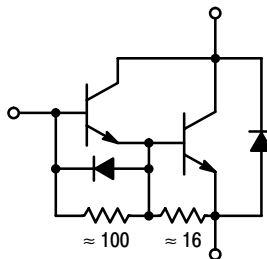


SWITCHMODE™ Series

NPN Silicon Power Darlington Transistors with Base-Emitter Speedup Diode

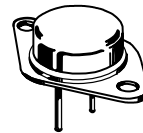
The BUT33 Darlington transistor is designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line operated SWITCHMODE applications such as:

- 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



BUT33

56 AMPERES
NPN SILICON
POWER DARLINGTON
TRANSISTOR
600 VOLTS
250 WATTS



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 @ $T_C = 25^\circ\text{C}$	P_D	250	Watts
Derate above 25°C @ $T_C = 100^\circ\text{C}$		140	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 $\leq 10\%$.

BUT33

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

Characteristic	Symbol	Min	Typ	Max	Unit
----------------	--------	-----	-----	-----	------

OFF CHARACTERISTICS

Collector–Emitter Sustaining Voltage (Table 1) ($I_C = 100\text{ mA}$, $I_B = 0$)	$V_{CEO(sus)}$	400	—	—	Vdc
Collector Cutoff Current ($V_{CEV} = \text{Rated Value}$, $V_{BE(off)} = 1.5\text{ Vdc}$) ($V_{CEV} = \text{Rated Value}$, $V_{BE(off)} = 1.5\text{ Vdc}$, $T_C = 100^\circ\text{C}$)	I_{CEV}	—	—	0.2 4.0	mAdc
Emitter Cutoff Current ($V_{EB} = 20\text{ V}$, $I_C = 0$)	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 ($I_C = 20\text{ A}$, $V_{CE} = 5\text{ V}$) ($I_C = 36\text{ A}$, $V_{CE} = 5\text{ V}$)	h_{FE}	30 20	— —	— —	
Collector–Emitter Saturation Voltage ($I_C = 20\text{ A}$, $I_B = 1\text{ A}$) ($I_C = 36\text{ A}$, $I_B = 3.6\text{ A}$) ($I_C = 44\text{ A}$, $I_B = 4.4\text{ A}$) ($I_C = 56\text{ A}$, $I_B = 11.2\text{ A}$)	$V_{CE(sat)}$	— — — —	— — — —	2.0 2.5 3.0 5.0	Vdc
Base–Emitter Saturation Voltage ($I_C = 20\text{ A}$, $I_B = 1\text{ A}$) ($I_C = 36\text{ A}$, $I_B = 3.6\text{ A}$) ($I_C = 44\text{ A}$, $I_B = 4.4\text{ A}$)	$V_{BE(sat)}$	— — —	— — —	2.5 2.9 3.3	Vdc
Diode Forward Voltage ($I_F = 44\text{ A}$)	V_f	—	—	4.0	Vdc

SWITCHING CHARACTERISTICS

Inductive Load Clamped (Table 1)

Storage Time	$T_C = 25^\circ\text{C}$	$I_C = 36\text{ A}$	$I_B = 3.6\text{ A}$	t_s	—	2.0	3.3	μs
Fall Time				t_f	—	0.8	1.6	μs
Storage Time	$T_C = 100^\circ\text{C}$	$I_C = 36\text{ A}$	$I_B = 3.6\text{ A}$	t_s	—	2.2	—	μs
Fall Time				t_f	—	0.8	—	μs

(1) Pulse Test: $PW = 300\ \mu\text{s}$, Duty Cycle $\leq 2\%$.

BUT33

TYPICAL CHARACTERISTICS

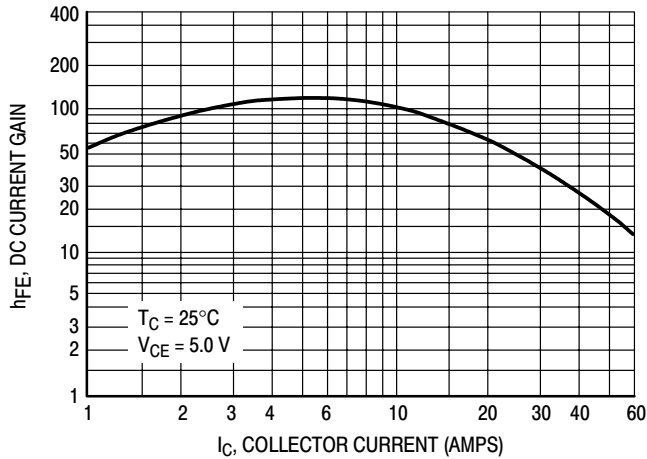


Figure 1. DC Current Gain

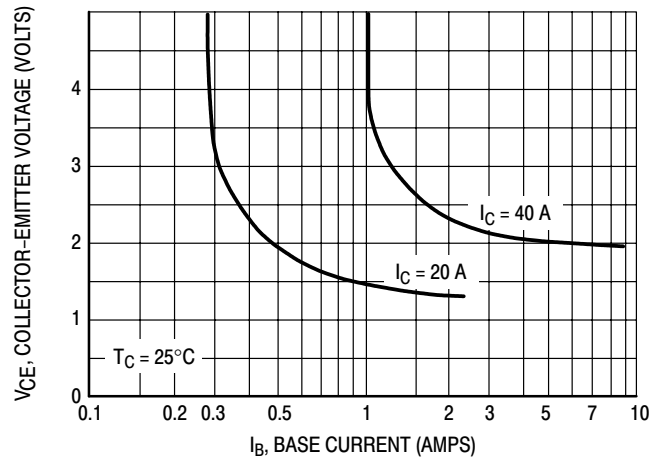


Figure 2. Collector Saturation Region

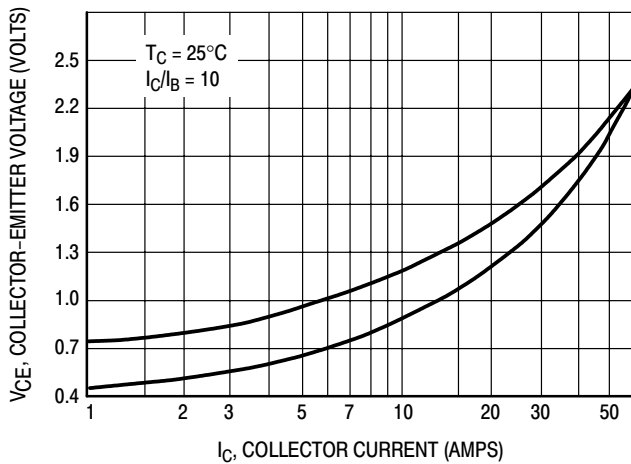


Figure 3. Collector-Emitter Saturation Voltage

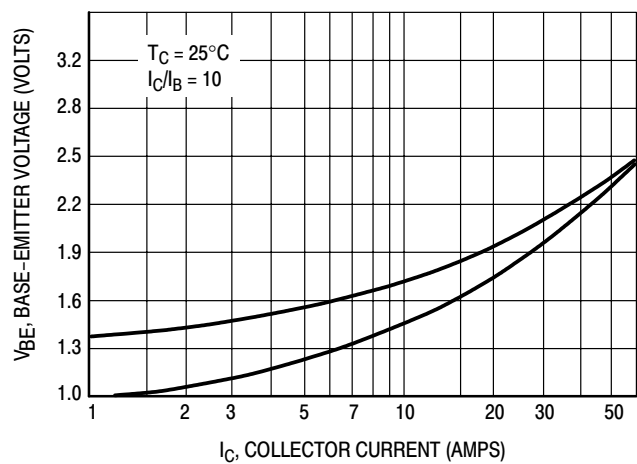


Figure 4. Base-Emitter Voltage

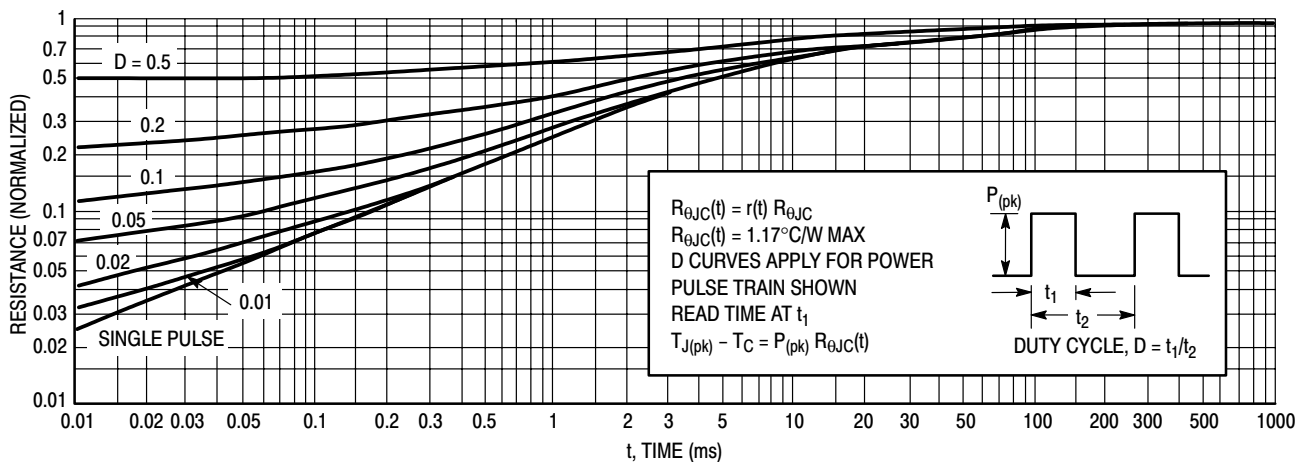
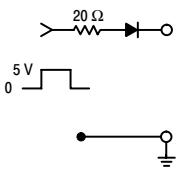
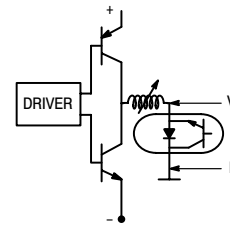
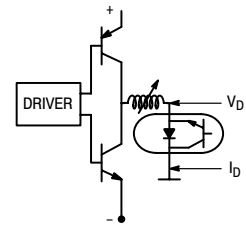
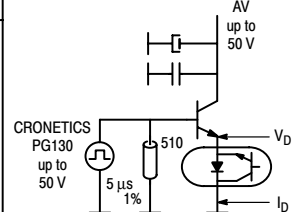
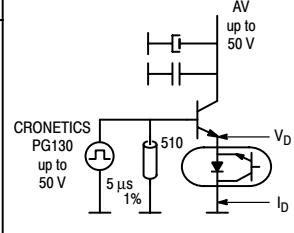
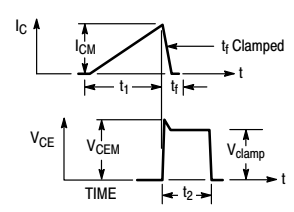
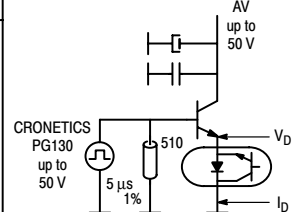


Figure 5. Thermal Response

BUT33

Table 1. Test Conditions for Dynamic Performance

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

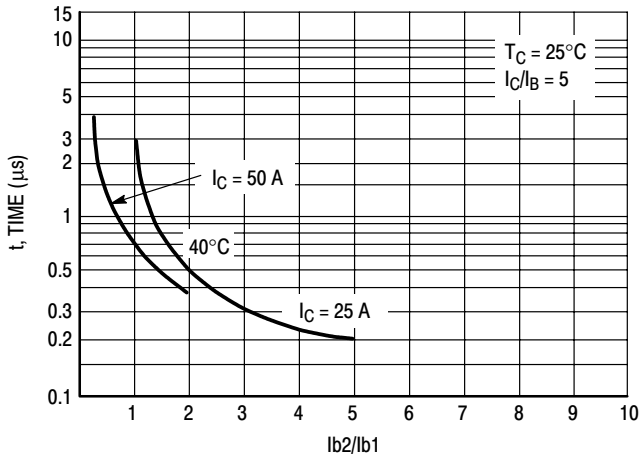


Figure 6. Fall Time versus I_{B2}/I_{B1}

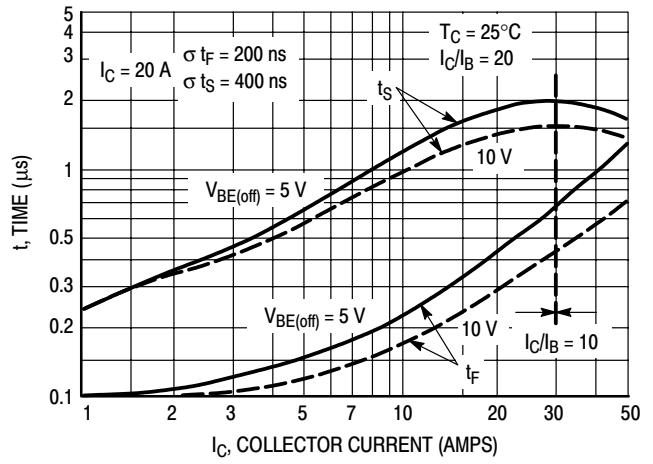


Figure 7. Turn-Off Time versus I_C

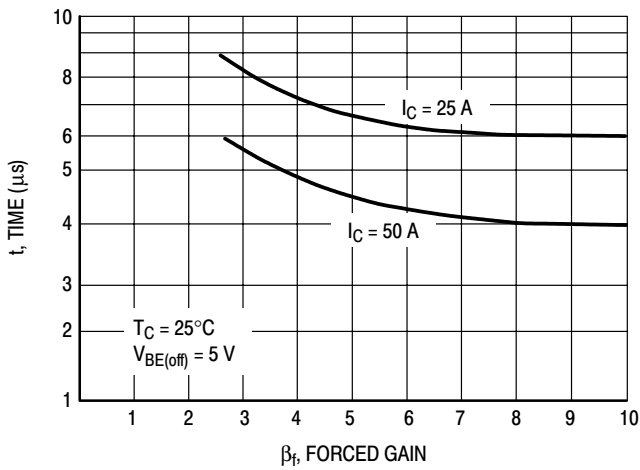


Figure 8. Storage Time versus Forced Gain

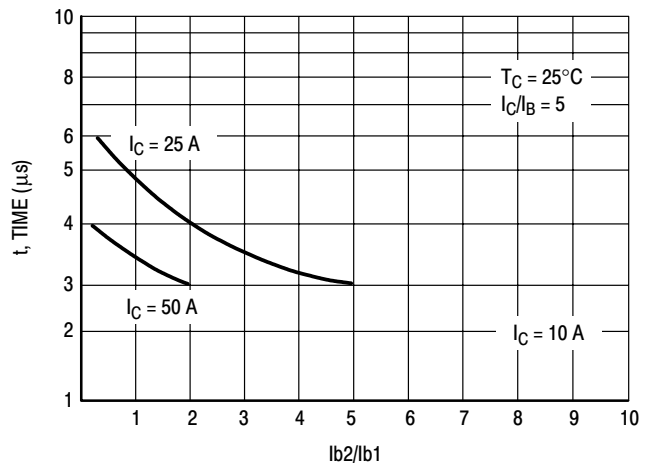


Figure 9. Storage Time versus I_{b2}/I_{b1}

FREE-WHEEL DIODE CHARACTERISTICS

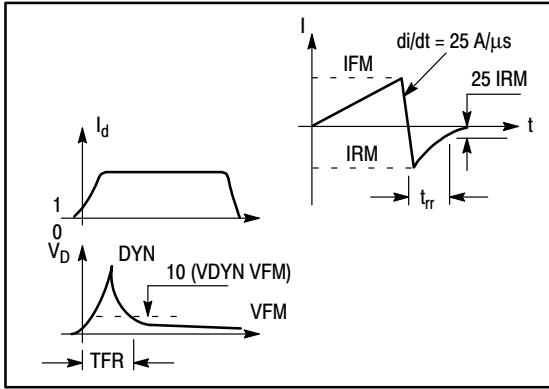


Figure 10. Free Wheel Diode Measurements

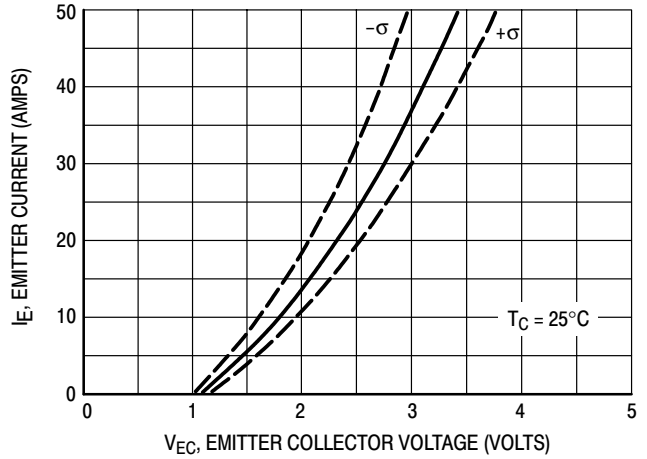


Figure 11. Forward Voltage

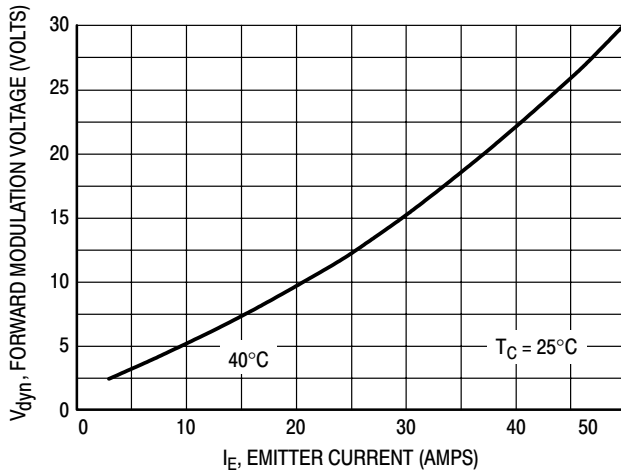


Figure 12. Forward Modulation Voltage

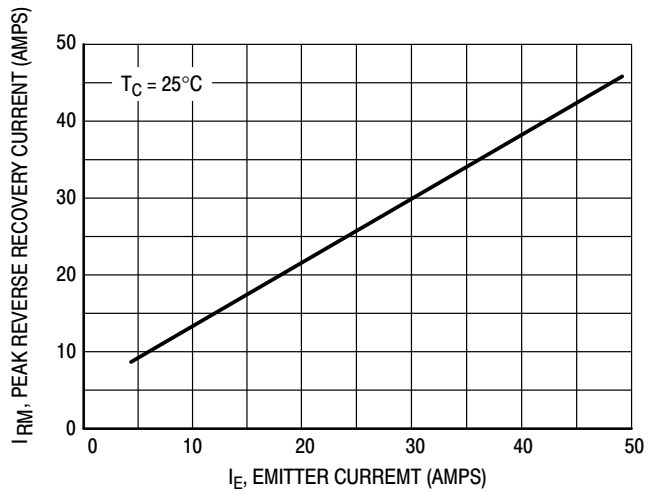


Figure 13. Peak Reverse Recovery Current

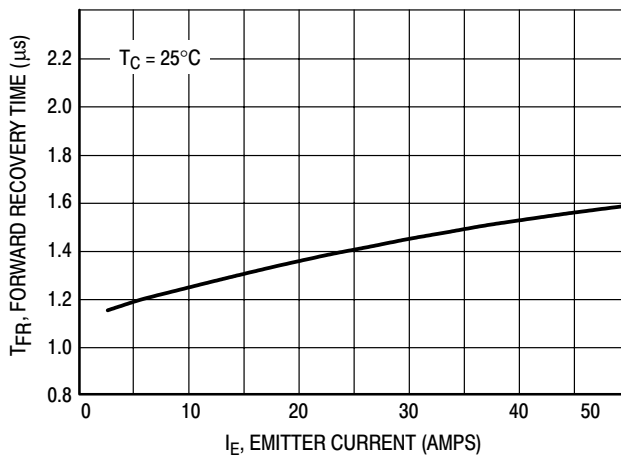


Figure 14. Forward Recovery Time

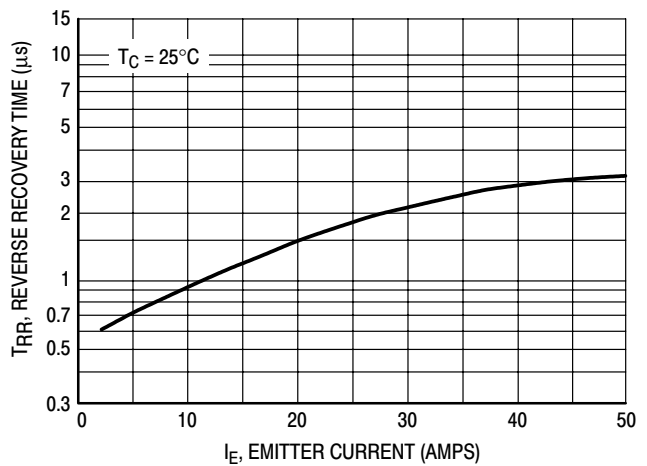


Figure 15. Reverse Recovery Time

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

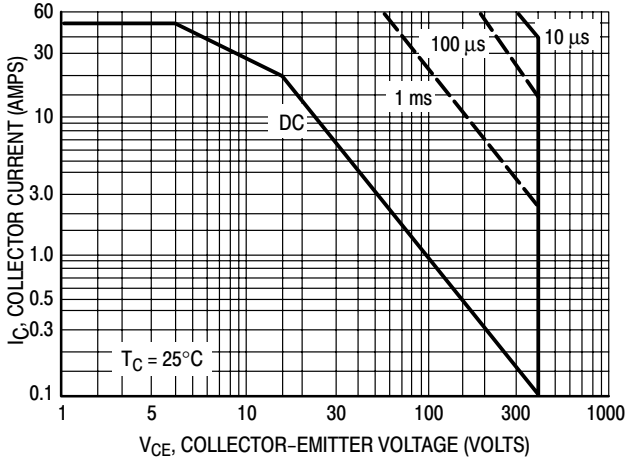


Figure 16. Safe Operating Area

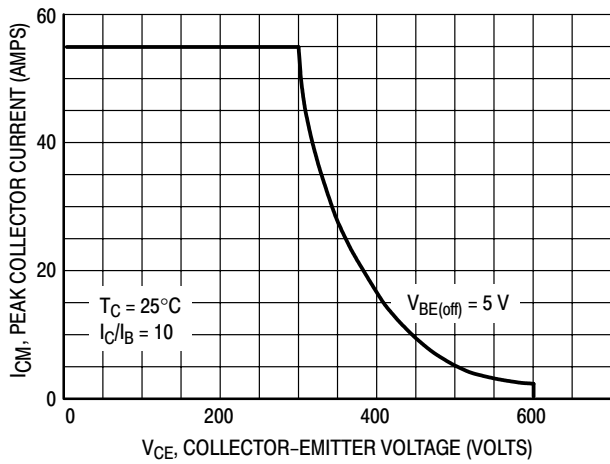


Figure 17. Reverse Bias Safe Operating Area

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 $T_C > 25^\circ\text{C}$. 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.

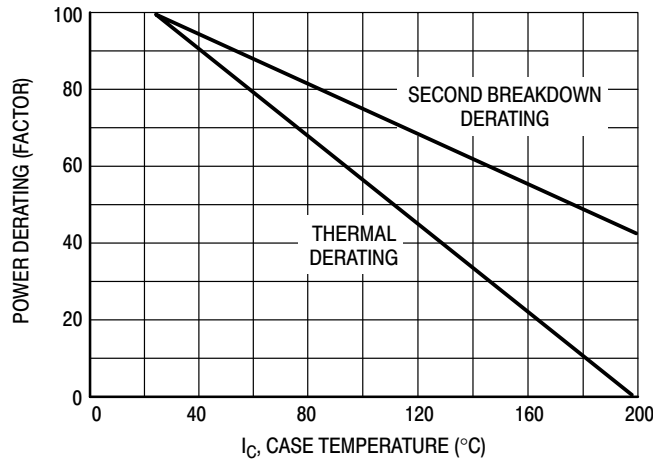
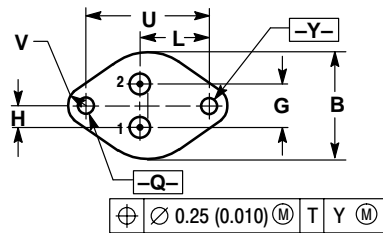
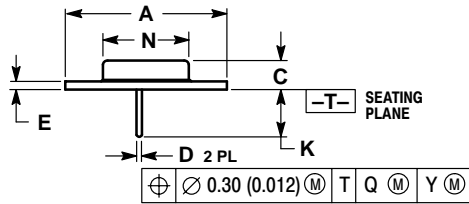


Figure 18. Power Derating

BUT33

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		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

SWITCHMODE is a trademark of ON Semiconductor, Inc.

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer.

PUBLICATION ORDERING INFORMATION

NORTH AMERICA Literature Fulfillment:

Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: ONlit@hibbertco.com
Fax Response Line: 303-675-2167 or 800-344-3810 Toll Free USA/Canada

N. American Technical Support: 800-282-9855 Toll Free USA/Canada

EUROPE: LDC for ON Semiconductor – European Support

German Phone: (+1) 303-308-7140 (Mon-Fri 2:30pm to 7:00pm CET)
Email: ONlit-german@hibbertco.com
French Phone: (+1) 303-308-7141 (Mon-Fri 2:00pm to 7:00pm CET)
Email: ONlit-french@hibbertco.com
English Phone: (+1) 303-308-7142 (Mon-Fri 12:00pm to 5:00pm GMT)
Email: ONlit@hibbertco.com

EUROPEAN TOLL-FREE ACCESS*: 00-800-4422-3781

*Available from Germany, France, Italy, UK, Ireland

CENTRAL/SOUTH AMERICA:

Spanish Phone: 303-308-7143 (Mon-Fri 8:00am to 5:00pm MST)
Email: ONlit-spanish@hibbertco.com
Toll-Free from Mexico: Dial 01-800-288-2872 for Access –
then Dial 866-297-9322

ASIA/PACIFIC: LDC for ON Semiconductor – Asia Support

Phone: 1-303-675-2121 (Tue-Fri 9:00am to 1:00pm, Hong Kong Time)
Toll Free from Hong Kong & Singapore:
001-800-4422-3781
Email: ONlit-asia@hibbertco.com

JAPAN: ON Semiconductor, Japan Customer Focus Center

4-32-1 Nishi-Gotanda, Shinagawa-ku, Tokyo, Japan 141-0031
Phone: 81-3-5740-2700
Email: r14525@onsemi.com

ON Semiconductor Website: <http://onsemi.com>

For additional information, please contact your local Sales Representative.