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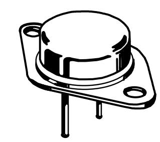
BUT33

SWITCHMODE™ Series NPN Silicon Power Darlington Transistors with Base-Emitter Speedup Diode

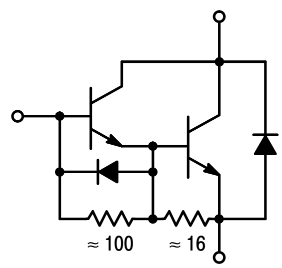
56 AMPERES
NPN SILICON
POWER DARLINGTON
TRANSISTOR
600 VOLTS
250 WATTS



CASE 197A–05
TO–204AE
(TO–3)

The BUT33 Darlington 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 such as:

- AC and DC Motor Controls
- Switching Regulators
- Inverters
- Solenoid and Relay Drivers
- Fast Turn Off Times
  - 800 ns Inductive Fall Time at 25°C (Typ)
  - 2.0 μs Inductive Storage Time at 25°C (Typ)
- Operating Temperature Range –65 to 200°C



MAXIMUM RATINGS

Rating	Symbol	BUT33	Unit
Collector–Emitter Voltage	$V_{CEO(sus)}$	400	Vdc
Collector–Emitter Voltage	V_{CEV}	600	Vdc
Emitter Base Voltage	V_{EB}	10	Vdc
Collector Current — Continuous — Peak (1)	I_C I_{CM}	56 75	Adc
Base Current — Continuous — Peak (1)	I_B I_{BM}	12 15	Adc
Free Wheel Diode Forward Current — Continuous — Peak	I_F I_{FM}	56 75	Adc
Total Power Dissipation @ T_C = 25°C @ T_C = 100°C Derate above 25°C	P_D	250 140	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 Purpose 1/8″ from Case for 5 Seconds	T_L	275	°C

(1) Pulse Test: Pulse Width = 5 ms, Duty Cycle ≦10%.

March, 2001 – Rev. 9
Publication Order Number:
BUT33/D

ELECTRICAL CHARACTERISTICS ($T_C = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector–Emitter Sustaining Voltage (Table 1) (I_C = 100 mA, I_B = 0)	$V_{CEO(sus)}$	400	—	—	Vdc
Collector Cutoff Current	I_{CEV}				mAdc
(V_{CEV} = Rated Value, $V_{BE(off)}$ = 1.5 Vdc)		—	—	0.2	
(V_{CEV} = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C = 100^\circ C$)		—	—	4.0	
Emitter Cutoff Current (V_{EB} = 20 V, I_C = 0)	I_{EBO}	—	—	350	mAdc
SECOND BREAKDOWN					
Second Breakdown Collector Current with base forward biased	$I_{S/b}$		See Figure 16		
Clamped Inductive SOA with Base Reverse Biased	RBSOA		See Figure 17		
ON CHARACTERISTICS (1)					
DC Current Gain	h_{FE}				
(I_C = 20 A, V_{CE} = 5 V)		30	—	—	
(I_C = 36 A, V_{CE} = 5 V)		20	—	—	
Collector–Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 20 A, I_B = 1 A)		—	—	2.0	
(I_C = 36 A, I_B = 3.6 A)		—	—	2.5	
(I_C = 44 A, I_B = 4.4 A)		—	—	3.0	
(I_C = 56 A, I_B = 11.2 A)		—	—	5.0	
Base–Emitter Saturation Voltage	$V_{BE(sat)}$				Vdc
(I_C = 20 A, I_B = 1 A)		—	—	2.5	
(I_C = 36 A, I_B = 3.6 A)		—	—	2.9	
(I_C = 44 A, I_B = 4.4 A)		—	—	3.3	
Diode Forward Voltage (I_F = 44 A)	V_f	—	—	4.0	Vdc

SWITCHING CHARACTERISTICS
Inductive Load Clamped (Table 1)

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
Storage Time	$T_C = 25^\circ C$ I_C = 36 A	t_s	—	2.0	3.3	µs
Fall Time	I_B = 3.6 A	t_f	—	0.8	1.6	µs
Storage Time	See Table 1	t_s	—	2.2	—	µs
Fall Time	$T_C = 100^\circ C$ $V_{BE(off)}$ = 5 V	t_f	—	0.8	—	µs

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

TYPICAL CHARACTERISTICS

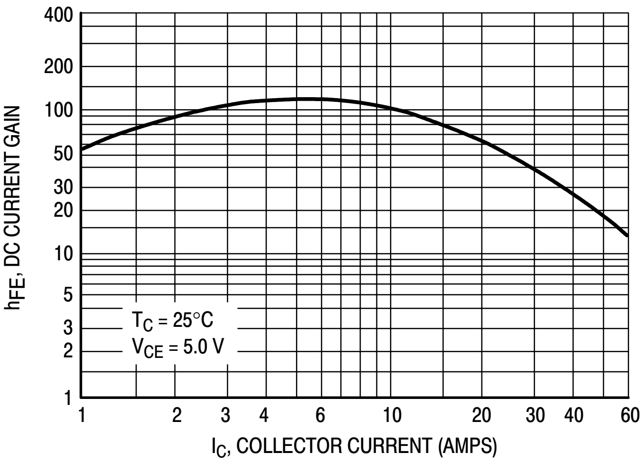


Figure 1. DC Current Gain

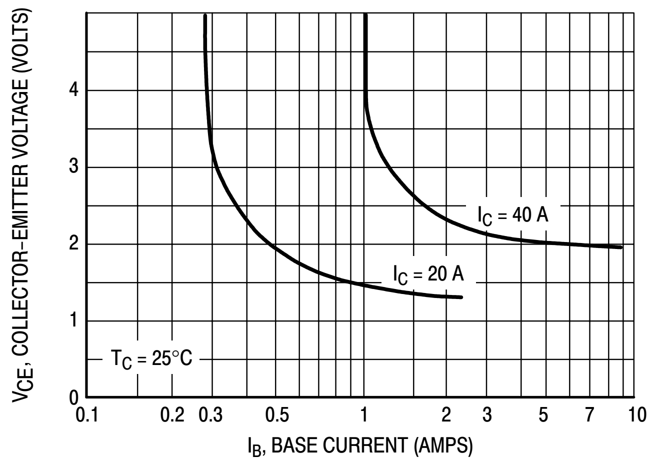


Figure 2. Collector Saturation Region

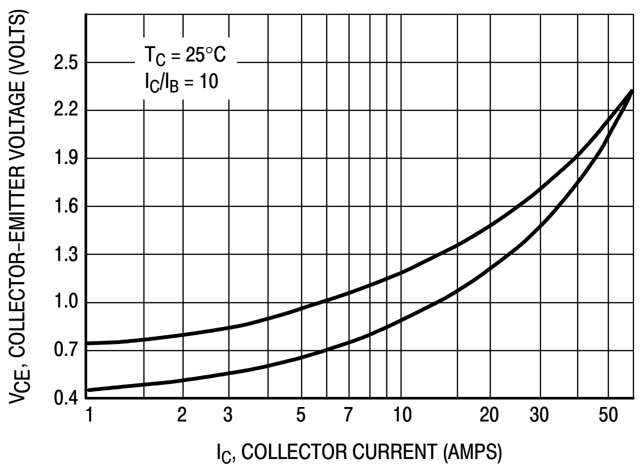


Figure 3. Collector–Emitter Saturation Voltage

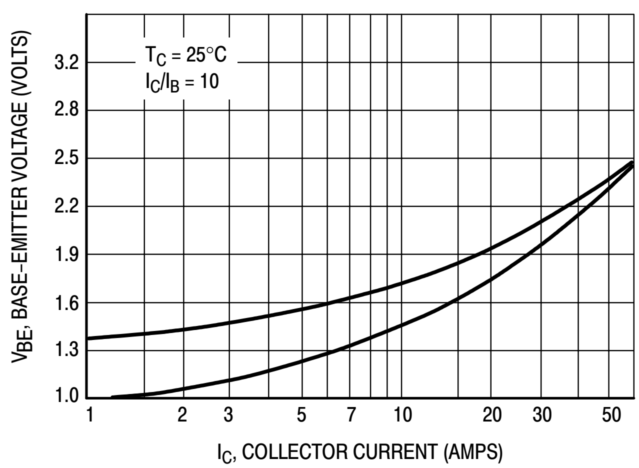


Figure 4. Base–Emitter Voltage

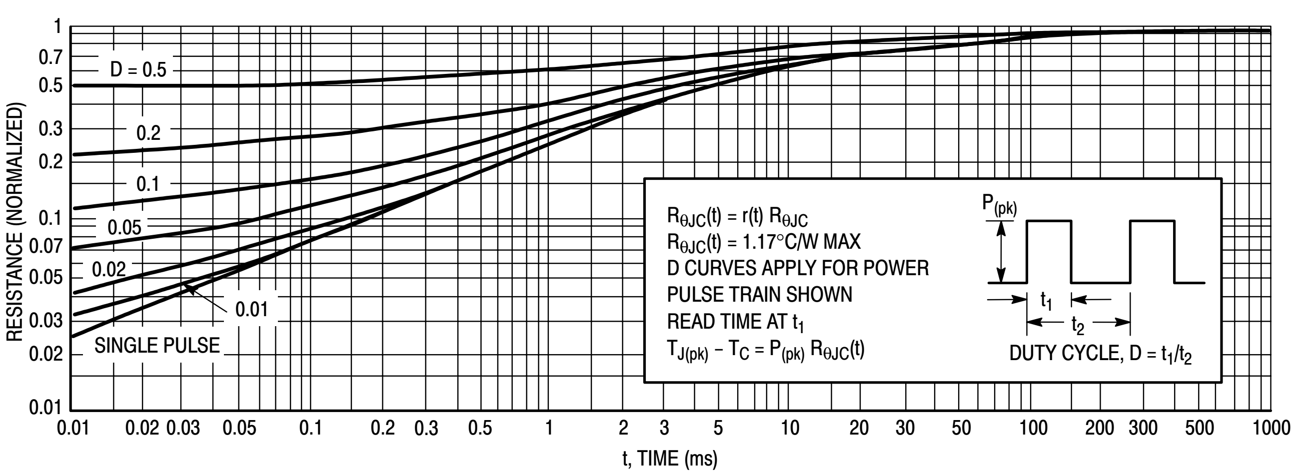
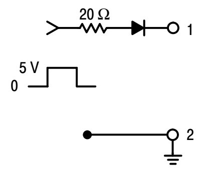
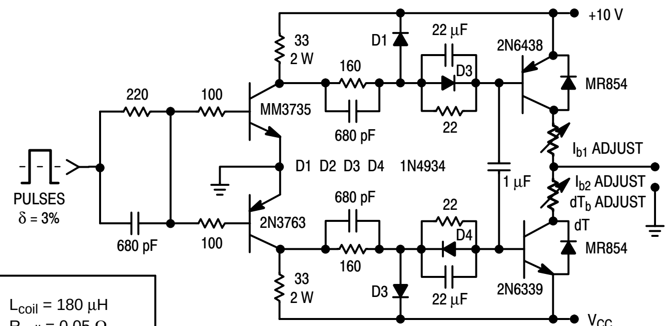
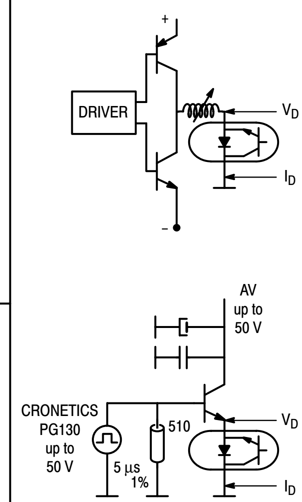
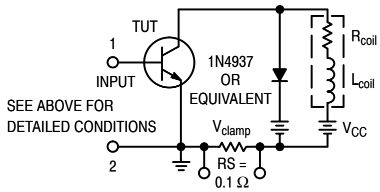
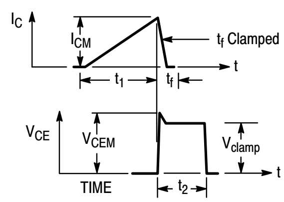


Figure 5. Thermal Response

Table 1. Test Conditions for Dynamic Performance

	$V_{CEO(sus)}$	RBSOA AND INDUCTIVE SWITCHING	TEST CIRCUIT for FREE–WHEEL DIODE
INPUT CONDITIONS	 PW Varied to Attain I_C = 100 mA		
CIRCUIT VALUES	L_{coil} = 10 mH, V_{CC} = 10 V R_{coil} = 0.7 Ω V_{clamp} = $V_{CEO(sus)}$	L_{coil} = 180 µH R_{coil} = 0.05 Ω V_{CC} = 10 V	
TEST CIRCUITS	**INDUCTIVE TEST CIRCUIT** 	**OUTPUT WAVEFORMS**  t_1 Adjusted to Obtain I_C $t_1 \approx \frac{L_{coil}\,(I_{CM})}{V_{CC}}$ $t_2 \approx \frac{L_{coil}\,(I_{CM})}{V_{clamp}}$ Test Equipment Scope — Tektronix 475 or Equivalent	

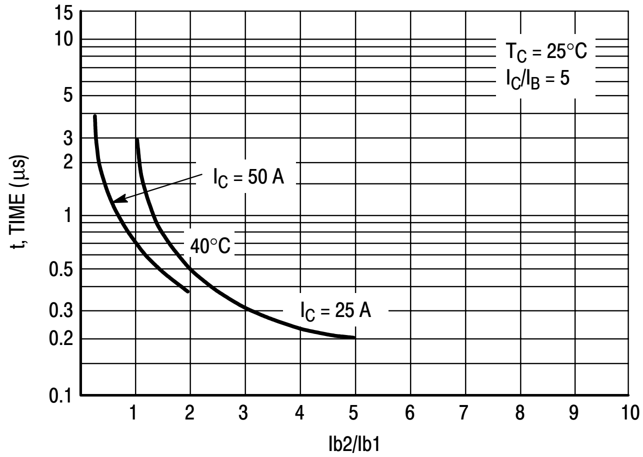


Figure 6. Fall Time versus IB2/IB1

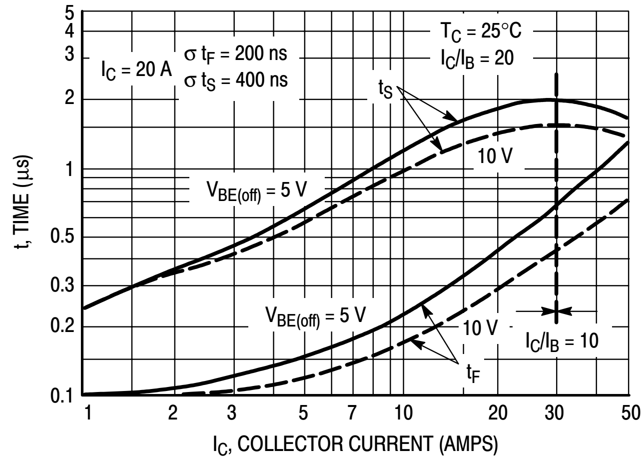


Figure 7. Turn–Off Time versus I_C

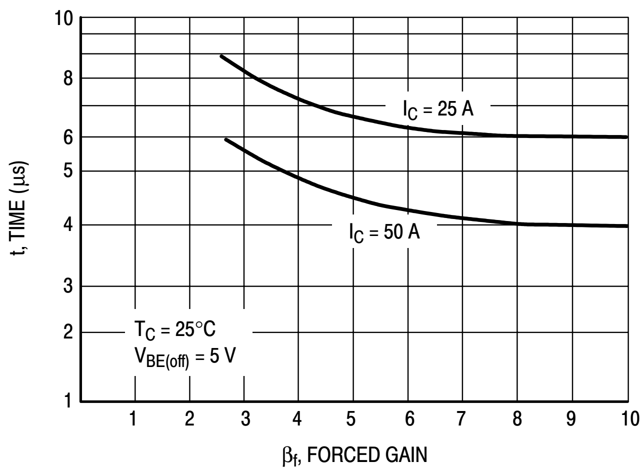


Figure 8. Storage Time versus Forced Gain

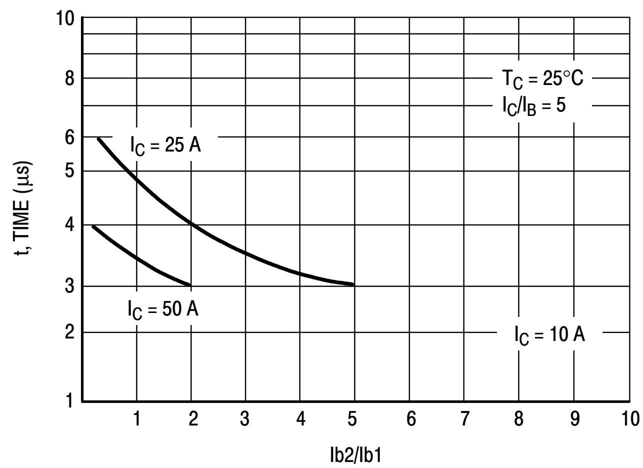


Figure 9. Storage Time versus Ib2/Ib1

FREE–WHEEL DIODE CHARACTERISTICS

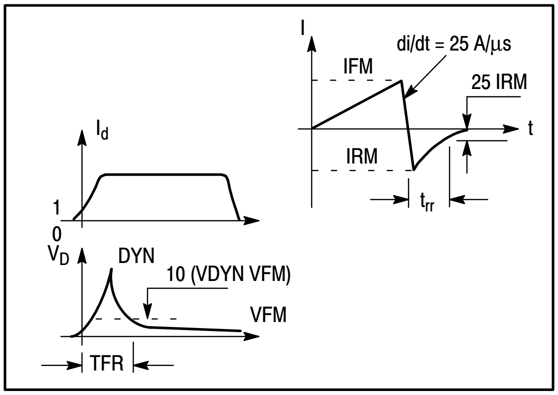


Figure 10. Free Wheel Diode Measurements

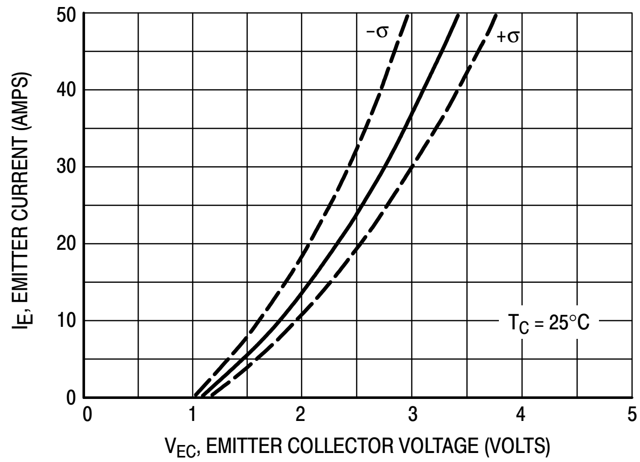


Figure 11. Forward Voltage

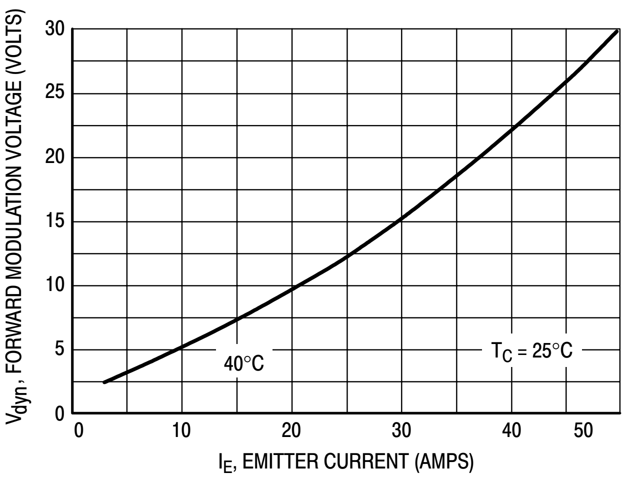


Figure 12. Forward Modulation Voltage

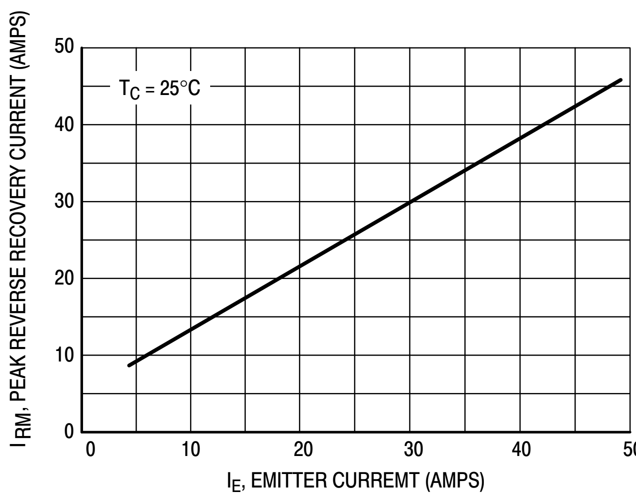


Figure 13. Peak Reverse Recovery Current

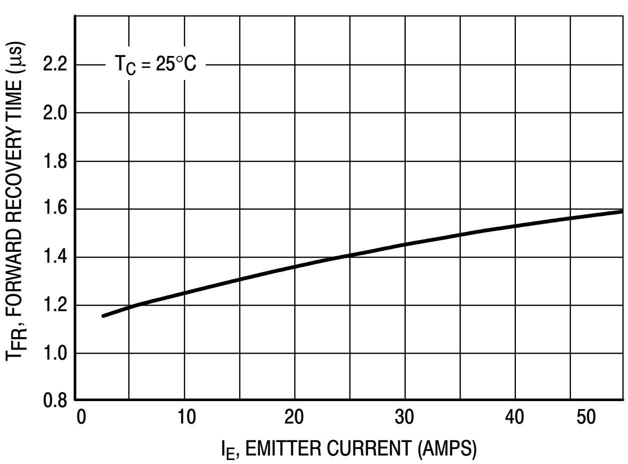


Figure 14. Forward Recovery Time

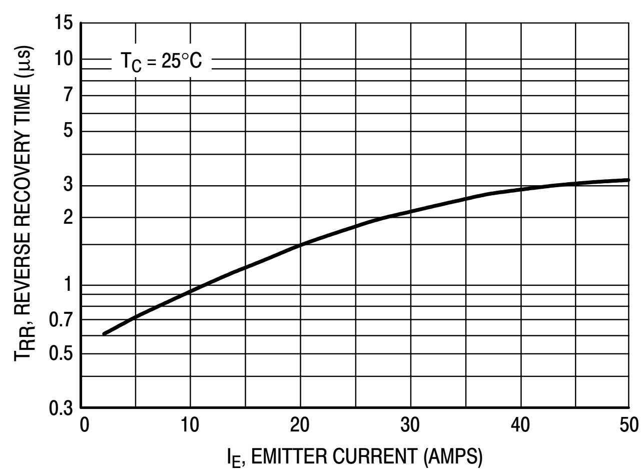


Figure 15. Reverse Recovery Time

The Safe Operating Area figures shown in Figures 16 and 17 are specified for the devices under the test conditioned shown.

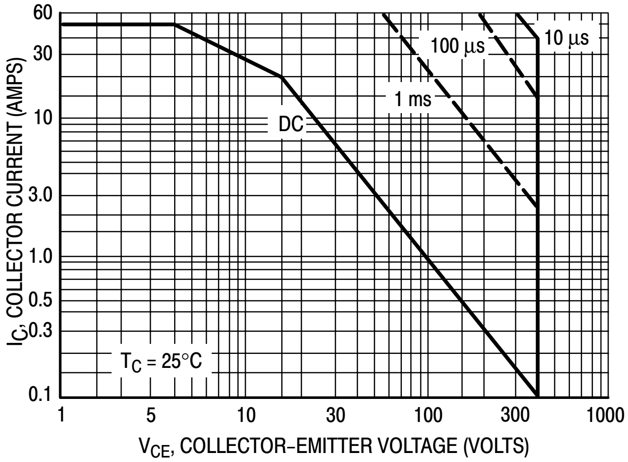


Figure 16. Safe Operating Area

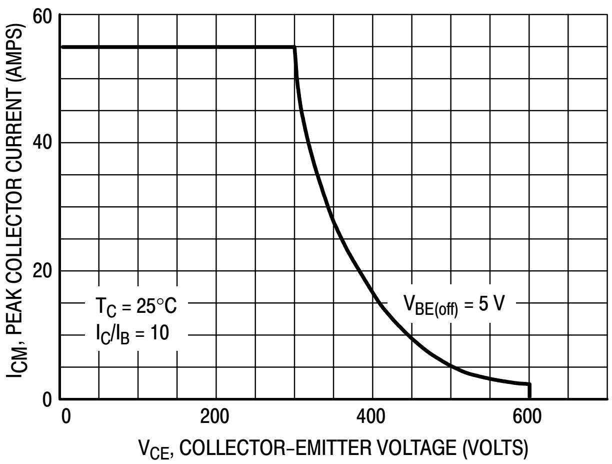


Figure 17. Reverse Bias Safe Operating Area

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 subject to greater dissipation than the curves indicate.

The data of Figure 16 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 y 25_C. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figure 16 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 5. 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 turnoff. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode Figure 17 gives the RBSOA characteristics.

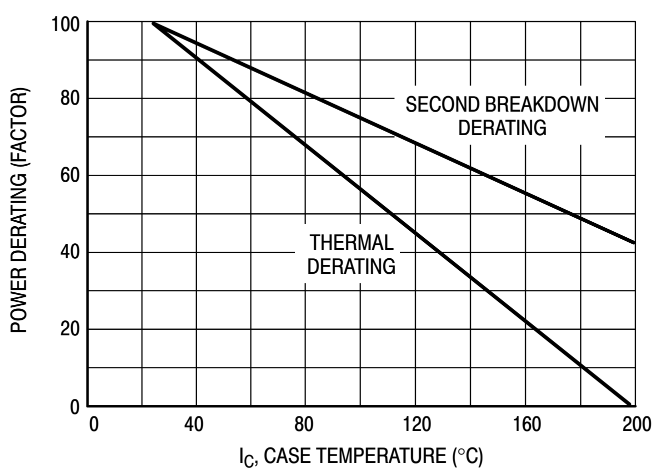
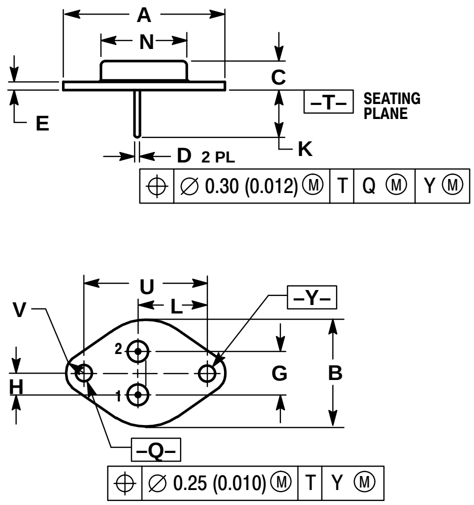


Figure 18. Power Derating

PACKAGE DIMENSIONS

TO–204 AE (TO–3)
CASE 197A–05
ISSUE J



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

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	1.530 REF		38.86 REF	
B	0.990	1.050	25.15	26.67
C	0.250	0.335	6.35	8.51
D	0.057	0.063	1.45	1.60
E	0.060	0.070	1.53	1.77
G	0.430 BSC		10.92 BSC	
H	0.215 BSC		5.46 BSC	
K	0.440	0.480	11.18	12.19
L	0.665 BSC		16.89 BSC	
N	0.760	0.830	19.31	21.08
Q	0.151	0.165	3.84	4.19
U	1.187 BSC		30.15 BSC	
V	0.131	0.188	3.33	4.77

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