ALPHANUMERIC INDEX — CROSS-REFERENCE (Continued)

Industry Part Number	Motorola Direct Replacement	Motorola Similar Replacement	Page Number
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BU807	BU807		3-380
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BUS12	BUX47		3-499
BUS12A	BUX47A		3-499
BUS13	BUX48		3-506
BUS13A	BUX48A		3-506
BUS14	BUX98		—
BUS14A	BUX98A		—
BUS46P		MJE16002	3-976
BUS47	BUX47		3-499
BUS47A	BUX47A		3-499
BUS47AP	BUV47A		3-462
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BUS48	BUX48		3-506
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BUS48AP	BUV48A		3-469
BUS48P	BUV48		3-469
BUS50	BUS50		3-382
BUS51	BUS51		3-384
BUS52		BUS51	3-384
BUS97	MJ16010		3-758
BUS97A	MJ16010A		3-766
BUS98	BUX98		—
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BUT13	BUT13		3-393
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BUV45	BUX47A		3-499
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BUV47A	BUV47A		3-462
BUV48	BUV48		3-469
BUV48A	BUV48A		3-469
BUW11	BUW11		3-476
BUW11A	BUW11A		3-476
BUW12	BUW12		3-476
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BUW13	BUV48P		3-469
BUW13A	BUV48A		3-469
BUW24	BU326A		3-363
BUW25	BU326A		3-363
BUW26	BUS326A		—
BUW34	BUX47		3-499
BUW35	BUX47		3-499
BUW36	BUX47A		3-499
BUW44	BUX48		3-506
BUW45	BUX48		3-506
BUW46	BUX48A		3-506
BUW72		MJE13008	3-950
BUW74	BUX47		3-499
BUW75	BUX47		3-499
BUW76	BUX47		3-499
BUW77	BUX47		3-499
BUW81	MJ10014		3-600
BUW81A	MJ10014		3-600
BUW84	MJE13003		3-938
BUW85	MJE13003		3-938
BUX13	BUX13		3-484
BUX14	BUX14		—
BUX14CECCF	BUX14		—
BUX14CECCL	BUX14		—
BUX15	BUX47A		3-499
BUX15CECCF	BUX47A		3-499
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BUX16	2N6543		3-215
BUX16A	2N6543		3-215
BUX16B	2N6543		3-215
BUX16C	2N6543		3-215
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BUX17A	BUX48		3-506
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BUX47	BUX47		3-499
BUX47A	BUX47A		3-499
BUX48	BUX48		3-506
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BUX48S	BUX48		3-506
BUX66	2N6211		3-161
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BUX67B	2N3585		3-20
BUX67C	2N4240		3-20
BUX81		MJ13335	3-700

*Consult Motorola if a direct replacement is necessary.

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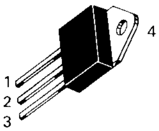
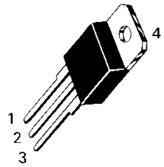
TABLE 4 — PLASTIC TO-218



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



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

CASE 340-02 (TO-218AC)

I_C Cont Amps Max	$V_{CEO(sus)}$ Volts Min	Device Type		h_{FE} Min/Max	@ I_C Amp	Resistive Switching			f_T MHz Min	P_D (Case) Watts @ 25°C
		NPN	PNP			t_s µs Max	t_f µs Max	@ I_C Amp		
3	750	MJH16032		4 min	3	2	1.5	2		125
	850	MJH16034		4 min	3	2	1.5	2		125
5	400	BUW11		6 min	3	4	0.8	3		125
	450	BUW11A		6 min	2.5	4	0.8	2.5		125
		MJH16002		5 min	5	3	0.3	3		100
		MJH16004		7 min	5	2.7	0.35	3		100
	500	MJH16002A		5 min	5	3	0.3	3		100
	1500*	MJH12004		2.5 min	4.5	—	1	4.5	4	100
6	375	BU426†		30 typ	0.6	2 typ	0.5 typ	2.5	6 typ	113
	400	BU426A†		30 typ	0.6	2 typ	0.5 typ	2.5	6 typ	113
8	400	BUW12		6 min	6	4	0.8	5		125
		MJH16106		6/25	8	2 typ	0.1 typ	5		125
	450	BUW12A		6 min	5	4	0.8	5		125
		MJH16006		5 min	8	2.5	0.25	5		125
		MJH16008		7 min	8	2.2	0.25	5		125
	500	BUT50P##†		30 min	2	0.75 typ	0.1 typ	5		100
		MJH16006A		5 min	8	2.5	0.25	5		125
	700	BU508,A		2.25 min	4.5	8 typ	0.5 typ	4.5	7	125
		BU508D,AD		2.25 min	4.5	8 typ	0.5 typ	4.5	7	125
	750	MJH12005					0.4 typ	5	4	100
9	400	BUV47†		7 min	5	2	0.4	6		128
	450	BUV47A†		7 min	6	2	0.4	6		128
10	40	TIP33	TIP34	20 min	3				3	80
	60	BDV65##†	BDV64##†	1k min	5					125
		TIP33A	TIP34A	20 min	3				3	80
		TIP140##	TIP145##	500 min	10	2.5 typ	2.5 typ	5	4#	125
	80	BDV65A##†	BDV64A##†	1k min	5					125
		TIP33B	TIP34B	20 min	3				3	80
		TIP141##	TIP146##	500 min	10	2.5 typ	2.5 typ	5	4#	125
	100	BDV65B##†	BDV64B##†	1k min	5					125
		TIP33C	TIP34C	20 min	3				3	80
		TIP142##	TIP147##	500 min	10	2.5 typ	2.5 typ	5	4#	125
	120	BDV65C##†	BDV64C##†	1k min	5					125
	200	BU323P##†		150 min	6	15	15	6		125
	250	BU323AP##†		150 min	6	15	15	6		125
	400	MJH10012##		100/2k	6	15	15	6		118
	800	MJH16018		4 min	5	4.5 typ	0.2 typ	5		150
15	60	TIP3055	TIP2955	5 min	10				2.5	80
	150	MJH11018##	MJH11017##	400/15k	10				3#	150
	200	MJH11020##	MJH11019##	400/15k	10				3#	150
	250	MJH11022##	MJH11021##	400/15k	10				3#	150

$|h_{fe}|$ @ 1 MHz, ## Darlington
* $V_{(BR)CEX}$ or $V_{(BR)CES}$
† These devices supplied in Case 340D-01. Consult Motorola for details.

(continued)

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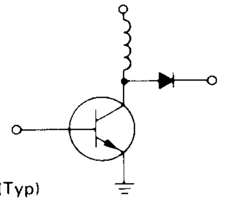
MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

BUV47
BUV47A

SWITCHMODE II▲ SERIES
NPN SILICON POWER TRANSISTORS

The BUV 47 and BUV 47A transistors are designed for high-voltage, high speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line-operated switch-mode applications such as:

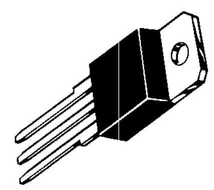
- Switching Regulators
- Inverters
- Solenoid and Relay Drivers
- Motor Controls
- Deflection Circuits

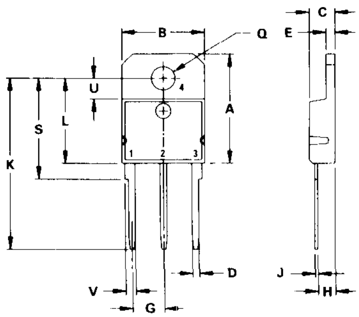


Fast Turn-Off Times
60 ns Inductive Fall Time — 25°C (Typ)
120 ns Inductive Crossover Time — 25°C (Typ)

Operating Temperature Range -65 to +175°C
100°C Performance Specified for:
Reverse-Biased SOA with Inductive Loads
Switching Times with Inductive Loads
Saturation Voltage
Leakage Currents (125°C)

9 AMPERES
NPN SILICON POWER TRANSISTORS
400 AND 450 VOLTS (BVCEO)
128 WATTS
850 - 1000 V (BVCEX)





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

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	19.00	19.60	0.749	0.771
B	14.00	14.50	0.551	0.570
C	4.20	4.70	0.165	0.185
D	1.00	1.30	0.040	0.051
E	1.45	1.65	0.058	0.064
G	5.21	5.72	0.206	0.225
H	2.60	3.00	0.103	0.118
J	0.40	0.60	0.016	0.023
K	28.50	32.00	1.123	1.259
L	14.70	15.30	0.579	0.602
Q	4.00	4.25	0.158	0.167
S	17.50	18.10	0.689	0.712
U	3.40	3.80	0.134	0.149
V	1.50	2.00	0.060	0.078

CASE 340D-01
TO-218 TYPE

MAXIMUM RATINGS

Rating	Symbol	BUV 47	BUV47A	Unit
Collector-Emitter Voltage	$V_{CEO(sus)}$	400	450	Vdc
Collector-Emitter Voltage (V_{BE} = -1.5V)	V_{CEX}	850	1000	Vdc
Emitter Base Voltage	V_{EB}	7		Vdc
Collector Current — Continuous — Peak (1) — Overload	I_C I_{CM} I_{OI}	9 18 36		Adc
Base Current — Continuous — Peak (1)	I_B I_{BM}	5 10		Adc
Total Power Dissipation — T_C = 25°C — T_C = 100°C Derate above 25°C	P_D	128 63.5 0.86		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.17	°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 ms, Duty Cycle ≤ 10%.

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

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS (1)						
Collector-Emitter Sustaining Voltage (Table 1) ($I_C = 200$ mA, $I_B = 0$) L = 25 mH	BUV 47 BUV 47A	$V_{CEO(sus)}$	400 450	–	–	Vdc
Collector Cutoff Current (V_{CEX} = Rated Value, $V_{BE(off)}$ = 1.5Vdc) (V_{CEX} = Rated Value, $V_{BE(off)}$ = 1.5Vdc, T_C = 125°C)		I_{CEX}	– –	– –	0.15 1.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEX}, R_{BE} = 10 Ω)	T_C = 25°C T_C = 125°C	I_{CER}	–	–	0.4 3.0	mAdc
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)		I_{EBO}	–	–	0.1	mAdc
Emitter-base breakdown Voltage (I_E = 50 mA - I_C = 0)		BV_{EBO}	7.0	–	–	Vdc
SECOND BREAKDOWN						
Second Breakdown Collector Current with Base Forward Biased		$I_{S/b}$	See Figure 12			
Clamped Inductive SOA with Base Reverse Biased		RBSOA	See Figure 13			
ON CHARACTERISTICS (1)						
DC Current Gain (I_C = 6 Adc, V_{CE} = 5 Vdc) (I_C = 5 Adc, V_{CE} = 5 V)	BUV47 BUV47A	h_{FE}	7	–	–	
Collector-Emitter Saturation Voltage (I_C = 6 Adc, I_B = 1.2 Adc) (I_C = 9 Adc, I_B = 1.8 Adc) (I_C = 6 Adc, I_B = 1.2 Adc, T_C = 100°C) (I_C = 5 Adc, I_B = 1 Adc) (I_C = 8 Adc, I_B = 1.6 Adc) (I_C = 5 Adc, I_B = 1 Adc, T_C = 100°C)	BUV47 BUV47A	$V_{CE(sat)}$	– – – – – –	– – – – – –	1.5 5.0 2.5 1.5 5.0 2.5	Vdc
Base-Emitter Saturation Voltage (I_C = 6 Adc, I_B = 1.2 Adc) (I_C = 6 Adc, I_B = 1.2 Adc, T_C = 100°C) (I_C = 5 Adc, I_B = 1 Adc) (I_C = 5 Adc, I_B = 1 Adc, T_C = 100°C)	BUV47 BUV47A	$V_{BE(sat)}$	– – – –	– – – –	1.6 1.6 1.6 1.6	Vdc
DYNAMIC CHARACTERISTICS						
Output capacitance (V_{CB} = 10 Vdc, I_E = 0, f_{test} = 1 MHz		C_{ob}	–	–	300	pF

SWITCHING CHARACTERISTICS

Resistive Load (Table 1)

			Symbol	Min	Typ	Max	Unit
Delay Time	I_C = 6A, I_{B_1} = 1.2A	BUV47	t_d	–	0.03	0.2	μs
Rise Time	Vcl = 300V, tp = 30μs		t_r	–	0.5	0.8	
Storage Time	Duty Cycle ≤ 2%, $V_{BE(off)}$ = 5V		t_s	–	0.8	2.0	
Fall Time	I_C = 5A, I_{B_1} = 1A	BUV47A	t_f	–	0.1	0.4	

Inductive Load, Clamped (Table 1)

				Symbol	Min	Typ	Max	Unit
Storage Time	($I_{C(pk)}$ = 6 A, I_{B1} = 1.2 A,	BUV47	(T_C = 25°C)	t_{sv}	–	0.9	–	μs
Fall Time				t_{fi}	–	0.06	–	
Storage Time	$I_{C(pk)}$ = 5 A I_{B1} = 1 A	BUV47A	(T_C = 100°C)	t_{sv}	–	1.0	2.5	
Crossover Time				t_c	–	0.2	0.5	
Fall Time				t_{fi}	–	0.06	0.3	

Vcl = 300 V, $V_{BE(off)}$ = 5V, Lc = 180μH

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

3

DC CHARACTERISTICS

FIGURE 1 — DC CURRENT GAIN

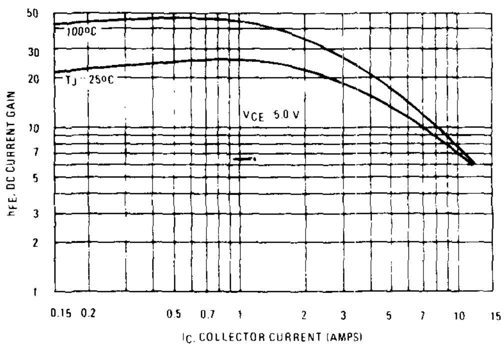


FIGURE 2 — COLLECTOR SATURATION REGION

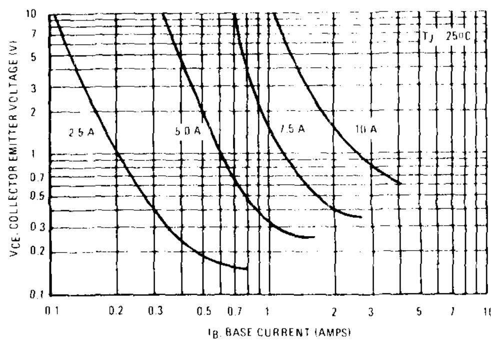


FIGURE 3 — COLLECTOR-EMITTER SATURATION VOLTAGE

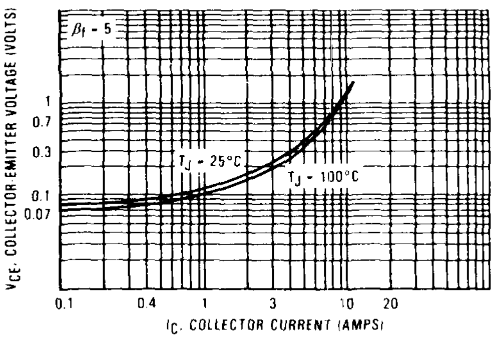


FIGURE 4 — BASE-EMITTER VOLTAGE

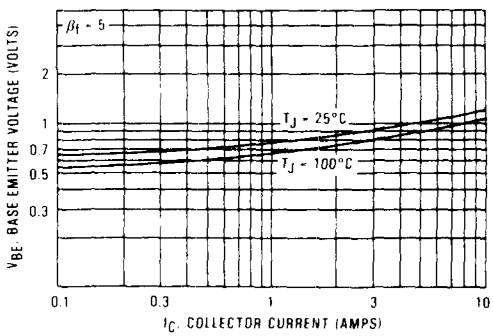


FIGURE 5 — COLLECTOR CUTOFF REGION

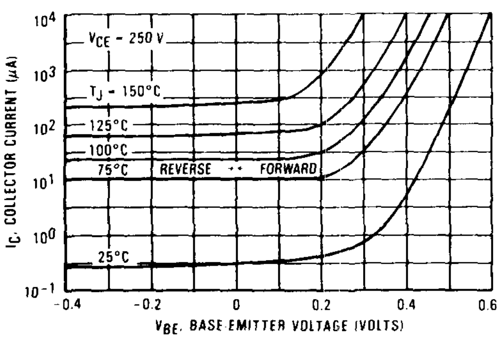
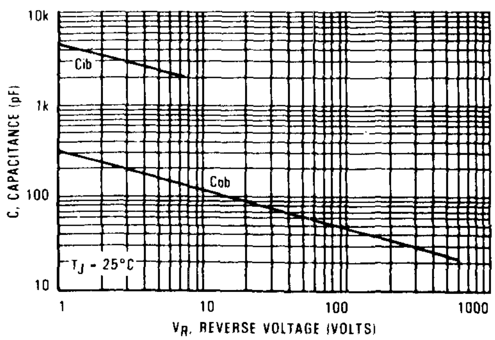


FIGURE 6 — CAPACITANCE



3

TABLE 1 – TEST CONDITIONS FOR DYNAMIC PERFORMANCE

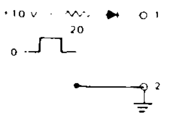
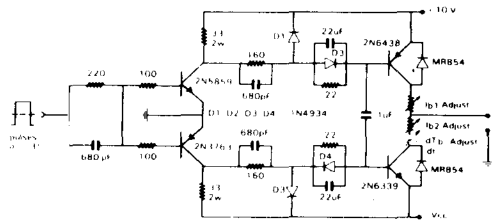
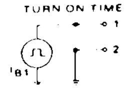
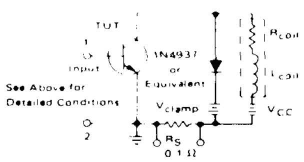
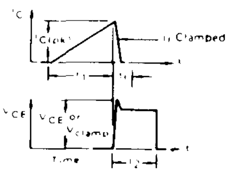
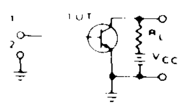
	$V_{CEO(sus)}$	RBSOA AND INDUCTIVE SWITCHING	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 200 mA		TURN ON TIME  I_{B1} adjusted to obtain the forced h_{FE} desired TURN OFF TIME Use inductive switching driver as the input to the resistive test circuit
CIRCUIT VALUES	L_{coil} 25mH V_{CC} = 10 V R_{coil} 0.7 Ω	L_{coil} 180 μH R_{coil} 0.05 Ω V_{CC} 20 V V_{clamp} = 300 V R_B adjusted to attain desired I_{B1}	V_{CC} = 300 V R_L 83 Ω Pulse Width 10 μs
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  See Above for Detailed Conditions	OUTPUT WAVEFORMS  t_1 Adjusted to Obtain I_C $t_1 \approx \frac{L_{coil}(I_{Cpk})}{V_{CC}}$ $t_2 \approx \frac{L_{coil}(I_{Cpk})}{V_{clamp}}$ Test Equipment Scope – Tektronix 475 or Equivalent	RESISTIVE TEST CIRCUIT 

FIGURE 7 – INDUCTIVE SWITCHING MEASUREMENTS

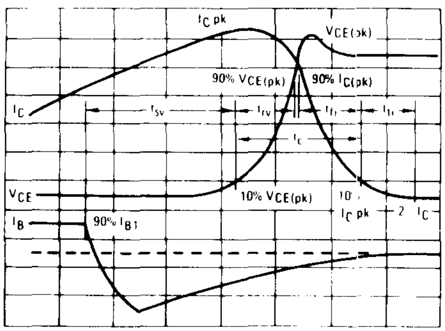
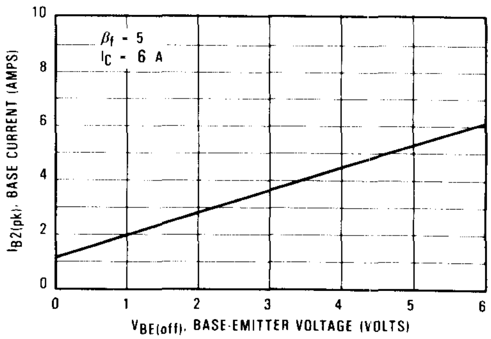


FIGURE 8 – PEAK-REVERSE CURRENT



3

SWITCHING TIMES NOTE

In resistive switching circuits, rise, fall, and storage times have been defined and apply to both current and *voltage waveforms since they are in phase. However,* for inductive loads which are common to SWITCHMODE power supplies and hammer drivers, current and voltage waveforms are not in phase. Therefore, separate measurements must be made on each waveform to determine the total switching time. For this reason, the following new terms have been defined.

t_{sv} = Voltage Storage Time, 90% I_{B1} to 10% V_{clamp}
t_{rv} = Voltage Rise Time, 10–90% V_{clamp}
t_{fi} = Current Fall Time, 90–10% I_C
t_{ti} = Current Tail, 10–2% I_C
t_c = Crossover Time, 10% V_{clamp} to 10% I_C

An enlarged portion of the inductive switching waveforms is shown in Figure 7 to aid in the visual identity of these terms.

For the designer, there is minimal switching loss during storage time and the predominant switching *power losses occur during the crossover interval and* can be obtained using the standard equation from AN-222:

$$P_{SWT} = 1/2\, V_{CC} I_C (t_c) f$$

In general, $t_{rv} + t_{fi} \simeq t_c$. However, at lower test currents this relationship may not be valid.

As is common with most switching transistors, resistive switching is specified at 25°C and has become a benchmark for designers. However, for designers of high frequency converter circuits, the user oriented specifications which make this a "SWITCHMODE" transistor are the inductive switching speeds (t_c and t_{sv}) which are guaranteed at 100°C.

INDUCTIVE SWITCHING

FIGURE 9 – STORAGE TIME

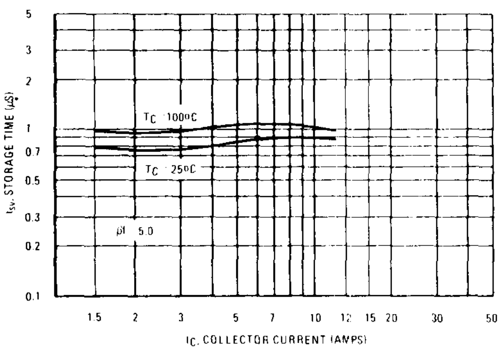


FIGURE 10 – CROSSOVER AND FALL TIMES

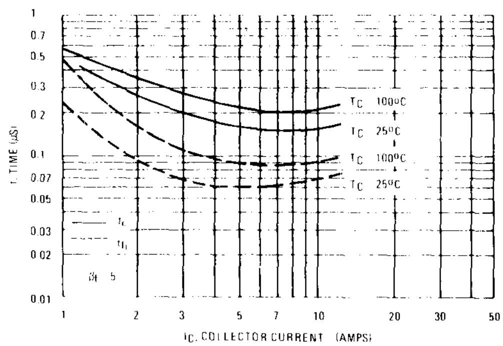


FIGURE 11a – TURN-OFF TIMES vs FORCED GAIN

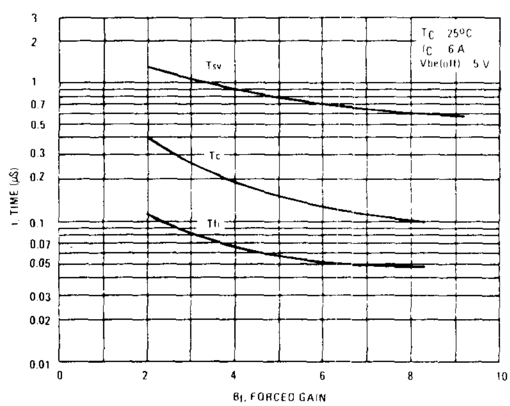
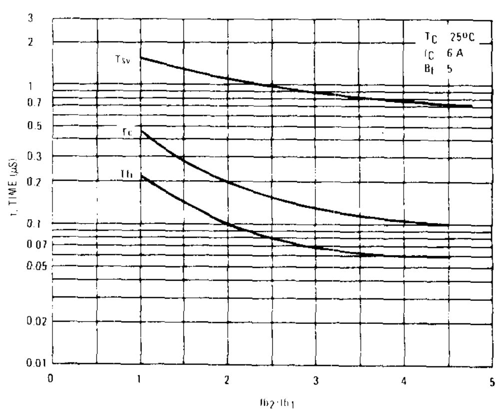


FIGURE 11b – TURN-OFF TIMES vs I_{b2}/I_{b1}



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The Safe Operating Area figures shown in Figures 12 and 13 are specified for these devices under the test conditions shown.

FIGURE 12 — FORWARD BIAS SAFE OPERATING AREA

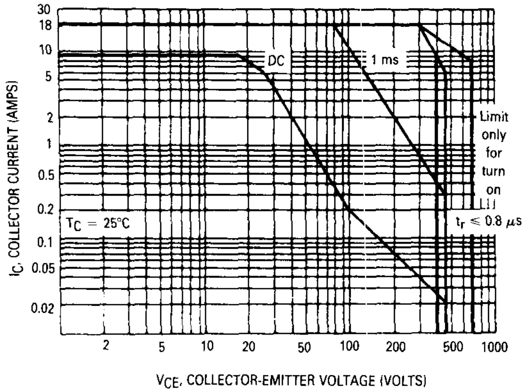


FIGURE 13 — REVERSE BIAS SAFE OPERATING AREA

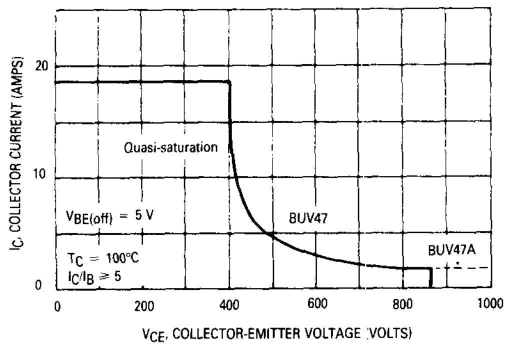
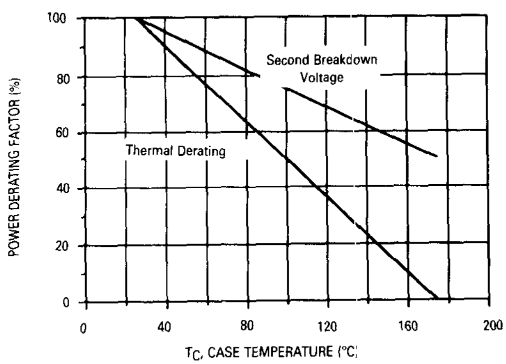


FIGURE 14 — POWER DERATING



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 12 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 12 may be found at any case temperature by using the appropriate curve on Figure 14.

$T_{J(pk)}$ may be calculated from the data in Figure 11. 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 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 13 gives RBSOA characteristics.

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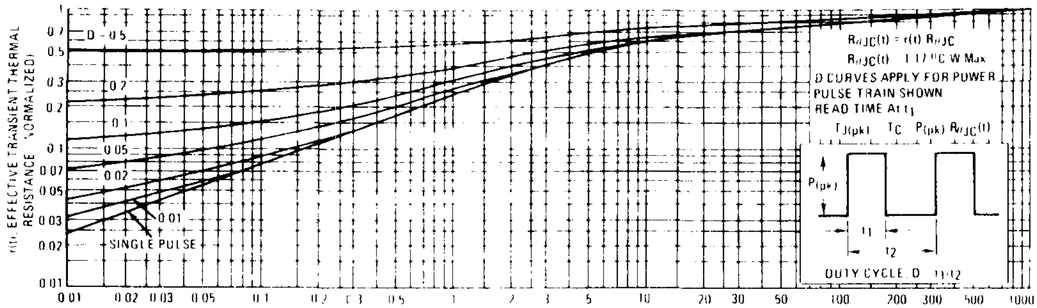
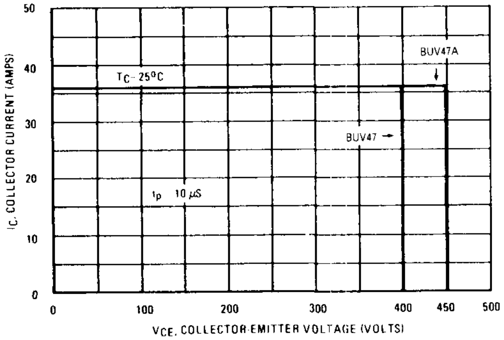
FIGURE 15 – THERMAL RESPONSE



OVERLOAD CHARACTERISTICS

FIGURE 16 – RATED OVERLOAD SAFE OPERATING AREA (OLSOA)



OLSOA

OLSOA applies when maximum collector current is limited and known. A good example is a circuit where an inductor is inserted between the transistor and the bus, which limits the rate of rise of collector current to a known value. If the transistor is then turned off within a specified amount of time, the magnitude of collector current is also known.

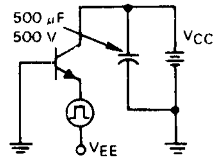
Maximum allowable collector-emitter voltage versus collector current is plotted for several pulse widths. (Pulse width is defined as the time lag between the fault condition and the removal of base drive.) Storage time of the transistor has been factored into the curve. Therefore, with bus voltage and maximum collector current known, Figure 16 defines the maximum time which can be allowed for fault detection and shutdown of base drive.

OLSOA is measured in a common-base circuit (Figure 17) which allows precise definition of collector-emitter voltage and collector current. This is the same circuit that is used to measure forward-bias safe operating area.

FIGURE 17 – OVERLOAD SOA TEST CIRCUIT

Notes:

- $V_{CE} = V_{CC} + V_{BE}$
- Adjust pulsed current source for desired I_C, t_p



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