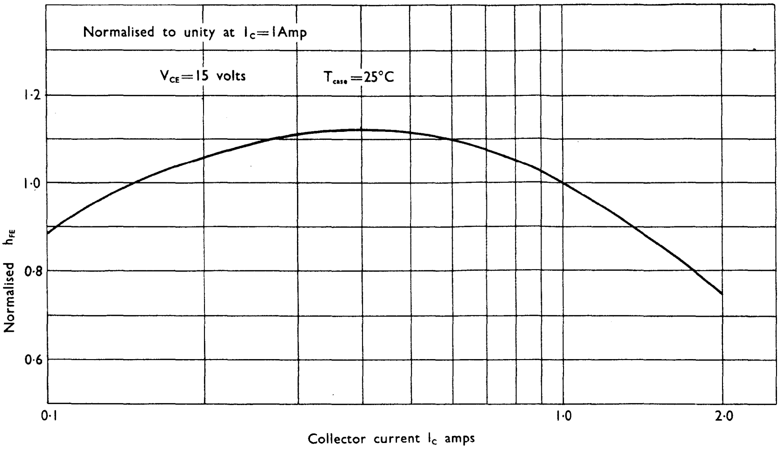
TYPICAL COMMON-EMITTER OUTPUT CHARACTERISTIC



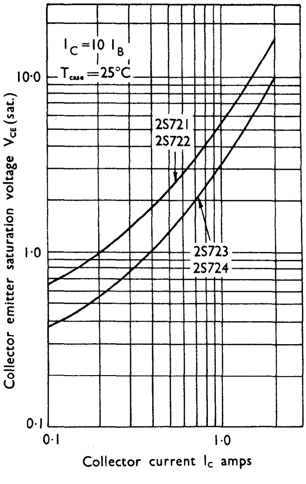
TYPICAL COMMON-EMITTER OUTPUT CHARACTERISTIC



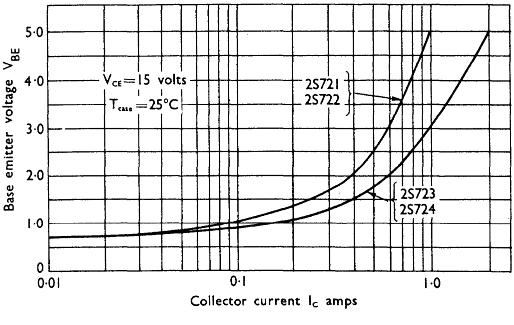
TYPICAL VARIATION OF NORMALISED h_{FE} WITH COLLECTOR CURRENT



TYPICAL VARIATION OF MAXIMUM V_{CE} (sat.) WITH COLLECTOR CURRENT



TYPICAL VARIATION OF V_{BE} WITH COLLECTOR CURRENT



Standard Mounting Hardware for Power Semiconductors

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

REVISED JULY 1975

This section identifies those standard hardware kits which are supplied with each device. At additional cost, nonstandard hardware items will be supplied.

The mounting hardware assembly drawings of Section A (Figures 1 through 11) specify the individual hardware items that are included in each mounting hardware kit. Section A also references the package outlines for which each kit is designed and shows the typical thermal resistance associated with the mounting hardware ($\Theta_{C\text{-}HS}$)†.

Section B contains mechanical drawings of the individual hardware items that are referenced in Figures 1 through 11.

DIRECTORY

OUTLINE	KIT No.
SO-10	11
TO-3	5
TO-3 (High Voltage)	6
TO-3 (Plastic)	9
TO-53	7
TO-59	1 and 2
TO-61	3
TO-63	4
TO-66 (Plastic)	10
TO-66	8
TO-111	1 and 2

Texas Instruments reserves the right to substitute similar parts at any time in order to expedite delivery or improve design.

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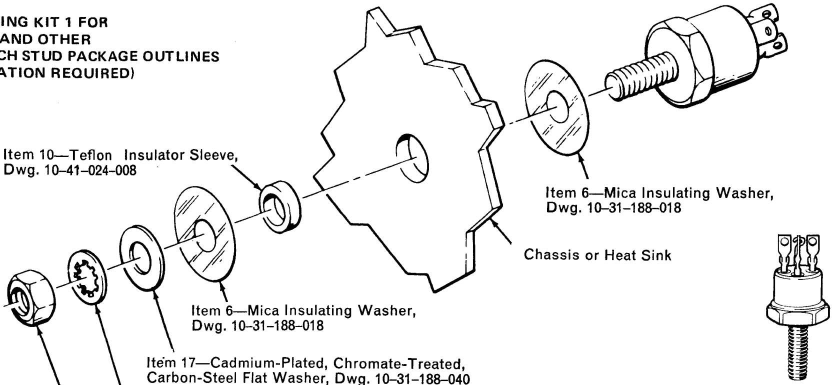
†$\Theta_{C\text{-}HS}$ is the thermal resistance from the mounting base of the semiconductor-device case to the mounting surface of the heat sink. The heat sink used to determine this value was a smooth, flat, copper plate, with the thermocouple mounted 1.3mm below the mounting surface in an area beneath the device. The device was mounted directly to a clean, dry heat-sink surface, without the use of a thermal compound and a torque of 0.113 Newton Meters (ten inch-pounds) was applied to the stud or each of the mounting screws.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

Section A – Mounting Hardware Assembly Drawings

MOUNTING KIT 1 FOR
TO-111 AND OTHER
7/16-INCH STUD PACKAGE OUTLINES
(INSULATION REQUIRED)



Item 10—Teflon Insulator Sleeve,
Dwg. 10–41–024–008

Item 6—Mica Insulating Washer,
Dwg. 10–31–188–018

Chassis or Heat Sink

Item 6—Mica Insulating Washer,
Dwg. 10–31–188–018

Item 17—Cadmium-Plated, Chromate-Treated,
Carbon-Steel Flat Washer, Dwg. 10–31–188–040

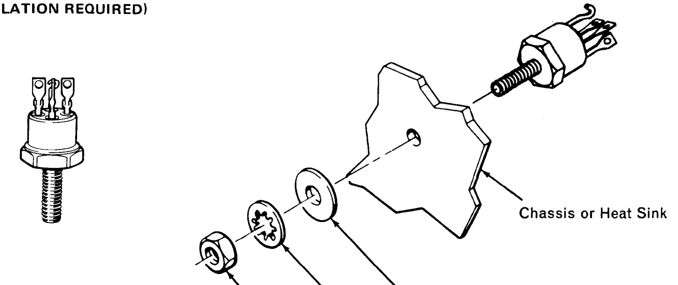
Item 20—Cadmium-Plated, Chromate-Treated,
Carbon-Steel Internal-Tooth Lock Washer,
Dwg. 10–31–152–006

Item 25—Cadmium-Plated, Chromate-Treated,
Carbon-Steel Hex Nut, Dwg. 10–31–036–009

TYPICAL THERMAL RESISTANCE		
$\theta_{C\text{-}HS}$	3·8	deg/W

FIGURE 1.

MOUNTING KIT 2 FOR
TO-59*, TO-111, AND OTHER
7/16-INCH STUD PACKAGE OUTLINES
(NO INSULATION REQUIRED)



Chassis or Heat Sink

Item 17—Cadmium-Plated, Chromate-Treated,
Carbon-Steel Flat Washer, Dwg. 10–31–188–040

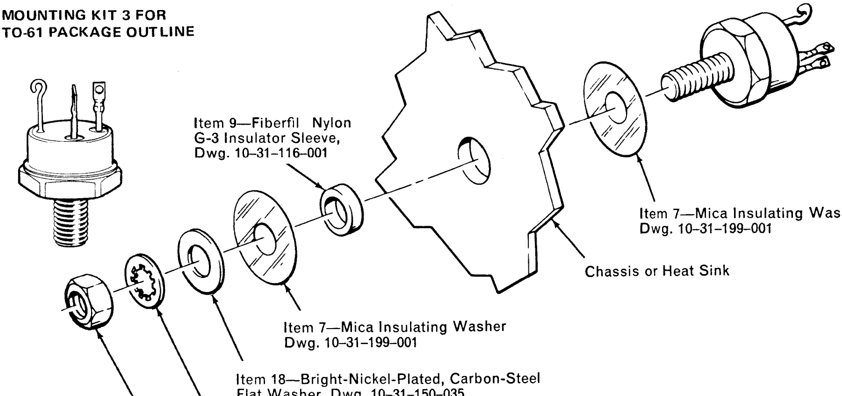
Item 20—Cadmium-Plated, Chromate-Treated,
Carbon-Steel, Internal-Tooth Lock Washer
Dwg. 10–31–152–006

Item 25—Cadmium-Plated, Chromate-Treated,
Carbon-Steel Hex Nut, Dwg. 10–31–036–009

FIGURE 2.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

MOUNTING KIT 3 FOR
TO-61 PACKAGE OUTLINE



Item 9—Fiberfil Nylon G-3 Insulator Sleeve, Dwg. 10-31-116-001

Item 7—Mica Insulating Washer Dwg. 10-31-199-001

Chassis or Heat Sink

Item 7—Mica Insulating Washer Dwg. 10-31-199-001

Item 18—Bright-Nickel-Plated, Carbon-Steel Flat Washer, Dwg. 10-31-150-035

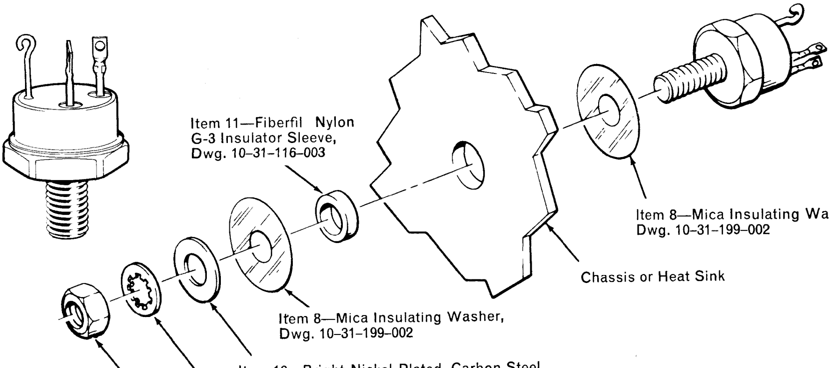
Item 22—Bright-Nickel-Plated, Carbon-Steel Internal-Tooth Lock Washer, Dwg. 10-31-152-017

Item 27—Bright-Nickel-Plated, Brass Hex Nut, Dwg. 10-31-036-016

TYPICAL THERMAL RESISTANCE		
$\theta_{C\text{-}HS}$	1·3	deg/W

FIGURE 3.

MOUNTING KIT 4 FOR
TO-63 PACKAGE OUTLINE



Item 11—Fiberfil Nylon G-3 Insulator Sleeve, Dwg. 10-31-116-003

Item 8—Mica Insulating Washer, Dwg. 10-31-199-002

Chassis or Heat Sink

Item 8—Mica Insulating Washer, Dwg. 10-31-199-002

Item 19—Bright-Nickel-Plated, Carbon Steel Flat Washer, Dwg. 10-31-150-034

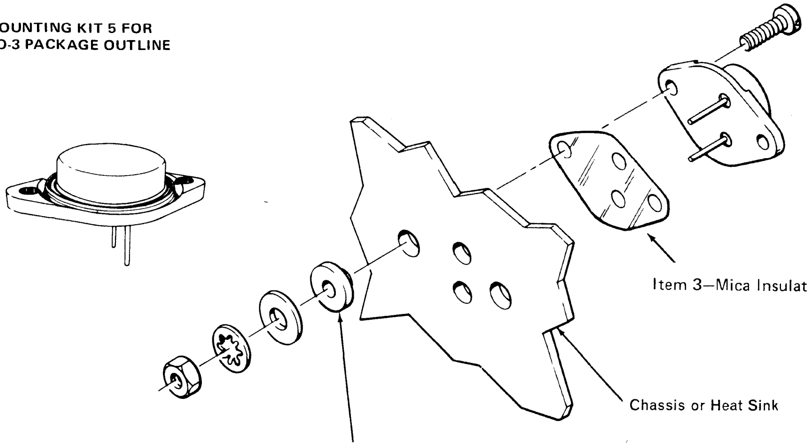
Item 23—Bright-Nickel-Plated, Carbon-Steel Internal-Tooth Lock Washer, Dwg. 10-31-152-016

Item 28—Bright-Nickel-Plated, Brass Hex Nut, Dwg. 10-31-036-015

TYPICAL THERMAL RESISTANCE		
$\theta_{C\text{-}HS}$	1·7	deg/W

FIGURE 4.

MOUNTING KIT 5 FOR
TO-3 PACKAGE OUTLINE



Item 3—Mica Insulator, Dwg. 80414

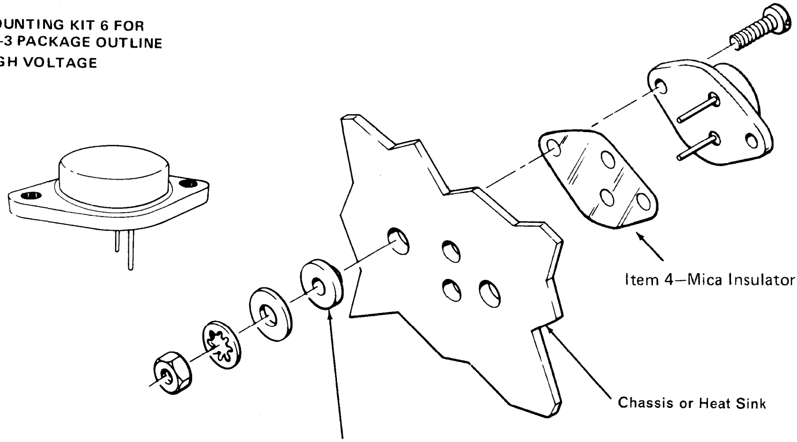
Chassis or Heat Sink

Item 15—Vulcanized-Fiber, Insulating Shoulder Washer, Dwg. 10-31-188-122

TYPICAL THERMAL RESISTANCE			
TO-3	$\theta_{C\text{-}HS}$	1·5	deg/W

FIGURE 5.

MOUNTING KIT 6 FOR
TO-3 PACKAGE OUTLINE
HIGH VOLTAGE



Item 4—Mica Insulator, Dwg. 80363

Chassis or Heat Sink

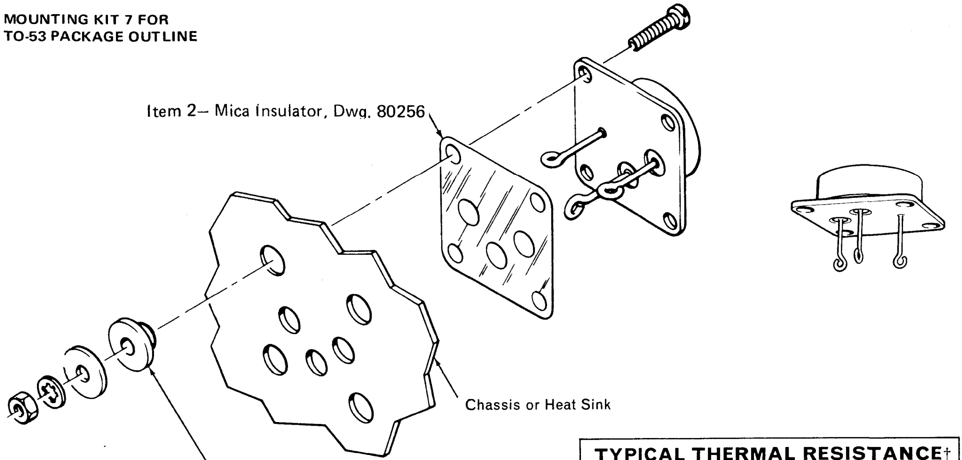
Item 5—Insulating Shoulder Washer, Dwg. 80364

TYPICAL THERMAL RESISTANCE			
TO-3	$\theta_{C\text{-}HS}$	1·5	deg/W

FIGURE 6.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

MOUNTING KIT 7 FOR TO-53 PACKAGE OUTLINE



Item 2– Mica Insulator, Dwg. 80256

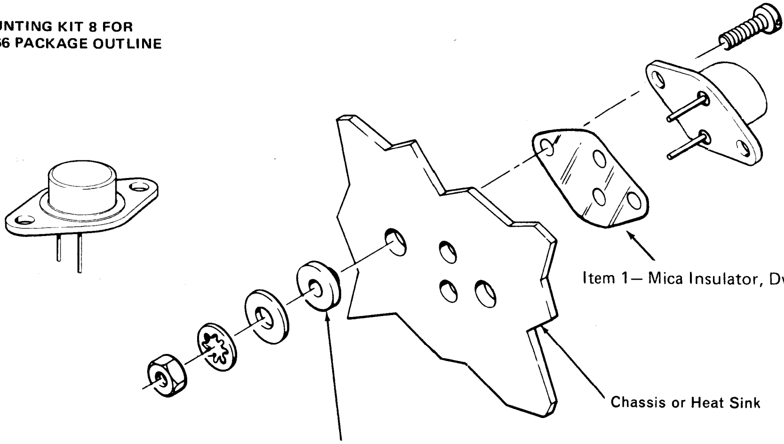
Chassis or Heat Sink

Item 13—Fiberfil Nylon G-3 Insulating Shoulder Washer, Dwg. 10–31–188–019

TYPICAL THERMAL RESISTANCE†		
$\theta_{C\text{-}HS}$	1·6	deg/W

FIGURE 7.

MOUNTING KIT 8 FOR TO-66 PACKAGE OUTLINE



Item 1– Mica Insulator, Dwg. 311–502–904

Chassis or Heat Sink

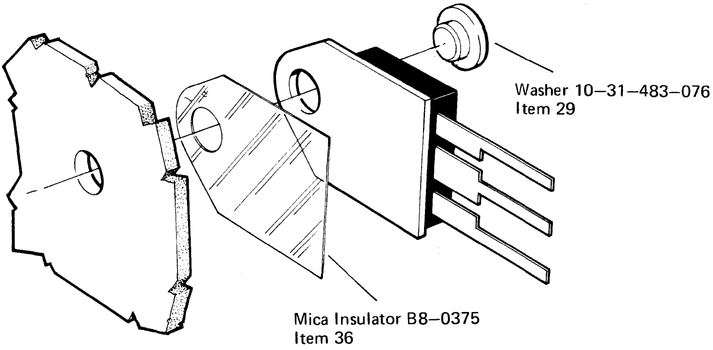
Item 15—Vulcanized-Fiber, Insulating Shoulder Washer, Dwg. 10–31–188–122

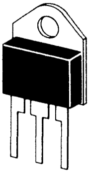
TYPICAL THERMAL RESISTANCE†			
TO-66	$\theta_{C\text{-}HS}$	3·75	deg/W

FIGURE 8.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

MOUNTING KIT 9 FOR
TO-3 PLASTIC PACKAGE OUTLINE

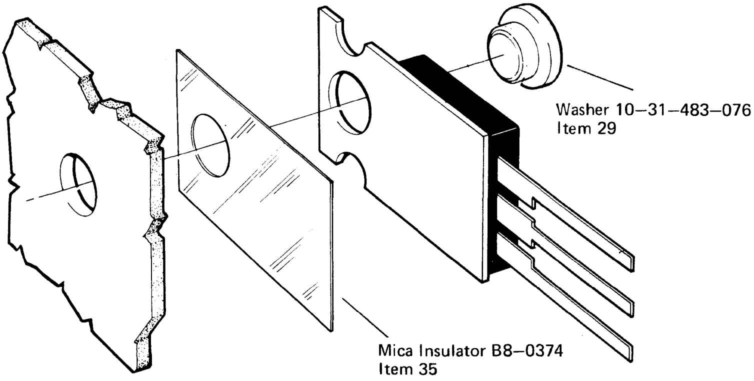


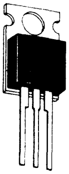


TYPICAL THERMAL RESISTANCE		
$\Theta_{C\text{-}HS}$	0.6	deg C/W

FIGURE 9.

MOUNTING KIT 10 FOR
TO-66 PLASTIC PACKAGE OUTLINE





TYPICAL THERMAL RESISTANCE		
$\Theta_{C\text{-}HS}$	0.7	deg C/W

FIGURE 10.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

MOUNTING KIT 11 FOR
SO-10 PACKAGE OUTLINE

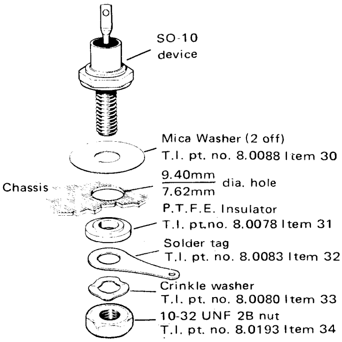
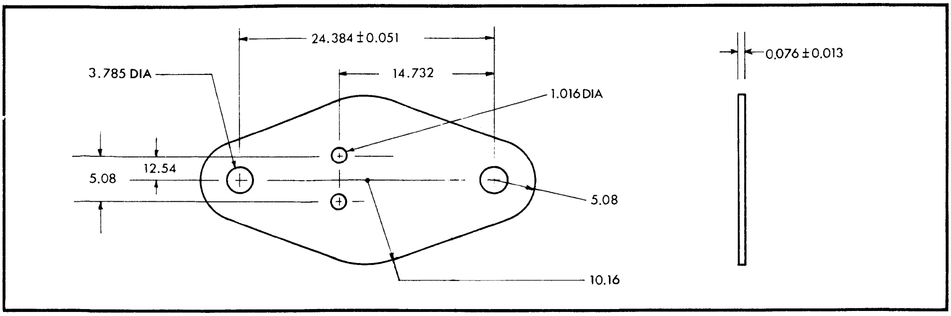


FIGURE 11.

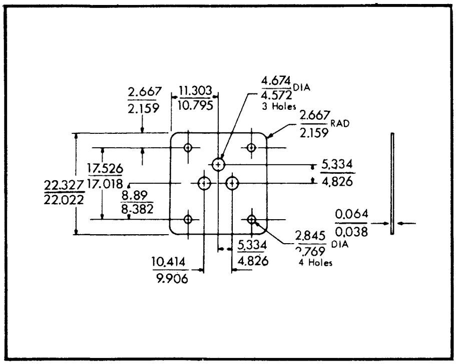
TYPICAL THERMAL RESISTANCE		
θC-HS	3.8	deg C/W.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS

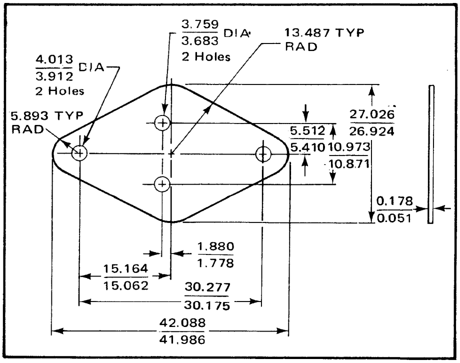
Section B – Mechanical Drawings of Hardware Items†



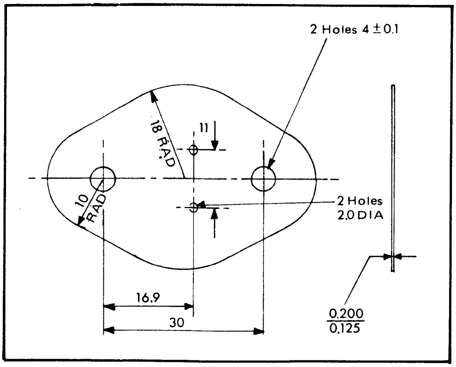
Item 1 INSULATOR



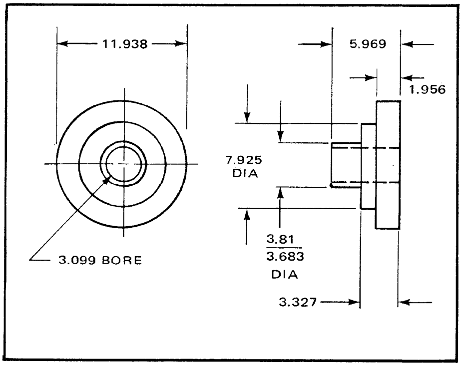
Item 2 INSULATOR



Item 3 INSULATOR

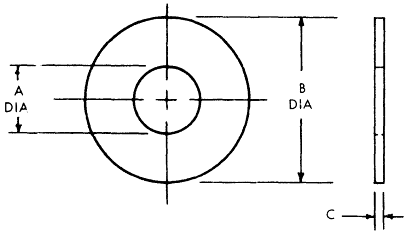


Item 4 INSULATOR



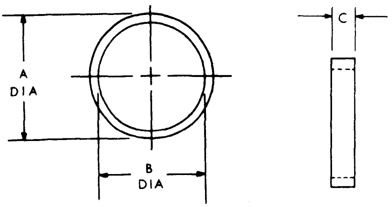
Item 5 INSULATOR SHOULDER WASHER

†All dimensions are in mm unless otherwise specified.



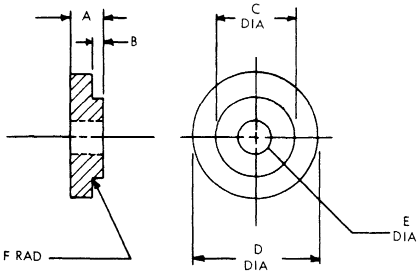
Item	A	B	C
6	5.207 4.953	13.614 13.360	0.127 0.025
7	6.858 6.604	22.479 21.971	0.064 0.038
8	8.458 8.204	26.797 26.289	0.089 0.038

INSULATING WASHER
Item 6 thru 8



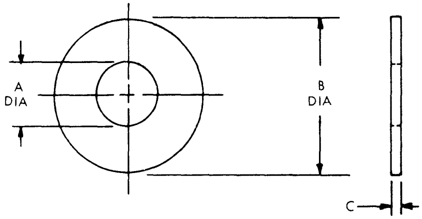
Item	A	B	C
9	8.636 8.382	6.858 6.604	1.829 1.321
10	6.883 6.375	5.156 4.851	1.27 0.889
11	10.287 10.033	8.458 8.204	1.829 1.321
12	5.309 5.055	3.683 3.429	0.914 0.660

INSULATING SLEEVE
Item 9 thru 12



Item	A	B	C	D	E	F
13	2.54 2.032	1.016 0.508	5.08 4.826	8.738 7.112	2.921 2.819	0.406 MAX
15	2.667 1.905	1.143 0.381	6.35 5.842	9.931 9.119	4.369 3.556	NA

INSULATING SHOULDER WASHER
Items 13 and 15



Item	A	B	C
16	3.81 3.607	7.239 6.985	0.356 0.229
17	5.283 5.029	12.827 12.573	1.295 1.041
18	7.010 6.477	16.129 15.621	1.753 0.864
19	8.204 7.671	19.304 18.796	2.032 1.295

Item 16 thru 19

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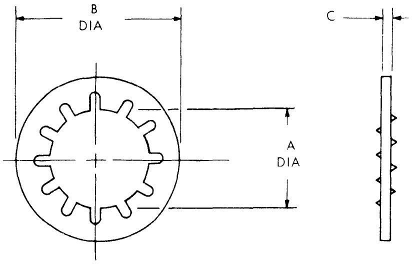
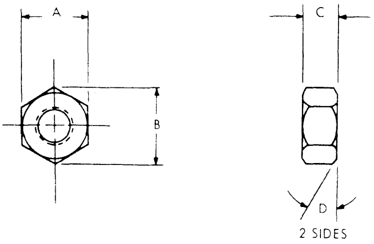
† All dimensions are in mm unless otherwise specified.

STANDARD MOUNTING HARDWARE FOR POWER SEMICONDUCTORS



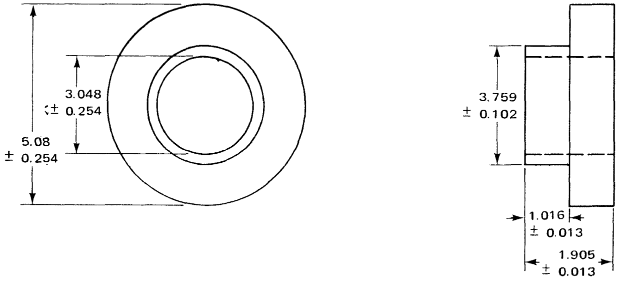
Item	A	B	C
20	5.182 4.953	9.677 9.271	0.635 0.508
21	3.81 3.607	7.493 6.985	0·031 0·015
22	6.781 6.502	12.141 11.836	0.685 0.584
23	8.433 8.128	15.418 15.088	0.813 0.711

INTERNAL TOOTH LOCK WASHER
Item 20 thru 23



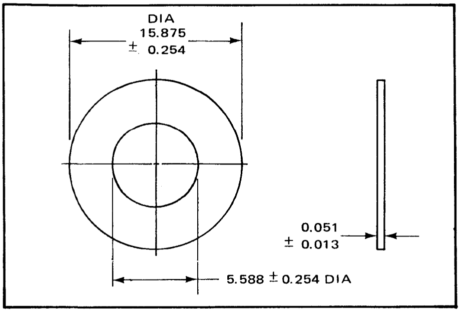
Item	Thread	A	B	C	D
25	10–32 UNF-2B	9.525 9.195	10.998 10.490	3.302 2.972	30°
26	6–32 UNC-2B	6.35 6.121	7.341 6.985	2.489 2.210	30°
27	1/4–28 UNF-2B	11.125 10.744	12.852 12.395	4.902 4.521	30°
28	5/16–24 UNF-2B	14.300 13.843	16.51 15.937	5.715 5.283	30°

HEXAGONAL NUT
Item 25 thru 28

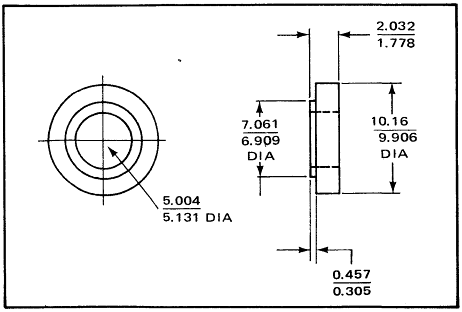


Item 29 WASHER

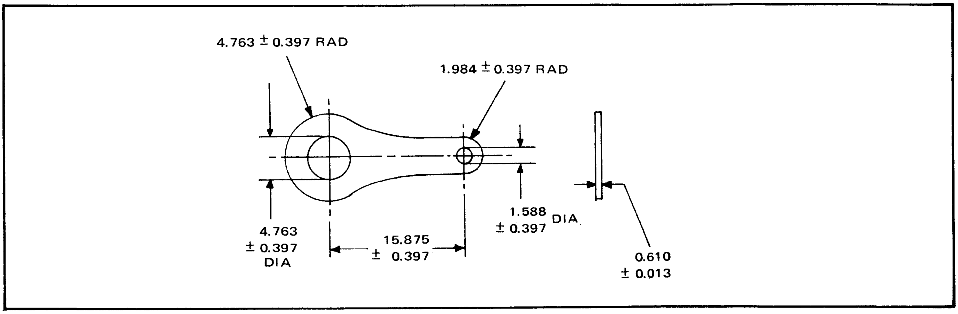
All dimensions are in mm unless otherwise stated



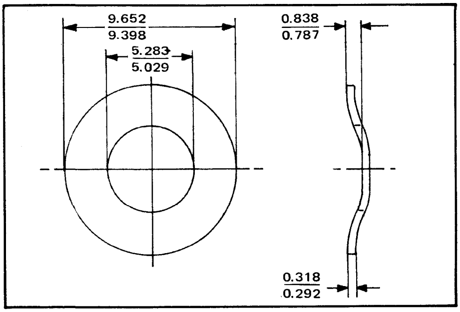
Item 30 WASHER



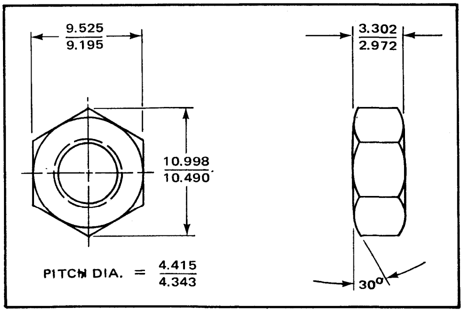
Item 31 INSULATOR



Item 32 SOLDER TAG

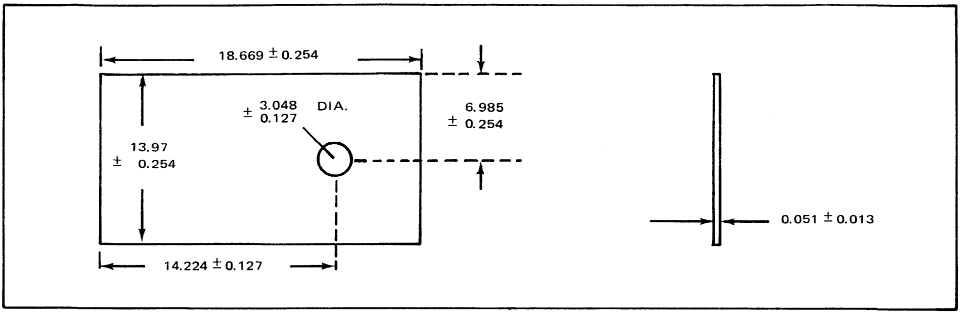


Item 33 CRINKLE WASHER

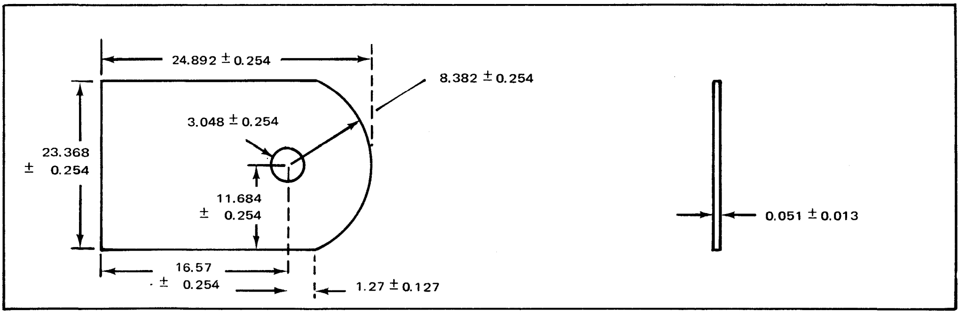


Item 34 NUT

All dimensions are in mm unless otherwise stated



Item 35 INSULATOR



Item 36 INSULATOR

Terms, Definitions, and Testing Procedures

POWER TRANSISTORS

POWER TRANSISTOR SAFETY CONSIDERATIONS

The designer, maker, and user of electrical equipment containing power transistors should give attention to the following points relative to the safety of personnel that may operate the equipment.

The electrical potentials of the collector, emitter, and base terminals on the transistor present an electrical shock hazard when the equipment is energized.

The normal operating case temperature of energized transistors is often high enough to present burn hazards to both operating personnel and flammable material touching the transistor.

If the transistor is falsely turned "on" or fails, power will be applied to the equipment load. Operator safety may be affected by an unexpected energizing of the load.

In the event that an equipment output short or internal fault condition develops, very high surge current can be passed through the transistor. If this condition exceeds transistor ratings for magnitude and duration, the transistor may be damaged; and if the surge is severe enough, internal heating can cause the transistor to rupture and perhaps sustain an arc.

POWER TRANSISTOR STANDARDS

Following are sources of standard material relating to Power Transistors:

EIA and JEDEC Standards:
Electronic Industries Association
2001 Eye St. N.W., Washington, D.C. 20006
Telephone: 202-659-2200

JC-25 Power Transistor Registration Formats RDF-1 to RDF-6

Test Procedures for Verification of Maximum Ratings of Power Transistors—JEDEC Publication No.65

Thermal Resistance Measurements of Conduction Cooled Power Transistors—EIA Standard RS-313-A

JEDEC Recommendations for Letter Symbols, Abbreviations, Terms, and Definitions for Semiconductor Device Data Sheets and Specifications—JEDEC Publication No. 77

Standard List of Values to be used in Power Transistor Device Registration and Minimum Differences for Discretness of Registration—JEDEC Publication NO. 74

IEC Standards

American National Standards Institute, Inc.
1430 Broadway
New York, N. Y. 10018
Telephone: 212-868-1220

IEC Publication 147: Essential Ratings and Characteristics of Semiconductor Devices and General Principles of Measuring Methods.

IEC Publication 148: Letter Symbols for Semiconductor Devices and Integrated Microcircuits

IEC Publication 191: Mechanical Standardization of Semiconductor Devices.

Military Standards
Commanding Officer, U.S. Naval Publications and Forms Center,
5801 Tabor Avenue, Philadelphia, Pa., 19120.

MIL-S-19500: Semiconductor Devices, General Specification for

MIL-STD-105: Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-202: Test Methods for Electronic and Electrical Component Parts

MIL-STD-750: Test Methods for Semiconductor Devices

MIL-STD-883: Test Methods and Procedures for Microelectronics

BSI Standards
British Standards Institute
101 Pentonville Rd
London N1

BS 204. Glossary of terms used in telecommunication (including radio) and electronics. (See also IEC publication 147–0.)
BS 2011. Methods for the environmental testing of electronic components and electronic equipment. (See also IEC publication 68.)
BS 3363. Schedule for letter symbols for semiconductor devices, (See also IEC publication 148.)
BS 3494. Recommendations on semiconductor devices.
BS 3934. Dimensions of semiconductor devices. (See also IEC publication 191–2.)
BS 3939. Graphical symbols for electrical power, telecommunications and electonics diagrams. (See also IEC publication 117.)

POWER TRANSISTOR TERMS, DEFINITIONS, AND LETTER SYMBOLS

Introduction

This part contains letter symbols, abbreviations, terms, and definitions commonly used with Power Transistors. Most of the information was obtained from JEDEC Publication No. 77. This document and the JC-25 JEDEC registration formats have over-riding authority where any conflict may occur.

Power Transistor Terms and Definitions

Term	Definition
base (B, b)*	A region which lies between an emitter and collector of a transistor and into which minority carriers are injected. (Ref. 60 IRE 28.S1)
breakdown	A phenomenon occurring in a reverse-biased semiconductor junction, the initiation of which is observed as a transition from a region of high small-signal resistance to a region of substantially lower small-signal resistance for an increasing magnitude of reverse current. (Ref RS-282 par. 1.38)
breakdown region	A region of the volt-ampere characteristic beyond the initiation of breakdown for an increasing magnitude of reverse current. (Ref RS-282 par. 1.37)
breakdown voltage	The voltage measured at a specified current in a breakdown region. (Ref MIL-S-19500D par. 20.3)
collector (C, c)*	A region through which a primary flow of charge carriers leaves the base. (Ref. 60 IRE 28.S1)
emitter (E, e)*	A region from which charge carriers that are minority carriers in the base are injected into the base. (Ref. 60 IRE 28.S1)
junction, collector	A semiconductor junction normally biased in the high-resistance direction, the current through which can be controlled by the introduction of minority carriers into the base. (Ref. 60 IRE 28.S1)
junction, emitter	A semiconductor junction normally biased in the low-resistance direction to inject minority carriers into the base. (Ref. 60 IRE 28.S1)
open-circuit	A circuit shall be considered as open-circuited if halving the magnitude of the terminating impedance does not produce a change in the parameter being measured greater than the required accuracy of the measurement. (Ref MIL-S-19500D par. 20.8)
reverse current	The current that flows through a semiconductor junction in the reverse direction.

*NOTE: References to base, collector, and emitter symbolism (B, b, C, c, E, and e) refer to the device terminals connected to those regions.

TERMS AND DEFINITIONS
POWER TRANSISTORS

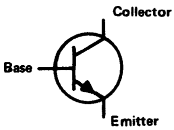
Term	Definition
reverse direction	The direction of current flow which results when the n-type semiconductor region is at a positive potential relative to the p-type region.
saturation	A base-current and a collector-current condition resulting in a forward-biased collector junction.
second breakdown	A condition of the transistor, resulting from a lateral current instability, in which the electrical characteristics are determined principally by the spreading resistance of a thermally maintained current constriction. The initiation of second breakdown is observed as a decrease in the voltage sustained by the collector. NOTE: Second breakdown differs from thermal failure in that its initiation can not be predicted from low-voltage thermal resistance measurements. Unless the current and duration in second breakdown are limited, the high junction temperature at the current constriction will result in failure, usually as a collector-to-emitter short-circuit. Second breakdown can occur at postitive, negative, or zero base current. (To protect a transistor against second breakdown, see section: "Safe Operating Areas for Power Transistors.")
semiconductor device	A device whose essential characteristics are due to the flow of charge carriers within a semiconductor. (Ref. RS-282 par. 1.09)
semiconductor junction	A region of transition between semiconductor regions of different electrical properties (e.g., n-n+, p-n, p-p+ semiconductors), or between a metal and a semiconductor. (Ref. RS-282 par. 1.0)
short-circuit	A circuit in which doubling the magnitude of the terminating impedance does not produce a change in the parameter being measured that is greater than the required accuracy of the measurement. (Ref. MIL-S-19500D par. 20.16)
small-signal	A signal which when doubled in magnitude does not produce a change in the parameter being measured that is greater than the required accuracy of the measurement. (Ref. MIL-S-19500D par. 20.17)
static value	A non-varying value or quantity of measurement at a specified fixed point, or the slope of the line from the origin to the operating point on the appropriate characteristic curve. (Ref. IEEE #255 par. 2.2.1)
terminal	An externally available point of connection to one or more electrodes. (Ref. RS-282 par. 1.14)
thermal resistance (steady-state)	The temperature difference between two specified points or regions divided by the power dissipation under conditions of thermal equilibrium. (Ref. IEEE #223)

Term	Definition
transient thermal impedance	The change of temperature difference between two specified points or regions at the end of a time interval divided by the step function change in power dissipation at the beginning of the same time interval causing the change of temperature difference. (Ref. IEEE #223)
transistor	An active semiconductor device capable of providing power amplification and having three or more terminals. (Ref. IEC #147-0 par. 0-2.8)
transistor, junction, multijunction type	A transistor having a base and two or more junctions.

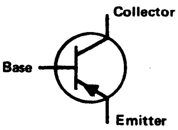
Graphic symbols for emitter, base, collector transistors: (Ref. ANS Y32.2)

NOTE: In the graphic symbols, the envelope is optional if no element is connected to the envelope.

N-P-N



P-N-P



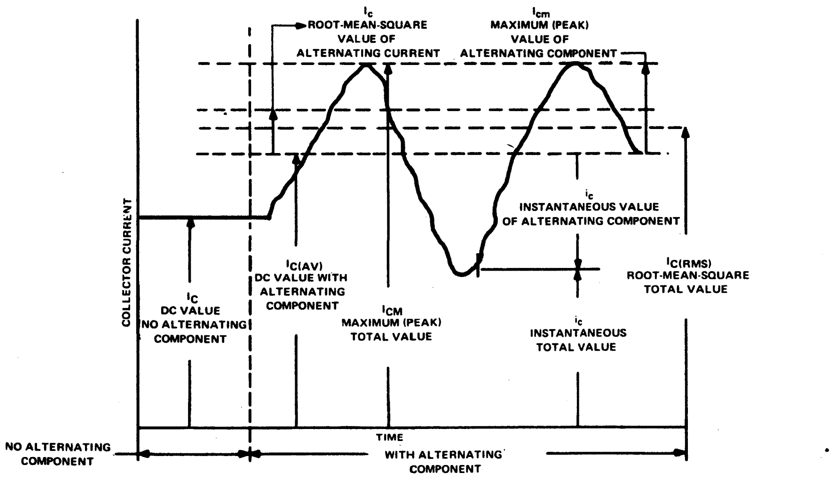
TERMS AND DEFINITIONS
POWER TRANSISTORS

Power Transistor Letter Symbols, Terms, and Definitions

Symbol	Term	Definition
C_{ibo}	open-circuit input capacitance	The capacitance measured across the input terminals (emitter and base) with the collector open-circuited for ac. (Ref. IEEE #255)
C_{obo}	open-circuit output capacitance	The capacitance measured across the output terminals (collector and base) with the input open-circuited to ac. (Ref. IEEE #255)
f_{hfe}	small-signal short-circuit forward current transfer ratio cutoff frequency (common-emitter)	The lowest frequency at which the magnitude of the small-signal short-circuit forward current transfer ratio is 0.707 of its value at a specified low frequency (usually 1 kHz or less). (Ref. IEEE #255)
f_T	transition frequency or frequency at which small-signal forward current transfer ratio (common-emitter) extrapolates to unity	The product of the modulus (magnitude) of the common-emitter small-signal short-circuit forward current transfer ratio, h_{fe}, and the frequency of measurement when this frequency is sufficiently high so that the modulus (magnitude) of h_{fe} is decreasing with a slope of approximately 6 dB per octave. (Ref. IEEE #255)
G_{PE}	large-signal insertion power gain (common-emitter)	The ratio, usually expressed in dB, of the signal power delivered to the load to the large-signal power delivered to the input.
h_{FE}	static forward current transfer ratio (common-emitter)	The ratio of the dc collector current to the dc base current. (Ref. MIL-S-19500D par. 30.28)
h_{fe}	small-signal short-circuit forward current transfer ratio (common-emitter)	The ratio of the ac collector current to the small-signal ac base current with the collector short-circuited to the emitter for ac. (Ref. MIL-S-19500D par. 30.20)
h_{IE}	static input resistance (common-emitter)	The ratio of the dc base-emitter voltage to the dc base current. (Ref. MIL-S-19500D par. 30.29)
h_{ie}	small-signal short-circuit input impedance (common-emitter)	The ratio of the small-signal ac base-emitter voltage to the ac base current with the collector short-circuited to the emitter for ac. (Ref. MIL-S-19500D par. 30.24)
$h_{ie(imag)}$	imaginary part of the small-signal short-circuit input impedance, (common-emitter)	The ratio of the out-of-phase (imaginary) component of the small-signal ac base-emitter voltage to the ac base current with the collector terminal short-circuited to the emitter terminal for ac.
$h_{ie(real)}$	real part of the small-signal short-circuit input impedance, (common-emitter)	The ratio of the in-phase (real) component of the small-signal ac base-emitter voltage to the ac base current with the collector terminal short-circuited to the emitter terminal for ac.
h_{oe}	small-signal open-circuit output admittance, (common-emitter)	The ratio of the ac collector current to the small-signal ac collector-emitter voltage with the base terminal open-circuited to ac. (Ref. MIL-S-19500D par. 30.15)

Symbol	Term	Definition
$h_{oe(imag)}$	imaginary part of the small-signal open-circuit output admittance, (common-emitter)	The ratio of the ac collector current to the out-of-phase (imaginary) component of the small-signal collector-emitter voltage with the base terminal open-circuited to ac.
$h_{oe(real)}$	real part of the small-signal open-circuit output admittance, (common-emitter)	The ratio of the ac collector current to the in-phase (real) component of the small-signal collector-emitter voltage with the base terminal open-circuited to ac.
I_B, I_C, I_E	current, dc (base-terminal, collector-terminal, emitter-terminal)	The value of the dc current into the terminal indicated by the subscript.
I_b, I_c, I_e	current, rms value of alternating component (base-terminal, collector-terminal, emitter-terminal)	The root-mean-square value of alternating current into the terminal indicated by the subscript.
i_B, i_C, i_E	current, instantaneous total value (base-terminal, collector-terminal, emitter-terminal)	The instantaneous total value of alternating current into the terminal indicated by the subscript.

DIAGRAM ILLUSTRATING FOREGOING CURRENTS (Ref IEEE # 255)



I_{CBO}	collector cutoff current, dc, emitter open	The dc current into the collector terminal when it is biased in the reverse direction with respect to the base terminal and the emitter terminal is open-circuited. (Ref. IEEE #255)

TERMS AND DEFINITIONS
POWER TRANSISTORS

Symbol	Term	Definition
I_{CEO}	collector cutoff current, dc (base open	The dc current into the collector terminal when it is biased in the reverse direction* with respect to the emitter terminal and the base terminal is (as indicated by the first subscript letter as follows): O = open-circuited R = returned to the emitter terminal through a specified resistance. S = short-circuited to the emitter terminal. V = returned to the emitter terminal through a speified voltage. X = returned to the emitter terminal through a speified circuit. (Ref. IEEE #255)
I_{CER}	resistance between base and emitter,	
I_{CES}	base short-circuited to emitter,	
I_{CEV}	voltage between base and emitter,	
I_{CEX}	circuit between base and emitter)	
I_{EBO}	emitter cutoff current, dc, collector open	The dc current into the emitter terminal when it is baised in the reverse direction with respect to the base terminal and the collector terminal is open-circuited. (Ref. IEEE #255)
P_{BE}	power input, dc (to the base, common-emitter)	The product of the dc input current and voltage with the common-emitter circuit configuration.
p_{BE}	power input; instantaneous total (to the base, common-emitter)	The product of the instantaneous input current and voltage with the common-emitter circuit configuration.
P_{OE}	large-signal output power (common-emitter)	The product of the large-signal ac output current and voltage with the common-emitter circuit configuration.
P_T	total nonreactive power input to all terminals	The sum of the products of the dc input currents and voltages, i.e.. $V_{BE} \cdot I_B + V_{CE} \cdot I_C$ or $V_{BE} \cdot I_E + V_{CB} \cdot I_C$
p_T	nonreactive power input, instantaneous total, to all terminals	The sum of the products of the instantaneous input currents and voltages.
$r_b'C_c$	collector-base time constant	The product of the intrinsic base resistance and collector capacitance under specified small-signal conditions.

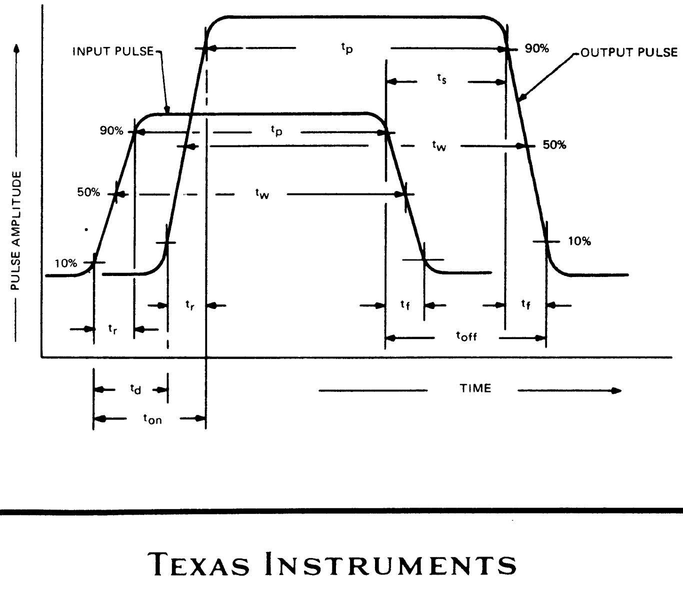
*For these parameters, the collector terminal is considered to be biased in the reverse direction when it is made positive for N-P-N transistors or negative for P-N-P transistors with respect to the emitter terminal.

Symbol	Term	Definition
R_θ (formerly θ)	thermal resistance	Refer to thermal resistance (steady state), page 1-4.
$R_{\theta CA}$	thermal resistance case-to-ambient	The thermal resistance (steady-state) from the device case to the ambient.
$R_{\theta JA}$ (formerly θ_{J-A})	thermal resistance junction-to-ambient	The thermal resistance (steady-state) from the semiconductor junction (s) to the ambient.
$R_{\theta JC}$ (formerly θ_{J-C})	thermal resistance junction-to-case	The thermal resistance (steady-state) from the semiconductor junction (s) to a stated location on the case.
$R_{\theta JM}$	thermal resistance junction-to-mounting surface	The thermal resistance (steady-state) from the semiconductor junction (s) to a stated location on the mounting surface.
T_A	ambient temperature or free-air temperature	The air temperature measured below a device, in an environment of substantially uniform temperature, cooled only by natural air convection and not materially affected by reflective and radiant surfaces. (Ref. MIL-S-19500D par. 20.20.1)
T_C	case temperature	The temperature measured at a specified location on the case of a device. (Ref. MIL-S-19500D par. 20.20.2)
T_J	virtual junction temperature	A theoretical temperature based on a simplified representation of the thermal and electrical behavior of the semiconductor device. NOTE: This term (and its definition) is taken from IEC standards. It is particularly applicable to multi-junction semiconductors and is used in this publication to denote the temperature of the active semiconductor element when required in specifications and test methods. The term "junction temperature" is used interchangeably with the term "virtual junction temperature" in this publication.
T_{stg}	storage temperature	The temperature at which the device, without any power applied, is stored. (Ref. MIL-S-19500D par. 20.20.3)
t_d	delay time	The time interval from the point at which the leading edge of the input pulse has reached 10 percent of its maximum amplitude to the point at which the leading edge of the output pulse has reached 10 percent of its maximum amplitude. (Ref. MIL-S-19500D par. 20.13)
t_f	fall time	The time duration during which the trailing edge of a pulse is decreasing from 90 to 10 percent of its maximum amplitude. (Ref. MIL-S-19500D par. 20.12)

TERMS AND DEFINITIONS
POWER TRANSISTORS

Symbol	Term	Definition
t_{off}	turn-off time	The sum of $t_s + t_f$.
t_{on}	turn-on time	The sum of $t_d + t_r$.
t_p	pulse time	The time duration from the point on the leading edge which is 90 percent of the maximum amplitude to the point on the trailing edge which is 90 percent of the maximum amplitude. (Ref. MIL-S-19500D par. 20.15)
t_r	rise time	The time duration during which the amplitude of the leading edge of a pulse is increasing from 10 to 90 percent of its maximum amplitude. (Ref. MIL-S-19500D par. 20.13)
t_s	storage time	The time interval from a point 90 percent of the maximum amplitude on the trailing edge of the input pulse to a point 90 percent of the maximum amplitude on the trailing edge of the output pulse. (Ref. MIL-S-19500D par. 20.14)
t_w	pulse average time	The time duration from the point on the leading edge which is 50 percent of the maximum amplitude to a point on the trailing edge which is 50 percent of the maximum amplitude. (Ref. MIL-S-19500D par. 20.10)

DIAGRAM ILLUSTRATING PULSE TIME SYMBOLOGY



TERMS AND DEFINITIONS
POWER TRANSISTORS

Symbol	Term	Definition
$V_{(BR)CBO}$ (formerly BV_{CBO})	breakdown voltage collector-to-base, emitter open	The breakdown voltage between the collector terminal and the base terminal when the collector terminal is biased in the reverse direction with respect to the base terminal and the emitter terminal is open-circuited. (Ref. IEEE #255)
$V_{(BR)CEO}$, (formerly BV_{CEO})	breakdown voltage, collector-to-emitter with (base open,	The breakdown voltage between the collector terminal and the emitter terminal when the collector terminal is biased in the reverse direction* with respect to the emitter terminal and the base terminal is (as indicated by the last subscript letter as follows): O = open-circuited. R = returned to the emitter terminal through a specified resistance. S = short-circuited to the emitter terminal. V = returned to the emitter terminal through a specified voltage. X = returned to the emitter terminal through a specified circuit. (Ref. IEEE #255)
$V_{(BR)CER}$, (formerly BV_{CER})	resistance between base and emitter,	
$V_{(BR)CES}$, (formerly BV_{CES})	base short-circuited to emitter,	
$V_{(BR)CEV}$, (formerly BV_{CEV})	voltage between base and emitter,	
$V_{(BR)CEX}$ (formerly BV_{CEX})	circuit between base and emitter)	
$V_{(BR)EBO}$, (formerly BV_{EBO})	breakdown voltage, emitter-to-base, collector open	The breakdown voltage between the emitter and base terminals when the emitter terminal is biased in the reverse direction with respect to the base terminal and the collector terminal is open-circuited. (Ref. IEEE #255)
V_{BB}, V_{CC}, V_{EE}	supply voltage, dc (base, collector, emitter)	The dc supply voltage applied to a circuit connected to the reference terminal.
V_{BC},	voltage, dc or average (base-to-collector,	The dc voltage between the terminal indicated by the first subscript and the reference terminal (stated in terms of the polarity at the terminal indicated by the first subscript).
V_{BE},	base-to-emitter,	
V_{CB},	collector-to-base,	
V_{CE}	collector-to-emitter,	
V_{EB},	emitter-to-base,	
V_{EC}	emitter-to-collector)	
$V_{BE(sat)}$	saturation voltage, dc, base-to-emitter	The dc voltage between the base and emitter terminals for specified base-current and collector-current conditions which are intended to ensure that the collector junction is forward-biased.

*For these parameters, the collector terminal is considered to be biased in the reverse direction when it is made positive for N-P-N transistors or negative for P-N-P transistors with respect to the emitter terminal.

TERMS AND DEFINITIONS
POWER TRANSISTORS

Symbol	Term	Definition
V_{CBO}	collector-to-base voltage, dc, emitter open	The dc voltage between the collector terminal and the base terminal when the emitter terminal is open-circuited.
$V_{CE(sat)}$	saturation voltage, dc, collector-to-emitter	The dc voltage between the collector and the emitter terminals for specified saturation conditions. (Ref. IEEE #255)
V_{CEO}	collector-to-emitter voltage, dc, with (base open,	The dc voltage between the collector terminal and the emitter terminal when the base terminal is (as indicated by the last subscript letter): O = open-circuited. R = returned to the emitter terminal through a specified resistance. S = short-circuited to the emitter terminal. V = returned to the emitter terminal through a specified voltage. X = returned to the emitter terminal through a specified circuit.
V_{CER}	resistance between base and emitter,	
V_{CES}	base short-circuited to emitter,	
V_{CEV}	voltage between base and emitter,	
V_{CEX}	circuit between base and emitter)	
$V_{CEO(sus)}$	sustaining voltage, collector-to-emitter with (base open,	The collector-to-emitter breakdown voltage at relatively high values of collector current where the breakdown voltage is relatively insensitive to changes in collector current. The base terminal is (as indicated by the third subscript letter as follows): O = open-circuited R = returned to the emitter terminal through a specified resistance S = short-circuited to the emitter terminal V = returned to the emitter terminal through a specified voltage X = returned to the emitter terminal through a specified circuit. NOTE: This would be the transient voltage between the collector and emitter terminals during switching with an inductive load from a forward-biased base-emitter to an external condition described by the third subscript letter.
$V_{CER(sus)}$	resistance between base and emitter,	
$V_{CES(sus)}$	base short-circuited to emitter,	
$V_{CEV(sus)}$	voltage between base and emitter,	
$V_{CEX(sus)}$	circuit between base and emitter)	
$V_{EB(fl)}$	dc open-circuit voltage (floating potential) (emitter-to-base)	The dc open-circuit voltage (floating potential) between the emitter terminal and the base terminal when the collector terminal is biased in the reverse direction with respect to the base terminal. (Ref. IEEE #255)

Symbol	Term	Definition
V_{EBO}	emitter-to-base voltage, dc, collector open	The dc voltage between the emitter terminal and the base terminal with the collector terminal open-circuited.
$Z_{\theta(t)}$ (formerly $\theta_{(t)}$)	transient thermal impedance	Refer to transient thermal impedance, page 1-5.
$Z_{\theta JA(t)}$ (formerly $\theta_{J-A(t)}$)	transient thermal impedance, junction-to-ambient	The transient thermal impedance from the semiconductor junction (s) to the ambient.
$Z_{\theta JC(t)}$ (formerly $\theta_{JC(t)}$)	transient thermal impedance, junction-to-case	The transient thermal impedance from the semiconductor junction (s) to a stated location on the case.

THYRISTORS

Thyristor Standards

The documents listed below have overriding authority where any conflict may occur with this data book.

EIA and JEDEC Standards

The thyristor terms and definitions presented in this data book were obtained from EIA Standards Proposal No. 1101. This standard is in the process of publication and will be available from:

Electronic Industries Association
2001 Eye St. N.W.,
Washington, D.C. 20006
Telephone: 202-659-2200

IEEE Standards

Institute of Electrical and Electronic Engineers, Inc.
345 East 47th. Street
New York, N.Y. 10017

IEEE No. 233: Standard Definitions of Terms for Thyristors

International Electrotechnical Commission Standards

American National Standards Institute, Inc.
1430 Broadway
New York, N.Y. 10018

IEC Publication 147-IC: Essential Ratings and Characteristics of Semiconductor Devices and General Principles of Measuring Methods

IEC Publication 148: Letter Symbols for Semiconductor Devices and Integrated Circuits

IEC Publication 191: Mechanical Standardization of Semiconductor Devices.

Military Standards

Commanding Officer, U.S. Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, Pa., 19120

MIL-S-19500: Semiconductor Devices, General Specification for

MIL-STD-105: Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-202: Test Methods for Electronic and Electrical Component Parts

MIL-STD-750: Test Methods for Semiconductor Devices

Classes of Thyristors

Bidirectional Diode Thyristor

A two-terminal thyristor having substantially the same switching behavior in the first and third quadrants of the principal voltage-current characteristic. (See Figure 4).

Bidirectional Triode Thyristor

A three-terminal thyristor having substantially the same switching behavior in the first and third quadrants of the principal voltage-current characteristic. (See Figure 4).

N-Gate Thyristor

A thyristor in which the gate terminal is connected to the N-region adjacent to the region to which the anode terminal is connected and which is normally switched to the on-state by applying a negative signal between gate and anode terminals.

P-Gate Thyristor

A thyristor in which the gate terminal is connected to the P-region adjacent to the region to which the cathode terminal is connected and which is normally switched to the on-state by applying a positive signal between gate and cathode terminals.

Reverse-Blocking Diode Thyristor

A two-terminal thyristor which switches only for positive anode-to-cathode voltages and exhibits a reverse-blocking state for negative anode-to-cathode voltages.

Reverse-Blocking Triode Thyristor

A three-terminal thyristor which switches only for positive anode-to-cathode voltages and exhibits a reverse-blocking state for negative anode-to-cathode voltages.

Reverse-Conducting Diode Thyristor

A two-terminal thyristor which switches only for positive anode-to-cathode voltages and conducts large currents at negative anode-to-cathode voltages comparable in magnitude to the on-state voltage.

Reverse-Conducting Triode Thyristor

A three-terminal thyristor which switches only for positive anode-to-cathode voltages and conducts large currents at negative anode-to-cathode voltages comparable in magnitude to the on-state voltage.

Semiconductor Controlled Rectifier (SCR)

An alternative name used for the reverse-blocking triode thyristor.

NOTE: Although not an official definition, the term unidirectional is sometimes used to describe the single switching class of thyristors consisting of reverse-blocking and reverse-conducting thyristors. This term is useful for comparing or contrasting this class of thyristor with bidirectional thyristors.

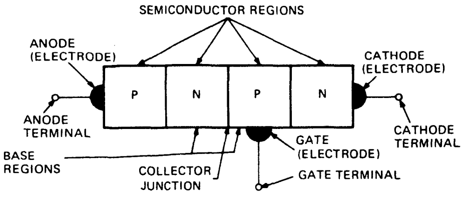
Thyristor

A bistable semiconductor device comprising three or more junctions, which can be switched from the off-state to the on-state or vice versa, such switching occuring within at least one quadrant of the principle voltage-current characteristic. (See Figures 1 through 5).

Turn-Off Thyristor

A thyristor which can be switched from the on-state to the off-state and vice versa by applying control signals of appropriate polarities to the gate terminal, with the ratio of triggering power to triggered power appreciably less than one.

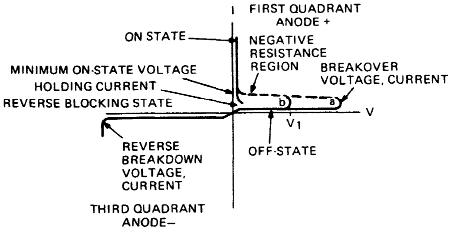
TERMS AND DEFINITIONS
THYRISTORS



Schematic representation of a reverse-blocking triode thyristor.

Note: The gate electrode is connected to the N-type base region in some structures or omitted in the case of a diode thyristor.

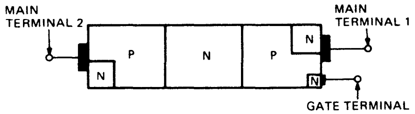
FIGURE 1



Principal voltage-current characteristics (anode-to-cathode voltage-current characteristic) of a typical reverse-blocking thyristor.

Note: Curve "a" applies for zero gate current or a diode thyristor. Curve "b" is with gate trigger current present when off-state voltage is V_1.

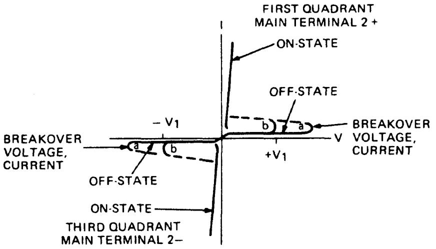
FIGURE 2



Schematic representation of typical bidirectional triode thyristor.

Note: Gate is omitted in a diode bidirectional thyristor.

FIGURE 3



Principal voltage-current characteristic of a typical bidirectional thyristor.

Note: Curve "a" applies for zero gate current or a diode bidirectional thyristor. Curve "b" applies for the case of gate trigger current applied when the off-state voltage is ± V_1.

FIGURE 4

Physical Structure Nomenclature

Anode

The electrode by which current enters the thyristor when the thyristor is in the on-state with the gate open-circuited.
NOTE: This term does not apply to bidirectional thyristors.

Anode Terminal

The terminal which is connected to the anode.
NOTE: This term does not apply to bidirectional thyristors.

Cathode

The electrode by which current leaves the thyristor when the thyristor is in the on-state with the gate open-circuited.
NOTE: This term does not apply to bidirectional thyristors.

Cathode Terminal

The terminal which is connected to the cathode.
NOTE: This term does not apply to bidirectional thyristors.

Collector Junction

The junction across which the polarity of the voltage reverses when switching occurs. (See Figure 1).

Electrode (of a Semiconductor Device)

An electrical and mechanical contact to a region of a semiconductor device.

Gate

An electrode connected to one of the semiconductor regions for introducing control current.

Gate Terminal

A terminal which is connected to a gate.

Junction (of a Semiconductor Device)

A region of transition between semiconductor regions of different electrical properties (e.g., n-n^+, p-n, p-p^+ semiconductors), or between a metal and a semiconductor.

Main Terminals

The terminals through which the principal current flows.

Main Terminal 1 (of a Bidirectional Thyristor)

The main terminal which is named "1" by the device manufacturer. This is normally the referance terminal for all voltages.

Main Terminal 2 (of a Bidirectional Thyristor)

The main terminal which is named "2" by the device manufacturer.

Terminal (of a Semiconductor Device)

The externally available point of connection to one or more electrodes.

Electrical Characteristic and Rating Terms (See Note at end of section)

Anode-to-Cathode Voltage (Anode Voltage)

The voltage between the anode terminal and the cathode terminal.

NOTE: It is called positive when the anode potential is more positive than the cathode potential, and called negative when the anode potential is less positive than the cathode potential.

Anode-to-Cathode Voltage-Current Characteristic (Anode Characteristic)

A function, usually represented graphically, relating the anode-to-cathode voltage to the principal current with gate current, where applicable, as a parameter.

NOTE: This term does not apply to bidirectional thyristors.

Breakover Point

Any point on the principal voltage-current characteristic for which the differential resistance is zero and where the principal voltage reaches a maximum value. (See Figures 2 and 4).

Negative-Differential-Resistance Region

Any portion of the principal voltage-current characteristic in the switching quadrant(s) within which the differential resistance is negative. (See Figures 2 and 4).

Off-Impedance

The differential impedance between the terminals through which the principal current flows when the thyristor is in the off-state at a stated operating point.

Off-State

The condition of the thyristor corresponding to the high-resistance, low-current portion of the principal voltage-current characteristic between the origin and the breakover point(s) in the switching quadrant(s).

On-Impedance

The differential impedance between the terminals through which the principal current flows when the thyristor is in the on-state at a stated operating point.

On-State

The condition of the thyristor corresponding to the low-resistance, low-voltage portion of the principal voltage-current characteristic in the switching quadrant(s).

NOTE: In the case of reverse-conducting thyristors, this definition is applicable only for a positive anode-to-cathode voltage.

Principal Voltage

The voltage between the main terminals.

NOTES: 1. In the case of reverse-blocking and reverse-conducting thyristors, the principal voltage is called positive when the anode potential is more positive then the cathode potential, and called negative when the anode potential is less positive than the cathode potential.

2. For bidirectional thyristors, the principal voltage is called positive when the potential of main terminal 2 is more positive than the potential of main terminal 1.

Principal Voltage-Current Characteristic (Principal Characteristic)

The function, usually represented graphically, relating the principal voltage to the principal current with gate current, where applicable, as a parameter.

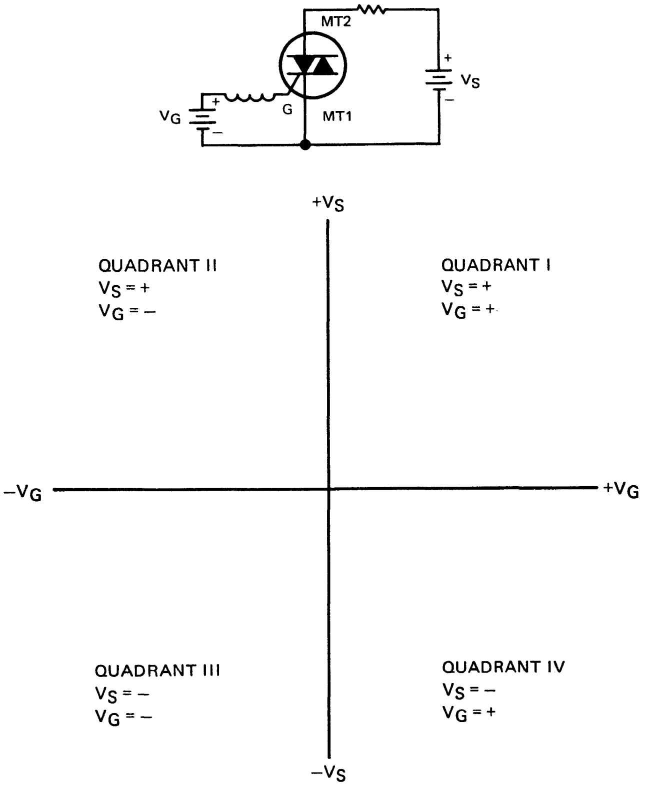
Reverse-Blocking Impedance (of a Reverse-Blocking Thyristor)

The differential impedance between the two terminals through which the principal current flows when the thyristor is in the reverse-blocking state at a stated operating point.

Reverse-Blocking State (of a Reverse-Blocking Thyristor)

The condition of a reverse-blocking thyristor corresponding to the portion of the anode-to-cathode voltage-current characteristic for which reverse currents are of lower magnitude than the reverse breakdown current. (See Figure 2).

QUADRANT DEFINITIONS



The polarities of V_S and V_G are with respect to Main Terminal 1.

FIGURE 5

TERMS AND DEFINITIONS
THYRISTORS

Symbols, Terms and Definitions

Symbol	Term	Definition
$I_{(BO)}$	Static Breakover Current	The principal current at the breakover point.
$i_{(BO)}$	Instantaneous Breakover Current	
$I_{(BR)R}$	Static Reverse Breakdown Current	The principal current at the reverse breakdown voltage.
$i_{(BR)R}$	Instantaneous Reverse Breakdown Current	
$I_{D(RMS)}$	RMS Off-State Current	The principal current when the thyristor is in the off-state.
I_D	Static Off-State Current	
$I_{D(AV)}$	Average Off-State Current	
i_D	Instantaneous Off-State Current	
I_{DM}	Peak Off-State Current	
I_{DRM}	Repetitive Peak Off-State Current	The maximum instantaneous value of the off-state current that results from the application of repetitive peak off-state voltage.
I_G	Static Gate Current	The current that results from the gate voltage. NOTES: 1. Positive gate current refers to conventional current entering the gate terminal. 2. Negative gate current refers to conventional current leaving the gate terminal.
$I_{G(AV)}$	Average Gate Current	
i_G	Instantaneous Gate Current	
I_{GM}	Peak Gate Current	
I_{GD}	Static Gate Nontrigger Current	The maximum gate current which will not cause the thyristor to switch from the off-state to the on-state.
i_{GD}	Instantaneous Gate Nontrigger Current	
I_{GDM}	Peak Gate Nontrigger Current	
I_{GQ}	Static Gate Turn-Off Current	The minimum gate current required to switch a thyristor from the on-state to the off-state.
i_{GQ}	Instantaneous Gate Turn-Off Current	
I_{GQM}	Peak Gate Turn-Off Current	
I_{GT}	Static Gate Trigger Current	The minimum gate current required to switch a thyristor from the off-state to the on-state.
i_{GT}	Instantaneous Gate Trigger Current	
I_{GTM}	Peak Gate Trigger Current	

TERMS AND DEFINITIONS
THYRISTORS

Symbol	Term	Definition
I_H	Static Holding Current	The minimum principal current required to maintain the thyristor in the on-state.
i_H	Instantaneous Holding Current	
I_L	Static Latching Current	The minimum principal current required to maintain the thyristor in the on-state immediately after switching from the off-state to the on-state has occurred and the triggering signal has been removed.
i_L	Instantaneous Latching Current	
$I_{R(RMS)}$	RMS Reverse Current	The current for negative anode-to-cathode voltage.
I_R	Static Reverse Current	
$I_{R(AV)}$	Average Reverse Current	
i_R	Instantaneous Reverse Current	
I_{RM}	Peak Reverse Current	
I_{RRM}	Repetitive Peak Reverse Current	The maximum instantaneous value of the reverse current that results from the application of repetitive peak reverse voltage.
$I_{T(RMS)}$	RMS On-State Current	The principal current when the thyristor is in the on-state.
I_T	Static On-State Current	
$I_{T(AV)}$	Average On-State Current	
i_T	Instantaneous On-State Current	
I_{TM}	Peak On-State Current	
$I_{T(OV)}$	Overload Peak On-State Current	An on-state current of substantially the same waveshape as the normal on-state current and having a greater value than the normal on-state current.
I_{TRM}	Repetitive Peak On-State Current	The peak value of the on-state current including all repetitive transient currents.
I_{TSM}	Surge (Nonrepetitive) Peak On-State Current	An on-state current of short-time duration and specified waveshape.
P_G	Static Gate Power Dissipation	
$P_{G(AV)}$	Average Gate Power Dissipation	
p_G	Instantaneous Gate Power Dissipation	
P_{GM}	Peak Gate Power Dissipation	

TERMS AND DEFINITIONS
THYRISTORS

Symbol	Term	Definition
T_A	Free-Air Temperature (Ambient Temperature)	The air temperature measured below a device, in an environment of substantially uniform temperature, cooled only by natural air convection and not materially affected by reflective and radiant surfaces. (Ref. MIL-S-19500D par. 20.20.1)
T_C	Case Temperature	The temperature measured at a specified location on the case of a device. (Ref. MIL-S-19500D par. 20.20.2)
T_J	Virtual Junction Temperature (Junction Temperature)	A theoretical temperature based on a simplified representation of the thermal and electrical behavior of the semiconductor device. NOTE: This term (and its definition) is taken from IEC standards. It is particularly applicable to multi-junction semiconductors and is used in this publication to denote the temperature of the active semiconductor element when required in specifications and test methods. The term "junction temperature" is used interchangeably with the term "virtual junction temperature" in this publication.
T_{stg}	Storage Temperature	The temperature at which the defice, without any power applied, is stored. (Ref. MIL-S-19500D par. 20.20.3)
t_{gt}	Gate-Controlled Turn-On Time	The time interval between a specified point at the beginning of the gate pulse and the instant when the principal voltage (current) has dropped (risen) to a specified low (high) value during switching of a thyristor from the off-state to the on-state by a gate pulse.
t_{gq}	Gate-Controlled Turn-Off Time	The time interval between a specified point at the beginning of the gate pulse and the instant when the principal current has decreased to a specified value during switching from the on-state to the off-state by a gate pulse.
t_q	Circuit-Commutated Turn-Off Time	The time interval between the instant when the principal current has decreased to zero after external switching of the principal voltage circuit, and the instant when the thyristor is capable of supporting a specified principal voltage without turning on.

TERMS AND DEFINITIONS
THYRISTORS

Symbol	Term	Definition
R_θ	Thermal Resistance	The temperature difference between two specified points or regions divided by the power dissipation under conditions of thermal equilibrium.
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case	
$R_{\theta CA}$	Thermal Resistance, Case-to-Ambient	
$V_{(BO)}$	Static Breakover Voltage	The principal voltage at the breakover point.
$v_{(BO)}$	Instantaneous Breakover Voltage	
$V_{(BR)R}$	Static Reverse Breakdown Voltage	The value of negative anode-to-cathode voltage at which the differential resistance between the anode and cathode terminals changes from a high value to a substantially lower value.
$v_{(BR)R}$	Instantaneous Reverse Breakdown Voltage	
$V_{D(RMS)}$	RMS Off-State Voltage	The principal voltage when the thyristor is in the off-state.
V_D	Static Off-State Voltage	
$V_{D(AV)}$	Average Off-State Voltage	
v_D	Instantaneous Off-State Voltage	
V_{DM}	Peak Off-State Voltage	
V_{DRM}	Repetitive Peak Off-State Voltage	The maximum instantaneous value of the off-state voltage which occurs across a thyristor, including all repetitive transient voltages, but excluding all nonrepetitive transient voltages.
V_{DSM}	Nonrepetitive Peak Off-State Voltage	The maximum instantaneous value of any nonrepetitive transient off-state voltage which occurs across the thyristor.
V_{DWM}	Working Peak Off-State Voltage	The maximum instantaneous value of the off-state voltage which occurs across a thyristor, excluding all repetitive and nonrepetitive transient voltages.
V_G	Static Gate Voltage	The voltage between a gate terminal and a specified main terminal. NOTE: Gate voltage polarity is referenced to the specified main terminal.
$V_{G(AV)}$	Average Gate Voltage	
v_G	Instantaneous Gate Voltage	
V_{GM}	Peak Gate Voltage	

TERMS AND DEFINITIONS
THYRISTORS

Symbol	Term	Definition
V_{GD}	Static Gate Nontrigger Voltage	The maximum gate voltage which will not cause the thyristor to switch from the off-state to the on-state.
v_{GD}	Instantaneous Gate Nontrigger Voltage	
V_{GDM}	Peak Gate Nontrigger Voltage	
V_{GQ}	Static Gate Turn-Off Voltage	The gate voltage required to produce the gate turn-off current.
v_{GQ}	Instantaneous Gate Turn-Off Voltage	
V_{GQM}	Peak Gate Turn-Off Voltage	
V_{GT}	Static Gate Trigger Voltage	The gate voltage required to produce the gate trigger current.
v_{GT}	Instantaneous Gate Trigger Voltage	
V_{GTM}	Peak Gate Trigger Voltage	
$V_{R(RMS)}$	RMS Reverse Voltage	A negative anode-to-cathode voltage.
V_R	Static Reverse Voltage	
$V_{R(AV)}$	Average Reverse Voltage	
v_R	Instantaneous Reverse Voltage	
V_{RM}	Peak Reverse Voltage	
V_{RRM}	Repetitive Peak Reverse Voltage	The maximum instantaneous value of the reverse voltage which occurs across the thyristor, including all repetitive transient voltages, but excluding all nonrepetitive transient voltages.
V_{RSM}	Nonrepetitive Peak Reverse Voltage	The maximum instantaneous value of any nonrepetitive transient reverse voltage which occurs across a thyristor.
V_{RWM}	Working Peak Reverse Voltage	The maximum instantaneous value of the reverse voltage which occurs across the thyristor, excluding all repetitive and nonrepetitive transient voltages.
$V_{T(RMS)}$	RMS On-State Voltage	The principal voltage when the thyristor is in the on-state.
V_T	Static On-State Voltage	
$V_{T(AV)}$	Average On-State Voltage	
v_T	Instantaneous On-State Voltage	
V_{TM}	Peak On-State Voltage	

Symbol	Term	Definition
$V_{T(MIN)}$	Static Minimum On-State Voltage	The minimum positive principal voltage for which the differential resistance is zero with the gate open-circuited.
$Z_{\theta(t)}$ $Z_{\theta JA(t)}$ $Z_{\theta JC(t)}$	Transient Thermal Impedance Transient Thermal Impedance, Junction-to-Ambient Transient Thermal Impedance, Junction-to-Case	The change of temperature difference between two specified points or regions at the end of a time interval divided by the step function change in power dissipation at the beginning of the same time interval causing the change of temperature difference.

POWER TRANSISTOR ELECTRICAL CHARACTERISTIC TESTS

INDEX

ELECTRICAL CHARACTERISTIC TESTS

GENERAL

In this section, accepted test practices are described as a guide to making power transistor characteristic tests. The material has been adapted from the forthcoming JEDEC Publication *Suggested Standards on Power Transistors.* Only those electrical characteristics included in EIA JC-25 registration formats are listed.

MEASUREMENTS

All measurements should be made at thermal equilibrium. A condition of thermal equilibrium is achieved if halving the time between application of power and measurement causes no change in the result within the required accuracy.

The connecting lines shown in the circuit diagrams have no resistance compared to their lowest terminating impedance. Shown are resistors, inductors, and capacitors having an ideal characteristic at the used frequency range. Voltage sources have zero impedance, and current sources have an infinite resistance. All voltmeters and scopes have infinite input resistance and all ammeters have zero resistance, unless otherwise noted.

The listing of the following tests does not imply that all must be performed by either the manufacturer or the user. It is the responsibility of the user and manufacturer to agree to any series of specific tests or test conditions, and the further responsibility of the user to establish meaningful relationship between these tests and the performance of the power transistor in a particular application.

An npn transistor is used in the test methods below. These test methods will also apply to pnp devices by changing polarities. For small-signal measurements, a signal is used which, when doubled in magnitude, does not produce a change in the measured parameter that is greater than the required accuracy.

The transistor connections are shown separate from the test circuits for "DC", "CT", and "P" techniques.

"DC" – D-C continuous condition

"CT" – Curve tracer (60 cycle full rectified sinewave)

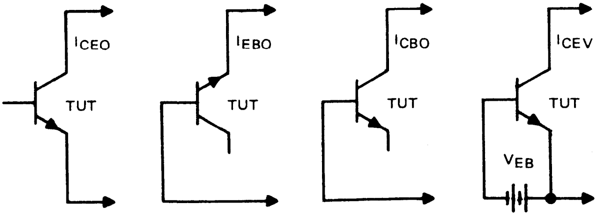
"P" – Pulsed by a 300 μs, 2% duty cycle pulse

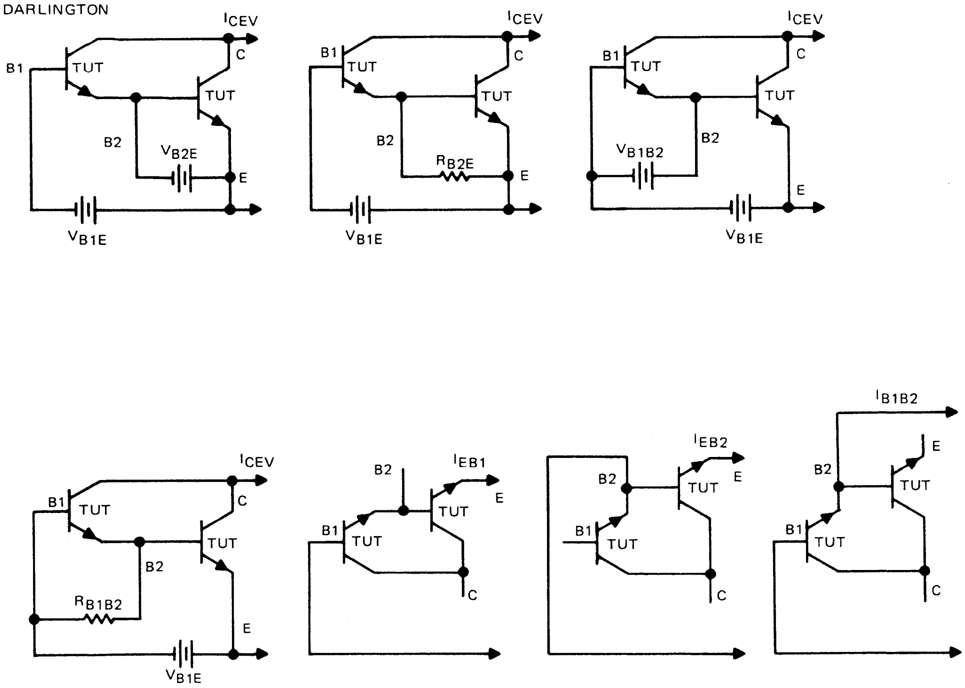
CUT-OFF CURRENT [I_{CEO}, I_{EBO}, I_{CBO}, I_{CEV}, I_{EB1}, I_{EB2}, I_{B1B2}]

Description

The reverse voltage is applied and the cut-off current is measured. The cut-off current is temperature sensitive. If testing is done at elevated temperature, a heat sink may be necessary to prevent thermal runaway.

Transistor Connections

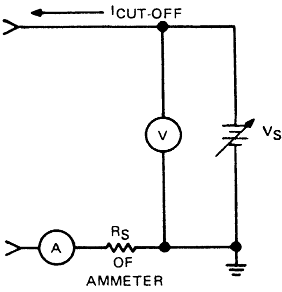




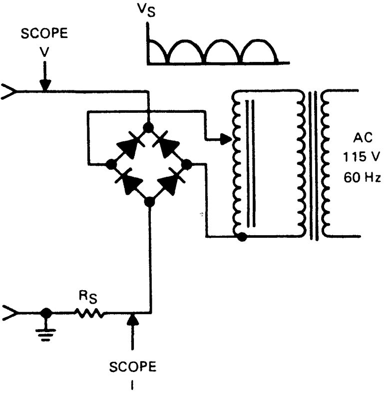
Test Circuits

The supply voltage V_S should equal R_S $I_{CUT\text{-}OFF}$ plus the specified test voltage. The current of the transistor in the pulse test circuit has to be small compared to the measured cut-off current. The cut-off current is measured with an ammeter or with an oscilloscope.

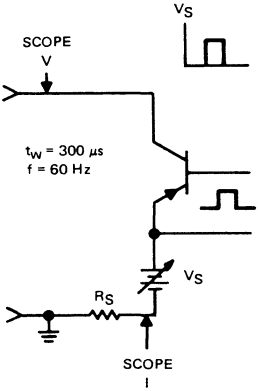
DC



CT



P



Test Conditions to be Specified

Case temperature if not T_C = 25°C

Voltage applied to the device: V_{CEO}, V_{EBO}, V_{CBO}, V_{CEV}, V_{EB1}, V_{B1B2}, V_{EB2}

Base termination: V_{EB}, V_{B2E}, R_{B2E}, V_{B1B2}, R_{B1B2}

Technique: DC, CT, P

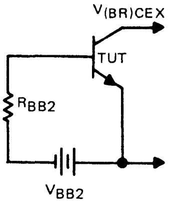
BREAKDOWN VOLTAGE [$V_{(BR)CEX}$, $V_{(BR)CEO}$ OR $V_{CEO(sus)}$, $V_{(BR)CES}$, $V_{(BR)EBO}$, $V_{(BR)CER}$]

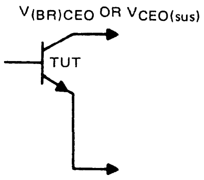
Description

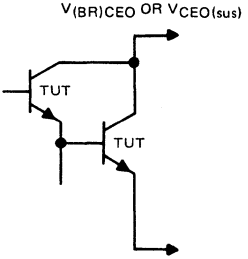
For breakdown measured in the sustaining region, the current should be high enough to ensure that the breakdown voltage is relatively insensitive to current changes.

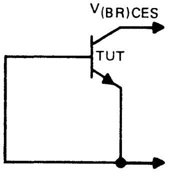
ELECTRICAL CHARACTERISTIC TESTS

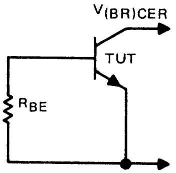
Transistor Connections

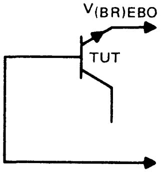




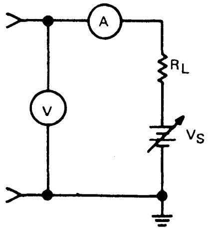


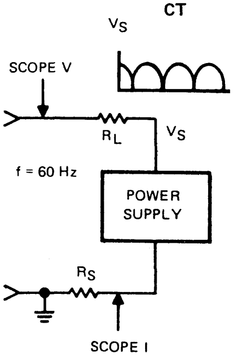


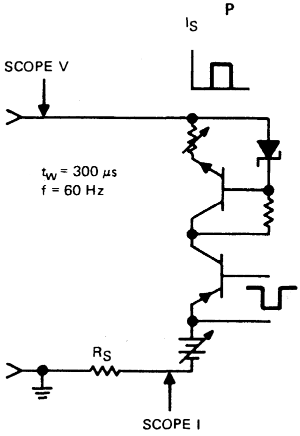


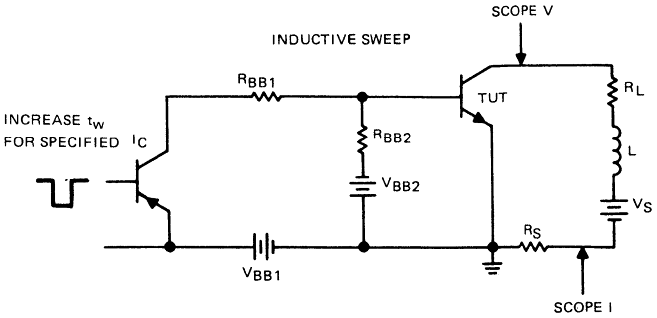


Test Circuits


DC


CT


P



In addition to the test circuits for "DC", "CT", and "P", an inductive sweep circuit is shown. This test circuit is particularly useful to measure transistors in their sustaining region.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Current applied to the device: I_{CEX}, I_{CEO}, I_{CES}, I_{EBO}, I_{CER}

Base termination: V_{BB2}, V_{BB1}, R_{BB2}, R_{BB1}, R_{BE}, pulse width, duty cycle

Technique: DC, CT, P, Inductive Sweep

Load resistance, inductance, and supply voltage where applicable: R_L, L, V_S

FLOATING POTENTIAL [$V_{EB(fl)}$]

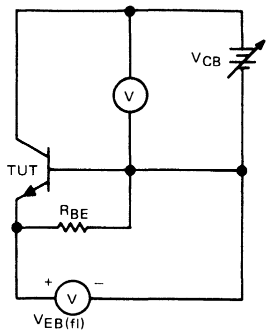
Description

This measurement is related to the thickness of the base region.

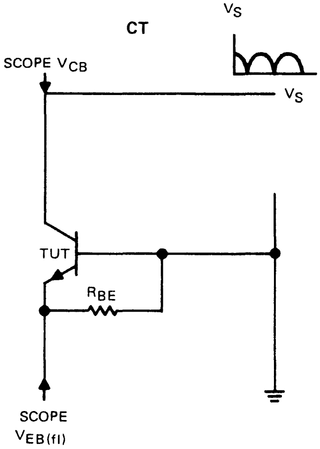
ELECTRICAL CHARACTERISTIC TESTS

Test Circuit

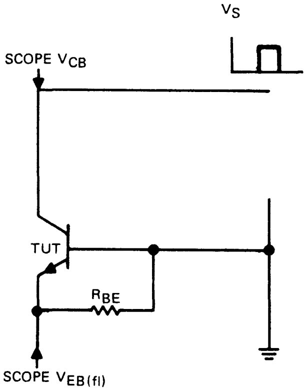
DC



CT



P



Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-base voltage: V_{CB}

Base-emitter resistance: R_{BE}

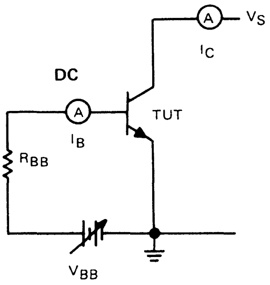
Technique: DC, CT, P

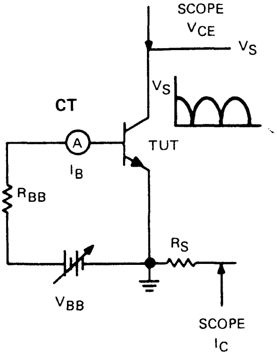
CURRENT GAIN [h_{FE}]

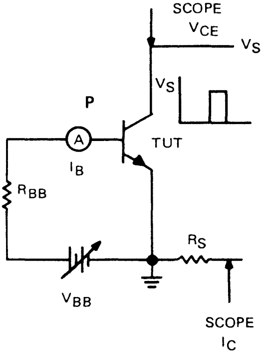
Description

The static forward current transfer ratio in the common-emitter configuration is one of the most important gain characteristic for power transistors. It measures the ratio of collector current to base current.

Test Circuit







The current gain is given by $h_{FE} = I_C/I_B$. For the CT and P tests, $V_{BB} >> \Delta V_{BE}^*$ so that I_B is constant and relatively independent of V_{BE}.

*ΔV_{BE} *is the range of* V_{BE} *for various devices to be tested.*

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-emitter voltage: V_{CE}

Collector current: I_C

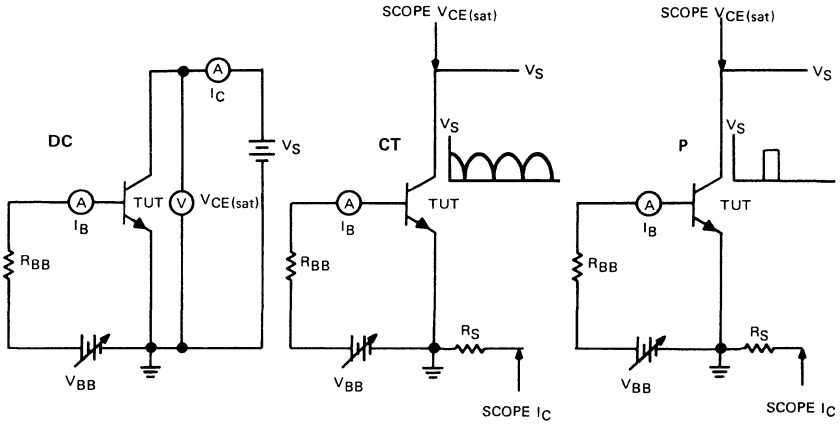
Technique: DC, CT, P

SATURATION VOLTAGE [$V_{CE(sat)}$]

Description

The collector-to-emitter saturation voltage is especially important for switching applications. Together with the collector current, it is the basis to calculate the power dissipation in the "on" state.

Test Circuit



For the CT and P tests, $V_{BB} >> V_{BE}$ in order to make I_B independent of V_{BE} changes during the "on" condition.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector current: I_C

Base current: I_B

Technique: DC, CT, P

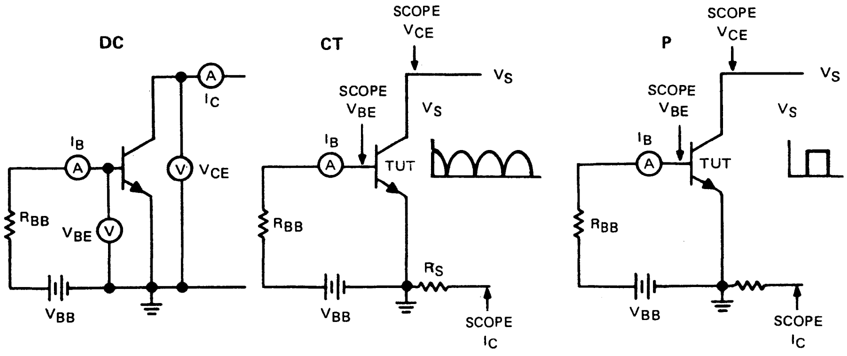
BASE-TO-EMITTER VOLTAGE [V_{BE}]

Description

There are two conditions of interest for the static base-to-emitter voltage:

1. The transistor in saturation (commonly referred to as $V_{BE(sat)}$)
2. The transistor out of saturation (V_{BE})

Test Circuit



For the CT and P tests, $V_{BB} >> V_{BE}$ in order to make I_B independent of V_{BE} changes during the "on" condition. The base terminal for Darlington transistors is B1.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

1. The transistor in saturation: ($V_{BE(sat)}$)

   Collector Current: I_C

   Base Current: I_B

2. The transistor out of saturation: (V_{BE})

   Collector current: I_C

   Collector-to-emitter voltage: V_{CE}

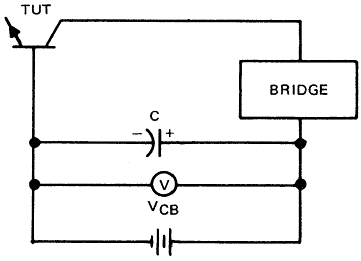
Technique: DC, CT, P

OPEN-CIRCUIT OUTPUT CAPACITANCE [C_{obo}]

Description

The open-circuit output capacitance indicates the frequency limitations of a transistor.

Test Circuit



Capacitor C has to be sufficiently large to provide a short-circuit at the test frequency. The bridge has to be nulled with the base-to-collector open. The base terminal for Darlington transistors is B1.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-to-base voltage: V_{CB}

Frequency: f

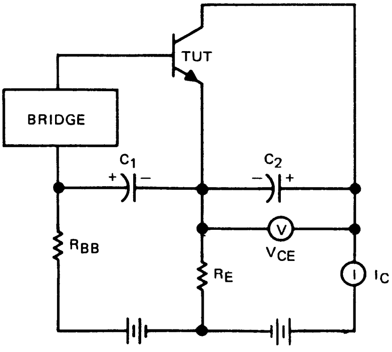
SMALL-SIGNAL SHORT-CIRCUIT INPUT IMPEDANCE [h_{ie}, $h_{ie(real)}$, $h_{ie(imag)}$]

Description

The input impedance is $h_{ie} = V_{be}/I_b$ with $V_{ce} = 0$. The real and imaginary components are important for input matching networks.

Circuits

Capacitors C1 and C2 must represent a short-circuit at the measuring frequency. The bridge must be nulled with a short across the base and emitter terminals and $V_{BB} = 0$. When h_{ie} is measured at 1 kHz, I_b can be measured with a current probe and V_{be} with a scope.



Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-to-emitter voltage: V_{CE}

Collector current: I_C

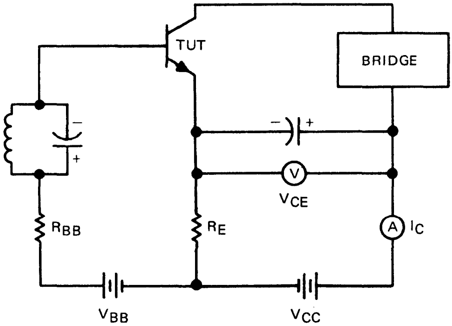
Frequency: f for $h_{ie(real)}$ and $h_{ie(imag)}$

SMALL-SIGNAL OPEN-CIRCUIT OUTPUT ADMITTANCE [$h_{oe(real)}$]

Description

The purpose of this test is to determine the real part of the output admittance.

Test Circuit



The L-C network in the base circuit must have a large impedance compared with h_{ie} at the test frequency. Capacitor C1 shall present a short-circuit at the test frequency.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-to-emitter voltage: V_{CE}

Collector current: I_C

Frequency: f

SMALL-SIGNAL FORWARD CURRENT TRANSFER RATIO [h_{fe}], CUT-OFF FREQUENCY [f_{hfe}], AND FREQUENCY AT WHICH $|h_{fe}|$ EXTRAPOLATES TO UNITY [f_T]

Description

These measurements indicate the gain h_{fe} and the frequency response capability of transistors. Both measurements are dependent on the operating point.

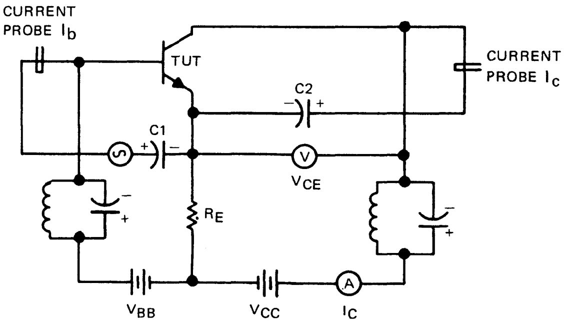
$h_{fe} = I_c/I_b$ (with $V_{ce} = 0$) at low frequency.

f_{hfe} = frequency at which h_{fe} is 3 dB down from its 1-kHz measurement

$f_T = |h_{fe}| \times f$. The absolute small-signal $|h_{fe}|$ has to be measured at a frequency f where $|h_{fe}|$ is decreasing approximately 6 dB per octave.

The measurement as specified does not assure the 6-dB-per-octave region. The 6-dB-per-octave region can be determined by plotting $|h_{fe}|$ versus f.

Test Circuit



The L-C networks must have a very large impedance compared to the capacitors C1 and C2. The amplitude of I_b and I_c is measured with a current probe.

The ac impedance represented by C2, the current probe for I_c, and associated wiring shall be small compared to the output impedance of the Transistor Under Test.

Test Conditions To Be Specified

Case temperature if not $T_C = 25°C$

Collector-to-emitter voltage: V_{CE}

Collector current: I_C

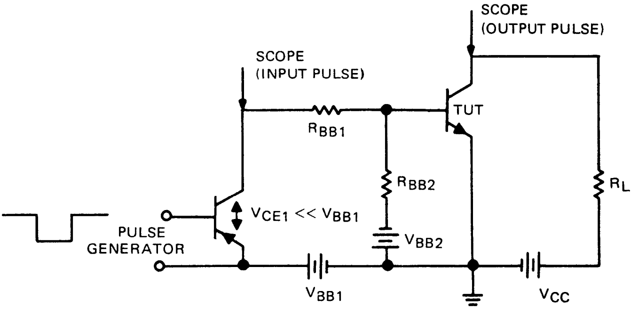
For h_{fe} and f_T only: f

SWITCHING TIME [t_d, t_r, t_s, t_f]

Description

It is desirable to minimize the large possible variations in switching circuits. A circuit similar to the following is recommended for switching times registered on the JC-25 RDF-2 format. For definition of t_d, t_r, t_s, and t_f, see section on "Letter Symbols, Abbreviations, Terms, and Definitions." The transistor parameter "rise time" refers to the time interval during which the magnitude of the collector current is increasing and the magnitude of the collector voltage is descreasing.

Test Circuit



The rise and fall time of the input pulse shall be smaller than 10% of the maximum specified rise and fall time of the output pulse. Changing the pulse width t_w by a factor of two should not change the storage time t_s by more than the desired accurancy of the measurement.

Test Conditions To Be Specified

Case temperature if not $T_C = 25^\circ C$

V_{BB1}, V_{BB2}, V_{CC}, R_{BB1}, R_{BB2}, R_L, t_w and f of pulse generator.

Power Semiconductor Technology

TABLE OF CONTENTS

TECHNOLOGY DISCUSSION

SILICON POWER TRANSISTORS AND THYRISTORS

Mesa versus Planar versus Glass-Mesa Designs

Contemporary silicon power devices can be classified into two, broad, structurally different categories; planar and mesa.

A typical double-diffused epitaxial planar transistor structure is shown in Figure 1. The P-N junctions are all formed by diffusion and passivated by the oxide (SiO_2). A typical mesa transistor structure is shown in Figure 2. In this illustration the emitter-base junction is of planar structure. The collector-base junction is formed by selectively etching the silicon into a mesa-like structure. The exposed junction is usually coated with some insulating substance to protect it from contamination, humidity, and other adverse environments.

Typically, the planar structure is well-suited for higher frequency and faster switching. This is because the base width of the planar device can be made very narrow.

For the same reason, however, the breakdown voltage rating is usually limited to only several hundred volts. The mesa structure, due to its process limitations, is generally used for lower frequency and moderate switching speed. It does allow higher voltage devices to be built, however.

When operated under high-temperature conditions, the planar structure is generally the superior one. Through the intensive and fruitful effort in the advancement of the planar process, the oxide-silicon has become the best understood system in the semiconductor field. As a result, when the knowledge of planar technology is properly applied, planar devices with extremely low leakage current can be produced routinely and maintained with very high reliability.

Even though, historically, the mesa devices were among the first devices developed, the passivation of the exposed junction has not been well understood. As a result, the leakage currents are moderately higher and less stable than those of the planar devices. The knowledge of the planar technology has impacted the improvement of mesa junction passivation quite strongly. The development of glass passivation has contributed significantly to the reduction of leakage currents and improvement in stability in mesa structures. A typical glass-passivated structure is shown in Figure 3. This glass-passivated device offers the advantages of both the mesa and planar structures. Once the glass is in place, the unit is sealed against the rigors of assembly and can even be dipped into liquid solder without damage. This advanced concept is used in many power transistors and thyristors manufactured by Texas Instruments.

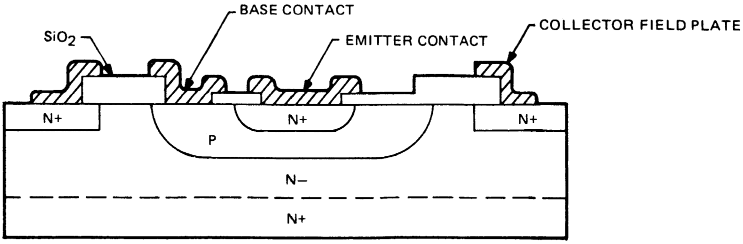


FIGURE 1—PLANAR TRANSISTOR STRUCTURE

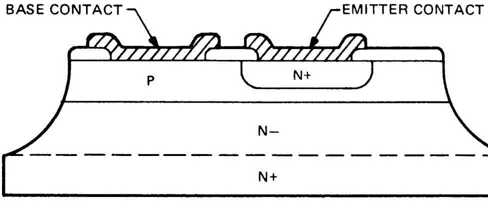


FIGURE 2—MESA TRANSISTOR STRUCTURE

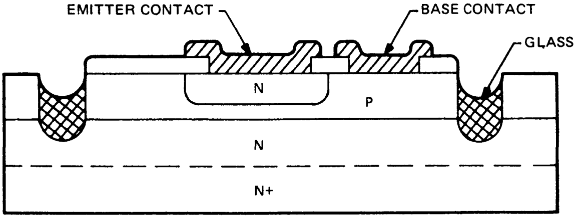


FIGURE 3—GLASS-PASSIVATED STRUCTURE

Forward and Reverse Energy Considerations

A power transistor must be designed not only to meet specific electrical specifications, but also to withstand the circuit application power requirements. A device with low thermal resistance does not guarantee that the device will operate in the circuit application. The application may exceed the second breakdown limitations of the device.

Transistors have two basic second breakdown modes. One mode is known as forward second breakdown and the other is reverse second breakdown. Forward second breakdown may occur when a device is operated in the amplifying mode. Most devices can handle more power in the low-voltage, high-current state than at the high-voltage, low-current condition. Second breakdown occurs when localized heating manifests itself in the emitter region. The cause for the "hot spot" is a non-uniform temperature profile across the emitter surface.

Because the V_{BE} characteristic of a transistor has a negative temperature coefficient, the "hot spot" area "hogs" the emitter current as the power is increased, thus leading to a thermal run-away condition. When the hot spot exceeds the eutectic temperature of the silicon-emitter-metal interface, the contact metal will diffuse through the emitter, causing a catastrophic failure.

Designing the emitter geometry such that the thermal resistance over the entire emitter region is constant will improve the forward second breakdown characteristics of the devices. All the recently announced TI power transistors utilize "isothermal" geometries to optimize the Safe Operating Area (SOA).

Reverse second breakdown may occur in a transistor during the turn-off transient. If a transistor is used for inductive switching, the device must dissipate the energy of the inductor when switching from a conducting state to an off state unless a protective circuit is used. The maximum energy that a transistor can dissipate in this transient condition is known as reverse energy capability. The reverse energy capability of a transistor can be increased by several orders of magnitude by using the optimum collector thickness and resistivity profile. Texas Instruments has developed a proprietary empirical method for calculating the starting material collector profile required to produce devices with optimum reverse energy capability versus other desired parameters.

Summary of Advantages and Disadvantages of Various Technologies

Now that these different general structures and design ideas have been discussed, a listing of specific designs and their advantages and disadvantages is provided below for ready reference.

Single-Diffused (Homogeneous-Base Mesa)

Advantages

- Excellent forward and reverse energy capability
- Low manufacturing cost

Disadvantages

- Low switching speed – excessive power dissipated during switching applications. Large-area heat sink required
- Very poor beta linearity versus collector current
- Inherent junction instabilities of a mesa device
- Requires at least 50% more silicon area for high-current performance
- Not practical for use in hybrid functions since junctions need to be passivated after assembly
- Complementary P-N-P type difficult to produce

TI Single-Diffused II (glass-passivated epi-base)

Advantages

- Excellent forward and reverse energy capability
- Low manufacturing cost
- Planar type leakages and stabilities due to glass-passivated junctions
- Faster switching speeds than homogeneous-base structure
- Complementary P-N-P types readily available at low cost
- No special processing required for utilization of chips in hybrid functions
- More linear beta versus collector current than homogeneous-base structure
- Less silicon required for high-current performance

Disadvantages

- Chip costs slightly higher due to additional slice processing

Triple-Diffused Mesa

Advantages

- Moderate switching speeds
- Good reverse energy capability
- Moderate saturation resistance
- High electrical yields

Disadvantages

- Mesa junction instabilities
- Long-duration high-temperature diffusions required for collector
- Chip must be passivated after being assembled to header
- Exposed junctions are sensitive to ambient conditions during wafer electrical probe

TI Triple-Diffused Glass-Passivated Mesa

Advantages

- Moderate switching speeds
- Good reverse energy capability
- Moderate saturation resistance
- High electrical yields
- No passivation of junction required after assembly
- Planar type leakage and stability due to glass-passivated junctions and N+ guard ring structure
- No special processing required for use of chips in hybrid functions.
- Wafer electrical probe can be set to tighter limits for high final test yields

Disadvantages

- Long-duration high-temperature diffusions required for collector

Epitaxial Planar

Advantages

- Fast switching speeds
- Excellent beta linearty versus collector current
- Low junction leakage and excellent stability
- P-N-P complement units are available
- Low saturation resistance

Disadvantages

- Generally lower energy capability
- Higher manufacturing costs

TI Isothermal Epitaxial Planar Transistors

Advantages

- Fast switching speeds
- Excellent beta linearity versus collector current
- Low junction leakage and excellent stability
- Good reverse and forward energy capability
- P-N-P complements available
- Low saturation resistance

Disadvantages

- Higher manufacturing costs

Chip-Mounting Techniques

Once the design of the silicon chip geometry has been achieved, the next problem to be addressed is how to assemble the unit.

The majority of mounting systems for power transistors and thyristors fall into two major categories—"hard" and "soft" solders. The "hard"-solder systems are often made up of a molybdenum mounting platform with a gold-base preform used to alloy the chip to the molybdenum. The coefficient of expansion of molybdenum approximates that of silicon such that the stresses of temperature excursions are minimized. In the "soft"-solder system, a lead-base solder is used to mount the chip directly to a copper platform. In this system, the flexible nature of the solder absorbs the stresses of mismatch between the silicon chip and the upper platform during temperature cycling. Disagreements exist as to which system is best but as with many similar questions, the answer depends upon the end use of the product. Both systems have their advantages and disadvantages. The hard-solder systems do not perform under repeated high-current surges as well as the soft-solder systems, and the soft systems, unless carefully chosen, tend to work-fatigue. Texas Instruments uses both systems with success.

Lead-Bonding Techniques

In bonding, as in mounting, there are two ways in which most power transistors and thyristors are assembled.

One method utilizes ultrasonic bonding of aluminum wire to the chip. The other technique is solder contact bonding. Again, each method has its advantages and disadvantages. When low volume and close control are available, the aluminum bond is very good, but the rugged solder contact method lends itself to volume production and is very readily process controlled. Texas Instruments uses both types of lead bonding methods in the construction of power transistors and thyristors,each serving the needs of the desired application.

Application Information

APPLICATIONS INFORMATION
APPLICATION REPORT SUMMARY

JULY 1975

A. APPLICATION REPORTS

Texas Instruments Applications Laboratories produce a series of Application Reports as an aid to the Design Engineer. Listed in this section are several reports which deal with applications of Power Semiconductors.

B61—Triacs—Theory and General Application 20p

The construction and electrical characteristics of the Triac are compared with the thyristor (SCR). Practical applications of the Triacs are given with advantages over thyristor circuits noted. Some guidance on protection and cooling is also included.

The appendix discusses Triacs with inductive loads.

B75—Solid State Switching Using Triacs and Thyristors 20p

Although most of the solid state switching circuits in this report are single phase, some three phase and D.C. circuits are included. The actuation of solid state contactors by logic, a light beam and pilot switches are described.

B76—Switching Mode Power Supplies 20p

This report deals with the practical possibilities of Switching mode power supplies to deliver stabilised voltages of 60 Volts at 2A and 30 Volts at 3A, directly from a half-wave rectified mains supply. The complexity of all stages and their associated problems are discussed. Some of the safeguards against failure modes are explained.

B83—Inverters 30p

General inverter principles are discussed emphasising their influence on device selection in the design stage. Transient losses, high frequency operation and device operating area are considered in detail. Thirteen practical converter circuits are included with maximum power outputs in the 10W to 300W range running at various frequencies between 400Hz and 50kHz.

B86—Burst Firing Techniques Using Triacs 20p

Two Triac Burst Firing circuits are discussed in this report. The first uses the transistor pump technique and the second mark-space control. The modes of operation of the circuit are described.

B100—Thyristor Reversible D.C. Supply 20p

The report describes a circuit which reverses the D.C. polarity across a load each time the supply is switched. With a simple modification to the switching a new circuit emerges giving a cycloconverter type of frequency changer.

B114—Monochrome TV Switching Regulator and Line Driver 20p

The concept described is a novel one which uses the low pass filter coil as the voltage step down transformer, and, employing the low cost BD410 transistor as the series switch offers considerable cost and power dissipation advantages over the conventional 135—150V regulated power sources for BU105 line output stages. Auxiliary low tension supplies may be obtained by additional windings on the filter choke and the circuit is protected against the rail being shorted to earth or a collector-emitter series switch short circuit.

APPLICATIONS INFORMATION
APPLICATION REPORT SUMMARY

B116—Chopper Power Supplies Using BUY69/70 High Voltage Power Transistors 20p

The BUY69/70 range of high power high voltage switching transistors has produced an upsurge of interest in switching mode regulators operating directly from mains. Isolation of the supply input and output and any step-up or down of the primary voltage required, is achieved by small size high frequency transformers. The basic design criteria are discussed. It is shown that power outputs of 800W are obtainable from a single device and 1500W from a push pull arrangement.

B118—H.V. Stacks, Parallel Operation and System Design 20p

The effect while running H.V. stacks in parallel of load sharing at nominal load and during fault conditions is considered and recommendations made for satisfactory current sharing and protection. One of the most common connections for H.V. power conversion being a three phase bridge, a complete circuit design approach for such a circuit is given. Practical figures are then used to illustrate the calculations necessary for such an approach.

B126—Monochrome TV Circuit Design Using the BUY71 2.2kV Transistor 20p

Advances in technology have made available 2200V silicon transistors (BUY71) suitable for monochrome television linescan applications. The impact of the BUY71 transistor's ratings on the associated television circuitry are examined from both cost and performance viewpoints. Detailed design procedures are given for the BUY71 transistor's operating conditions and its driver stage. The report concludes with a circuit diagram detailing all the power functions of a monochrome television.

B130—Power Control with Triacs 20p

Various ways in which Triacs controlling a load can be switched are described, starting with simple circuits using instance; contacts, integrated circuits with and without isolation, and optoelectronic devices. More sophisticated methods then given include using the zero voltage switching integrated circuit. SN72440, as an automatic temperature controller, and employing it with burst firing techniques to switch transformer and inductive loads. Finally circuits are given and explained where the phase control is achieved by the variation of the voltage input.

B131—High Voltage Switching Transistor 20p

The ratings and characteristics of high voltage switching transistors are described including methods of measurement. Although the transistor is intended for any high voltage switching circuits it is commonly used in television line output stages and this application has been used as a basis for characterization. The effectiveness in operation is determined by the control of the switching waveforms and the circuit designer is given sufficient information to simplify design in any high voltage application.

B139—Inverter/Converter Systems

The general principles of various inverter/converters are described. No in-depth calculations or explanations are supplied but a number of examples are given to illustrate practical circuits.

These include e.g., inverters which operate from a 12V battery and provide a 300W 50Hz output or drive a 13W fluorescent lamp; a 120W power supply unit; and a stage by stage construction of a switching mode power supply.

APPLICATION REPORT SUMMARY

B157—Television Horizontal Deflection using the BU124 Plastic Encapsulated Transistor 20p

The BU124 is a high voltage silicon transistor designed primarily for horizontal deflection applications in small and medium size monochrome T.V. sets. The device replaces germanium pnp transistors with a few simple circuit modifications and offers a more cost effective solution than silicon devices in the metal can T03 package. The plastic T03 package is immediately interchangeable with the metal can version. In designing the device, particular attention has been paid to its ability to withstand picture tube flashover.

B159—Industrial Switching Mode Power Supplies 20p

Employing power transistors, and switching techniques, three power supplies are described. The first uses a shunt chopper circuit, operates from simply rectified a.c. mains or 24 ± 8V d.c., provides a multiple number of isolated outputs, and, using a range of output stages, delivers total output currents of 1A (15W) to 30A (300W). The second system is a multi-purpose high current (40A) supply suitable for, e.g. certain welding, spark erosion or battery charging equipment. The third shows how the disadvantage encountered when using a single saturating transformer converter with a high turns ratio, can be turned into advantage by adapting it into a sinewave converter to give a high voltage 14kV (@ 1mA) supply suitable for, e.g. use with photo-multipliers, high vacuum systems using thermionic emission, etc.

B167—Second Breakdown and Power Transistors Area of Operation 20p

A description and explanation of forward biased second breakdown is given. It is then shown how these characteristics may be measured and explains the need for the area of operation specification of power transistors.

D4—DC Power Supply Circuits Using Silicon Rectifiers 20p

The aim of this report is to draw attention to the particular design features of circuits using silicon rectifiers. The more common single-phase and three-phase rectifier circuits are described. Design procedures are discussed for circuits using capacitor input and choke input filters and for additional filter sections. Worked examples are given and attention is drawn to the precautions necessary to avoid misuse of silicon rectifiers. For convenience graphs used in the design procedure are collated at the end of the report.

Copies of these reports and a summary of the complete range of Application Reports can be obtained in the UK from: Texas Instruments Ltd., Data Service Department, Manton Lane, Bedford MK41 7PA. Overseas Customers should contact their local Sales Office.

B. SAFE OPERATING AREAS FOR POWER TRANSISTORS

The Safe Operating Area encloses all points representing simultaneous values of two variables which a transistor can safely handle under specified conditions. The majority of transistor applications can be reduced to one or more of the following operations:

Forward-Biased Continuous Operation

Pulsed Forward-Biased Operation

Switching Between Saturation and Cutoff

Each operation is discussed in reference to:

Presentation

Test Circuit

Test Points

Test Procedure

Temperature Derating

The maximum operating capability of each individual transistor is a complex function of I_C, V_{CE}, I_B, T_C and t_p. To characterize the full capability of a device would require an unreasonable number of test points. Therefore, it is necessary to simplify a rating and derating theory. No reference to the type of failure mode is made.

FORWARD-BIASED CONTINUOUS OPERATION

Presentation

Figure 1 shows a Forward-Biased Continuous Safe Operating Area. For $V_{CE} \leqslant V_{CE1}$ the total power dissipation P_T is limited by $I_{C\ max}$. At increasing V_{CE} the power dissipation capability of most transistors is decreasing gradually. Because the rate of decrease depends on the individual transistor, it is suggested to use P_{T3} for $V_{CE2} < V_{CE} \leqslant V_{CE3}$ and P_{T4} for $V_{CE3} < V_{CE} \leqslant V_{CE4}$.

For the area given in Figure 1, safe operation is assured with forward bias only (I_B is positive for npn transistors, negative for pnp transistors). High-current germanium transistors may have I_{CEO} leakage currents of 1 A or more at high junction temperatures. It is not recommended to operate transistors continuously at currents smaller than I_{CEO} except in a temperature-stable cutoff condition.

Test Circuit

The Forward-Biased Continuous Safe Operating Area can be verified by using the temperature-stable common-base circuit illustrated in Figure 2. The Transistor Under Test (TUT) dissipates $P_T \approx I_C\ V_{CE}$ for $V_{CE} >> 1$ V.

Test Points

The number of test points is arbitrary. The Safe Operating Area in Figure 1 requires three (3) test points: I_{C2} at V_{CE2}, I_{C3} at V_{CE3} and I_{C4} at V_{CE4}. Test points should be selected using the principle that only the verified P_{Tn} is assured for V_{CE}'s smaller than the test point voltage V_{CEn}.

Test Procedure

Test Point Example: $I_C = I_{C2}$

$V_{CE} = V_{CE2}$

$T_C = 55°C$ for $T_{J\,max} \leqslant 125°C$

$T_C = 100°C$ for $T_{J\,max} > 125°C$

Test Duration: 1 minute

Determine: $R_C = \frac{V_{CE2}}{I_{C2}}$

$R_E \geqslant \frac{5\text{ V}}{I_{C2}}$

Test Sequence:

1. Start with V_{CC} and V_{EE} at low voltage.
2. Increase V_{CC} to approximately V_{CE2}.
3. Increase V_{EE} to obtain I_{C2}.
4. Increase V_{CC} to two times V_{CE2}.
5. Adjust V_{EE} to obtain V_{CE2} and I_{C2}.
6. Operate transistor at specified case temperature for one (1) minute. The transistor is not acceptable if I_C varies more than $0.1 \cdot I_{C2}$ during the one (1) minute test.
7. Decrease V_{CC} to V_{CE2}.
8. Turn off V_{EE}.
9. Turn off V_{CC}.

Evaluation:

The device shall be capable of meeting the specification.

APPLICATION INFORMATION
SAFE OPERATING AREAS FOR POWER TRANSISTORS

Temperature Derating for Continuous Operation

The maximum allowable case temperature for a given P_T can be calculated as follows:

$$T_C \leqslant T_{J\,max} - \frac{P_T}{P_{Tn}}\,(T_{J\,max} - 55^\circ C) \text{ for } T_{J\,max} \leqslant 125^\circ C$$

$$T_C \leqslant T_{J\,max} - \frac{P_T}{P_{Tn}}\,(T_{J\,max} - 100^\circ C) \text{ for } T_{J\,max} > 125^\circ C$$

T_C = Case Temperature

$T_{J\,max}$ = Maximum Operating Junction Temperature

P_T = Total power dissipation at $V_{CE} \leqslant V_{CEn}$

P_{Tn} = Total power Dissipation at Test Point V_{CEn} and $T_C = 55^\circ C$ for $T_{J\,max} \leqslant 125^\circ C$ or $T_C = 100^\circ C$ for $T_{J\,max} > 125^\circ C$.

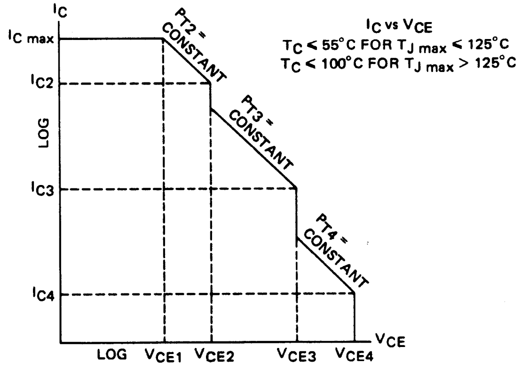


FIGURE 1

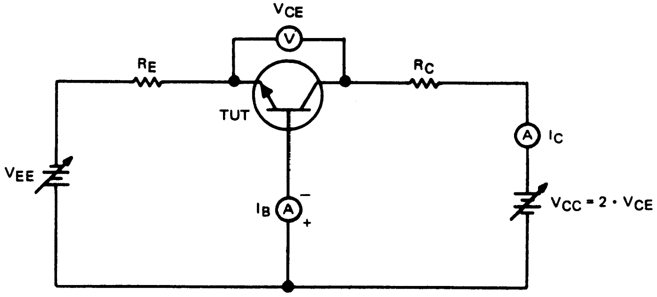


FIGURE 2

PULSED FORWARD-BIASED OPERATION

Presentation

Figure 3 shows three pulse width areas for $t_{p1} \geqslant t_{p2} \geqslant t_{p3}$; however additional pulse width areas may be added. The presentation in Figure 3 has the advantage of specifying the maximum capability of a transistor type at $I_{C\ max}$ whereas the area in Figure 4 is based on maximum capability at highest allowable V_{CE}. The area in Figure 4 is limited by $I_{C\ max}$ and curves representing constant $I_C \cdot V_{CE}$ product. Therefore, the test point at highest V_{CE} assures all other operating points within a given t_p area, but on the other hand, this method derates the capability of a transistor at $I_{C\ max}$.

Test Circuits

In test circuit Figure 5 the Pulsed Forward-Biased capability of a transistor can be verified. The transistor Q_1 can be replaced by a switch such as a mercury relay. Some test circuits require an emitter resistor for the Transistor Under Test (TUT). Such a resistor is not desirable because it complicates specification writing as well as testing procedures.

Test Points

The number of test points equals the number of pulse width areas. The following table shows the required specification for verification at $T_C = 25°C$:

FIGURE	TEST POINT	I_C	V_{CE}	t_p
3	#1	$I_{C\ max}$	V_{CE5}	t_{p1}
	#2	$I_{C\ max}$	V_{CE6}	t_{p2}
	#3	$I_{C\ max}$	V_{CE7}	t_{p3}
4	#1	I_{C1}	V_{CE8}	t_{p1}
	#2	I_{C2}	V_{CE8}	t_{p2}
	#3	I_{C3}	V_{CE8}	t_{p3}

In addition the duty cycle has to be specified.

Test Procedure

Test Point Example: $T_C = 25°C$

$I_C = I_{C\,max}$

$V_{CE} = V_{CE5}$

$t_p = t_{p1}$

Duty Cycle = d1

Determine: $V_{CC1} = V_{CE5} + I_{C\,max}\,R_S$

The collector current capability of Q_1 should be approximately:

$$I_{CQ1} = 2\left(\frac{V_{BB2} + 1.5\ V}{R_{BB2}} + \frac{I_{C\,max}}{h_{FE\,min\,(TUT)}}\right)$$

The current supplied to the base of Q_1 should be sufficient to drive Q_1 into saturation for I_{CQ1}. Transistor Q_1 may be replaced by a rela,. The rise and fall time of the collector current should be small compared to the pulse width t_p.

Test Sequence:

1. With all voltage supplies turned off adjust the pulse generator for $t_p = t_{p1}$ and d = d1.
2. Turn on V_{CC} to V_{CC1}.
3. Increase V_{BB1} until i_c reaches $I_{C\,max}$ by applying single pulses.
4. Check that the following conditions are met:

   $t_r << t_p$

   $t_f << t_p$

   $T_C = 25°C$
5. The transistor is not acceptable if i_c varies more than $0.1 \cdot I_{C\,max}$ during t_{p1}. The duration of test is only that time adequate to make the reading.
6. Adjust V_{BB1} to zero and turn off V_{CC}.

For subsequent transistors to be tested, only steps 2, 3, 5 and 6 have to be repeated.

Evaluation:

The device shall still be capable of meeting the specification.

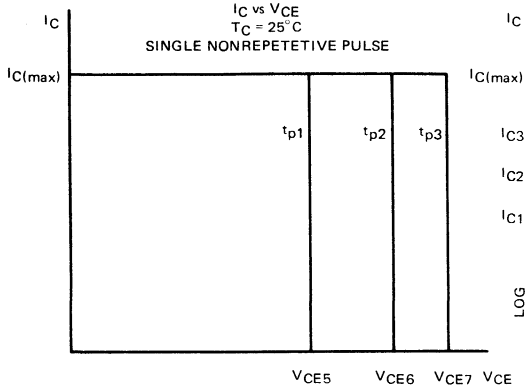


FIGURE 3

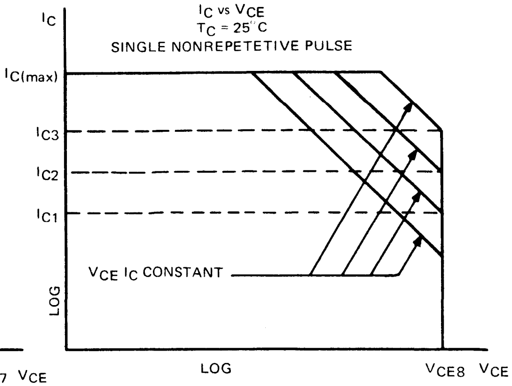


FIGURE 4

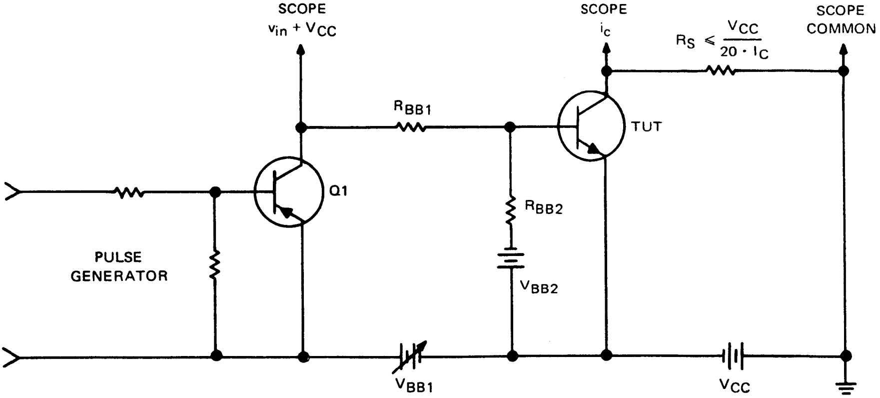


FIGURE 5

SWITCHING BETWEEN SATURATION AND CUTOFF

Resistive Load

Presentation

Figure 6 shows the area within which the load line has to be located for safe operation with a resistive load.

Test Circuit

Verification of the Safe Operating Area is performed by switching the transistor on and off with a single non-repetitive pulse in circuit Figure 7.

Test Points

Only one test point has to be verified. This is accomplished by switching from $V_{CE\ max}$ to saturation at $I_{C\ max}$ and back again to $V_{CE\ max}$.

Test Procedure

Test Point Example: $T_C = 25^\circ C$

$I_C = I_{C\ max}$

$V_{CE} = V_{CE\ max}$

$R_{BB1} = R_{BB1(1)}$

$R_{BB2} = R_{BB2(1)}$

$V_{BB1} = V_{BB1(1)}$

$V_{BB2} = V_{BB2(1)}$

Determine:

$$R_L = \frac{V_{CE\ max}}{I_{C\ max}}$$

$$V_{CC} = V_{CE\ max}$$

The collector current capability of Q_1 should be approximately:

$$I_{CQ1} = 2\left(\frac{V_{BB2} + 1.5\ V}{R_{BB2}} + \frac{V_{BB1} - 1.5\ V}{R_{BB1}}\right)$$

The current supplied to be base of Q_1 should be sufficient to drive Q_1 into saturation for I_{CQ1}.

Test Sequence

1. Adjust V_{BB1}, V_{BB2}, and V_{CC}.
2. Apply single pulses with increasing pulse width until $I_C = I_{C\ max}$ using the specified duty cycle.
3. The transistor is not acceptable if the cutoff state after the pulse cannot be maintained. The duration of the test is only that time adequate to make the reading.
4. Turn off all supplies.

Evaluation:

The device shall still be capable of meeting the specification.

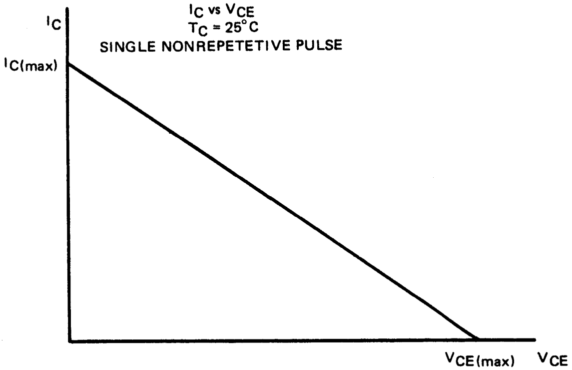


FIGURE 6

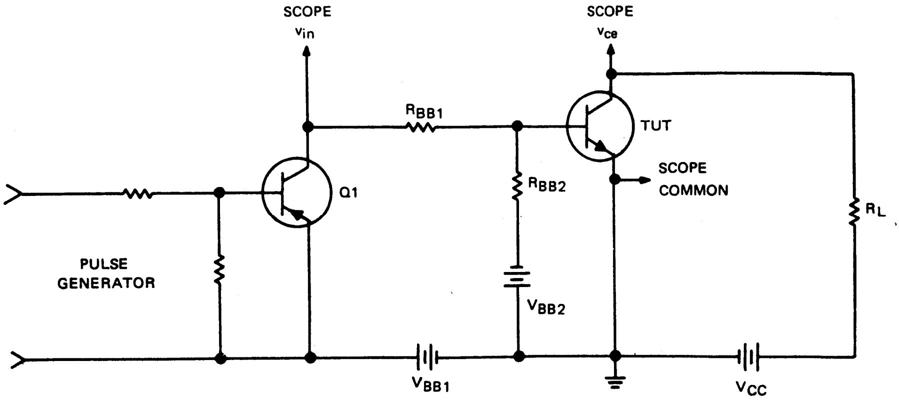


FIGURE 7

Clamped Inductive Load

Presentation

Figure 8 shows the area within which the load line has to be located for safe operation with a clamped inductive load.

Test Circuit

The test circuit in Figure 9 is similar to the one shown in Figure 7 except for the load in the collector circuit. R_{LOAD} represents the total resistive part of the load.

Test Points

By switching through the worst allowable load line during turn off, the Safe Operating Area of Figure 8 can be verified.

Test Precedure:

Test Point Example: $T_C = 25°C$
$I_C = I_{C\,max}$
$V_{CE} = V_{CE9}$
$R_L = R_{L1}$
$L = L_1$
$R_{BB1} = R_{BB1(1)}$
$R_{BB2} = R_{BB2(1)}$
$V_{BB1} = V_{BB1(1)}$
$V_{BB2} = V_{BB2(1)}$
CR = 1NXXXX
$V_{CC} = V_{CE9}$

The collector current capability of Q_1 should be approximately:

$$I_{CQ1} = 2 \left(\frac{V_{BB2(1)} + 1.5\text{ V}}{R_{BB2(1)}} + \frac{V_{BB1(1)} - 1.5\text{ V}}{R_{BB1(1)}} \right)$$

The current supplied to the base of Q_1 should be sufficient to drive Q_1 into saturation for I_{CQ1}.

Test Sequence

1. Adjust V_{BB1} to make $v_{in} = V_{BB1(1)}$, V_{BB2} to $V_{BB2(1)}$, and V_{CC} to V_{CE9}.
2. Apply single pulses with increasing pulse width until $i_c = I_{C\ max}$ with duty cycle as specified.
3. The transistor is not acceptable if the cutoff state after the pulse cannot be maintained. The duration of the test is only that time adequate to make the reading.
4. Turn off all supplies.

Evaluation:

The device shall still be capable of meeting the specification.

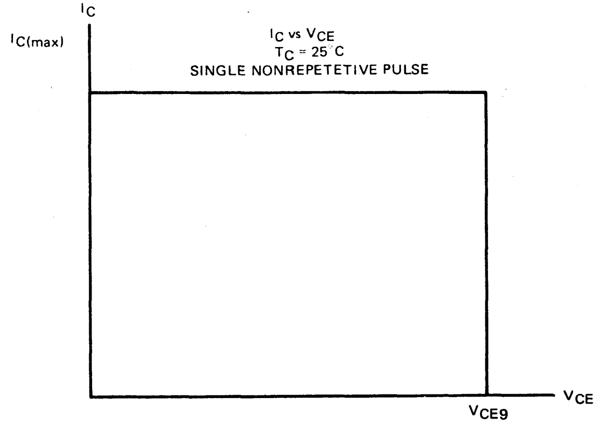


FIGURE 8

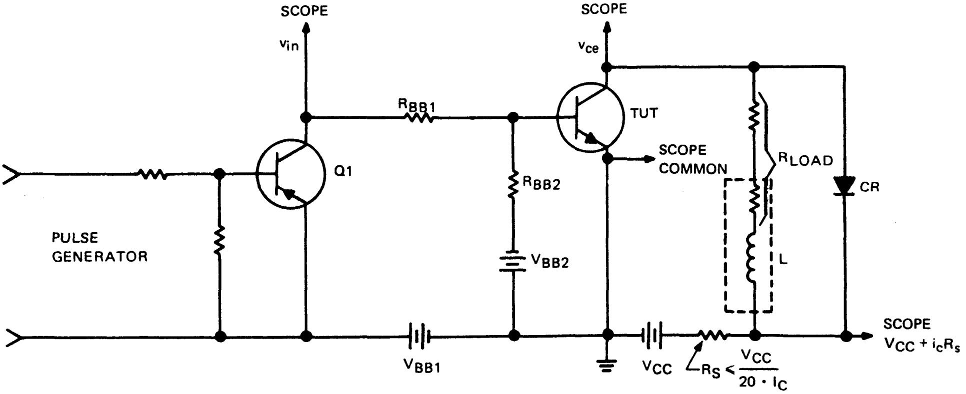


FIGURE 9

Unclamped Inductive Load

Presentation

Figure 10 shows three different areas depending on V_{BB2} and R_{BB2}. The number of areas is arbitrary. The areas are limited by $I_{C\,max}$, curves representing constant energy, $I_C{}^2L/2$, and a reasonable amount of maximum inductance L_1 associated with circuits for which the transistor type is intended for.

Test Circuit

Verification of the Safe Operating Area is performed by switching the transistor from cutoff to saturation to cutoff with a single non-repetitive pulse in the circuit of Figure 11.

Test Points

Testing transistors with I_{C4}, I_{C5}, and I_{C6} and L_1 assures the respective safe operating areas because the capability of absorbing inductive energy increases with increasing collector current. This method derates the capability of a transistor at $I_{C\,max}$ but decreases the amount of testing at higher currents otherwise necessary to verify a curve which attempts to follow the actual capability of the device.

The energy absorbed by the transistor is given by:

$$E_T = E_L + E_S - E_R = \frac{3 \cdot L \cdot I_C{}^2 \cdot V_{(BR)CEX}}{6\ V_{(BR)CEX} - 6\ V_{CC} + 4\ R_L\ I_C}$$

where:

E_L = Inductive Energy Stored in L. $E_L = I_C{}^2L/2$

E_S = Energy from Power Supply During "Turnoff" Transient

E_R = Energy Absorbed by Resistive Component of the Load During "Turnoff" Transient

E_T = Energy Absorbed by Transistor During "Turnoff" Transient.

$V_{(BR)CEX}$ = Breakdown Voltage of Transistor Under Test ($V_{(BR)CEO}$, $V_{(BR)CER}$ or $V_{(BR)CEX}$ – Depending on V_{BB2} and R_{BB2}).

Transistors with $V_{(BR)CEX} \gg V_{CC}$ absorb a lower energy E_T during the test than transistors with $V_{(BR)CEX} \approx V_{CC}$. If the E_T capability of a transistor has to be predicted without knowing $V_{(BR)CEX}$, the following E_T can be absorbed at $T_C = 25°C$ for a single non-repetitive pulse:

$$E_T = \frac{1}{2} L \cdot I_C{}^2$$

It is desirable to choose $V_{CC} \leqslant 15$ V. This tends to decrease damage to transistors which are unable to pass the specified test point.

Test Procedure

Test Point Example: $T_C = 25°C$

$I_C = I_{C4}$

$V_{CC} = V_{CC2} \leqslant 15$ V

$R_L = R_{L2} \leqslant V_{CC2}/2I_{C4}$

$L = L_2$

$R_{BB1} = R_{BB1(2)}$

$R_{BB2} = R_{BB2(2)}$

$V_{BB1} = V_{BB1(2)}$

$V_{BB2} = V_{BB2(2)}$

Determine:

The approximate required pulse-width to reach I_{C4} is given by:

$$t_{p4} = \frac{L_2}{V_{CC}} I_C$$

The collector current capability of Q_1 should be approximately:

$$I_{CQ1} = 2 \left(\frac{V_{BB2(2)} + 1.5\text{ V}}{R_{BB2(2)}} + \frac{V_{BB1(2)} - 1.5\text{ V}}{R_{BB1(2)}} \right)$$

The current supplied to the base of Q_1 should be sufficient to drive Q_1 into saturation for I_{CQ1}.

Test Sequence

1. Adjust V_{BB1} to make $v_{in} = V_{BB1(2)}$, V_{BB2} to $V_{BB2(2)}$, and V_{CC} to V_{CC2}.
2. Apply single pulses with $t_p << t_{p4}$. Increase pulse width until $i_c = I_{C4}$. (Duty cycle should be such that $T_{J(AVG)} \approx 25°C$.)
3. The transistor is not acceptable if the collector-emitter voltage collapses or oscillates during the collector current fall time t_f. The transistor must be capable to maintain $V_{(BR)CEX}$ during t_f within ±10% of $V_{(BR)CEX}$. The duration of the test is only that time adequate to make the reading.
4. Turn off all supplies.

Evaluation:

The device shall still be capable of meeting the specification.

APPLICATION INFORMATION
SAFE OPERATING AREAS FOR POWER TRANSISTORS

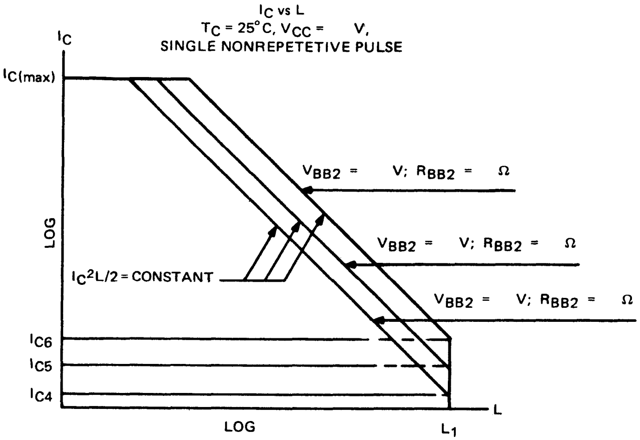


FIGURE 10

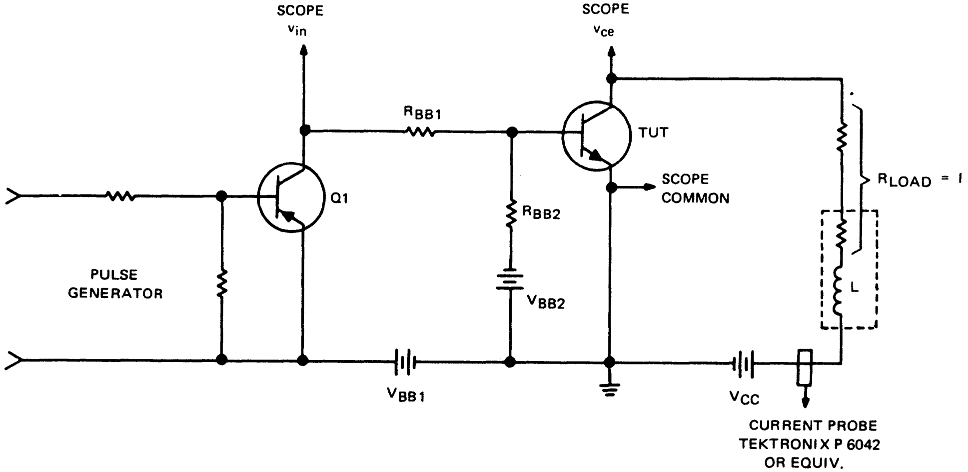


FIGURE 11

Temperature Derating for Pulsed Forward-Biased Operation and Switching

A safe maximum case temperature ($T_C \geqslant 25°C$) for a given I_C and average total power dissipation $P_{T(AVG)}$ due to repetitive pulses can be calculated as follows:

$$T_C \leqslant T_{J\,max} - \frac{I_C}{I_{Cn}} (T_{J\,max} - 25°C) - R_{\theta JC} P_{T(AVG)}$$

T_C = Case temperature

$T_{J\,max}$ = Maximum operating junction temperature.

I_C = Collector current during saturation

I_{Cn} = Maximum allowed collector current at $T_C = 25°C$

$R_{\theta JC}$ = Thermal resistance junction to case

$P_{T(AVG)}$ = Average total power dissipation

C. THERMAL CONSIDERATIONS

Heat Flow

To understand the flow of heat through a solid, it is helpful to use an electrical analogy.

ELECTRICAL TERM	THERMAL TERM
V—Voltage differential [V]	T—Temperature differential [°C]
I—Current [A]	P—Power [W]
R—Resistance [Ω]	R_θ—Thermal resistance [°C/W]

Figure 1 illustrates the thermal circuit as it applies to a semiconductor device dissipating a continuous power into an air-cooled heat sink.

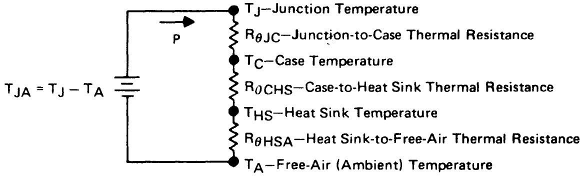


FIGURE 1

The corresponding thermal circuit for a device dissipating continuous power in free air is shown in Figure 2.

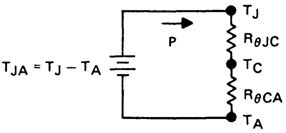


FIGURE 2

The most frequent thermal requirement which must be met is $T_J \leqslant T_{J(max)}$. For a given power dissipation this means the sum of all thermal resistances from junction-to-ambient must be:

$$R_{\theta JA} \leqslant \frac{T_{J(max)} - T_A}{P}$$

Junction-to-Case Thermal Resistance—$R_{\theta JC}$

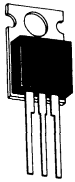
$R_{\theta JC}$ is the temperature difference between the power dissipating junction and a point specified on the case divided by the power dissipation. Most TI power device data sheets specify $R_{\theta JC}$. The case temperature measurement point is shown under "Mechanical Data". Derating should be performed as outlined in SECTION B, Safe Operating Areas for Power Transistors, under "Temperature Derating for Continuous Operation". This is necessary because $R_{\theta JC}$ increases with increasing collector-emitter voltage. Depending on the transistor construction, there is an additional increase or decrease of $R_{\theta JC}$ with increasing collector current. In applying the Safe Operating Area concept, $R_{\theta JC}$ variations with operating point do not have to be considered.

Case-to-Heat-Sink Thermal Resistance—$R_{\theta CHS}$.

$R_{\theta CHS}$ is a function of the following conditions:

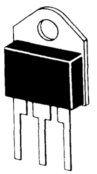
- Torque applied to the machine screw or stud
- Use of thermal compound and type of compound
- Use of insulator and material of insulator
- Flatness of device and heat sink
- Surface finish
- Heat-sink material

The effect of mounting torque as well as insulator material is shown in Figure 3 and Figure 4 for plastic transistors.



PLASTIC REPLACEMENT FOR TO-66

GG



PLASTIC REPLACEMENT FOR TO-3

H

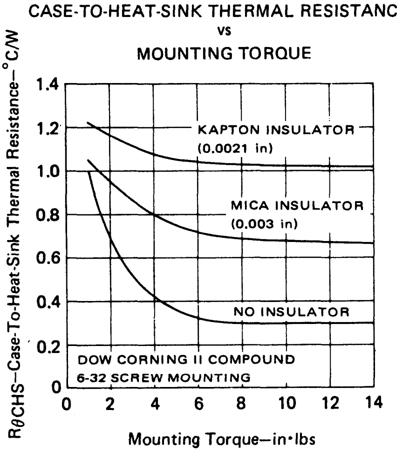


FIGURE 3

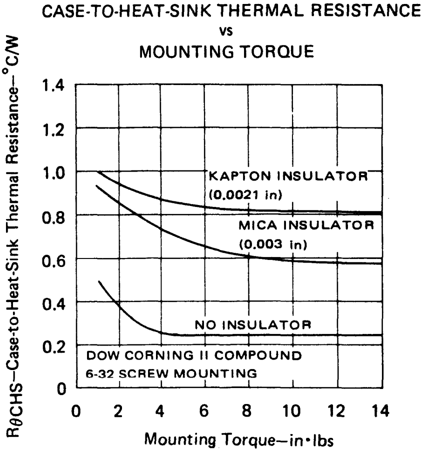


FIGURE 4

Following is a table of $R_{\theta CHS}$ using a mica insulating washer. The heat sink used to determine this value was a smooth, flat, copper plate, with the thermocouple mounted 0.05 inch below the mounting surface in an area beneath the device. The device was mounted using a 2-mil mica washer to a clean, dry, heat-sink surface, without the use of a thermal compound. A torque of ten inch-pounds was applied to the stud or to each of the mounting screws.

PACKAGE	$R_{\theta CHS}$ [°C/W]
TO-3	1.5
TO-53	1.6
TO-59, TO-60, TO-111	3.8
TO-61	1.3
TO-63	1.1

By using a thermal compound, the above thermal resistances can be decreased more than 0.6 °C/W, depending upon the type of compound used.

Case-to-Free-Air Thermal Resistance—$R_{\theta CA}$

$R_{\theta CA}$ is more of a constant than $R_{\theta CHS}$ because $R_{\theta CA}$ is not dependent on so many variables. Most TI power device data sheets specify $R_{\theta JA}$ which is $R_{\theta JC} + R_{\theta CA}$.

Quality and Reliability Information

The Quality Control System

The Quality Assurance organisation at Texas Instruments Ltd. is completely independent of Manufacturing and Marketing. It is approved by a number of external bodies including EQD (Electronic Quality Directorate) for release under DEF STD 05-21 ("6/49") conditions, BSI (British Standards Institution) for BS9000 release, and CAA (Civil Aviation Authority). These bodies from time to time perform detailed audits on the whole QA operation to ensure that standards are being maintained.

Control of product quality is achieved by two main methods, process control and process surveillance. The former is concerned with the measureable quality of the product being made and utilises the conventional lot acceptance and control chart approach to material flowing through the lines. The latter ensures that specifications are properly followed and operators and inspectors adequately trained. These two activities apply to all phases of the manufacturing operation from the wafer diffusion stage through to final test.

The QA department is also responsible for many other aspects of quality control and the facilities include Failure Analysis, Chemical, Environmental and Standards Laboratories. All life testing and burn-in is under the direct control of QA which is responsible for the continual monitoring of product quality and reliability.

Goods inwards inspection and vendor rating is the responsibility of QA and all suppliers must be QA approved before an order can be placed.

A customer drawing register is maintained by QA and no order may be entered unless a current issue of the customer's drawing is available and approved.

New products and significant design or process changes are evaluated by QA and must be documented and approved before implementation.

QUALITY AND RELIABILITY INFORMATION
PRODUCT RELIABILITY DATA

Single-Diffused Plastic Power Transistors

TIP29-TIP32, TIP41, TIP42

BACKGROUND

Texas Instruments continuing Plastic Single-Diffused Reliability Program, an evaluation program for plastic power devices, has resulted in lowering device failure rates. All devices utilized in the reliability program are standard product "off-the-shelf" devices which have received no special screening or electrical tests. Since starting the reliability program we have generated over 500,000 actual life-test hours. Over 15,000 devices have undergone testing in the reliability program. Failures are based on leakage greater than twice the data sheet limit, h_{FE} outside data sheet limits by 20%, or $V_{CE(sat)}$ above data sheet limits. For the test environments listed below, MIL-STD-750 was used as the applicable test specification.

1. Mechanical Shock, Method 2016.
2. Vibration, Variable-Frequency, Method 2056.
3. Constant Acceleration, Method 2006.
4. Thermal Shock, Method 1056, Condition B.
5. Temperature Cycling, Method 1051.
6. Moisture Resistance (non-operating), Method 1021.
7. Humidity with Bias, $T_A = 85°C$, RH = 85% $V_{CES} = 45$ V.
8. Humidity $T_A = 65°C$, RH = 100%.
9. Pressure Cooker, $T_A = 121°C$, 15 psi.
10. Solderability, Method 2026.
11. Salt Atmosphere, Method 1041.
12. Terminal Strength, Method 2036, Condition A.
13. Storage Life, Method 1032, $T_A = 150°C$.
14. Operating Life, Method 1026, $T_A = 25°C$, P = 2 watts.
15. Intermittent Operating, Method 1037, $\Delta T_C = 60°C$, P = 1.8 watts, 5 minutes on, 5 minutes off.

LIFE TEST EVALUATIONS

Test devices employed in this evaluation were subjected to operational, intermittent operational, and storage life test conditions that were selected to demonstrate device capability in excess of normal operating requirements. The operating life test circuits used for testing power devices are in the parallel, common-base configuration. Voltage is applied collector to base. A resistor is in series with the emitter, dropping at least 10% of the collector-base voltage to set the emitter current. For intermittent operating tests, the same circuit is used with the power being interrupted at specific time intervals.

Table 1-1
Summary of Life Testing for NPN Devices

Test Description	Number of Devices	Device Hours	Number of Failures	Failure Rate X10^{-5}	
				Point Est.	60% Conf.
150°C Storage	50	100,000	0	0	0.9
25°C Operating	140	212,500	2	0.9	1.4

Table 1-2
Summary of Life Testing for PNP Devices

Test Description	Number of Devices	Device Hours	Number of Failures	Failure Rate X10^{-5}	
				Point Est.	60% Conf.
150°C Storage	49	73,500	3	4.1	5.6
25°C Operating	50	62,500	3	4.8	6.5

Table 1-3
Summary of Intermittent Life Testing For NPN Devices

Test Description	Number of Devices	Device Cycles	Number of Failures	Failure Rate X10^{-5}	
				Point Est.	60% Conf.
Δ 60°C Interm. Operating	88	880,000	0	0	0.1

ENVIRONMENTAL TESTING

Environmental evaluations are performed on power devices in order to establish capability for the mechanical and thermal stresses considered to be standard in the electronics industry. Sequential or step-stress testing is likewise employed to demonstrate package reliability in excess of standard product requirements. A brief description of test procedures follows:

1. Mechanical Shock – Performed from 1500 g to 6000 g in three orientations for 0.2 ms to 0.5 ms duration: 5 blows/plane, 15 blows total (non-operating).
2. Vibration, Variable Frequency – Performed from 20 g to 60 g in three orientations at 100 Hz to 2000 Hz (non-operating); 4 sweeps/plane, 4 minutes/sweep.
3. Constant Acceleration – Performed from 10,000 g to 40,000 g in six orientations; 1 minute/plane.
4. Thermal Shock–Performed from 0°C to 100°C for 50 cycles. Extreme times are 5 minutes with a maximum transfer time of 10 seconds. Liquid to liquid.
5. Temperature Cycle – Performed from −65°C to 150°C for 100 cycles. Extreme times are 30 minutes with a maximum transfer time of 5 minutes.
6. Temperature Cycle – Performed from −55°C to 125°C for 15 cycles. Extreme times are 10 minutes with a maximum transfer time of 5 minutes.

   Thermal Shock – Performed in freezer at −30°C and boiling water. Extreme times are 10 minutes with immediate transfer.

   Power Surge – Performed by storing at −45°C for 20 minutes and then applying maximum rated power for 1 minute. Total of 15 cycles.

   Humidity – Performed by placing devices in humidity chamber at 40°C with 95% relative humidity for 96 hours.
7. Moisture Resistance – Performed in a non-operating state with the preconditioning omitted. Temperature cycling chamber conditions:
   25°C for 5 hours.
   65°C for 5 1/2 hours.
   Chamber maintained at 90 to 98% relative humidity, −10°C chill excursion on all test cycles.
8. Humidity with Bias – Performed by placing devices in humidity chamber at 85°C with 85% relative humidity for 200 hours. A V_{CES} of 45 V is applied to each device.
9. Humidity – Performed by placing devices in humidity chamber at 65°C with 100% relative humidity for 200 hours.
10. Pressure Cooker – Performed by placing devices in sealed chamber with 100% relative humidity at 121°C. Air pressure applied at 15 psi over atmosphere. Test repeated in 8-hour increments.
11. Solderability – Performed by dipping leads into type-W flux at 25°C to within 0.05 inches of case for a period of 5 to 10 seconds. Leads then dipped in molten solder at 230°C ± 15°C to within 0.05 inches of case at rate of 1 ± 1/4 inches per second for a period of 5 ± 1/2 seconds.
12. Salt Atmosphere – Performed by exposing devices to 35°C fog environment. Test duration: 72 hours (initial conditioning omitted). DC electrical test and visual examination endpoints.
13. Terminal Strength – Performed by attaching a 5-ounce weight to each external lead at a distance of 1/16 inch from case. A force is applied once in each of the 2 mutually perpendicular directions (90° + 10° −0°). Test duration: 3 bending cycles.

SUMMARY

The Plastic Single-Diffused Reliability Program was designed to establish reliability data for encapsulated devices for commercial and consumer applications. The results of the tests show that these devices can also be used in military applications.

To obtain this objective over 15,000 transistors have undergone tests. Over 500,000 life-test hours have been accumulated. Detailed results have been listed in this report with summaries of the test procedures and conditions. If further information is required, please contact your nearest TI sales office or address inquiries to Texas Instruments Incorporated, Quality Reliability Assurance, Power Dept., Mail Station 2, P.O. Box 5012, Dallas, Texas 75222.

Table 2-1
Summary of Mechanical-Stability Testing for Both PNP and NPN Devices

Test No.	Test Description	Number of Devices	Failures
(1)	Mechanical Shock		
	1500 g, 0.5 ms	24	0
	3000 g, 0.5 ms	24	0
	6000 g, 0.3 ms	24	0
(2)	Vibration, Var. Freq.		
	20 g	25	0
	30 g	25	0
	40 g	25	0
	50 g	25	0
	60 g	25	0
(3)	Constant Acceleration		
	10,000 g	24	0
	15,000 g	24	0
	20,000 g	24	0
	30,000 g	24	0
	40,000 g	24	0

NOTE: Stressing in each category is sequential. For example, the devices stressed on shock at 6000 g were pre-stressed on shock at 3000 g.

Table 3-1
Summary of Thermal-Stability Testing for Both PNP and NPN Devices

Test No.	Test Description	Number of Devices	Failures
(4)	Thermal Shock (0° C to +100° C)		
	10 cycles	25	0
	20 cycles	25	0
	30 cycles	25	0
	40 cycles	25	0
	50 cycles	25	0
(5)	Temp Cycle (−65° C to +150° C)		
	50 cycles	75	0
	100 cycles	75	0
(6)	Environmental Test Sequence		
	Temperature Cycle	15	0
	Thermal Shock	15	0
	Power Surge	15	0
	Humidity	15	0

Table 4-1
Summary of Humidity Testing for Both PNP and NPN Devices

Test No.	Test Description	Number of Devices	Failures
(7)	Moisture Resistance		
	10 cycles	25	0
	20 cycles	25	0
	30 cycles	25	1*
(8)	Humidity with Bias	50	0
(9)	Humidity	50	0
(10)	Pressure Cooker		
	8 hours	25	0
	16 hours	25	0
	24 hours	25	0
	32 hours	25	0

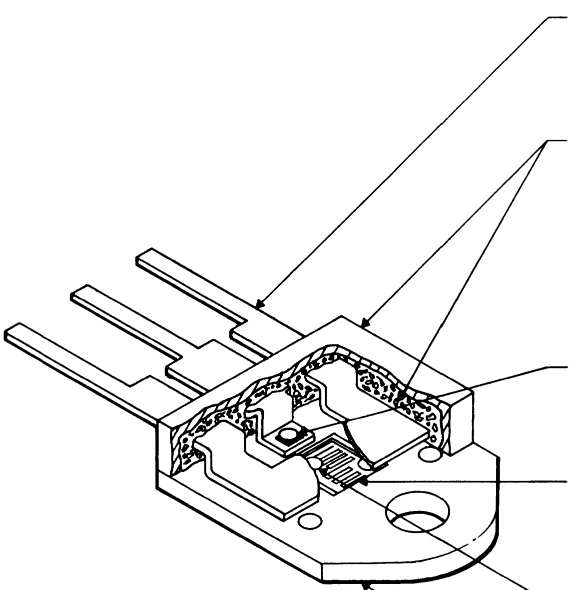
*I_{CES} failure, read 423 μA, limit is 400 μA.

Table 5-1
Summary of Solderability, Salt-Atmosphere, and Terminal-Strength Testing for Both PNP and NPN Devices

Test No.	Test Description	Number of Devices	Number of Failures		
			Electrical	Visual	Mechanical
(11)	Solderability	50	0	0	N/A
(12)	Salt Atmosphere	50*	0	0	0
(13)	Terminal Strength	36	0	N/A	0

*For salt atmosphere, a visual failure is for marking and a mechanical failure is for corrosion.

Advanced design for greater reliability:



SOLDER-CLAD, COPPER LEADS FACILITATE SOLDERABILITY.

PLASTIC CAP AND EPOXY FILL ARE FEATURES OF THE NEW DESIGN WHICH RESULT IN AN UNSTRESSED INTERNAL CONSTRUCTION WITH ALL LEADS LOCKED SOLIDLY INTO THE PACKAGE.

PINNED AND SOLDERED COLLECTOR LEAD ELIMINATES INTERMITTENT COLLECTOR LEAD PROBLEMS.

GLASS-PASSIVATED CHIP IMPROVES MOISTURE RESISTANCE, PROVIDES LOWER LEAKAGE AND BETTER STABILITY.

ALL-SOLDERED CONTACTS INCREASE LEAD CONNECTION RELIABILITY BY IMPROVING RESISTANCE TO THERMAL SHOCK AND VIBRATION.

NICKEL-PLATED, COPPER HEAT SINK IMPROVES THERMAL SINKING CAPACITY.

QUALITY AND RELIABILITY INFORMATION
HIGH RELIABILITY OPTION

HIGH RELIABILITY OPTION FOR POWER SEMICONDUCTORS

It is generally accepted that reliability must be built into, rather than tested into, a product. Nevertheless there will always be a small percentage of devices – potential early failures – which can cause considerable problems in critical applications. Most of these devices can be removed by well designed screening programmes. Through our High-Rel department Power Semiconductors are available tested to several different levels of screening.

THE ADVANTAGES OF SPECIAL SCREENING

The distribution of failures in time is not random the failure rate being significantly higher during early life. Because of the comparatively low level of semiconductor failures the actual form of the failure rate vs time curve is difficult to establish precisely but most authorities agree that the conventional "bath-tub" curve shown in fig. 1 is appropriate to semiconductors.

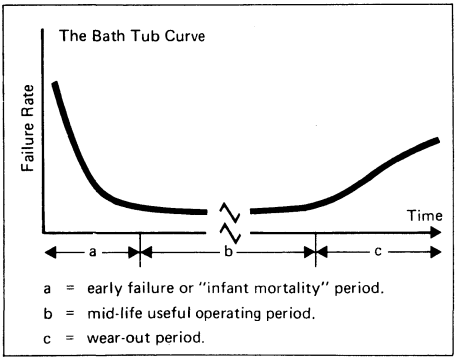


Fig. 1.

A relatively high initial failure rate ("infant mortality") is followed by a long period of constant failure rate Eventually wear-out mechanisms begin to operate causing a steep rise in the curve. Overstress studies have shown that under normal operating conditions, the wear-out phase will not occur during the life time of most equipments. We will therefore confine ourselves to a consideration of periods (a) and (b) in fig. 1.

The shape of this part of the curve has been confirmed by reliability studies carried out by Texas Instruments Ltd on discrete devices involving over 35 million operating hours at maximum ratings. By burning in components for a time comparable to period (a) the initial failure rate of delivered product can be substantially reduced.

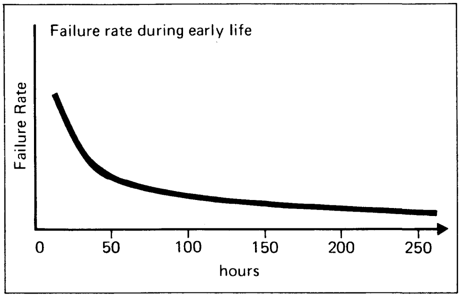


Fig. 2.

At maximum ratings the failure rate v time curve early in life usually takes the form shown in fig. 2.

Under the conservative stresses encountered in well designed equipment the time scale will be greatly extended, but even at maximum ratings the failure rate is still decreasing at 250 hours and beyond. Indeed it can continue to decrease for 1000 hours or more. It is obviously not economic to use such a long burn-in duration. The cost of burn-in must be balanced against its effectiveness.

In general by 48 hours 30% of all potential failures have occurred if data sheet limits are used to define a failure, but by applying the statistical preconditioning techniques described in section 7 of appendix I a further 10% or more of potential drift failures can also be removed although at the 48 hour point they are still within data sheet limits.

Burn-in screening removes both early inoperative failures and devices prone to severe parameter degradation such as could result from poor sealing, the presence of contamination or localised material faults. During middle life, (period (b) of fig. 1) many of the random failures are catastrophic in nature and arise from assembly faults. Analysis of the data available has indicated that 50 to 60% of middle life failures can be removed by comprehensive pre-encapsulation screening and a further 15% by the mechanical screening sequence of temperature cycling and high impact shock or centrifuge followed by fine and gross leak test.

The most cost effective screening will depend on the intended application. Where high fault-finding costs are incurred due to early failures during the commissioning of complex equipments, burn-in alone can offer substantial savings. If the equipment is required to operate reliably for long periods or is relatively inaccessible for maintenance there is an advantage in adding pre-encapsulation and mechanical screening. The variety of options which are offered should enable each discriminating user to select the one most appropriate to his unique requirements.

TABLE 1. SCREENING OPTIONS FOR TRANSISTORS

LEVEL A

Process	Reference paragraph
Standard assembly	1
Stabilisation bake, 24 hours 150° C	6
Test and QA lot acceptance	4
Distribution measurement	7
Reverse bias burn in 48 hours 150° C	15
Attribute measurement	17
Sample solderability	20
QA final acceptance	21
STOCK	

LEVEL B

Process	Reference paragraph
Standard assembly	1
Stabilisation bake, 24 hours 150° C	6
Test and QA lot acceptance	4
Stabilisation bake, 24 hours 150° C	6
Distribution measurement	7
Temp cycling 5 cycles −55° C to +150° C	8
High impact shock or centrifuge	9
Fine leak	11
Gross leak	12
Reverse bias burn in 48 hours 150° C	15
Attribute measurement	17
Sample solderability	20
QA final acceptance	21
STOCK	

LEVEL C

Process	Reference paragraph
Special assembly	2
Pre-cap visual inspection	3
Stabilisation bake, 48 hours 150°C	6
Test and QA lot acceptance	4
Distribution measurement	7
Reverse bias burn in 48 hours 150°C	15
or	
Operating burn in at rated power, 48 hours	16
Attribute measurement	17
Sample solderability	20
QA final acceptance	21
STOCK	

QUALITY AND RELIABILITY INFORMATION
HIGH RELIABILITY OPTION

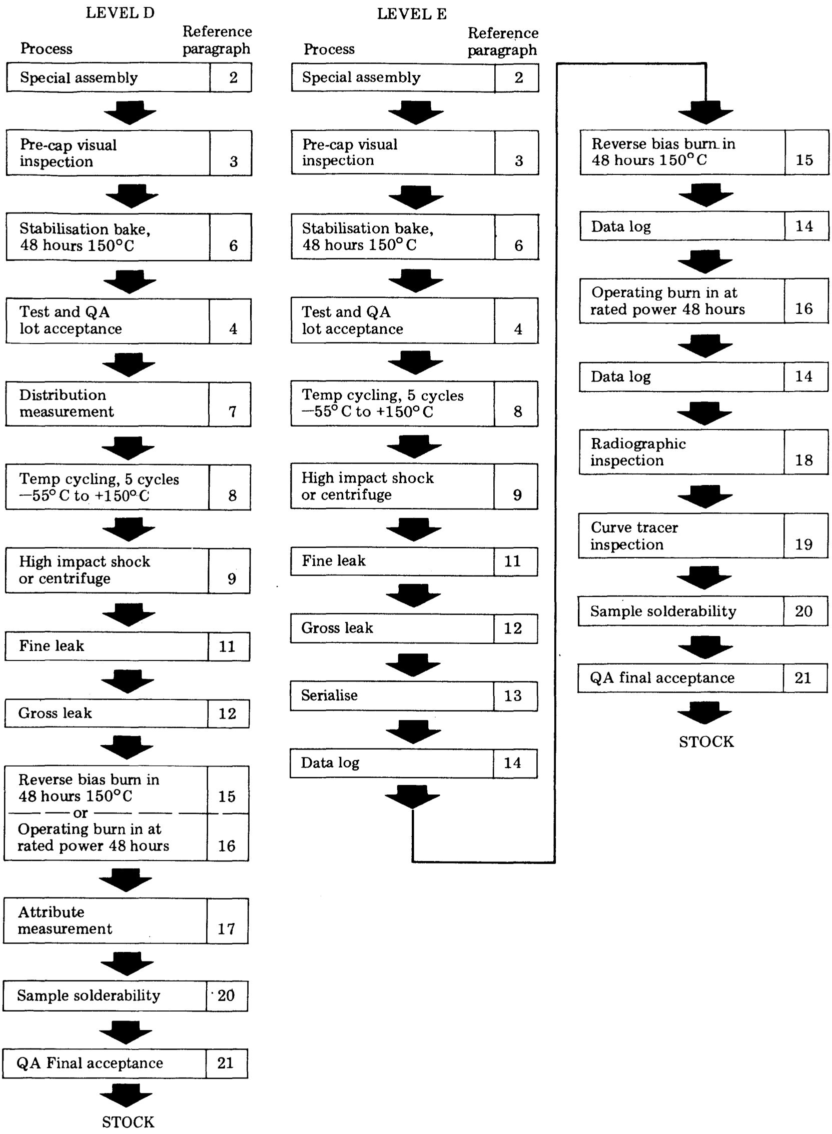


TABLE 2. SCREENING OPTIONS FOR METAL CASE RECTIFIERS REGULATORS AND THYRISTORS

LEVEL A

Process	Reference paragraph
Standard assembly	1
Stabilisation bake 48 hours 150°C	6
Test and QA lot acceptance	4
Distribution measurement	7
Operating burn in at rated power 48 hours	16
Attribute measurement	17
Sample solderability	20
QA final acceptance	21
STOCK	

LEVEL B

Process	Reference paragraph
Standard assembly	1
Stabilisation bake 24 hours 150°C	6
Test and QA lot acceptance	4
Stabilisation bake 24 hours 150°C	6
Distribution measurement	7
Temp cycling, 5 cycles −55°C to +150°C	8
Fine leak	11
Gross leak	12
Operating burn in rated power 48 hours	16
Attribute measurement	17
Sample solderability	20
QA final acceptance	21
STOCK	

LEVEL C

Process	Reference paragraph
Standard assembly	1
Stabilisation bake 24 hours 150°C	6
Test and QA lot acceptance	4
Stabilisation bake 24 hours 150°C	6
Temp cycling, 5 cycles −55° C to +150° C	8
Fine leak	11
Gross leak	12
Serialise	13
Data log	14
Reverse bias burn in 48 hours 150°C	15
Data log	14
Operating burn in at rated power 48 hours	16
Data log	14
Radiographic inspection	18
Curve tracer inspection	19
Sample solderability	20
QA final acceptance	21
STOCK	

QUALITY AND RELIABILITY INFORMATION
HIGH RELIABILITY OPTION

EXPLANATION OF SCREENING METHODS AND PROCESSING

Details of the screening and conditioning tests referenced by the flow charts, tables 1 and 2, are given below. As far as possible these will be followed exactly, but in some circumstances it may be necessary to modify these slightly, but such changes will first be agreed with the customer.

1. Standard assembly
Unless otherwise indicated, product is derived from standard production and subjected to post encapsulation screening tests. All the assembly operations are under continual surveillance by QA, while the QA controls themselves are regularly audited by EQD (see Appendix II).

2. Special assembly
Small signal planar transistors are assembled in a separate clean area under closely controlled conditions and employing highly trained operators. Emphasis is on quality of work rather than volume of throughput. Special assembly is not available for high power or silicon alloy transistors.

3. Pre-encapsulation visual inspection
This is designed to ensure a high standard of visual quality and is backed up by stringent quality controls. Special attention is paid to quality of bonding and alloying, control of length and position of internal connecting wires, positioning of wafer, freedom from metallisation defects, foreign matter and physical damage.
This inspection is performed in accordance with the applicable sub-section of RRE specification X6487 section 2.

4. Test and QA lot acceptance
All major parameters are screened by the product group and verified by QA sample testing. Typical inspection levels and AQL's are:

Inoperatives, Inspection level II, AQL 0.25%

Major parameters, Inspection level II, AQL 0.65%

Minor parameters, Inspection level II, AQL 2.5%

5. Post seal visual inspection
This inspection is used for glass diodes for which pre-encapsulation inspection is not appropriate. It is used to screen out devices exhibiting physical damage, poor sealing, misalignment and foreign particles.

6. Stabilisation bake
The normal manufacturing procedure is to subject metal case devices to a bake at 150°C for 24 hours prior to final test in order to stabilise parameters. This is not carried out on glass diodes since they are furnace sealed. For the higher levels of special screening of metal case devices the total duration is increased to 48 hours, either by performing an additional 24 hour bake between QA lot acceptance and distribution measurement or by increasing the pre-test duration to 48 hours. In the case of glass diodes levels B and C, the bake takes place after QA lot acceptance and is of 24 hours duration. The tests are carried out in accordance with BS9300 section 1.2.6.2.1. and RRE/X6487 section 3.

7. Distribution measurement (statistical preconditioning)
This procedure is used to determine post test end points such that devices which are likely to drift excessively in service are removed. Using a sample of 125 devices or 100% of the batch, whichever is the lesser, measurements are recorded of one or two key parameters, e.g. current gain and leakage current for transistors, or forward voltage drop and reverse leakage current for diodes. By this means the natural distribution of the parameter is defined. Post test end points are set in such a way as to screen out not only those devices which drift excessively but also those while, while meeting data sheet limits, may be considered as abnormal because their values fall outside the main distribution. This is achieved by applying the following rules:

a. Leakage currents
The limit must be no slacker than the tightest of the following:

i. The upper specification limit

ii. 2 x the "Higher end of the main distribution".

iii. The value corresponding to half the difference between the highest value measured during statistical pre-conditioning and the upper specification limit.

Note (ii) and (iii) only apply if more than 10nA otherwise use 10nA. Where data sheet limit is also 10nA inset to 9nA.

b. Current gain h_{FE} or h_{fe}, upper limit
The limit must be no slacker than the tightest of

i. As 1 (i)

ii. As 1 (iii)

iii. +20% above the "End of the main distribution".

c. Current gain h_{FE} or h_{fe}, lower limit
The limit must be no slacker than the tightest of

i. The lower specification limit

ii. The value corresponding to half the difference between the lowest value measured during statistical pre-conditioning and the lower specification limit.

iii. 20% below the "End of the main distribution".

d. Forward voltage drop (V_F) Upper Limit
The limit must be no slacker than the tightest of

i. The value corresponding to half the difference between the highest value measured during statistical pre-conditioning and the lower specification limit.

ii. 10% above the "End of the main distribution".

These rules are in accordance with, and slightly more stringent than those defined in section 3 of RRE specification X6487.

8. Temperature cycling
Poor bonding or alloying will be further weakened and cracks in seals deepened by temperature cycling so that devices with such faults will be subsequently eliminated by the high g stress or hermetic seal tests.
The devices are subjected to 5 cycles over the range −55°C to +150°C with a duration of 15 minutes minimum at each temperature extreme, the transition time between extremes not exceeding 5 minutes. The test is carried out in accordance with RRE/X6487 section 3.

9. High impact shock/centrifuge
To ensure that mechanically poor transistors – i.e. potential open circuits, are screened out, devices are subjected to tests at high g level in order to disrupt weak bonds or alloying. The direction of the acceleration is such as would tend to pull the wafer off the header or the bonds off the bonding pads. Small signal transistors are normally subjected to the high impact shock (airgun) test – 1 blow of 20,000 g (196Km/sec^2) in the Y_1 direction for devices where the wafer is mounted directly on to the header, or 10,000 g for all other types (see RRE/X6487 section 3.1.4.)
In special cases, including all transistors in outlines larger than TO-5, centrifuge for a duration of one minute in the Y_1 direction may be substituted for the airgun test. The acceleration is 10,000 g (98KM/sec^2) except for devices in TO-5 or smaller outline with the wafer mounted directly on to the header where the acceleration is increased to 20,000 g (196Km/sec^2).
This test is in accordance with BS9300 section 1.2.6.6.

10. Hermetic seal (glass diodes)
The diode is immersed in a fluorescent dye at 25°C for 3 hours minimum at 400KN/m^2 (58 p.s.i.) min., and then examined under ultraviolet light at a magnification of 5 x minimum. Diodes are rejected if they fluoresce in the cavity or more than 20% along the glass-to-plug seal from the lead wire end. This is in accordance with RRE/X6487 section 3.5.4.

11. Fine leak
The test is performed either in accordance with MIL-STD-750 method 1071.1 condition H (helium mass spectrograph) or condition G (radio active krypton method) with a limit of 1×10^{-7} cc/sec max.

12. Gross leak (fluorocarbon method)
The devices are pressurised in a liquid of low boiling point (50°C max.) at 25°C to 58 p.s.i. (400KN/m^2) for at least 3 hours. They are transferred to a liquid of high boiling point maintained at 125°C. Bubbles from a specimen indicate a failure. This test is in accordance with MIL-STD-750 method 1071.1 condition C except for the pressure level.

13. Serialise
Devices will be allocated serial numbers for use during data logging. If required the serial numbers may be retained to enable the customer to identify the device against the data logged results.

14. Data logging
Devices exhibiting undue parameter drift during process conditioning present a possible reliability hazard. By recording measurements of sensitive parameters before and after operating or reverse bias burn-in it is possible to remove those showing excessive drift. Typically, drift of a small signal transistor would be considered unacceptable if a change in leakage current exceeded 5nA or a change in current gain exceeded 15%.

15. Reverse bias burn-in
Reverse bias burn-in is particularly effective in detecting devices which are prone to inversion which is responsible for high leakage currents. The conditions used are as follows:

Glass diodes – 48 hours minimum at 75 to 85% of rated voltage at a temperature of 100°C.

Metal case rectifiers – 48 hours minimum at 75 to 85% of rated voltage at a temperature of 150°C.

Transistors – 48 hours minimum at 75 to 85% of V_{CB} or V_{GS} rating at a temperature of 150°C.

N.B. For power transistors, operating burn-in is sometimes substituted for reverse bias storage. Regulators and reference diodes are not normally subjected to reverse bias storage. Burn-in is substituted, since under reverse power dissipation conditions reverse voltage stress is continuously applied (see Section 16 below).
These tests are generally in accordance with RRE/X6487 section 3 except for the test duration for PNP transistors where X6487 calls for 72 hours.

16. Operating burn-in

This is intended to simulate the worse case conditions likely to be met in service, and is designed to remove those rogue failures which are responsible for "infant mortality". Bipolar transistors are normally burnt-in at maximum rated power at an ambient temperature of 25°C, with V_{CB} at 75% to 85% of rating. Burn-in duration is 48 hours minimum. This test is in accordance with BS9300 section 1.2.7.6.1.

Field effect transistors are not normally subjected to operating burn-in. Instead reverse bias storage at high temperature is substituted (see section 15).

Diodes and rectifiers are burnt-in for 48 hours at maximum rated P.I.V. and the maximum rated average forward current in accordance with BS9300 section 1.2.7.4. Regulators and reference diodes are operated in the reverse dissipation mode at the maximum rated dissipation for a minimum of 48 hours in accordance with BS9300 section 1.2.7.3.

17. Attribute measurement

After burn-in devices are retested on key parameters and rejected if they fail to meet the limits established during distribution measurement (see section 7).

18. Radiographic inspection

This provides a check on the internal connections, positioning of the semiconductor element and incidence of foreign particles and is performed in accordnace with MIL–STD-750 method 2076.

19. Curve tracer inspection

Reverse junction characteristics are examined on a curve tracer and devices with abnormal, soft or unstable breakdowns are rejected.

20. Sample solderability

At the completion of all conditioning tests a sample is checked for solderability in accordance with BS9300 1.2.6.10. using inspection level S4 AQL 4.0%.

21. QA Final acceptance

After devices have completed all the prescribed processing, the last step before they are packaged and shipped is a QA sample inspection to ensure electrical, mechanical and processing integrity. AQLs and inspection levels are similar to those referenced in section 4.

Further information on High Reliability products is available from: High-Rel Department, Texas Instruments Ltd., Manton Lane, Bedford, MK41 7PA or your local Texas Instruments Sales Office.