ALPHANUMERIC INDEX — CROSS-REFERENCE (Continued)

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2SA1002		2N6438	3-203
2SA1003		2N6438	3-203
2SA1007		MJ15002	3-710
2SA1008		TIP32C	3-1073
2SA1010		TIP42C	3-1083
2SA1011		MJE15031	3-972
2SA1012		TIP42A	3-1083
2SA1020		TIP32	3-1073
2SA1040		2N6438	3-203
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2SA1213		MJD32C	3-797
2SA1225		MJD5731-1	—
2SA1241		MJD45H11-1	3-808
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Industry Part Number	Motorola Direct Replacement	Motorola Similar Replacement	Page Number
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2SA627		MJ15016	3-9
2SA633		2N4918	3-75
2SA634		2N4919	3-75
2SA635		2N4919	3-75
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2SA646		2N4919	3-75
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2SA653		2N6420	3-20
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2SA714		MJ15016	3-9
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2SA739		MJ6503	3-540
2SA755		2N6125	3-154
2SA756		MJ15016	3-9
2SA757		MJ15016	3-9
2SA758		MJ15016	3-9
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2SA835		MJE350	3-880
2SA837		MJ15016	3-9
2SA839		TIP32C	3-1073
2SA843		MJE15031	3-972

*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
15		MJ16012		7 min	15	0.9 typ	0.15 typ	10		175
		2N6836		10/30	10	3	0.35	10	10	175
	500	MJ16010A		5 min	15	3	0.4	10		175
	850*	MJ12022		5 min	15		0.1 typ	10		175
16	100		BD318	25 min	5				1	200
		2N5629	2N6029	25/100	8	1.2 typ	1.2 typ	8	1	200
	120	2N5630	2N6030	20/80	8	1.2 typ	1.2 typ	8	1	200
	140	2N3773	2N6609	15/60	8	1.1 typ	1.5 typ	8	4	150
		2N5631	2N6031	15/60	8	1.2 typ	1.2 typ	8	1	200
	200	MJ15022	MJ15023	15/60	8				5	250
	250	MJ15024	MJ15025	15/60	8				5	250
18	160	BUX41N		8 min	12	1.2	0.25	12	8	120
20	60	2N3772		15/60	10				2	150
		2N6282##	2N6285##	750/18k	10	2.5 typ	2.5 typ	10	4#	160
	75	2N5039		20/100	10	1.5	0.5	10	60	140
	80	2N5303	2N5745	15/60	10	2	1	10	2	200
		2N6283##	2N6286##	750/18k	10	2.5 typ	2.5 typ	10	4#	160
	90	2N5038		20/100	12	1.5	0.5	12	60	140
	100	2N6284##	2N6287##	750/18k	10	2.5 typ	2.5 typ	10	4#	160
	125	BUX40		8 min	15	1	0.25	15	8	120
	140	MJ15003	MJ15004	25/150	5				2	250
	160	BUV11N		10 min	15	1.2	0.25	15	8	150
	200	BUV11		10 min	12	1.8	0.4	12	8	150
		MJ13330		8/40	10	3.5	0.7	10	5 to 40	175
	250	BUV12		10 min	10	1.5	0.5	10	8	150
		MJ13331		8/40	10	3.5	0.7	10	5 to 40	175
	350	MJ10000##		40/400	10	3	1.8	10	10#	175
		MJ10004##		40/400	10	1.5	0.5	10	10#	175
	400	MJ10001##		40/400	10	3	1.8	10	10#	175
		MJ10005##		40/400	10	1.5	0.5	10	10#	175
		MJ13333		10/60	5	4	0.7	10		175
	450	MJ10008##		30/300	10	2	0.6	10	8#	175
		MJ16014		5 min	20	2.7	0.35	20		250
		MJ16016		7 min	20	2.2	0.25	20		250
		2N6837		10/30	15	2.5	0.25	15		250
	500	MJ10009##		30/300	10	2	0.6	10	8#	175
		MJ13335		10/60	5	4	0.7	10		175
	700	BUT15##		15 min	12	2.5	0.8	12		175
	750	MJ10024##		50/600	20	5	1.8	10		250
	850	MJ10025##		50/600	20	5	1.8	10		250

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

(continued)

JAN, JTX, JTXV Available

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TABLE 14 — SWITCHMODE POWER TRANSISTORS (continued)

						Resistive Switching					
$V_{CEO(sus)}$ Volts Min	I_CCont Amps Max	V_{CEV} Volts Min	Device Type NPN unless otherwise noted	h_{FE} Min/Max	@ I_C Amp	t_s μs Max	t_f μs Max	@ I_C Amp	f_T MHz Min	P_D (Case) Watts @ 25°C	Case JEDEC/MOT
750	3	1500	MJE16032	4 min	3	2	1.5	2		80	TO-220/221A
		1500	MJH16032	4 min	3	2	1.5	2		125	TO-218/340
	2.5	1500	MJ12002★	1.11 min	2		1	2	4 typ		TO-204/1
		1500	MJE12007★	1.1 min	2		1	2	4 typ		TO-220/221A
700	40	1000	BUT35##	15 min	24	4	1.2	24		250	TO-204/197
	20	1000	BUT15##	15 min	12	2.5	0.8	12		175	TO-204/1
	10	1200	MJ8504★	7.5 min	1.5	4	2	5			TO-204/1
	8	1400	MJ10011#	20 min	4		1	4			TO-204/1
		1500	BU508,A	2.25 min	4.5	8 typ	0.5 typ	4.5	7	125	TO-218/340
		1500	BU508D,AD	2.25 min	4.5	8 typ	0.5 typ	4.5	7	125	TO-218/340
	5	1200	MJ8502★	7.5 min	1	4	2	2.5			TO-204/1
		1200	MJE8502★	7.5 min	1	4	2	2.5			TO-220/221A
		1500	BU208A	2.25 min	4.5	8 typ	0.4 typ	4.5	4 typ	90	TO-204/1
		1500	BU208D	2.25 min	4.5		0.6 typ	4.5			TO-204/1
	2.5	1200	MJE8500★	7.5 min	0.5	4	2	1			TO-220/221A
600	10	700	MJ10014##★	10/250	10	2.5	0.8	10			TO-204/1
500	50	750	MJ10016##★	10 min	40	2.5	1	20			TO-204/197
		850	BUT34##	15 min	32	3	1.5	32		250	TO-204/197
	25	850	BUT14##	15 min	16	2.8	0.8	16		175	TO-204/1
	20	600	MJ10009##★	30/300	10	2	0.6	10	8**		TO-204/1
		800	MJ13335★	10/60	5	4	0.7	10			TO-204/1
	15	850	BUT51P##	40 min	5	1.1	0.16	10		125	TO-218/340D
		1000	MJ16010A★	5 min	15	3	0.4	10			TO-204/1
		1000	MJH16010A★	5 min	15	3	0.4	10			TO-218/340
	8	850	BUT50P##	30 min	2	0.75 typ	0.1 typ	5		100	TO-218/340D
		1000	MJ16006A★	5 min	15	3	0.4	10			TO-204/1
		1000	MJH16006A★	5 min	15	3	0.4	10			TO-218/340
	5	1000	MJ16002A★	5 min	15	3	0.3	3			TO-204/1
		1000	MJH16002A★	5 min	15	3	0.3	3			TO-218/340
450	30	850	MJ16020	5 min	30	1.8	0.2	20		250	TO-204/1
		850	MJ16022	7 min	30	1.5	0.15	20		250	TO-204/1
		1000	BUS98A	8 min	16	2.3	0.4	16		250	TO-204/197
	20	650	MJ10008##★	30/300	10	2	0.6	10	8**		TO-204/1
		850	2N6837★	10/30	15	2.5	0.25	15	15		TO-204/1
		850	MJ16014★	5 min	20	2.7	0.35	20			TO-204/197
		850	MJ16016★	7 min	20	2.2	0.25	20			TO-204/197
	15	850	2N6836★	10/30	10	3	0.35	10	10		TO-204/1
		850	MJ12022★	5 min	15		0.1 typ	10			TO-204/1
		850	MJ16010★	5 min	15	1.2 typ	0.2 typ	10			TO-204/1
		850	MJ16012★	7 min	15	0.9 typ	0.15 typ	10			TO-204/1
		850	MJH16010★	5 min	15	1.2	0.2	10		175	TO-218/340
		850	MJH16012★	7 min	15	0.9	0.15	10		150	TO-218/340
		1000	BUX48A	8 min	10	2	0.4	10		175	TO-204/1

★ Designers Data Sheet characterization

Darlington ## Darlington with speed-up diode * t_{off} ** $|h_{fe}|$ @ 1 MHz

(continued)

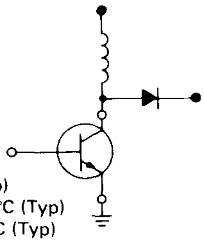
MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

2N6837

Designer's Data Sheet

SWITCHMODE III SERIES
ULTRA-FAST NPN SILICON POWER TRANSISTORS

This transistor is designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line-operated switchmode applications.



Typical Applications:

- Switching Regulators
- Inverters
- Motor Controls
- Deflection Circuits
- Fast Turn-Off Times
  - 30 ns Inductive Fall Time — 75°C (Typ)
  - 40 ns Inductive Crossover Time — 75°C (Typ)
  - 800 ns Inductive Storage Time — 75°C (Typ)
- Operating Temperature Range −65 to +200°C
- 100°C Performance Specified for:
  - Reverse-Biased SOA with Inductive Loads
  - Switching Times with Inductive Loads
  - Saturation Voltages
  - Leakage Currents

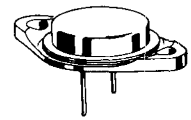
20 AMPERE

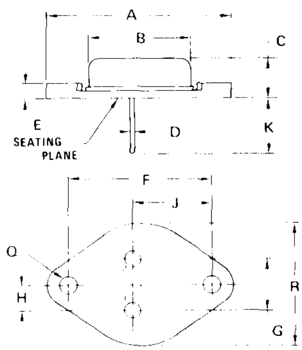
NPN SILICON POWER TRANSISTORS

450 VOLTS
250 WATTS

Designer's Data for "Worst Case" Conditions

The Designers Data Sheet permits the design of most circuits entirely from the information presented. Limit data — representing device characteristics boundaries — are given to facilitate "worst case" design.





DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	38.35	39.37	1.510	1.550
B	19.30	21.08	0.760	0.830
C	6.35	7.62	0.250	0.300
D	1.45	1.60	0.057	0.063
E	–	3.43	–	0.135
F	29.90	30.40	1.177	1.197
G	10.67	11.18	0.420	0.440
H	5.21	5.72	0.205	0.225
J	16.64	17.15	0.655	0.675
K	11.18	12.19	0.440	0.480
Q	3.84	4.09	0.151	0.161
R	24.89	26.67	0.980	1.050

CASE 197-01
TO-204AE TYPE
(TO-3 TYPE)

MAXIMUM RATINGS

Rating	Symbol	Max	Unit
Collector-Emitter Voltage*	$V_{CEO(sus)}$	450	Vdc
Collector-Emitter Voltage*	V_{CEV}	850	Vdc
Emitter Base Voltage*	V_{EB}	6.0	Vdc
Collector Current — Continuous* — Peak (1)	I_C I_{CM}	20 30	Adc
Base Current — Continuous* — Peak (1)	I_B I_{BM}	15 20	Adc
Total Power Dissipation @ T_C = 25°C* @ T_C = 100°C Derate above 25°C	P_D	250 143 1.43	Watts W/°C
Operating and Storage Junction* Temperature Range	T_J, T_{stg}	−65 to +200	°C

*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case*	$R_{\theta JC}$	0.7	°C/W
Maximum Lead Temperature for Soldering* Purposes: 1/8" from Case for 5 Seconds	T_L	275	°C

(1) Pulse Test: Pulse Width = 5.0 ms, Duty Cycle ≤ 10%.
*Indicate JEDEC Registered Data

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ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted).

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (Table 2) (I_C = 100 mA, I_B = 0)	$V_{CEO(sus)}$	450*	—	—	Vdc
Collector Cutoff Current	I_{CEV}				mAdc
(V_{CEV} = 850 Vdc, $V_{BE(off)}$ = 1.5 Vdc)		—	—	0.25*	
(V_{CEV} = 850 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 100°C)		—	—	1.5*	
Collector Cutoff Current (V_{CE} = 850 Vdc, R_{BE} = 50 Ω, T_C = 100°C)	I_{CER}	—	—	2.5	mAdc
Emitter Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)	I_{EBO}	—	—	1.0*	mAdc
SECOND BREAKDOWN					
Second Breakdown Collector Current with Base Forward Biased	$I_{S/b}$	See Figure 15*			
Clamped Inductive SOA with Base Reverse Biased	RBSOA	See Figure 16			
ON CHARACTERISTICS (1)					
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 10 Adc, I_B = 1.2 Adc)		—	—	1.5	
(I_C = 15 Adc, I_B = 2.0 Adc)		—	—	3.0*	
(I_C = 15 Adc, I_B = 2.0 Adc, T_C = 100°C)		—	—	3.0*	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$				Vdc
(I_C = 15 Adc, I_B = 2.0 Adc)		—	—	1.5*	
(I_C = 15 Adc, I_B = 2.0 Adc, T_C = 100°C)		—	—	1.5	
DC Current Gain	h_{FE}				—
(I_C = 15 Adc, V_{CE} = 5.0 Vdc)		7.5*	—	30*	
(I_C = 20 Adc, V_{CE} = 5.0 Vdc)		5.0	—	—	
DYNAMIC CHARACTERISTICS (2)					
Current Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 0.25 Adc, f_{test} = 10 MHz)	f_T	10*	—	75*	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f_{test} = 1.0 kHz)	C_{ob}	100*	—	500*	pF

SWITCHING CHARACTERISTICS

Characteristic	Conditions		Symbol	Min	Typ	Max	Unit
Resistive Load (Table 1)							
Delay Time	(I_C = 15 Adc, V_{CC} = 250 Vdc, I_{B1} = 2.0 Adc, PW = 30 μs, Duty Cycle ≤ 2.0%)	(I_{B2} = 4.0 Adc, R_{B2} = 1.6 Ω)	t_d	—	20	100*	ns
Rise Time			t_r	—	200	500*	
Storage Time			t_s	—	1200	2700*	
Fall Time			t_f	—	200	350*	
Storage Time		($V_{BE(off)}$ = 5.0 Vdc)	t_s	—	650	—	
Fall Time			t_f	—	80	—	
Inductive Load (Table 2)							
Storage Time	(I_C = 15 Adc, I_{B1} = 2.0 Adc, $V_{BE(off)}$ = 5.0 Vdc, $V_{CE(pk)}$ = 400 Vdc)	(T_C = 100°C)	t_{sv}	—	800	2700*	ns
Fall Time			t_{fi}	—	50	200*	
Crossover Time			t_c	—	90	250*	
Storage Time		(T_C = 150°C)	t_{sv}	—	1050	—	
Fall Time			t_{fi}	—	70	—	
Crossover Time			t_c	—	120	—	

(1) Pulse Test: PW — 300 μs, Duty Cycle ≤ 2.0%.
(2) $f_T = |h_{FE}| f_{test}$
*Indicates JEDEC Registered Limit

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TYPICAL STATIC CHARACTERISTICS

FIGURE 1 — DC CURRENT GAIN

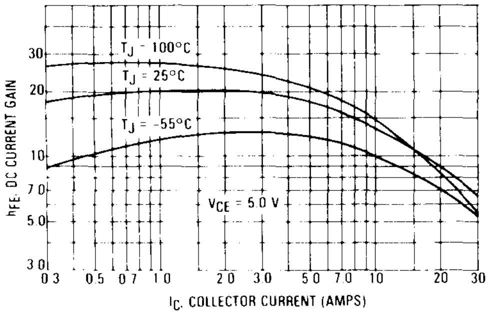


FIGURE 2 — COLLECTOR SATURATION REGION

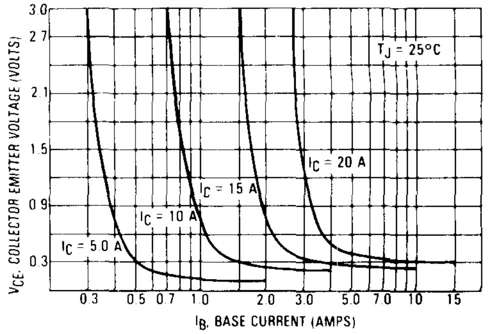


FIGURE 3 — COLLECTOR-EMITTER SATURATION REGION

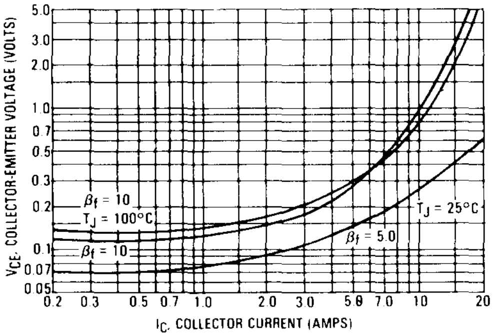


FIGURE 4 — BASE-EMITTER VOLTAGE

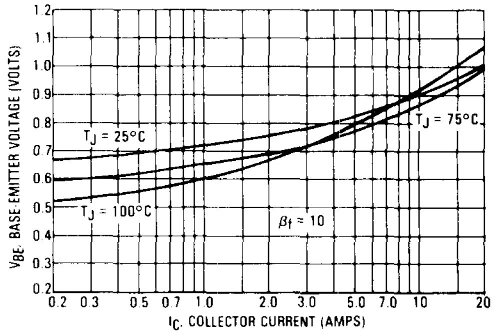


FIGURE 5 — COLLECTOR CUTOFF REGION

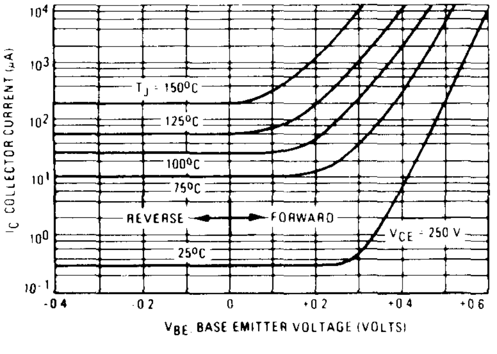
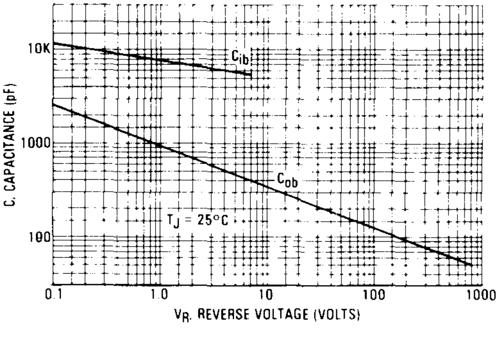


FIGURE 6 — CAPACITANCE



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TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 7 — STORAGE TIME

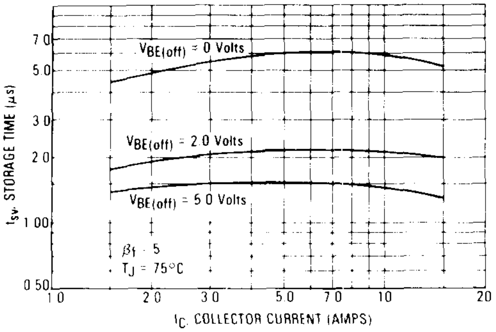

FIGURE 8 — STORAGE TIME

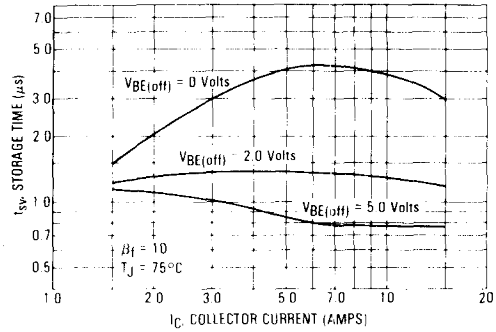

FIGURE 9 — COLLECTOR CURRENT FALL TIME

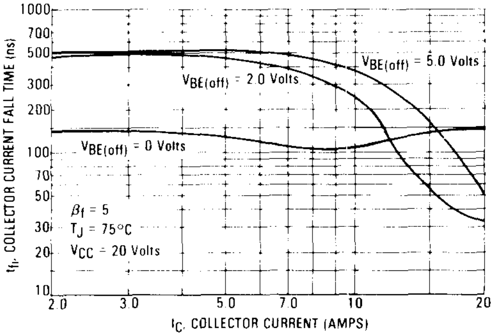

FIGURE 10 — COLLECTOR CURRENT FALL TIME

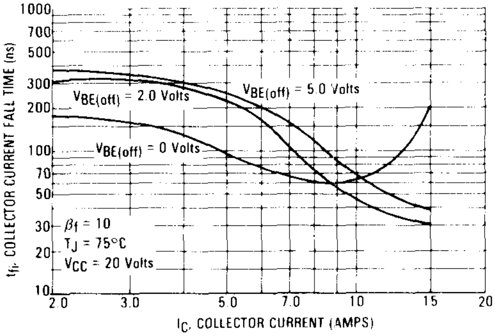

FIGURE 11 — CROSSOVER TIME

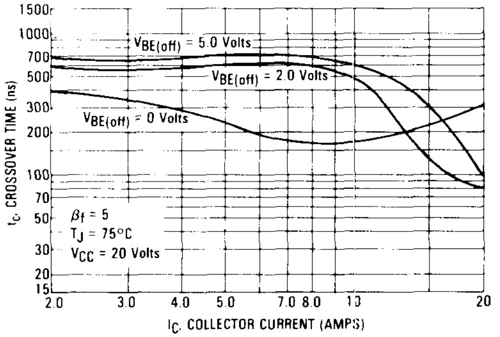

FIGURE 12 — CROSSOVER TIME

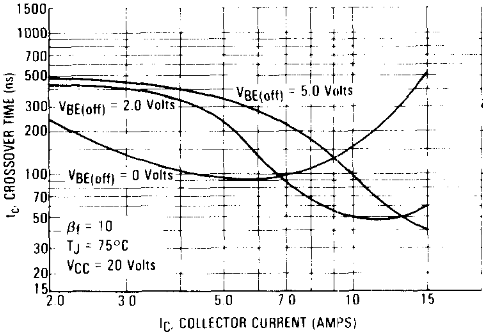

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FIGURE 13 — INDUCTIVE SWITCHING MEASUREMENTS

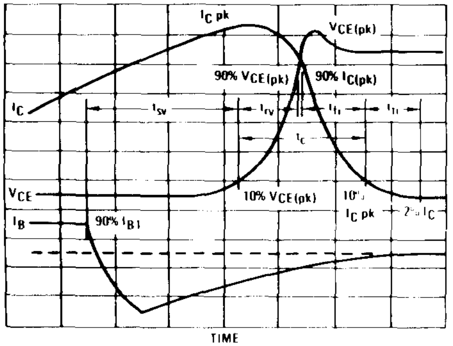
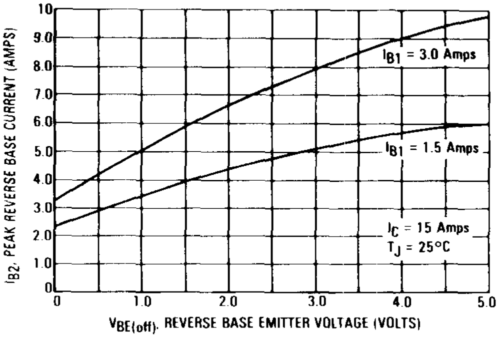


FIGURE 14 — REVERSE BASE CURRENT



GUARANTEED SAFE OPERATING AREA LIMITS

FIGURE 15 — MAXIMUM FORWARD BIAS SAFE OPERATING AREA

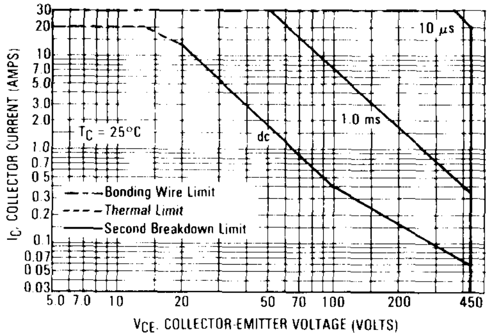
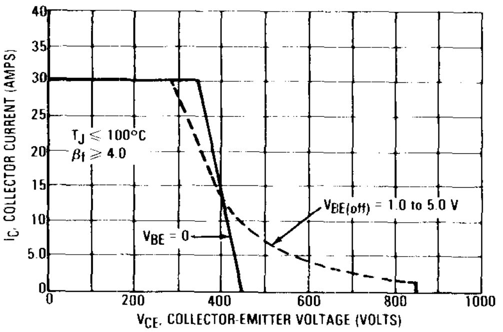


FIGURE 16 — MAXIMUM RATED REVERSE BIAS SAFE OPERATING AREA



SAFE OPERATING AREA INFORMATION

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 15 is based on T_C = 25°C; $T_{J(pk)}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_C \geq 25°C$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figure 15 may be found at any case temperature by using the appropriate curve on Figure 18.

$T_{J(pk)}$ may be calculated from the data in Figure 17. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

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 condition allowable during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 16 gives the RBSOA characteristics.

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FIGURE 17 — THERMAL RESPONSE

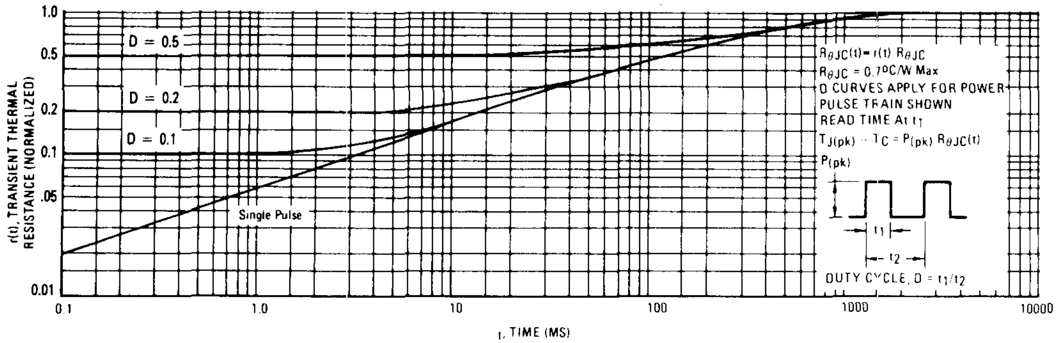


FIGURE 18 — POWER DERATING

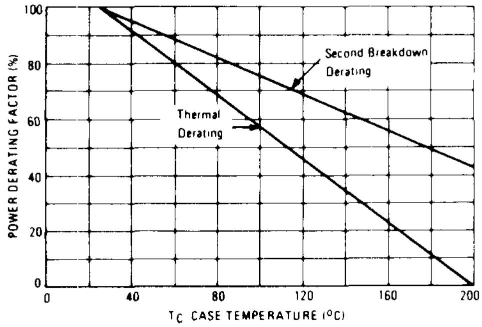
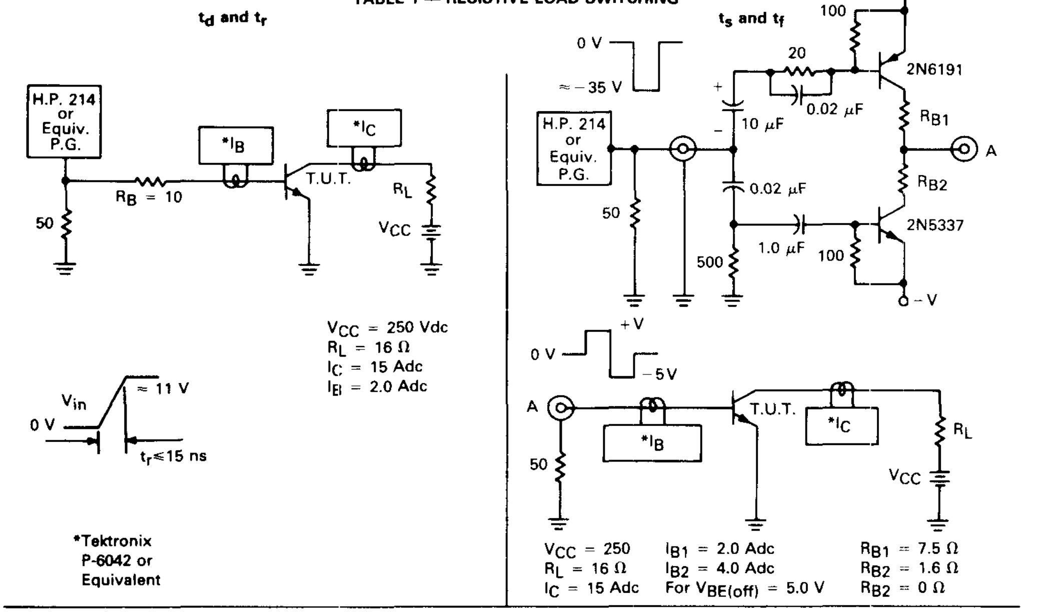


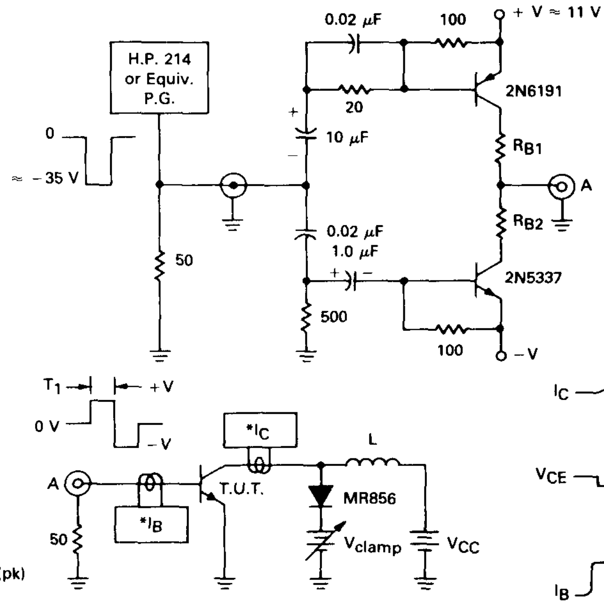
TABLE 1 — RESISTIVE LOAD SWITCHING

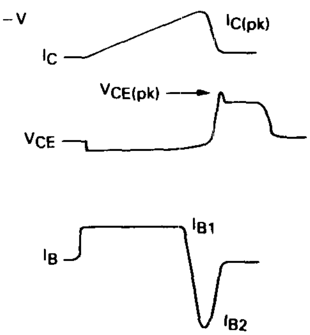


*Note: Adjust −V to obtain desired $V_{BE(off)}$ at Point A.

3

TABLE 2 — INDUCTIVE LOAD SWITCHING





$T_1 \approx \frac{L_{coil}\,(I_{Cpk})}{V_{CC}}$

T_1 adjusted to obtain $I_{C(pk)}$

$V_{(BR)CEO}$
$L = 10$ mH
$R_{B2} = \infty$
$V_{CC} = 20$ Volts

*Tektronix
P-6042 or
Equivalent

Inductive Switching
$L = 200\ \mu H$
$R_{B2} = 0$
$V_{CC} = 20$ Volts
R_{B1} selected for desired I_{B1}

Scope — Tektronix
7403 or
Equivalent

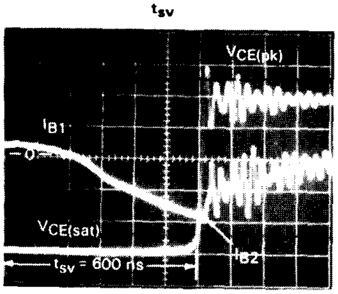
RBSOA
$L = 200\ \mu H$
$R_{B2} = 0$
$V_{CC} = 20$ Volts
R_{B1} selected for desired I_{B1}

Note: Adjust — V to obtain desired $V_{BE(off)}$ at Point A.

TYPICAL INDUCTIVE SWITCHING WAVEFORMS

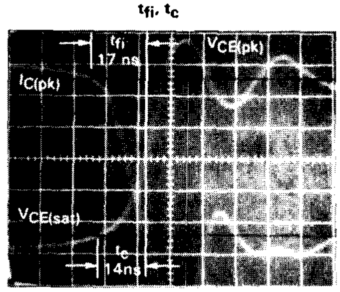
t_{sv}

$I_{C(pk)} = 15$ A
$I_{B1} = 2.0$ A
$V_{BE(off)} = 5.0$ Volts
$V_{CE(pk)} = 400$ Volts
$T_C = 25°C$
Time Base = 200 ns/cm



t_{fi}, t_c

$I_{C(pk)} = 15$ A
$I_{B1} = 2.0$ A
$V_{BE(off)} = 5.0$ Volts
$V_{CE(pk)} = 400$ Volts
$T_C = 25°C$
Time Base = 200 ns/cm



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