

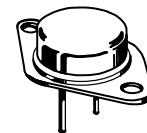
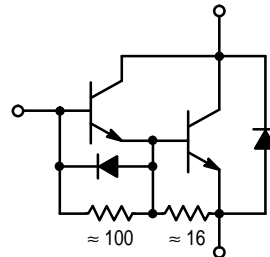
**BUT33**

*Designer's™ Data Sheet*  
**SWITCHMODE Series**  
**NPN Silicon Power Darlington**  
**Transistors with Base-Emitter**  
**Speedup Diode**

**56 AMPERES**  
**NPN SILICON**  
**POWER DARLINGTON**  
**TRANSISTOR**  
**600 VOLTS**  
**250 WATTS**

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



**CASE 197A-05**  
**TO-204AE**  
**(TO-3)**

**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	$I_C$	56	Adc
— Peak (1)	$I_{CM}$	75	
Base Current — Continuous	$I_B$	12	Adc
— Peak (1)	$I_{BM}$	15	
Free Wheel Diode Forward Current — Continuous	$I_F$	56	Adc
— Peak	$I_{FM}$	75	
Total Power Dissipation @ $T_C = 25^\circ C$	$P_D$	250	Watts
@ $T_C = 100^\circ C$		140	
Derate above 25°C			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  $\leq 10\%$ .

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**Designer's Data for "Worst Case" Conditions** — The Designer's Data Sheet permits the design of most circuits entirely from the information presented. SOA Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

# BUT33

## ELECTRICAL CHARACTERISTICS (T<sub>C</sub> = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>OFF CHARACTERISTICS</b>					
Collector–Emitter Sustaining Voltage (Table 1) (I <sub>C</sub> = 100 mA, I <sub>B</sub> = 0)	V <sub>CEO(sus)</sub>	400	—	—	Vdc
Collector Cutoff Current (V <sub>CEV</sub> = Rated Value, V <sub>BE(off)</sub> = 1.5 Vdc) (V <sub>CEV</sub> = Rated Value, V <sub>BE(off)</sub> = 1.5 Vdc, T <sub>C</sub> = 100°C)	I <sub>CEV</sub>	—	—	0.2 4.0	mAdc
Emitter Cutoff Current (V <sub>EB</sub> = 20 V, I <sub>C</sub> = 0)	I <sub>EBO</sub>	—	—	350	mAdc

## SECOND BREAKDOWN

Second Breakdown Collector Current with base forward biased	I <sub>S/b</sub>		See Figure 16	
Clamped Inductive SOA with Base Reverse Biased	RBSOA		See Figure 17	

## ON CHARACTERISTICS (1)

DC Current Gain (I <sub>C</sub> = 20 A, V <sub>CE</sub> = 5 V) (I <sub>C</sub> = 36 A, V <sub>CE</sub> = 5 V)	h <sub>FE</sub>	30 20	— —	— —	
Collector–Emitter Saturation Voltage (I <sub>C</sub> = 20 A, I <sub>B</sub> = 1 A) (I <sub>C</sub> = 36 A, I <sub>B</sub> = 3.6 A) (I <sub>C</sub> = 44 A, I <sub>B</sub> = 4.4 A) (I <sub>C</sub> = 56 A, I <sub>B</sub> = 11.2 A)	V <sub>CE(sat)</sub>	— — — —	— — — —	2.0 2.5 3.0 5.0	Vdc
Base–Emitter Saturation Voltage (I <sub>C</sub> = 20 A, I <sub>B</sub> = 1 A) (I <sub>C</sub> = 36 A, I <sub>B</sub> = 3.6 A) (I <sub>C</sub> = 44 A, I <sub>B</sub> = 4.4 A)	V <sub>BE(sat)</sub>	— — —	— — —	2.5 2.9 3.3	Vdc
Diode Forward Voltage (I <sub>F</sub> = 44 A)	V <sub>f</sub>	—	—	4.0	Vdc

## SWITCHING CHARACTERISTICS

Inductive Load Clamped (Table 1)

Storage Time	T <sub>C</sub> = 25°C	I <sub>C</sub> = 36 A	I <sub>B</sub> = 3.6 A	t <sub>s</sub>	—	2.0	3.3	μs
Fall Time				t <sub>f</sub>	—	0.8	1.6	μs
Storage Time	T <sub>C</sub> = 100°C	I <sub>C</sub> = 36 A	I <sub>B</sub> = 3.6 A	t <sub>s</sub>	—	2.2	—	μs
Fall Time				t <sub>f</sub>	—	0.8	—	μs

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

TYPICAL CHARACTERISTICS

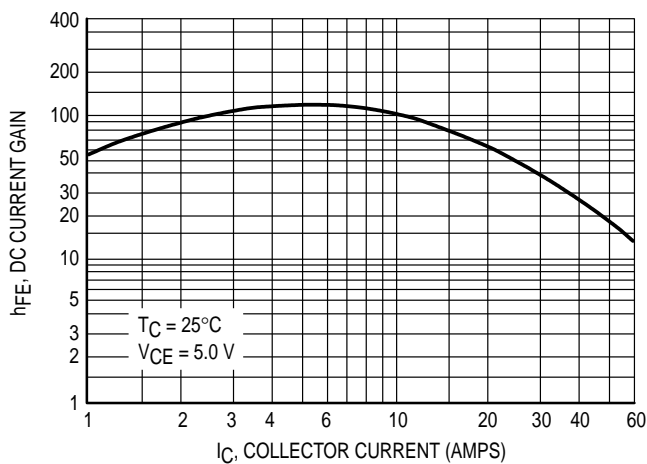


Figure 1. DC Current Gain

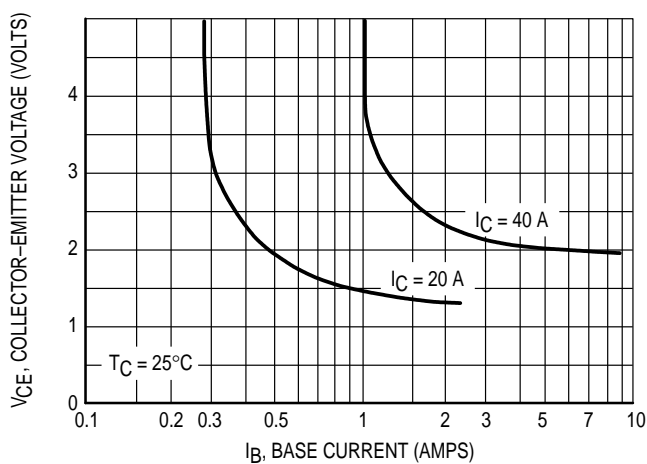


Figure 2. Collector Saturation Region

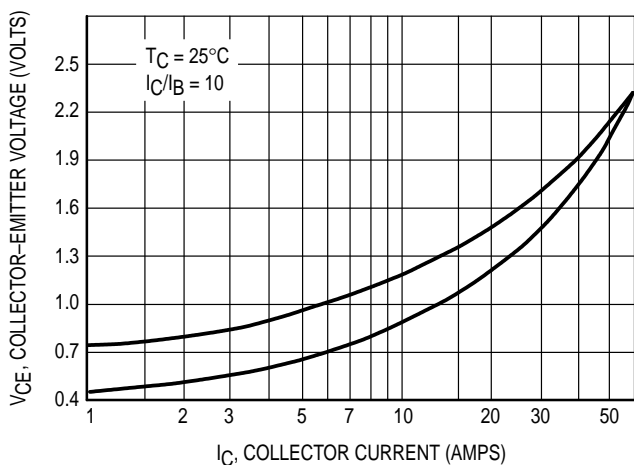


Figure 3. Collector-Emitter Saturation Voltage

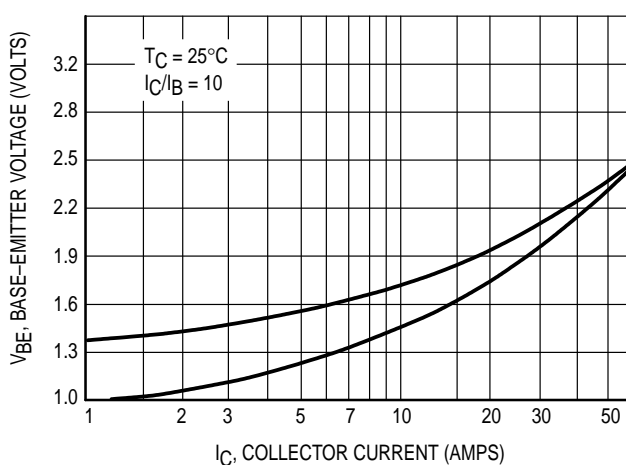


Figure 4. Base-Emitter Voltage

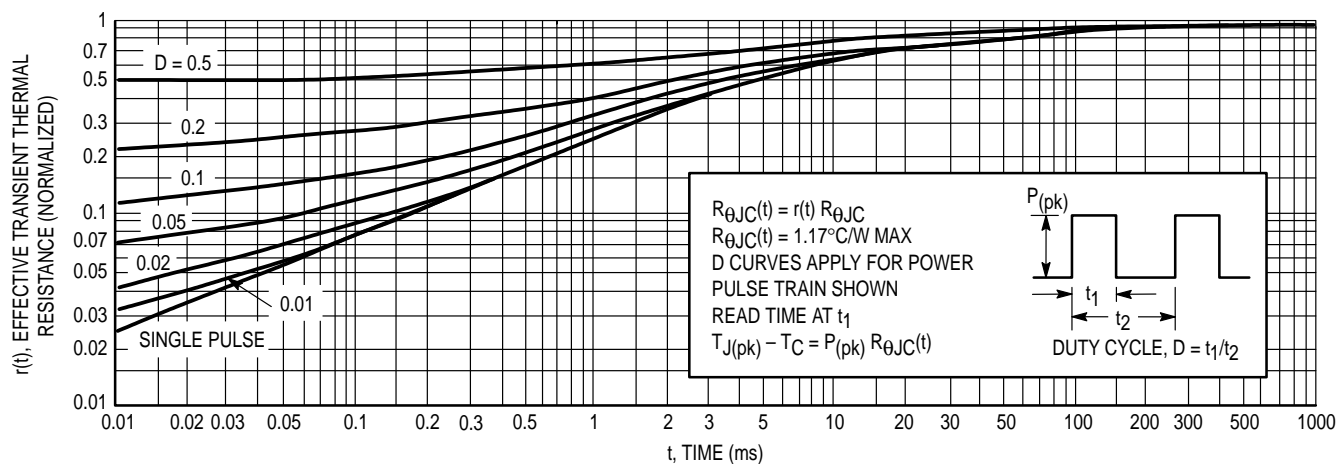
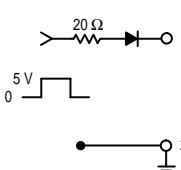
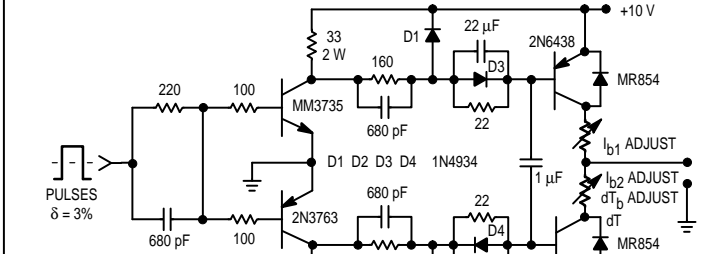
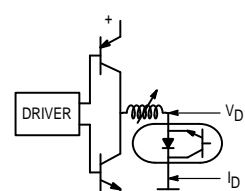
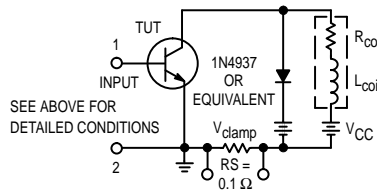
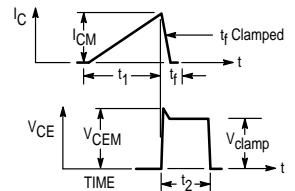
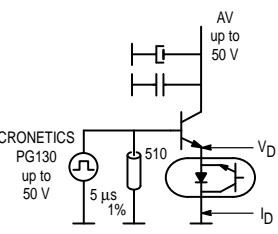


Figure 5. Thermal Response

Table 1. Test Conditions for Dynamic Performance

<p><b>INPUT CONDITIONS</b></p>  <p>PW Varied to Attain <math>I_C = 100 \text{ mA}</math></p>	<p><b>RBSOA AND INDUCTIVE SWITCHING</b></p> 		<p><b>TEST CIRCUIT for FREE-WHEEL DIODE</b></p> 
<p><b>CIRCUIT VALUES</b></p> <p><math>L_{\text{coil}} = 10 \text{ mH}</math>, <math>V_{CC} = 10 \text{ V}</math>  <math>R_{\text{coil}} = 0.7 \Omega</math>  <math>V_{\text{clamp}} = V_{CE0(\text{sus})}</math></p>	<p><math>L_{\text{coil}} = 180 \mu\text{H}</math>  <math>R_{\text{coil}} = 0.05 \Omega</math>  <math>V_{CC} = 10 \text{ V}</math></p>		
<p><b>TEST CIRCUITS</b></p> <p><b>INDUCTIVE TEST CIRCUIT</b></p>  <p>SEE ABOVE FOR DETAILED CONDITIONS</p>	<p><b>OUTPUT WAVEFORMS</b></p>  <p><math>t_1</math> Adjusted to Obtain <math>I_C</math></p> $t_1 \approx \frac{L_{\text{coil}} (I_{CM})}{V_{CC}}$ $t_2 \approx \frac{L_{\text{coil}} (I_{CM})}{V_{\text{clamp}}}$ <p>Test Equipment          Scope — Tektronix 475 or Equivalent</p>		<p><b>TEST CIRCUIT for FREE-WHEEL DIODE</b></p> 

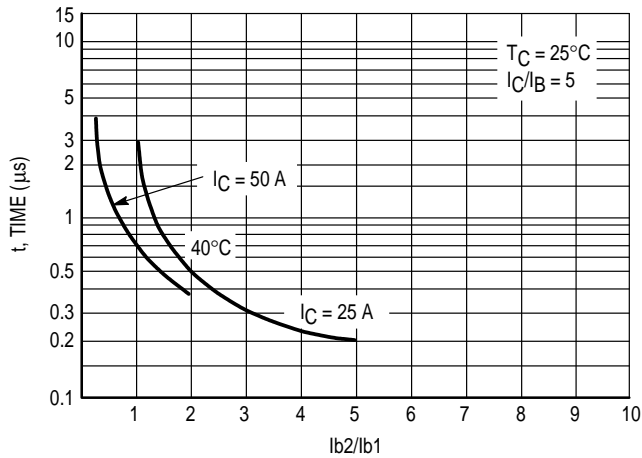


Figure 6. Fall Time versus  $I_{B2}/I_{B1}$

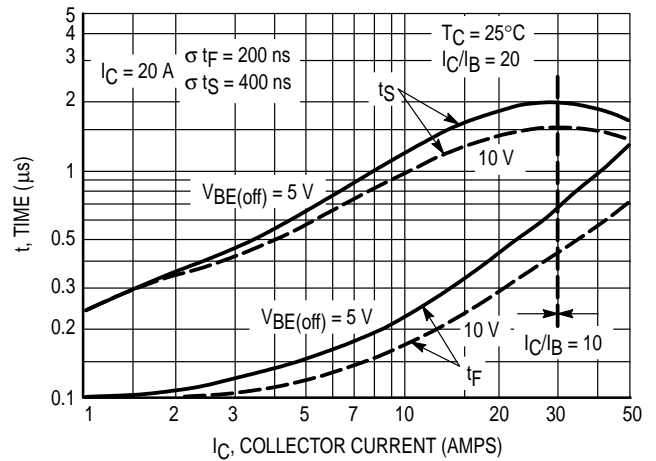


Figure 7. Turn-Off Time versus  $I_C$

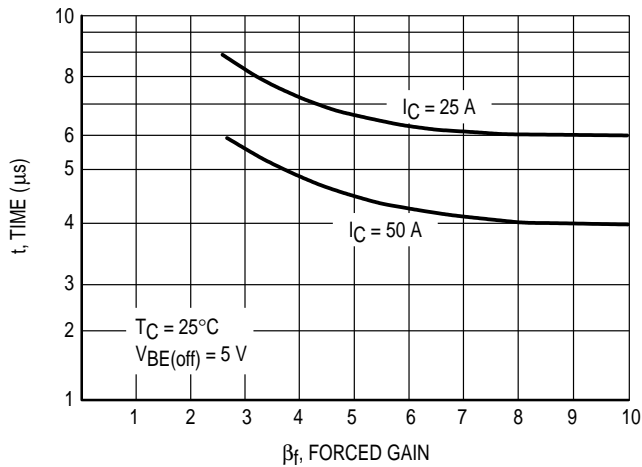


Figure 8. Storage Time versus Forced Gain

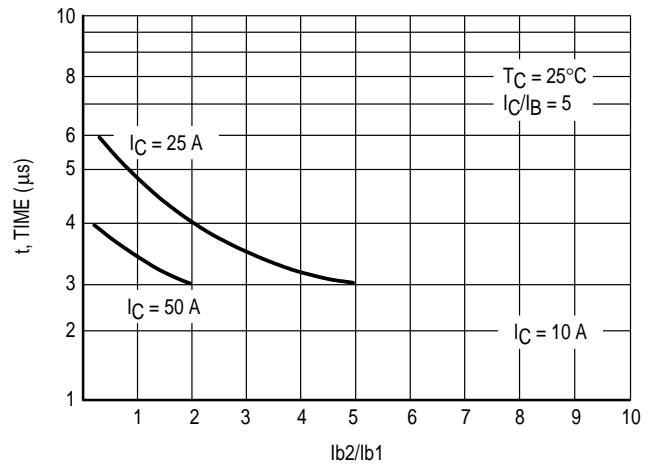


Figure 9. Storage Time versus  $I_{B2}/I_{B1}$

FREE-WHEEL DIODE CHARACTERISTICS

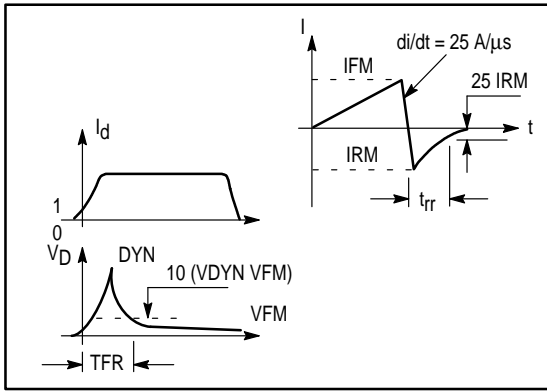


Figure 10. Free Wheel Diode Measurements

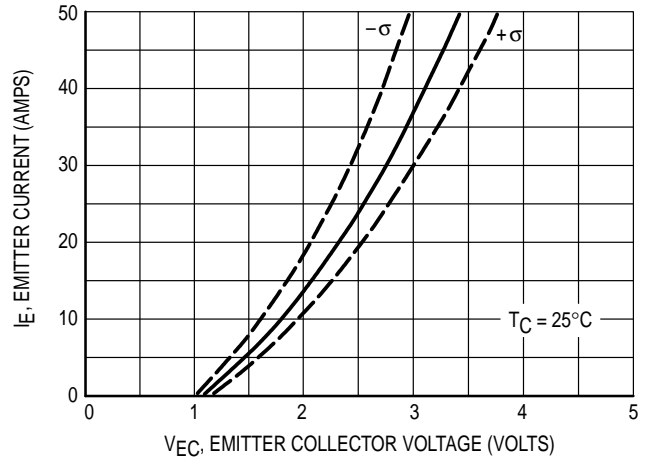


Figure 11. Forward Voltage

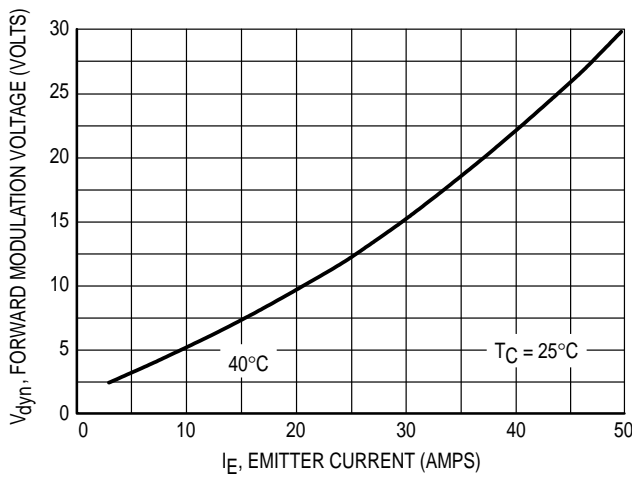


Figure 12. Forward Modulation Voltage

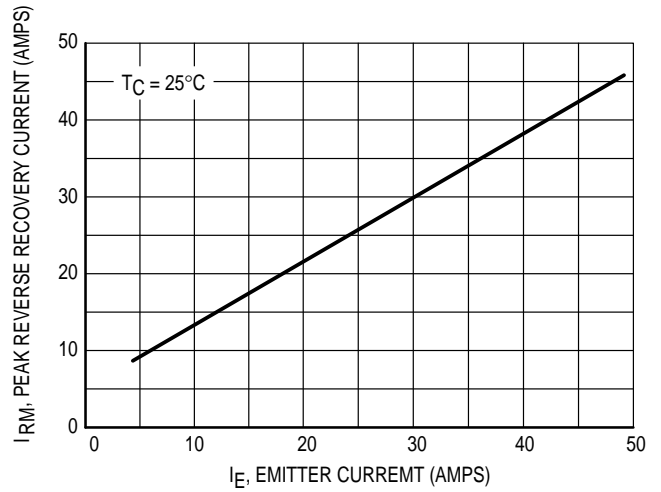


Figure 13. Peak Reverse Recovery Current

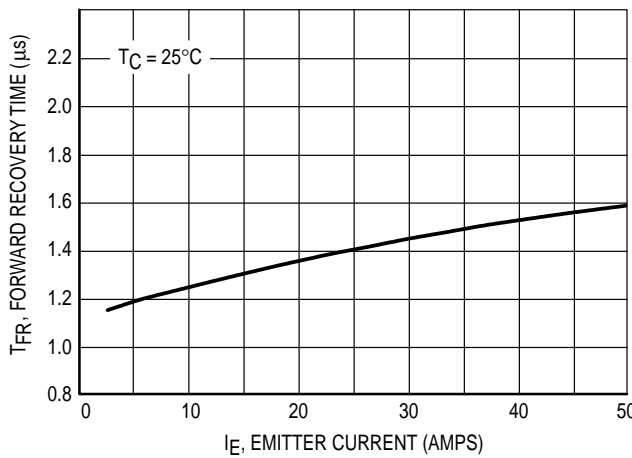


Figure 14. Forward Recovery Time

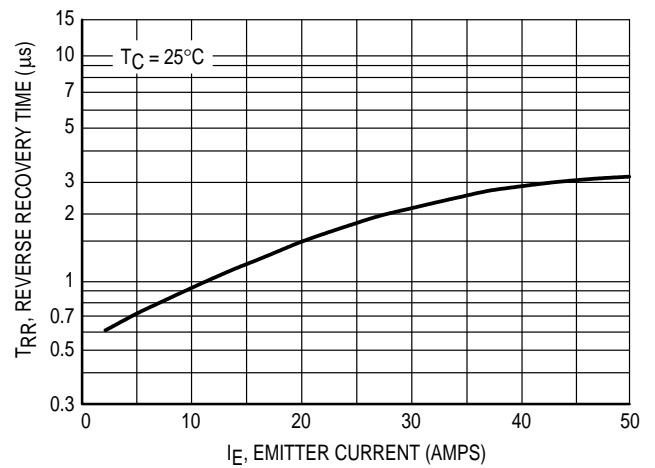


Figure 15. Reverse Recovery Time

## BUT33

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

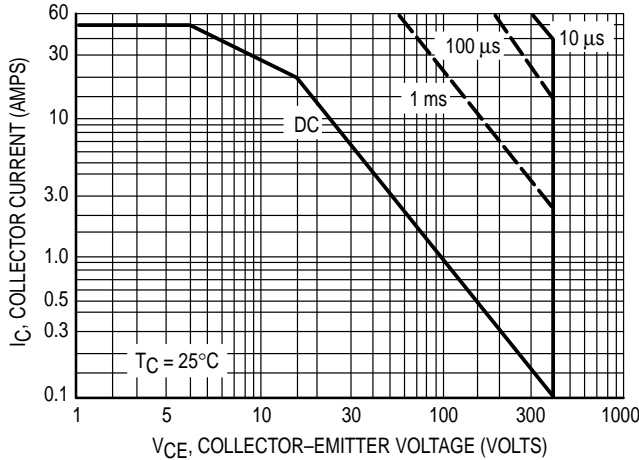


Figure 16. Safe Operating Area

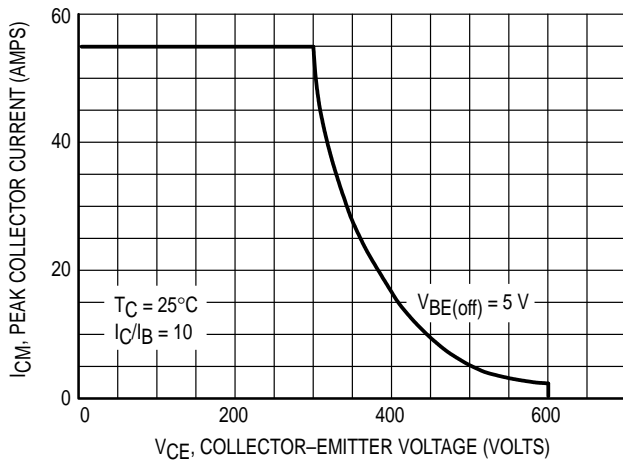


Figure 17. Reverse Bias Safe Operating Area

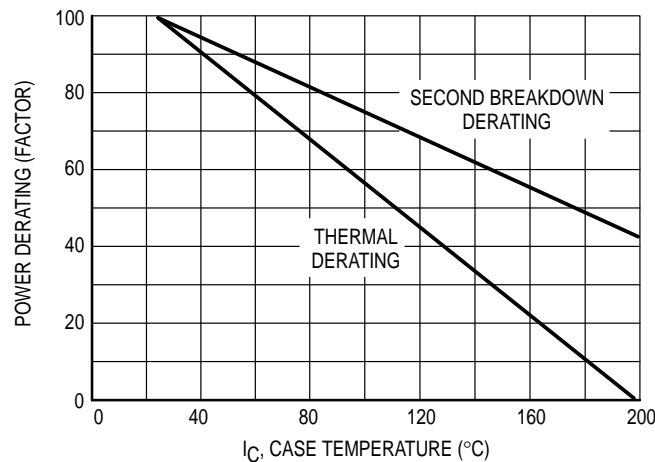


Figure 18. Power Derating

## 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 subject to greater dissipation than the curves indicate.

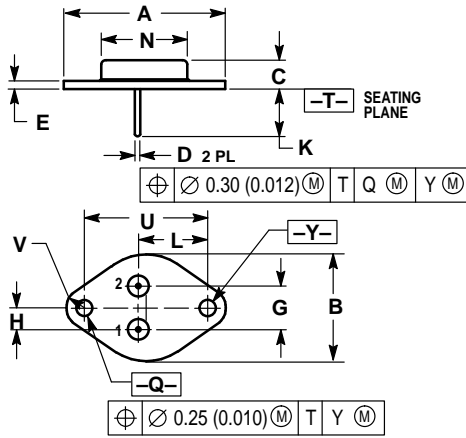
The data of Figure 16 is based on  $T_C = 25^\circ\text{C}$ ;  $T_{J(pk)}$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ\text{C}$ . Second breakdown limitations do not derate the same as thermal limitations. 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.

PACKAGE DIMENSIONS




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

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	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

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

CASE 197A-05  
 TO-204AE (TO-3)  
 ISSUE J

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