ALPHANUMERIC INDEX — CROSS-REFERENCE (Continued)

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KSB772		MJE170	3-862
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KSB795		MJE703	3-888
KSB834		2N6125	3-154
KSC1507		MJE2360T	3-900
KSC1520		MJE3440	3-908
KSC1520A		MJE2360T	3-900
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KSC2233		TIP41C	3-1083
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KSC2688		MJE3439	3-908
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KSC2749		MJH16008	3-742
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KSD288		TIP41A	3-1083
KSD362		D44H11	3-518
KSD363		MJE15028	3-972
KSD401		MJE15030	3-972
KSD526		2N6122	3-154
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KSD819		MJH16032	3-984
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KSD868		MJH16032	3-984
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MJ10009	MJ10009		3-588
MJ1001	MJ1001		3-528
MJ10011	MJ10011		3-594
MJ10012	MJ10012		3-596
MJ10013	MJ10014		3-600
MJ10014	MJ10014		3-600
MJ10015	MJ10015		3-606
MJ10016	MJ10016		3-606
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MJ10021	MJ10021		3-611
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MJ11012	MJ11012		3-629
MJ11013	MJ11013		3-629
MJ11014	MJ11014		3-629
MJ11015	MJ11015		3-629
MJ11016	MJ11016		3-629
MJ11017	MJ11017		3-631
MJ11018	MJ11018		3-631
MJ11019	MJ11019		3-631
MJ11020	MJ11020		3-631
MJ11021	MJ11021		3-631
MJ11022	MJ11022		3-631
MJ11028	MJ11028		3-635
MJ11029	MJ11029		3-635
MJ11030	MJ11030		3-635
MJ11031	MJ11031		3-635
MJ11032	MJ11032		3-635
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MJ12020	MJ12020		3-660
MJ12021	MJ12021		3-660
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MJ13080	MJ13080		3-682
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*Consult Motorola if a direct replacement is necessary.

TABLE 1 — METAL TO-204, TO-204AE (continued)

I_CCont Amps Max	$V_{CEO(sus)}$ Volts Min	Device Type NPN	Device Type PNP	h_{FE} Min/Max	@ I_C Amp	Resistive Switching t_s µs Max	Resistive Switching t_f µs Max	Resistive Switching @ I_C Amp	f_T MHz Min	P_D (Case) Watts @ 25°C
10	250	MJ15011	MJ15012	20/100	2					200
	300	MJ3041##		250 min	2.5					175
	325	MJ413		20/80	0.5				2.5	125
		MJ423		30/90	1				2.5	125
		MJ431		15/35	2.5				2.5	125
	350	BU323##		150 min	6	7.5 typ	5.2 typ	6		175
		MJ3042##		250 min	2.5					175
		MJ13014		8/20	5	2	0.5	5		150
		MJ10002##		3/300	5	2.5	1	5	10#	150
		MJ10006##		30/300	5	1.5	0.5	5	10#	150
	400	BU323A##		150 min	6	7.5 typ	5.2 typ	6		175
		MJ10007##		30/300	5	1.5	0.5	5	10#	150
		MJ10012##		100/2k	6	15	15	6		175
		MJ13015		8/20	5	2	0.5	5		150
	600	MJ10014##		10/250	10	2.5	0.8	10		175
	700	MJ8504		7.5 min	1.5	4	2	5		175
	800	MJ8505		7.5 min	1.5	4	2	5		175
		MJ16018		4 min	5	4.5 typ	0.2 typ	5		150
	950*	MJ12010		4.2 min	5		1	5		100
12	60	2N6057##	2N6050##	750/18k	6	1.6 typ	1.5 typ	6	4#	150
	80	2N6058##	2N6051##	750/18k	6	1.6 typ	1.5 typ	6	4#	150
	100	2N6059##	2N6052##	750/18k	6	1.6 typ	1.5 typ	6	4#	150
15	60	2N3055	MJ2955	20/70	4	0.7 typ	0.3 typ	4	2.5	115
		2N3055A	MJ2955A	20/70	4				0.8	115
		2N6576##		2k/20k	4	2	7	10	10–200#	120
		2N5881	2N5879	20/100	6	1	0.8	6	4	160
	80	2N5882	2N5880	20/100	6	1	0.8	6	4	160
	90	2N6577##		2k/20k	4	2	7	10	10-200#	120
	120	MJ15015	MJ15016	20/70	4				1	180
		2N6578##		2k/20k	4	2	7	10	10-200#	120
	140	MJ15001	MJ15002	25/150	4				2	200
	150	MJ11018##	MJ11017##	100 min	15				3#	175
	200	BUX41		8 min	8	1.5	0.4	8	8	120
		2N6249		10/50	10	3.5	1	10	2.5	175
		MJ11020##	MJ11019##	100 min	15				3#	175
	250	MJ11022##	MJ11021##	100 min	15				3#	175
	275	2N6250		8/50	10	3.5	1	10	2.5	175
	300	2N6546		6/30	10	4	0.7	10	6 to 24	175
	325	BUX13		8 min	8	2.5	0.8	8	8	150
	400	BUX48		8 min	10	2	0.4	10		175
		2N6547		6/30	10	4	0.7	10	6 to 24	175
		MJ13090		8 min	10	2.5	0.5	10		175
		MJ16110		6/20	15	0.8 typ	0.1 typ	10		175
	450	BUX48A		8 min	8	2	0.4	10		175
		MJ16010		5 min	15	1.2 typ	0.2 typ	10		175

* $V_{(BR)CEX}$, # $|h_{fe}|$ @ 1 MHz, ## Darlington

(continued)

☐ JAN, JTX, JTXV Available

TABLE 12 — POWER DARLINGTONS (continued)

I_C Cont Amps Max	$V_{CEO(sus)}$ Volts Min	Device Type NPN	Device Type PNP	h_{FE} Min/Max	@ I_C Amp	Resistive Switching t_s μs Max	Resistive Switching t_f μs Max	Resistive Switching @ I_C Amp	$\|h_{fe}\|$ @ 1 MHz Min	P_D (Case) Watts @ 25°C	Case JEDEC/MOT
10	400	MJ10012		100/2k	6	15	15	6		175	TO-204/1
	600	MJ10014•		10/250	10	2.5	0.8	10		175	TO-204/1
12	60	2N6057	2N6050	750/18k	6	1.6 typ	1.5 typ	6	4	150	TO-204/1
	80	2N6058	2N6051	750/18k	6	1.6 typ	1.5 typ	6	4	150	TO-204/1
	100	2N6059	2N6052	750/18k	6	1.6 typ	1.5 typ	6		150	TO-204/1
	1000	BUT16•		5 min	8	3.3	1.5	8		150	TO-204/1
15	60	2N6576		2k/20k	4	2	7	10	10/200	120	TO-204/1
	90	2N6577		2k/20k	4	2	7	10	10/200	120	TO-204/1
	120	2N6578		2k/20k	4	2	7	10	10/200	120	TO-204/1
	150	MJ11018 MJH11018	MJ11017 MJH11017	100 min 100 min	15 15				3 3	175 150	TO-204/1 TO-218/340
	200	MJ11020 MJH11020	MJ11019 MJH11019	100 min 100 min	15 15				3 3	175 150	TO-204/1 TO-218/340
	250	MJ11022 MJH11022	MJ11021 MJH11021	100 min 100 min	15 15				3 3	175 150	TO-204/1 TO-218/340
	500	BUT51P		40 min	5	1.1	0.16	10		125	TO-218/340D
20	60	2N6282 MJH6282	2N6285 MJH6285	750/18k 750/18k	10 10	2.5 typ 2.5 typ	2.5 typ 2.5 typ	10 10	4 4	160 125	TO-204/1 TO-218/340
	80	2N6283 MJH6283	2N6286 MJH6286	750/18k 750/18k	10 10	2.5 typ 2.5 typ	2.5 typ 2.5 typ	10 10	4 4	160 125	TO-204/1 TO-218/340
	100	2N6284 MJH6284	2N6287 MJH6287	750/18k 750/18k	10 10	2.5 typ 2.5 typ	2.5 typ 2.5 typ	10 10	4 4	160 125	TO-204/1 TO-218/340
	350	MJ10000 MJ10004•		40/400 40/400	10 10	3 1.5	1.8 0.5	10	10 10	175 175	TO-204/1 TO-204/1
	400	MJ10001 MJ10005•		40/400 40/400	10 10	3 1.5	1.8 0.5	10	10 10	175 175	TO-204/1 TO-204/1
	450	MJ10008•		30/300	10	2	0.6	10	8	175	TO-204/1
	500	MJ10009•		30/300	10	2	0.6	10	8	175	TO-204/1
	700	BUT15•		15 min	12	2.5	0.8	12		175	TO-204/1
	750	MJ10024•		50/600	5	5	1.8	10		250	TO-204/1
	850	MJ10025•		50/600	5	5	1.8	10		250	TO-204/1
25	500	BUT14•		15 min	16	2.8	0.8	16		175	TO-204/1
28	400	BUT13•		20 min	20	2.6	0.8	18		175	TO-204/1
30	60	MJ11012	MJ11011	1k min	20				4	200	TO-204/1
	90	MJ11014	MJ11013	1k min	20				4	200	TO-204/1
	120	MJ11016	MJ11015	1k min	20				4	200	TO-204/1
40	350	MJ10022•		50/600	10	2.5	0.9	20		250	TO-204/197
	400	MJ10023•		50/600	10	2.5	0.9	20		250	TO-204/197
	700	BUT35•		15 min	24	4	1.2	24		250	TO-204/197
50	60	MJ11028	MJ11029	400 min	50					300	TO-204/197

• Darlington with speed-up diode.

(continued)

TABLE 14 — SWITCHMODE POWER TRANSISTORS (continued)

$V_{CEO(sus)}$ Volts Min	I_C Cont Amps Max	V_{CEV} Volts Min	Device Type NPN unless otherwise noted	h_{FE} Min/Max	@ I_C Amp	Resistive Switching t_s μs Max	Resistive Switching t_f μs Max	Resistive Switching @ I_C Amp	f_T MHz Min	P_D (Case) Watts @ 25°C	Case JEDEC/MOT
300	**0.5**	**300**	**MJ4646-PNP**	20 min	0.5	0.72*		0.05	40		TO-205AD/79
275	**15**	**300**	**2N6250**	8/50	10	3.5	1	10	2.5		TO-204/1
250	**60**	**350**	**MJ10021##★**	25 min	30	3.5	0.5	30			TO-204/197
	40	**300** **350**	**BUV22** **BUS52**	10 min 15 min	20 40	1.1	0.35	20	8	250 350	TO-204/1 TO-204/1
	20	**300** **450**	**BUV12** **MJ13331★**	10 min 8/40	10 10	1.5 3.5	0.5 0.7	10 10	8 5/40	150	TO-204/1 TO-204/1
	15	**250** **250**	**MJ11021#-PNP** **MJ11022#**	100 min 100 min	15 15				3# 3#		TO-204/1 TO-204/1
	8	**500** **400**	**2N6306** ***MJ6502-PNP★***	15/75 *15 min*	3 2	1.6 2	0.4 0.5	3 4	5		TO-204/1 *TO-204/1*
	5	**500** **350**	**MJ3029** **2N6497**	30 min 10/75	0.4 2.5	1.8	1 0.8	3 2.5	5		TO-204/1 TO-220/221A
	2	**375** **375**	**2N3584** **2N6421-PNP**	25/100 25/100	1 1	4 4	3 3	1 1	10 10		TO-213AA/80 TO-213AA/80
	1	**250**	**2N5344-PNP**	25/100	0.5	0.6	0.1	0.5	60		TO-213AA/80
225	**2**	**275**	**2N6211**	10/100	1	2.5	0.6	1	20		TO-213AA/80
200	**60**	**300**	**MJ10020##★**	25 min	30	3.5	0.5	30			TO-204/197
	50	**300**	**BUS51**	15 min	50					350	TO-204/1
	40	**250**	**BUV21**	*10 min*	25	1.8	0.4	25	8	150	*TO-204/1*
	20	**250** **400**	**BUV11** **MJ13330★**	10 min 8/40	12 10	1.8 3.5	0.4 0.7	12 10	8 5/40	150	TO-204/1 TO-204/1
	15	**225** **250** **200** **200**	**2N6249** **BUX41** **MJ11019#-PNP** **MJ11020#**	10/50 8 min 100 min 100 min	10 8 15 15	3.5 1.5	1 0.4	10 8	2.5 8 3# 3#	120	TO-204/1 TO-204/1 TO-204/1 TO-204/1
	3	**250**	**BUY49P**	30 min	0.5				25	20	TO-225AA/77

★ Designers Data Sheet characterization
Darlington ## Darlington with speed-up diode * t_{off} ** $|h_{fe}|$ @ 1 MHz

MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

PNP	NPN
MJ11017	**MJ11018**
MJ11019	**MJ11020**
MJ11021	**MJ11022**

COMPLEMENTARY DARLINGTON SILICON POWER TRANSISTORS

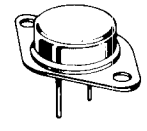
. . . designed for use as general purpose amplifiers, low frequency switching and motor control applications.

- High dc Current Gain @ 10 Adc — h_{FE} = 400 Min (All Types)
- Collector-Emitter Sustaining Voltage
  $V_{CEO(sus)}$ = 150 Vdc (Min) — MJ11018, 17
  = 200 Vdc (Min) — MJ11020, 19
  = 250 Vdc (Min) — MJ11022, 21
- Low Collector-Emitter Saturation
  $V_{CE(sat)}$ = 1.0 V (Typ) @ I_C = 5.0 A
  = 1.8 V (Typ) @ I_C = 10 A
- Monolithic Construction
- 100% SOA Tested @ V_{CE} = 44 V, I_C = 4.0 A, t = 250 ms.

15 AMPERE

DARLINGTON POWER TRANSISTORS COMPLEMENTARY SILICON

150, 200, 250 VOLTS
175 WATTS



MAXIMUM RATINGS

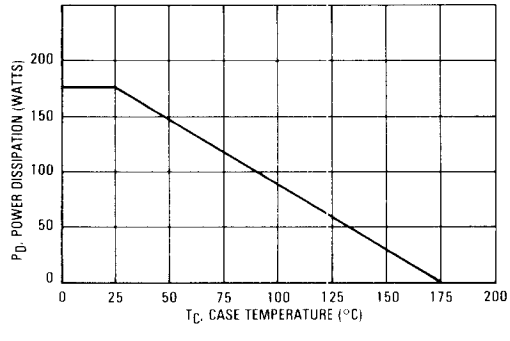
Rating	Symbol	MJ11018 MJ11017	MJ11020 MJ11019	MJ11022 MJ11021	Unit
Collector-Emitter Voltage	V_{CEO}	150	200	250	Vdc
Collector-Base Voltage	V_{CB}	150	200	250	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous Peak	I_C	15 30			Adc
Base Current	I_B	0.5			Adc
Total Device Dissipation @ T_C = 25°C Derate Above 25°C	P_D	175 1.16			Watts W/°C
Operating and Storage Junction Temperature Range	T_J T_{stg}	−65 to +175 −65 to +200			°C °C

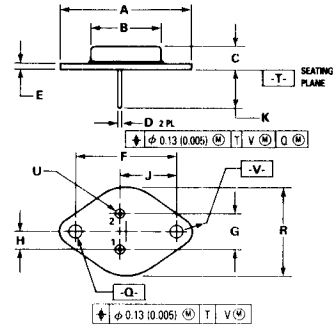
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	0.86	°C/W

(1) Pulse Test: Pulse Width 5.0 ms, Duty Cycle ≤ 10%

FIGURE 1 — POWER DERATING





NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. ALL RULES AND NOTES ASSOCIATED WITH REFERENCED TO-204AA OUTLINE SHALL APPLY.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	—	39.37	—	1.550
B	—	21.08	—	0.830
C	6.35	8.25	0.250	0.325
D	0.97	1.09	0.038	0.043
E	1.40	1.77	0.055	0.070
F	30.15 BSC		1.187 BSC	
G	10.92 BSC		0.430 BSC	
H	5.46 BSC		0.215 BSC	
J	16.89 BSC		0.665 BSC	
K	11.18	12.19	0.440	0.480
Q	3.84	4.19	0.151	0.165
R	—	26.67	—	1.050
U	4.83	5.33	0.190	0.210
V	3.84	4.19	0.151	0.165

STYLE 1.
PIN 1. BASE
2. EMITTER
CASE COLLECTOR

CASE 1-06
TO-204AA
(TO-3)

3

ELECTRICAL CHARACTERISTICS (T_C = 25°C Unless Otherwise Noted)

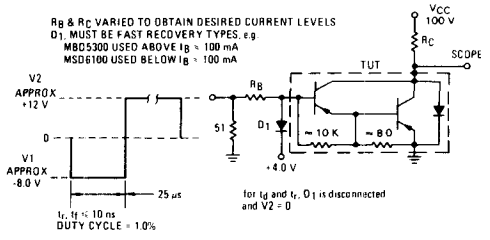
Characteristics	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (1)	$V_{CEO(sus)}$			Vdc
(I_C = 0.1 Adc, I_B = 0) MJ11017, MJ11018		150	—	
MJ11019, MJ11020		200	—	
MJ11021, MJ11022		250	—	
Collector Cutoff Current	I_{CEO}			mAdc
(V_{CE} = 75, I_B = 0) MJ11017, MJ11018		—	1.0	
(V_{CE} = 100, I_B = 0) MJ11019, MJ11020		—	1.0	
(V_{CE} = 125, I_B = 0) MJ11021, MJ11022		—	1.0	
Collector Cutoff Current	I_{CEV}			mAdc
(V_{CE} = Rated V_{CB}, $V_{BE(off)}$ = 1.5 Vdc)		—	0.5	
(V_{CE} = Rated V_{CB}, $V_{BE(off)}$ = 1.5 Vdc, T_J = 150°C)		—	5.0	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	—	2.0	mAdc
ON CHARACTERISTICS (1)				
DC Current Gain	h_{FE}			—
(I_C = 10 Adc, V_{CE} = 5.0 Vdc)		400	15,000	
(I_C = 15 Adc, V_{CE} = 5.0 Vdc)		100	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 10 Adc, I_B = 100 mA)		—	2.0	
(I_C = 15 Adc, I_B = 150 mA)		—	3.4	
Base-Emitter On Voltage (I_C = 10 A, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	—	2.8	Vdc
Base-Emitter Saturation Voltage (I_C = 15 Adc, I_B = 150 mA)	$V_{BE(sat)}$	—	3.8	Vdc
DYNAMIC CHARACTERISTICS				
Magnitude of Common Emitter Small Signal Short Circuit Forward Current Transfer Ratio (I_C = 10 Adc, V_{CE} = 3.0 Vdc, f = 1.0 MHz)	$\lvert h_{fe} \rvert$	3.0	—	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz)	C_{ob}			pF
MJ11018, MJ11020, MJ11022		—	400	
MJ11017, MJ11019, MJ11021		—	600	
Small-Signal Current Gain (I_C = 10 Adc, V_{CE} = 3.0 Vdc, f = 1.0 kHz	h_{fe}	100	—	—

SWITCHING CHARACTERISTICS

Characteristics		Symbol	Typical NPN	Typical PNP	Unit
Delay Time	(V_{CC} = 100 V, I_C = 10 A, I_B = 100 mA $V_{BE(off)}$ = 5.0 V) (See Figure 2.)	t_d	150	75	ns
Rise Time		t_r	1.2	0.5	μs
Storage Time		t_s	4.4	2.7	μs
Fall Time		t_f	10.0	2.5	μs

(1)Pulsed Test: Pulse Width = 300 μs, Duty Cycle ≤ 2%.

FIGURE 2 — SWITCHING TIMES TEST CIRCUIT



For NPN test circuit reverse diode and voltage polarities.

FIGURE 3 — THERMAL RESPONSE

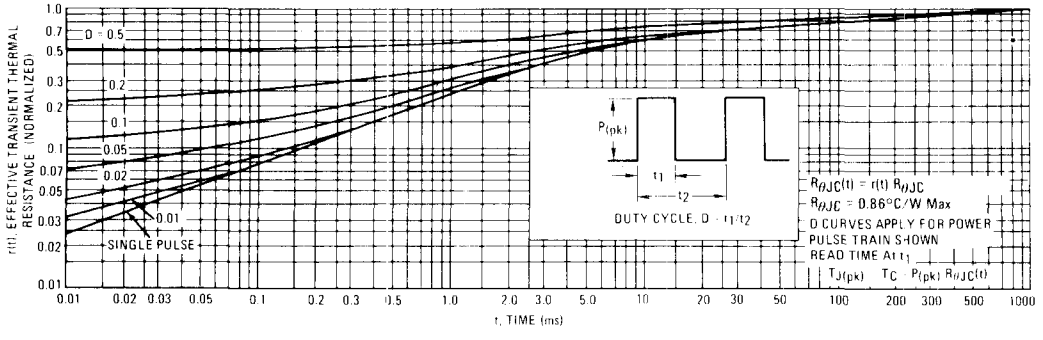
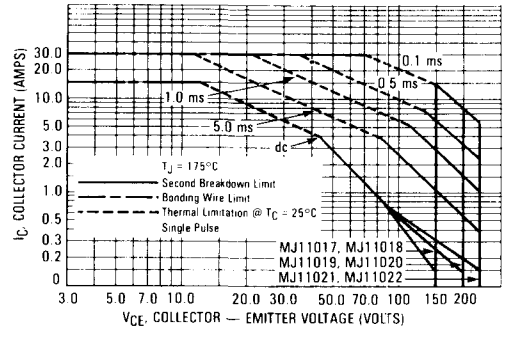


FIGURE 4 — MAXIMUM RATED FORWARD BIAS SAFE OPERATING AREA (FBSOA)

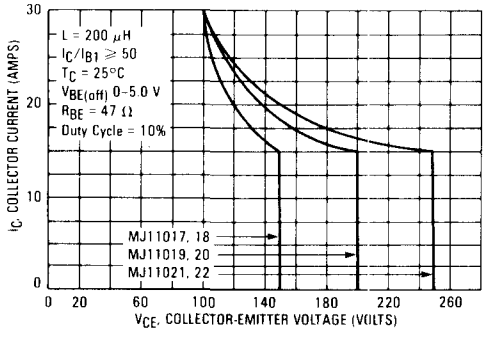


FORWARD BIAS

There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate I_C V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 4 is based on $T_{J(pk)} = 175°C$; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)} \leq 175°C$. $T_{J(pk)}$ may be calculated from the data in Figure 3. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

FIGURE 5 — MAXIMUM RBSOA, REVERSE BIAS
SAFE OPERATING AREA



REVERSE BIAS

For inductive loads, high voltage and high current must be sustained simultaneously during turn-off, in most cases, with the base to emitter junction reverse biased. Under these conditions the collector voltage must be held to a safe level at or below a specific value of collector current. This can be accomplished by several means such as active clamping, RC snubbing, load line shaping, etc. The safe level for these devices is specified as Reverse Bias Safe Operating Area and represents the voltage-current conditions during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 5 gives RBSOA characteristics.

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FIGURE 6 — DC CURRENT GAIN

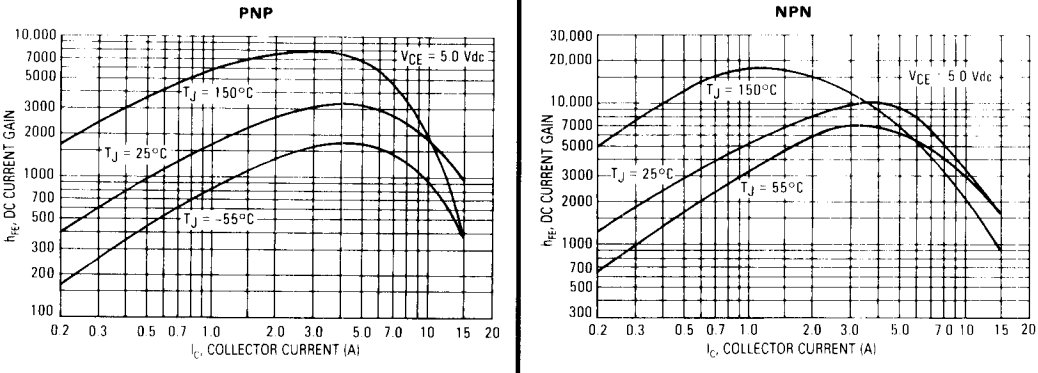

FIGURE 7 — COLLECTOR SATURATION REGION

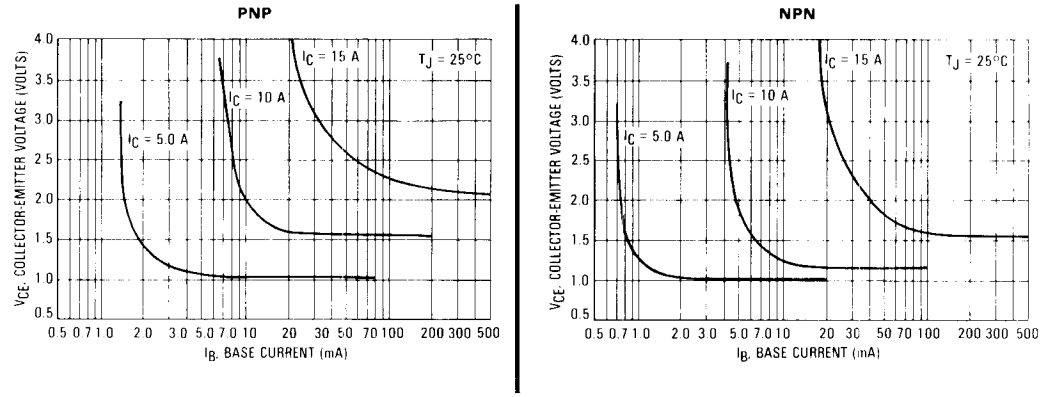

FIGURE 8 — "ON" VOLTAGES