

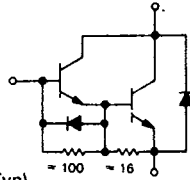
**MOTOROLA**  
**SEMICONDUCTOR**  
**TECHNICAL DATA**

**BUT15**

**SWITCHMODE SERIES**  
**NPN SILICON POWER DARLINGTON TRANSISTORS**  
**WITH BASE-EMITTER SPEEDUP DIODE**

The BUT15 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  
300 nS Inductive Fall Time at 25°C (Typ)  
1.2 μS Inductive Storage Time at 25°C (Typ)
- Operating Temperature Range - 65 to 200°C

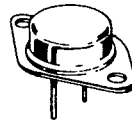


**20 AMPERES**  
**NPN SILICON**  
**POWER DARLINGTON**  
**TRANSISTORS**

**1000 VOLTS**  
**175 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.



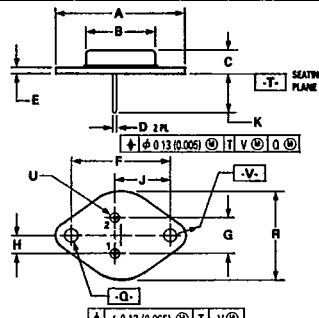
**MAXIMUM RATINGS**

Rating	Symbol	BUT15	Unit
Collector-Emitter Voltage	V <sub>CEO(sus)</sub>	700	Vdc
Collector-Emitter Voltage	V <sub>CEV</sub>	1000	Vdc
Emitter Base Voltage	V <sub>EB</sub>	10	Vdc
Collector Current	I <sub>C</sub>	20	Adc
- Continuous	I <sub>CM</sub>	25	
- Peak (1)			
Base Current	I <sub>B</sub>	5	Adc
- Continuous	I <sub>BM</sub>	10	
- Peak (1)			
Free Wheel Diode:			
Forward current - Continuous	I <sub>F</sub>	20	Adc
- Peak	I <sub>FM</sub>	25	
Total Power Dissipation @ T <sub>C</sub> = 25°C	P <sub>D</sub>	175	Watts
@ T <sub>C</sub> = 100°C		100	
Derate above 25°C			W/°C
Operating and Storage Junction Temperature Range	T <sub>J</sub> , T <sub>stg</sub>	- 65 to +200	°C

**THERMAL CHARACTERISTICS**

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	R <sub>θJC</sub>	1.0	°C/W
Maximum Lead Temperature for Soldering Purpose: 1/8" from Case for 5 Seconds	T <sub>L</sub>	275	°C

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



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: INCH
  3. ALL RULES AND NOTES ASSOCIATED WITH REFERENCED TO-204AA OUTLINE SHALL APPLY

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	—	39.37	—	1.550
B	—	21.08	—	0.830
C	6.35	8.25	0.250	0.325
D	0.97	1.09	0.038	0.043
E	1.40	1.77	0.055	0.070
F	30.15 BSC		1.187 BSC	
G	10.92 BSC		0.430 BSC	
H	5.46 BSC		0.215 BSC	
J	16.89 BSC		0.665 BSC	
K	11.18	12.19	0.440	0.480
Q	3.94	4.19	0.151	0.165
R	—	26.67	—	1.050
U	4.83	5.33	0.190	0.210
V	3.84	4.19	0.151	0.165

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

**CASE 1-06**  
**TO-204AA**  
**(TO-3)**

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**ELECTRICAL CHARACTERISTICS** (TC = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>OFF CHARACTERISTICS</b>					
Collector-Emitter Sustaining Voltage (Table 1) (IC = 100 mA, IB = 0)	VCE(sus)	700	-	-	Vdc
Collector Cutoff Current (VCEV = Rated Value, VBE(off) = 1.5 Vdc) (VCEV = Rated Value, VBE(off) = 1.5 Vdc, TC = 100°C)	ICEV	-	-	0.1 2.0	mAdc
Emitter Cutoff Current (VEB = 2.0 V, IC = 0)	IEBO	-	-	175	mAdc

**SECOND BREAKDOWN**

Second Breakdown Collector Current with base forward biased	IS/b		See Figure 16	
Clamped Inductive SOA with Base Reverse Biased	RBSOA		See Figure 17	

**ON CHARACTERISTICS (1)**

DC Current Gain (IC = 6 A, VCE = 5 V) (IC = 12 A, VCE = 5 V)	hFE	30 15	- -	- -	
Collector-Emitter Saturation Voltage (IC = 6 A, IB = 0.3 A) (IC = 12 A, IB = 1.2 A) (IC = 16 A, IB = 1.6 A) (IC = 20 A, IB = 4 A)	VCE(sat)	- - - -	- - - -	2.0 3.0 3.5 5.0	Vdc
Base-Emitter Saturation Voltage (IC = 6 A, IB = 0.3 A) (IC = 12 A, IB = 1.2 A) (IC = 16 A, IB = 1.6 A)	VBE(sat)	- - -	- - -	2.5 2.9 3.3	Vdc
Diode Forward Voltage (IF = 16 A)	Vf	-	-	4.0	Vdc

**SWITCHING CHARACTERISTICS**

Inductive Load, Clamped (Table 1)

Storage Time	TC = 25°C	See Table 1 IC = 12 A	ts	-	1.2	2.5	μs
Fall Time			tf	-	0.3	0.8	μs
Storage Time	TC = 100°C	IB1 = 1.2 A VBE(off) = 5 V	ts	-	1.4	-	μs
Fall Time			tf	-	0.35	-	μs

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

TYPICAL CHARACTERISTICS

FIGURE 1 - DC CURRENT GAIN

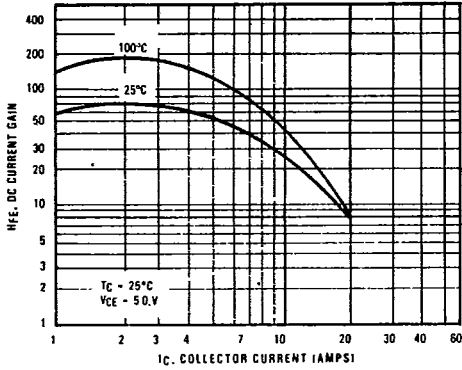


FIGURE 2 - COLLECTOR SATURATION REGION

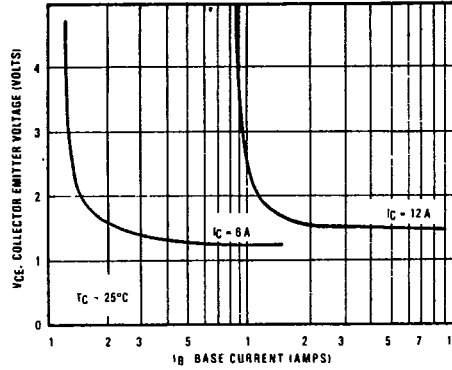


FIGURE 3 - COLLECTOR-EMITTER SATURATION VOLTAGE

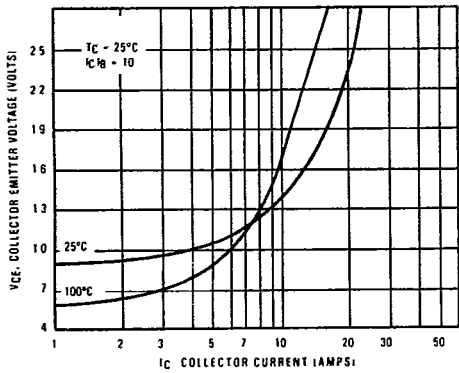


FIGURE 4 - BASE-EMITTER VOLTAGE

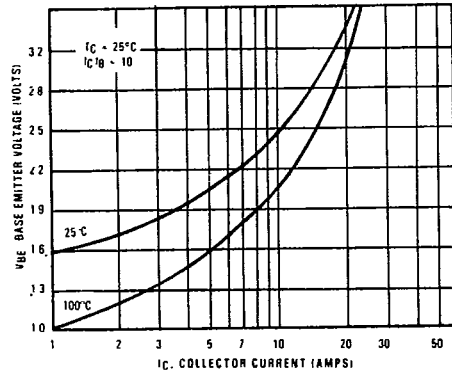
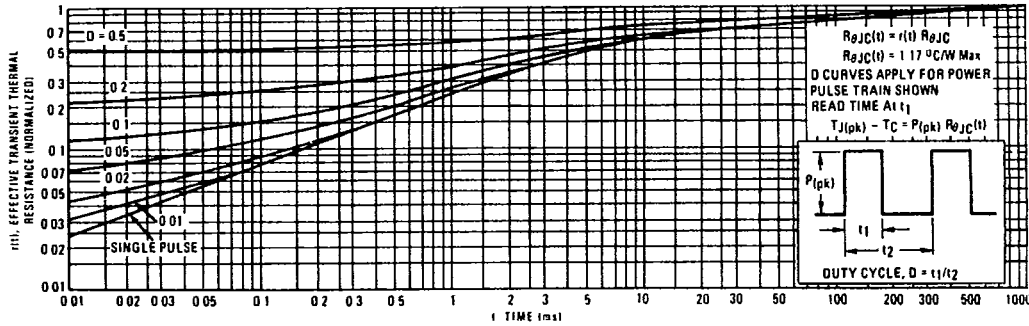


FIGURE 5 - THERMAL RESPONSE



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TABLE 1 - TEST CONDITIONS FOR DYNAMIC PERFORMANCE

<p><b>INPUT CONDITIONS</b></p> <p>20 ns</p> <p>5 V</p> <p>Pulse Width to 0.1 V</p> <p><math>I_C</math> 100 mA</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_{coil}</math> 10 mH VCC 10V</p> <p><math>R_{coil}</math> = 0.7 <math>\Omega</math></p> <p><math>V_{clamp}</math> = VCE(sust)</p>	<p><math>L_{coil}</math> = 180 <math>\mu</math>H</p> <p><math>R_{coil}</math> = 0.05 <math>\Omega</math></p> <p>VCC = 10 V</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> <p><math>t_1 \approx L_{coil}(I_{CM}) / V_{CC}</math></p> <p><math>t_2 \approx L_{coil}(I_{CM}) / V_{clamp}</math></p> <p>Test Equipment Scope - Tektronix 475 or Equivalent</p>	

FIGURE 6 - FALL TIME vs  $I_{B2}/I_{B1}$

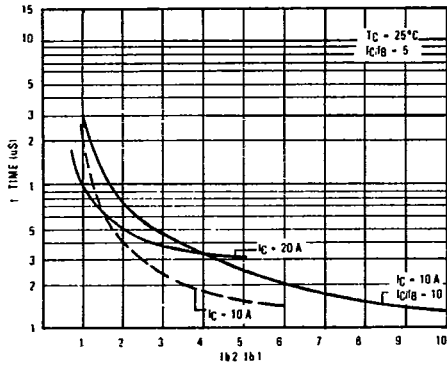


FIGURE 7 - TURN-OFF TIME vs  $I_C$

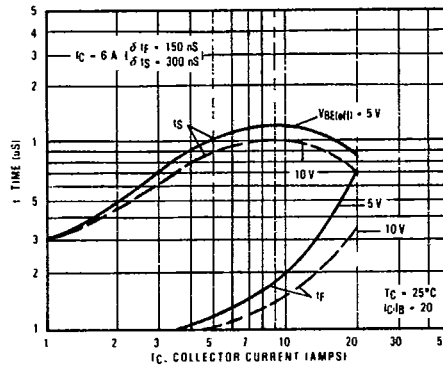


FIGURE 8 - STORAGE TIME vs FORCED GAIN

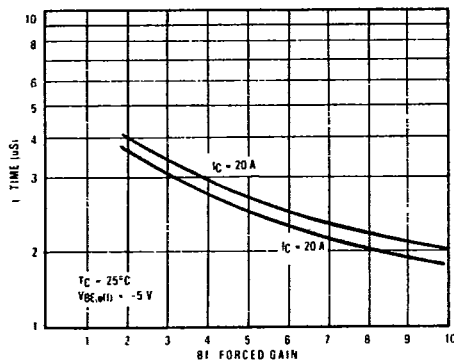
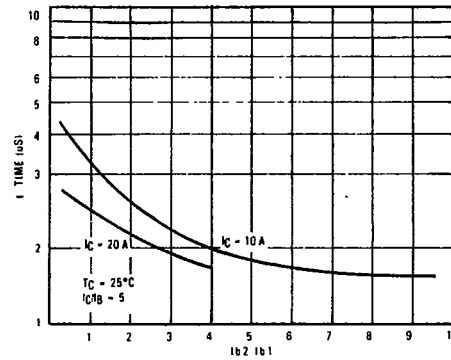


FIGURE 9 - STORAGE TIME vs  $I_{B2}/I_{B1}$



FREE-WHEEL DIODE CHARACTERISTICS

FIGURE 10 — FREE WHEEL DIODE MEASUREMENTS

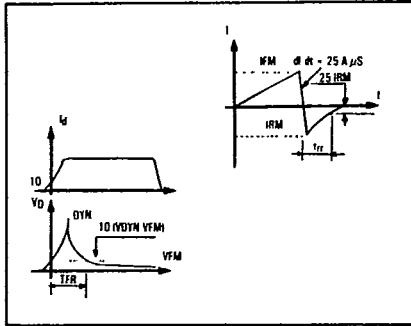


FIGURE 11 — FORWARD VOLTAGE

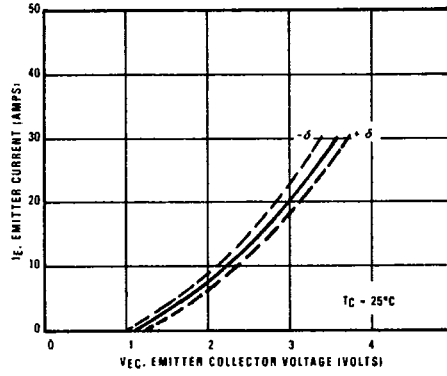


FIGURE 12 — FORWARD MODULATION VOLTAGE

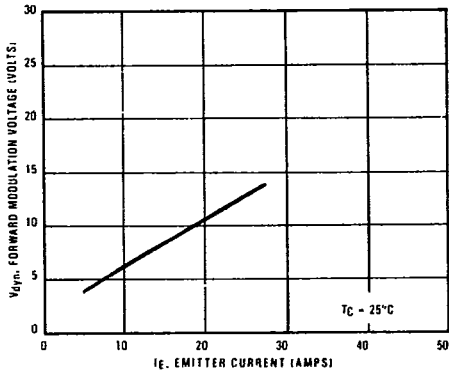


FIGURE 13 — PEAK REVERSE RECOVERY CURRENT

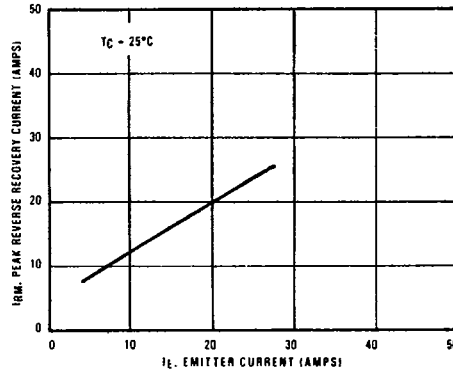


FIGURE 14 — FORWARD RECOVERY TIME

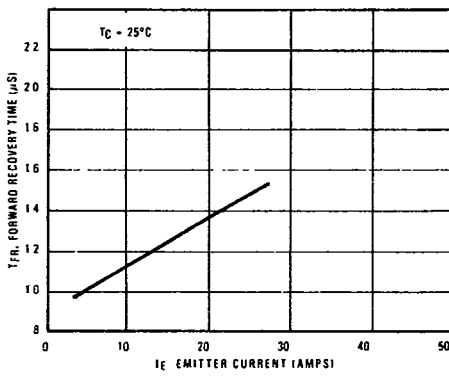
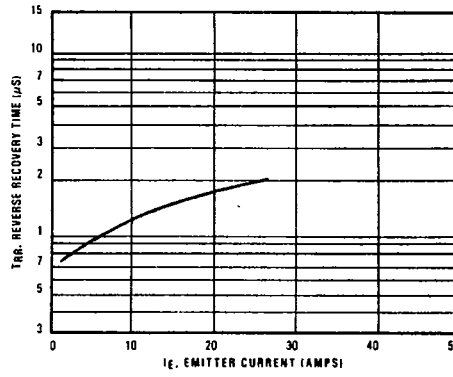


FIGURE 15 — REVERSE RECOVERY TIME



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

FIGURE 16 - SAFE OPERATING AREA

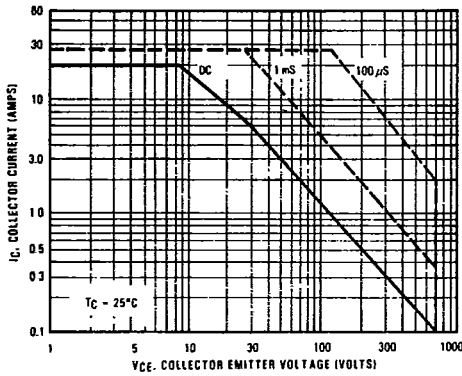


FIGURE 17 - REVERSE BIAS SAFE OPERATING AREA

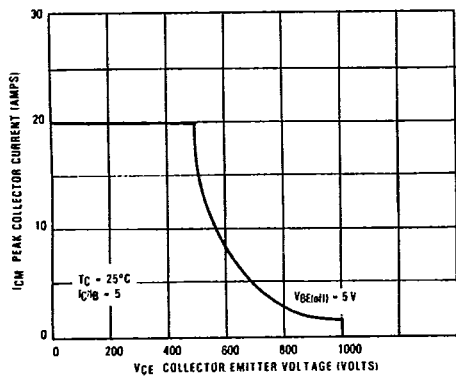
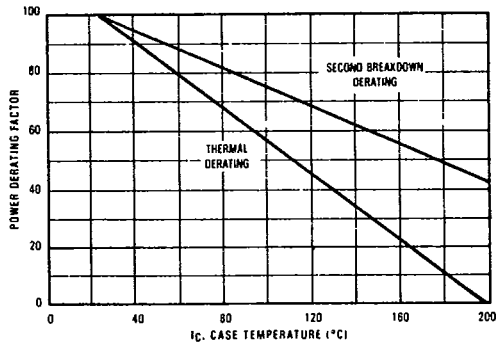


FIGURE 18 - POWER DERATING



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  $T_C = 25^\circ C$ ;  $T_{J(pk)}$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ C$ . 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 turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 17 gives the RBSOA characteristics.