## Advance Information

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

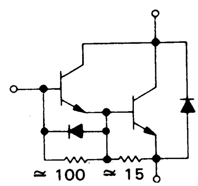
The BUT14 darlington transistor is designed for high voltage, high speed, high power switching in circuits where fall/storage time is critical. It is particularly suited for line operated switchmode applications such as:

- Switching regulators
- Inverters
- Motor controls
- Solenoïd and relay drivers

**25 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**850 VOLTS / 175 WATTS**

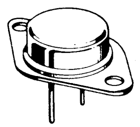


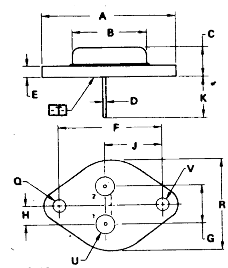

### MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 500 | Vdc |
| Collector-Emitter Voltage | $V_{CES}$ | 850 | Vdc |
| Emitter-Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector-Current — Continuous<br>— Peak | $I_C$<br>$I_{CM}$ | 25<br>35 | Adc |
| Base-Current — Continuous<br>— Peak | $I_B$<br>$I_{BM}$ | 5.0<br>7.5 | Adc |
| Total Power Dissipation @ $T_C = 25\,°C$<br>Derate above 25 °C | $P_D$ | 175<br>1.0 | Watts<br>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 | $R_{\theta JC}$ | 1.0 | °C/W |






NOTES:
1. DIMENSIONS Q AND V ARE DATUMS.
2. -T- IS SEATING PLANE AND DATUM.
3. POSITIONAL TOLERANCE FOR MOUNTING HOLE Q:
   | ⌖ | ∅ 0.13 (0.005) Ⓜ | T | V Ⓜ |

   FOR LEADS:
   | ⌖ | ∅ 0.13 (0.005) Ⓜ T | V Ⓜ | Q Ⓜ |
4. DIMENSIONS AND TOLERANCES PER ANSI Y14.5, 1973.

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | – | 39.37 | – | 1.550 |
| B | – | 21.08 | – | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 0.97 | 1.09 | 0.038 | 0.043 |
| E | – | 3.43 | – | 0.135 |
| 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 | 3.81 | 4.19 | 0.150 | 0.165 |
| R | – | 26.67 | – | 1.050 |
| U | 4.83 | 5.33 | 0.190 | 0.210 |
| V | 3.81 | 4.19 | 0.150 | 0.165 |

**CASE 1-05 TO-3**

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

| Characteristics | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $V_{clamp}$ = Rated $V_{CEO}$) | $V_{CEO(sus)}$ | 500 | – | – | Vdc |
| Collector-Cutoff Current ($V_{CES}$ = Rated Value, | $I_{CES}$ | – | – | 0.1 | mAdc |
| Emitter-Cutoff Current ($V_{EB}$ = 2 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 175 | mAdc |
| **ON CHARACTERISTICS**[2] | | | | | |
| DC Current Gain | $h_{FE}$ | | | | |
| ($I_C$ = 8 Adc, $V_{CE}$ = 5 Vdc) | | 30 | – | – | |
| ($I_C$ = 16 Adc, $V_{CE}$ = 5 Vdc) | | 15 | – | – | |
| Collector-Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_C$ = 8 Adc, $I_B$ = 0.4 Adc) | | – | – | 2.0 | |
| ($I_C$ = 16 Adc, $I_B$ = 1.6 Adc) | | – | – | 3.0 | |
| ($I_C$ = 20 Adc, $I_B$ = 2.0 Adc) | | – | – | 3.5 | |
| ($I_C$ = 25 Adc, $I_B$ = 5 Adc) | | – | – | 5.0 | |
| Base-Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_C$ = 8 Adc, $I_B$ = 0.4 Adc) | | – | – | 2.5 | |
| ($I_C$ = 16 Adc, $I_B$ = 1.6 Adc) | | – | – | 2.9 | |
| ($I_C$ = 20 Adc, $I_B$ = 2.0 Adc) | | – | – | 3.3 | |
| Diode Forward Voltage[1] ($I_F$ = 20 Adc) | $V_f$ | – | – | 4.0 | Vdc |

| | | | | | | |
|---|---|---|---|---|---|---|
| Collector Emitter Sustaining Voltage<br>$R_{coil}$ = 0.05Ω, $L_{coil}$ = 180μH<br>$V_{clamp}$ = rated $V_{CEX}$<br>$V_{BE\ (off)}$ = −5Vdc<br>$T_C$ = 100°C<br>$\frac{I_C}{I_{B1}} = 20$ | | | | | | Vdc |
| | $I_C$ = 16 Adc | $V_{CEX1\ (sus)}$ | 350 | – | – | |
| | $I_C$ = 8Adc | $V_{CEX2\ (sus)}$ | 400 | – | – | |
| | $I_C$ = 2Adc | $V_{CEX3\ (sus)}$ | 500 | – | – | |

**SWITCHING CHARACTERISTICS**
**RESISTIVE LOAD**

| | | | | | | |
|---|---|---|---|---|---|---|
| Turn-on Time | ($V_{CC}$ = 250 Vdc, $I_C$ = 8 A, $I_{B1}$ = 0.4 A, $V_{BE(off)}$ = 5 Vdc, $t_p$ = 25 μs Duty Cycle ⩽ 2%). | $t_{on}$ | – | 0.6 | 1.9 | μs |
| Storage Time | | $t_s$ | – | 0.85 | 3.2 | μs |
| Fall Time | | $t_f$ | – | 0.20 | 0.9 | μs |

[1] The internal Collector-to-Emitter diode can eliminate the need for an external diode to clamp inductive loads. Tests have shown that the Forward Recovery Voltage ($V_f$) of this diode is comparable to that of typical fast recovery rectifiers.

[2] Pulse Test. PW = 300 μs, Duty Cycle ⩽ 2%.

# Advance Information

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

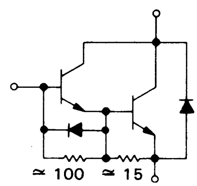
The BUT15 darlington transistor is designed for high voltage, high speed, high power switching in circuits where fall/storage time is critical. It is particularly suited for line operated switchmode applications such as:

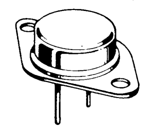
- Switching regulators
- Inverters
- Motor controls
- Solenoïd and relay drivers

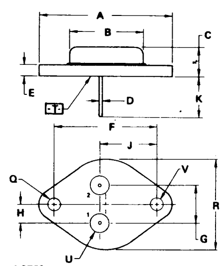
**20 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**1000 VOLTS / 175 WATTS**






NOTES:
1. DIMENSIONS Q AND V ARE DATUMS.
2. -T- IS SEATING PLANE AND DATUM.
3. POSITIONAL TOLERANCE FOR MOUNTING HOLE Q:

| ⌖ | ⌀.13 (0.005) Ⓜ | T | V Ⓜ |
|---|---|---|---|

FOR LEADS:

| ⌖ | ⌀.13 (0.005) Ⓜ T | V Ⓜ | Q Ⓜ |
|---|---|---|---|

4. DIMENSIONS AND TOLERANCES PER ANSI Y14.5, 1973.

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | – | 39.37 | – | 1.550 |
| B | – | 21.08 | – | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 0.97 | 1.09 | 0.038 | 0.043 |
| E | – | 3.43 | – | 0.135 |
| 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 | 3.81 | 4.19 | 0.150 | 0.165 |
| R | – | 26.67 | – | 1.050 |
| U | 4.83 | 5.33 | 0.190 | 0.210 |
| V | 3.81 | 4.19 | 0.150 | 0.165 |

**CASE 1-05 TO-3**

### MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 700 | Vdc |
| Collector-Emitter Voltage | $V_{CES}$ | 1000 | Vdc |
| Emitter-Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector-Current — Continuous<br>— Peak | $I_C$<br>$I_{CM}$ | 20<br>25 | Adc |
| Base-Current — Continuous<br>— Peak | $I_B$<br>$I_{BM}$ | 5.0<br>10 | Adc |
| Total Power Dissipation @ $T_C = 25\,°C$<br>Derate above 25 °C | $P_D$ | 175<br>1.0 | Watts<br>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 | $R_{\theta JC}$ | 1.0 | °C/W |

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

| Characteristics | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $V_{clamp}$ = Rated $V_{CEO}$) | $V_{CEO(sus)}$ | 700 | – | – | Vdc |
| Collector-Cutoff Current ($V_{CES}$ = Rated Value, | $I_{CES}$ | – | – | 0.2 | mAdc |
| Emitter-Cutoff Current ($V_{EB}$ = 2 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 175 | mAdc |
| **ON CHARACTERISTICS**[2] | | | | | |
| DC Current Gain | $h_{FE}$ | | | | |
| ($I_C$ = 6 Adc, $V_{CE}$ = 5 Vdc) | | 30 | – | – | |
| ($I_C$ = 12 Adc, $V_{CE}$ = 5 Vdc) | | 15 | – | – | |
| Collector-Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_C$ = 6 Adc, $I_B$ = 0.3 Adc) | | – | – | 2.0 | |
| ($I_C$ = 12 Adc, $I_B$ = 1.2 Adc) | | – | – | 3.0 | |
| ($I_C$ = 16 Adc, $I_B$ = 1.6 Adc) | | – | – | 3.5 | |
| ($I_C$ = 20 Adc, $I_B$ = 4.0 Adc) | | – | – | 5.0 | |
| Base-Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_C$ = 6 Adc, $I_B$ = 0.3 Adc) | | – | – | 2.5 | |
| ($I_C$ = 12 Adc, $I_R$ = 1.2 Adc) | | – | – | 2.9 | |
| ($I_C$ = 16 Adc, $I_B$ = 1.6 Adc) | | – | – | 3.3 | |
| Diode Forward Voltage[1] ($I_F$ = 16 Adc) | $V_f$ | – | – | 4.0 | Vdc |

| | | | | | | |
|---|---|---|---|---|---|---|
| Collector Emitter Sustaining Voltage $R_{coil} = 0.05\Omega$, $L_{coil} = 180\mu H$ | | | | | | Vdc |
| $V_{clamp}$ = rated $V_{CEX}$ | $I_C$ = 12Adc | $V_{CEX1\ (sus)}$ | 400 | – | – | |
| $V_{BE\ (off)} = -5$Vdc, $T_C = 100°C$ | $I_C$ = 6Adc | $V_{CEX2\ (sus)}$ | 425 | – | – | |
| $\frac{I_C}{I_{B1}} = 20$ | $I_C$ = 2Adc | $V_{CEX3\ (sus)}$ | 700 | – | – | |

## SWITCHING CHARACTERISTICS
### RESISTIVE LOAD

| | Conditions | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Turn-on Time | ($V_{CC}$ = 250 Vdc, $I_C$ = 6 A, $I_{B1}$ = 0.3 A, $V_{BE(off)}$ = 5 Vdc, $t_p$ = 25 µs Duty Cycle ⩽ 2%). | $t_{on}$ | – | 0.3 | 1.2 | µs |
| Storage Time | | $t_s$ | – | 0.75 | 3.0 | µs |
| Fall Time | | $t_f$ | – | 0.3 | 1.0 | µs |

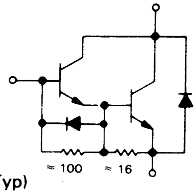
[1] The internal Collector-to-Emitter diode can eliminate the need for an external diode to clamp inductive loads. Tests have shown that the Forward Recovery Voltage ($V_f$) of this diode is comparable to that of typical fast recovery rectifiers.

[2] Pulse Test. PW = 300 µs, Duty Cycle ⩽ 2%.

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

The BUT 16 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
  2.0 uS Inductive Fall Time at 100°C (Typ)
  0.8 uS Inductive Storage Time at 100°C (Typ)
- Operating Temperature Range −65 to 175°C



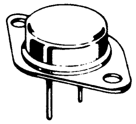

**12 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**1400 VOLTS**
**150 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.



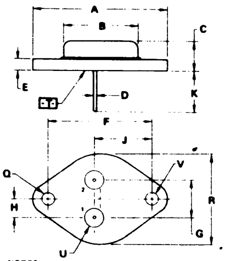
### MAXIMUM RATINGS

| Rating | Symbol | | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 1000 | Vdc |
| Collector-Emitter Voltage | $V_{CEV}$ | 1400 | Vdc |
| Emitter Base Voltage | $V_{EB}$ | 10 | Vdc |
| Collector Current – Continuous<br>– Peak (1) | $I_C$<br>$I_{CM}$ | 12<br>20 | Adc |
| Base Current – Continuous<br>– Peak (1) | $I_B$<br>$I_{BM}$ | 8<br>10 | Adc |
| Free Wheel Diode: Forward current – Continuous<br>– Peak | $I_F$<br>$I_{FM}$ | 12<br>20 | Adc |
| Total Power Dissipation @ $T_C$ = 25°C<br>@ $T_C$ = 100°C<br>Derate above 25°C | $P_D$ | 150<br>75 | Watts<br>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 | $R\theta_{JC}$ | 1.0 | °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%.




NOTES:
1. DIMENSIONS Q AND V ARE DATUMS.
2. T IS SEATING PLANE AND DATUM.
3. POSITIONAL TOLERANCE FOR MOUNTING HOLE Q:
   ⌖ | ∅0.13 (0.005) Ⓜ | T | V Ⓜ
   FOR LEADS:
   ⌖ | ∅0.13 (0.005) Ⓜ T | V Ⓜ | Q Ⓜ
4. DIMENSIONS AND TOLERANCES PER ANSI Y14.5, 1973.

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | – | 39.37 | – | 1.550 |
| B | – | 21.08 | – | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 0.97 | 1.09 | 0.038 | 0.043 |
| E | – | 3.43 | – | 0.135 |
| 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 | 3.81 | 4.19 | 0.150 | 0.165 |
| R | – | 26.67 | – | 1.050 |
| U | 4.83 | 5.33 | 0.190 | 0.210 |
| V | 3.81 | 4.19 | 0.150 | 0.165 |

**CASE 1-05 TO-3**

3

**ELECTRICAL CHARACTERISTICS** ($T_C$ = 25°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) | $V_{CEO(sus)}$ | 1000 | – | – | Vdc |
| Collector Cutoff Current ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc) ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C$ = 100 °C) | $I_{CEV}$ | – –| – – | 0.1 2.0 | mAdc |
| Emitter Cutoff Current ($V_{EB}$ = 2.0 V, $I_C$ = 0) | $I_{EBO}$ | – | – | 175 | 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 ($I_C$ = 4 A, $V_{CE}$ = 5 V) ($I_C$ = 8 A, $V_{CE}$ = 5 V) | $h_{FE}$ | 20 5 | – – | – – | |
| Collector-Emitter Saturation Voltage ($I_C$ = 12 A, $I_B$ = 6 A) | $V_{CE(sat)}$ | – | – | 5.0 | Vdc |
| Base-Emitter Saturation Voltage ($I_C$ = 8 A, $I_B$ = 1.6 A) | $V_{BE(sat)}$ | – | – | 3.3 | Vdc |
| Diode Forward Voltage ($I_F$ = 12 A) | $V_f$ | – | – | 4.0 | Vdc |

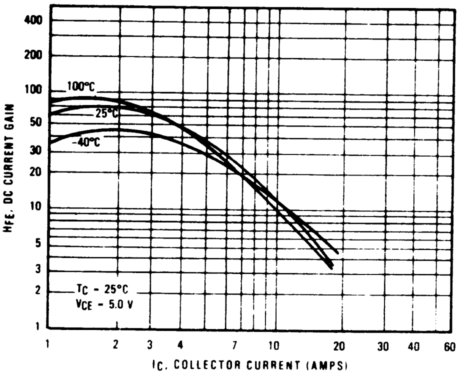
**SWITCHING CHARACTERISTICS**
Inductive Load, Clamped (Table 1)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Storage Time | $T_C$ = 25°C | See Table 1 | $t_s$ | – | – | 3.3 | μs |
| Fall Time | | $I_C$ = 8 A | $t_f$ | – | – | 1.5 | μs |
| Storage Time | $T_C$ = 100°C | $I_{B1}$ = 1.6 A | $t_s$ | – | 2.0 | – | μs |
| Fall Time | | $V_{BE(off)}$ = 5 V | $t_f$ | – | 0.8 | – | μs |

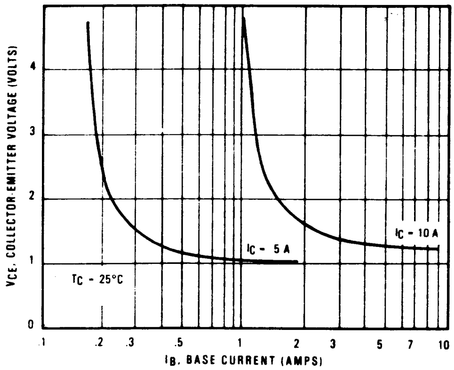
(1) Pulse Test: PW = 300 μs, Duty Cycle ≦ 2%.

## TYPICAL CHARACTERISTICS

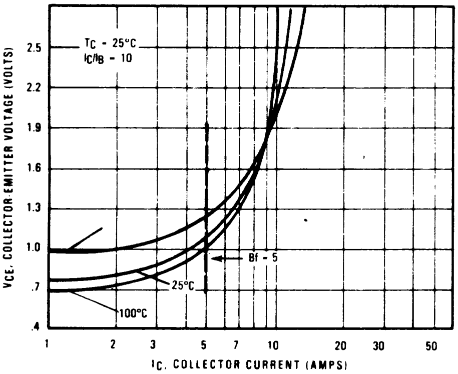
### FIGURE 1 — DC CURRENT GAIN



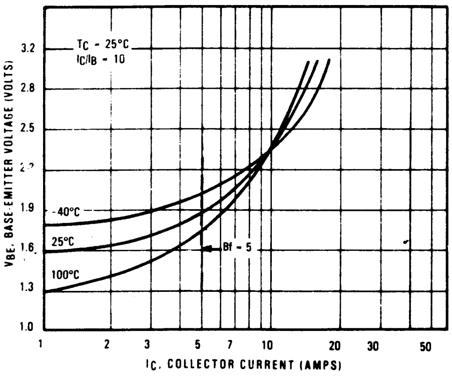

### FIGURE 2 — COLLECTOR SATURATION REGION



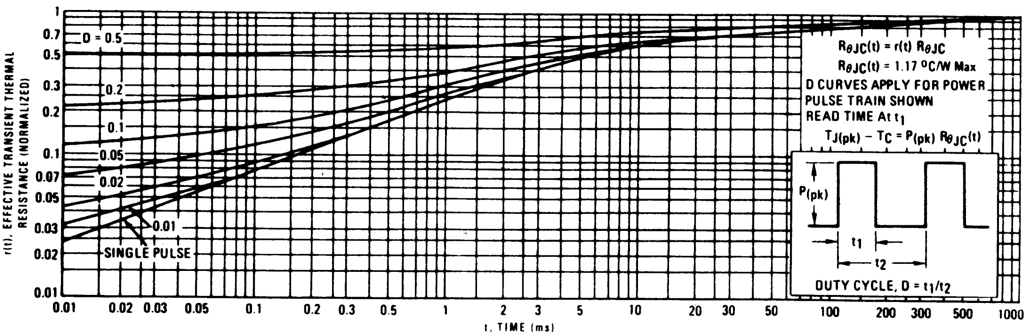

### FIGURE 3 — COLLECTOR-EMITTER SATURATION VOLTAGE



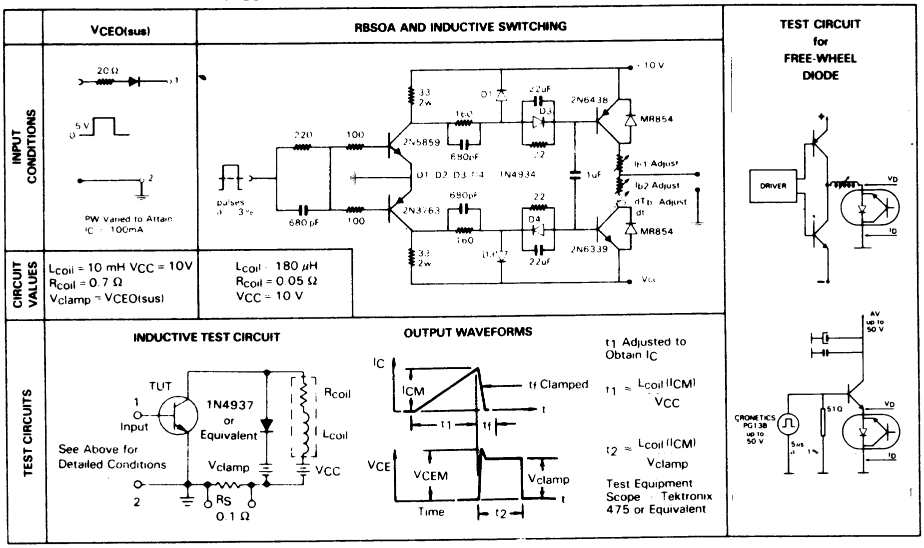

### FIGURE 4 — BASE-EMITTER VOLTAGE




### FIGURE 5 — THERMAL RESPONSE



## TABLE 1 – TEST CONDITIONS FOR DYNAMIC PERFORMANCE



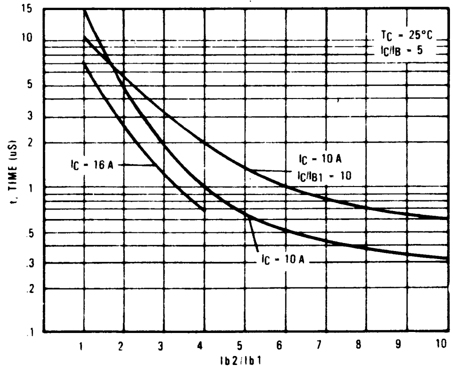




FIGURE 6 – FALL TIME vs IB2/IB1

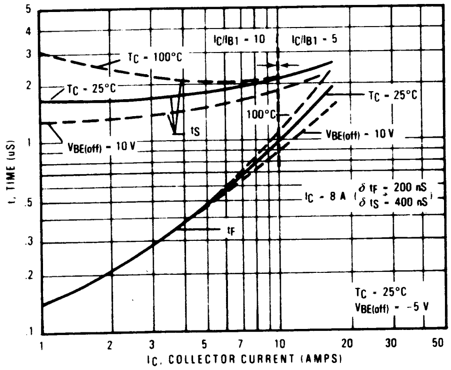



FIGURE 7 – TURN-OFF TIME vs Ic

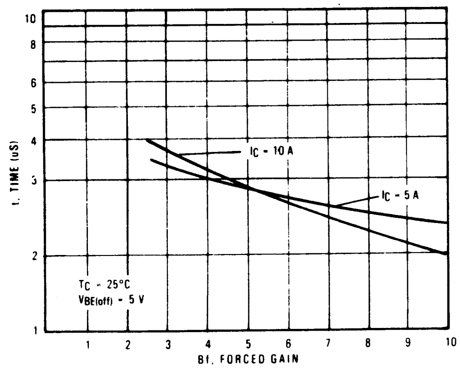



FIGURE 8 – STORAGE TIME vs FORCED GAIN

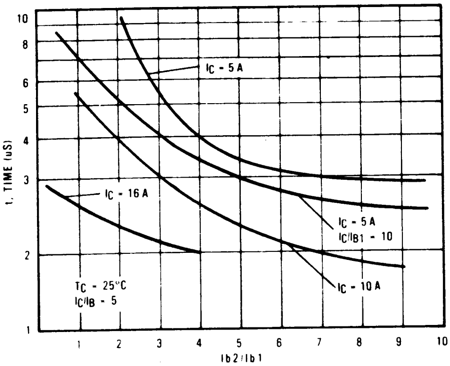



FIGURE 9 – STORAGE TIME vs Ib2/Ib1

## FREE-WHEEL DIODE CHARACTERISTICS

**FIGURE 10 — FREE WHEEL DIODE MEASUREMENTS**

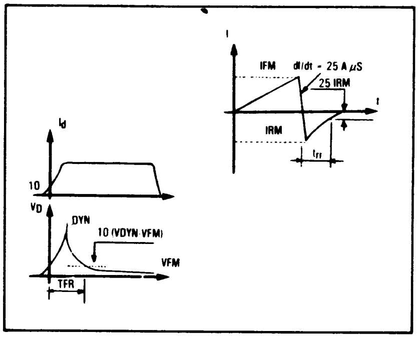



**FIGURE 11 — FORWARD VOLTAGE**

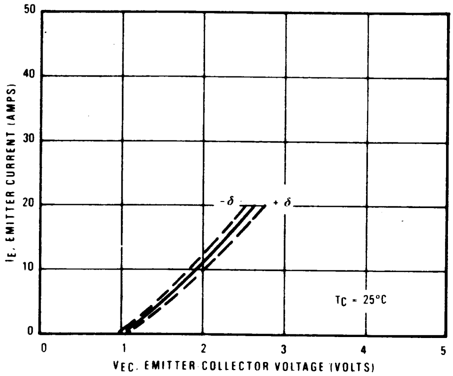



**FIGURE 12 — FORWARD MODULATION VOLTAGE**

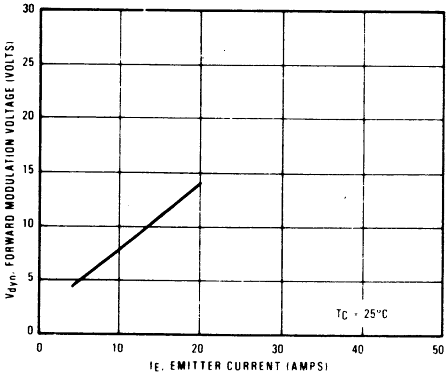



**FIGURE 13 — PEAK REVERSE RECOVERY CURRENT**

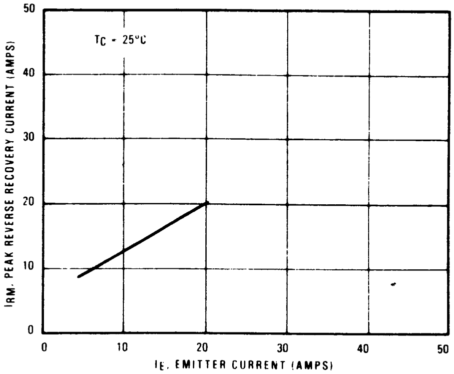



**FIGURE 14 — FORWARD RECOVERY TIME**

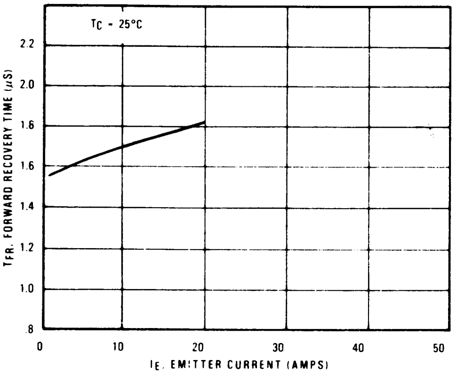
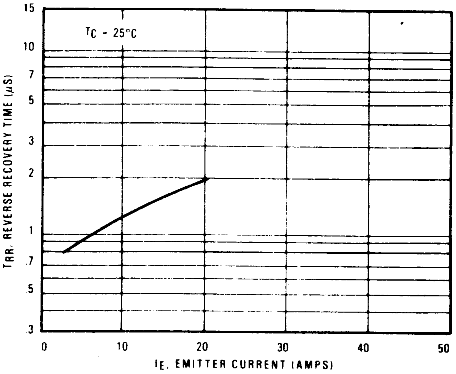



**FIGURE 15 — REVERSE RECOVERY TIME**



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

**FIGURE 16 — SAFE OPERATING AREA**

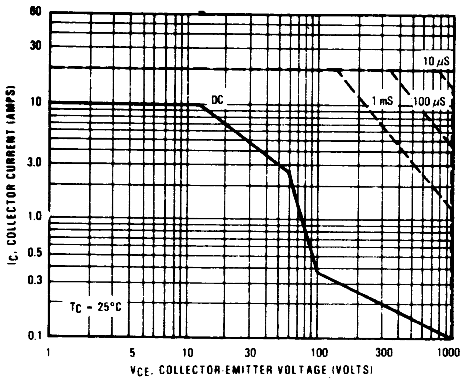
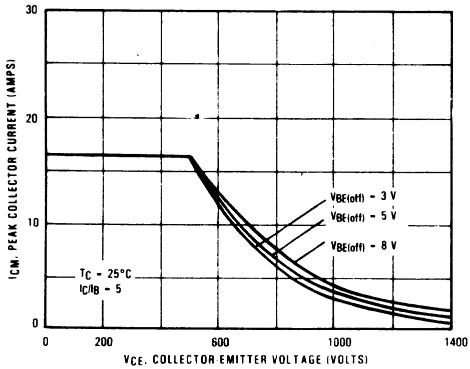



**FIGURE 17 — REVERSE BIAS SAFE OPERATING AREA**




## 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 grater dissipation than the curves indicate.

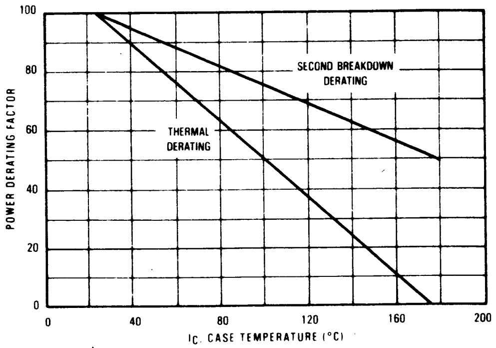
The data of Figure 16 is based on $T_C = 25°C$; $T_{J(pk)}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_C \geq 25°C$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the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

**FIGURE 18 — POWER DERATING**



# Advance Information

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

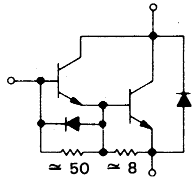
The BUT33 darlington transistor is designed for high voltage, high speed, high power switching in circuits where fall/storage time is critical. It is particularly suited for line operated switchmode applications such as:

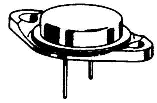
- Switching regulators
- Inverters
- Motor controls
- Solenoïd and relay drivers

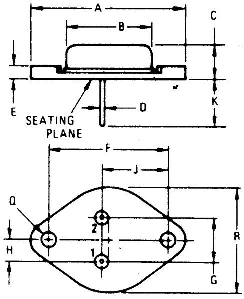
**50 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**600 VOLTS / 250 WATTS**






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

| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 38.35 | 39.37 | 1.510 | 1.550 |
| B | 19.30 | 21.08 | 0.760 | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 1.45 | 1.60 | 0.057 | 0.063 |
| E | – | 3.43 | – | 0.135 |
| F | 29.90 | 30.40 | 1.177 | 1.197 |
| G | 10.67 | 11.18 | 0.420 | 0.440 |
| H | 5.21 | 5.72 | 0.205 | 0.225 |
| J | 16.64 | 17.15 | 0.655 | 0.675 |
| K | 11.18 | 12.19 | 0.440 | 0.480 |
| Q | 3.84 | 4.09 | 0.151 | 0.161 |
| R | 24.89 | 26.67 | 0.980 | 1.050 |

**CASE 197-01**

MODIFIED TO-3

### MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 400 | Vdc |
| Collector-Emitter Voltage | $V_{CES}$ | 600 | Vdc |
| Emitter-Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector-Current — Continuous<br>— Peak | $I_C$<br>$I_{CM}$ | 50<br>75 | Adc |
| Base-Current — Continuous<br>— Peak | $I_B$<br>$I_{BM}$ | 12<br>15 | Adc |
| Total Power Dissipation @ $T_C$ = 25 °C<br>Derate above 25 °C | $P_D$ | 250<br>1.428 | Watts<br>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 |

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

| Characteristics | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $V_{clamp}$ = Rated $V_{CEO}$) | $V_{CEO(sus)}$ | 400 | – | – | Vdc |
| Collector-Cutoff Current ($V_{CES}$ = Rated Value, | $I_{CES}$ | – | – | 0.2 | mAdc |
| Emitter-Cutoff Current ($V_{EB}$ = 2 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 350 | mAdc |
| **ON CHARACTERISTICS**[2] | | | | | |
| DC Current Gain<br>($I_C$ = 20 Adc, $V_{CE}$ = 5 Vdc)<br>($I_C$ = 36 Adc, $V_{CE}$ = 5 Vdc) | $h_{FE}$ | <br>30<br>20 | <br>–<br>– | <br>–<br>– | |
| Collector-Emitter Saturation Voltage<br>($I_C$ = 20 Adc, $I_B$ = 1.0 Adc)<br>($I_C$ = 36 Adc, $I_B$ = 3.6 Adc)<br>($I_C$ = 44 Adc, $I_B$ = 4.4 Adc)<br>($I_C$ = 56 Adc, $I_B$ = 11.2 Adc) | $V_{CE(sat)}$ | <br>–<br>–<br>–<br>– | <br>–<br>–<br>–<br>– | <br>2.0<br>2.5<br>3.0<br>5.0 | Vdc |
| Base-Emitter Saturation Voltage<br>($I_C$ = 20 Adc, $I_B$ = 1.0 Adc)<br>($I_C$ = 36 Adc, $I_B$ = 3.6 Adc)<br>($I_C$ = 44 Adc, $I_B$ = 4.4 Adc) | $V_{BE(sat)}$ | <br>–<br>–<br>– | <br>–<br>–<br>– | <br>2.5<br>2.9<br>3.3 | Vdc |
| Diode Forward Voltage[1] ($I_F$ = 44 Adc) | $V_f$ | – | – | 4.0 | Vdc |

| Characteristics | | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Collector Emitter Sustaining Voltage<br>$R_{coil}$ = 0.05Ω, $L_{coil}$ = 180μH<br>$V_{clamp}$ = rated $V_{CEX}$<br>$V_{BE\ (off)}$ = −5Vdc<br>$T_C$ = 100°C<br>$\frac{I_C}{I_{B1}}$ = 20 | $I_C$ = 36Adc<br>$I_C$ = 20Adc<br>$I_C$ = 5Adc | $V_{CEX1\ (sus)}$<br>$V_{CEX2\ (sus)}$<br>$V_{CEX3\ (sus)}$ | 275<br>325<br>400 | –<br>–<br>– | –<br>–<br>– | Vdc |

## SWITCHING CHARACTERISTICS

### RESISTIVE LOAD

| Characteristic | Conditions | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Turn-on Time | ($V_{CC}$ = 250 Vdc, $I_C$ = 20 A, $I_{B1}$ = 1 A, $V_{BE(off)}$ = 5 Vdc, $t_p$ = 25 μs Duty Cycle ≤ 2%). | $t_{on}$ | – | 0.45 | 1.3 | μs |
| Storage Time | | $t_s$ | – | 0.8 | 2.5 | μs |
| Fall Time | | $t_f$ | – | 0.3 | 1.0 | μs |

[1] The internal Collector-to-Emitter diode can eliminate the need for an external diode to clamp inductive loads. Tests have shown that the Forward Recovery Voltage ($V_f$) of this diode is comparable to that of typical fast recovery rectifiers.

[2] Pulse Test. PW = 300 μs, Duty Cycle ≤ 2%.

# Advance Information

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

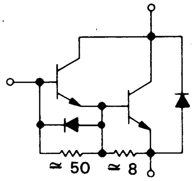
The BUT34 darlington transistor is designed for high voltage, high speed, high power switching in circuits where fall/storage time is critical. It is particularly suited for line operated switchmode applications such as:

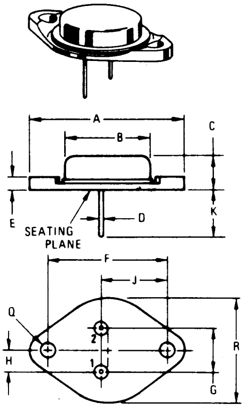
- Switching regulators
- Inverters
- Motor controls
- Solenoïd and relay drivers

**50 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**850 VOLTS / 250 WATTS**




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

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 38.35 | 39.37 | 1.510 | 1.550 |
| B | 19.30 | 21.08 | 0.760 | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 1.45 | 1.60 | 0.057 | 0.063 |
| E | – | 3.43 | – | 0.135 |
| F | 29.90 | 30.40 | 1.177 | 1.197 |
| G | 10.67 | 11.18 | 0.420 | 0.440 |
| H | 5.21 | 5.72 | 0.205 | 0.225 |
| J | 16.64 | 17.15 | 0.655 | 0.675 |
| K | 11.18 | 12.19 | 0.440 | 0.480 |
| Q | 3.84 | 4.09 | 0.151 | 0.161 |
| R | 24.89 | 26.67 | 0.980 | 1.050 |

**CASE 197-01**

MODIFIED TO-3

### MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 500 | Vdc |
| Collector-Emitter Voltage | $V_{CES}$ | 850 | Vdc |
| Emitter-Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector-Current — Continuous<br>— Peak | $I_C$<br>$I_{CM}$ | 50<br>75 | Adc |
| Base-Current — Continuous<br>— Peak | $I_B$<br>$I_{BM}$ | 10<br>15 | Adc |
| Total Power Dissipation @ $T_C = 25\,°C$<br>Derate above 25 °C | $P_D$ | 250<br>1.428 | Watts<br>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 |

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

| Characteristics | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $V_{clamp}$ = Rated $V_{CEO}$) | $V_{CEO(sus)}$ | 500 | – | – | Vdc |
| Collector-Cutoff Current ($V_{CES}$ = Rated Value | $I_{CES}$ | – | – | 0.2 | mAdc |
| Emitter-Cutoff Current ($V_{EB}$ = 2 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 350 | mAdc |
| **ON CHARACTERISTICS**[2] | | | | | |
| DC Current Gain | $h_{FE}$ | | | | |
| ($I_C$ = 16 Adc, $V_{CE}$ = 5 Vdc) | | 30 | – | – | |
| ($I_C$ = 32 Vdc, $V_{CE}$ = 5 Vdc) | | 15 | – | – | |
| Collector-Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_C$ = 16 Adc, $I_B$ = 0.8 Adc) | | – | – | 2.0 | |
| ($I_C$ = 32 Adc, $I_B$ = 3.2 Adc) | | – | – | 3.0 | |
| ($I_C$ = 40 Adc, $I_B$ = 4.0 Adc) | | – | – | 3.5 | |
| ($I_C$ = 50 Adc, $I_B$ = 10 Adc) | | – | – | 5.0 | |
| Base-Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_C$ = 16 Adc, $I_B$ = 0.8 Adc) | | – | – | 2.5 | |
| ($I_C$ = 32 Adc, $I_B$ = 3.2 Adc) | | – | – | 2.9 | |
| ($I_C$ = 40 Adc, $I_B$ = 4.0 Adc) | | – | – | 3.3 | |
| Diode Forward Voltage[1] ($I_F$ = 40 Adc) | $V_f$ | – | – | 4.0 | Vdc |

| | | | | | | |
|---|---|---|---|---|---|---|
| Collector Emitter Sustaining Voltage<br>$R_{coil} = 0.05\Omega$, $L_{coil} = 180\mu H$<br>$V_{clamp}$ = rated $V_{CEX}$<br>$V_{BE\ (off)} = -5Vdc$<br>$T_C = 100°C$<br>$\frac{I_C}{I_{B1}} = 20$ | | | | | | Vdc |
| | $I_C$ = 32Adc | $V_{CEX1\ (sus)}$ | 350 | – | – | |
| | $I_C$ = 16Adc | $V_{CEX2\ (sus)}$ | 400 | – | – | |
| | $I_C$ = 5Adc | $V_{CEX3\ (sus)}$ | 500 | – | – | |

## SWITCHING CHARACTERISTICS
### RESISTIVE LOAD

| | | | | | | |
|---|---|---|---|---|---|---|
| Turn-on Time | ($V_{CC}$ = 250 Vdc, $I_C$ = 16 A, $I_{B1}$ = 0.8 A, $V_{BE(off)}$ = 5 Vdc, $t_p$ = 25 µs Duty Cycle ≤ 2%). | $t_{on}$ | – | 0.40 | 1.3 | µs |
| Storage Time | | $t_s$ | – | 0.8 | 2.5 | µs |
| Fall Time | | $t_f$ | – | 0.22 | 0.9 | µs |

[1] The internal Collector-to-Emitter diode can eliminate the need for an external diode to clamp inductive loads. Tests have shown that the Forward Recovery Voltage ($V_f$) of this diode is comparable to that of typical fast recovery rectifiers.

[2] Pulse Test. PW ≐ 300 µs, Duty Cycle ≤ 2%.

# Advance Information

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

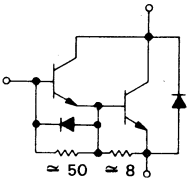
The BUT35 darlington transistor is designed for high voltage, high speed, high power switching in circuits where fall/storage time is critical. It is particularly suited for line operated switchmode applications such as:

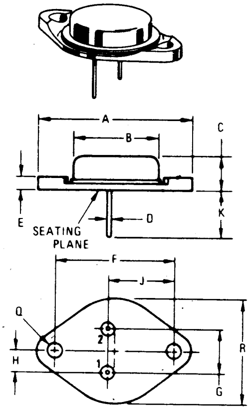
- Switching regulators
- Inverters
- Motor controls
- Solenoïd and relay drivers

**40 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**1000 VOLTS / 250 WATTS**




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

| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 38.35 | 39.37 | 1.510 | 1.550 |
| B | 19.30 | 21.08 | 0.760 | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 1.45 | 1.60 | 0.057 | 0.063 |
| E | – | 3.43 | – | 0.135 |
| F | 29.90 | 30.40 | 1.177 | 1.197 |
| G | 10.67 | 11.18 | 0.420 | 0.440 |
| H | 5.21 | 5.72 | 0.205 | 0.225 |
| J | 16.64 | 17.15 | 0.655 | 0.675 |
| K | 11.18 | 12.19 | 0.440 | 0.480 |
| Q | 3.84 | 4.09 | 0.151 | 0.161 |
| R | 24.89 | 26.67 | 0.980 | 1.050 |

**CASE 197-01**
MODIFIED TO-3

## MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 700 | Vdc |
| Collector-Emitter Voltage | $V_{CES}$ | 1000 | Vdc |
| Emitter-Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector-Current — Continuous<br>— Peak | $I_C$<br>$I_{CM}$ | 40<br>50 | Adc |
| Base-Current — Continuous<br>— Peak | $I_B$<br>$I_{BM}$ | 10<br>20 | Adc |
| Total Power Dissipation @ $T_C = 25\,°C$<br>Derate above 25 °C | $P_D$ | 250<br>1.428 | Watts<br>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 |

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

| Characteristics | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0, $V_{clamp}$ = Rated $V_{CEO}$) | $V_{CEO(sus)}$ | 700 | – | – | Vdc |
| Collector-Cutoff Current ($V_{CES}$ = Rated Value | $I_{CES}$ | – | – | 0.2 | mAdc |
| Emitter-Cutoff Current ($V_{EB}$ = 2 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 350 | mAdc |
| **ON CHARACTERISTICS[2]** | | | | | |
| DC Current Gain | $h_{FE}$ | | | | |
| ($I_C$ = 12 Adc, $V_{CE}$ = 5 Vdc) | | 30 | – | – | |
| ($I_C$ = 24 Adc, $V_{CE}$ = 5 Vdc) | | 15 | – | – | |
| Collector-Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_C$ = 12 Adc, $I_B$ = 0.6 Adc) | | – | – | 2.0 | |
| ($I_C$ = 24 Adc, $I_B$ = 2.4 Adc) | | – | – | 3.0 | |
| ($I_C$ = 32 Adc, $I_B$ = 3.2 Adc) | | – | – | 3.5 | |
| ($I_C$ = 40 Adc, $I_B$ = 8.0 Adc) | | – | – | 5.0 | |
| Base-Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_C$ = 12 Adc, $I_B$ = 0.6 Adc) | | – | – | 2.5 | |
| ($I_C$ = 24 Adc, $I_B$ = 2.4 Adc) | | – | – | 2.9 | |
| ($I_C$ = 32 Adc, $I_B$ = 3.2 Adc) | | – | – | 3.3 | |
| Diode Forward Voltage[1] ($I_F$ = 32 Adc) | $V_f$ | – | – | 4.0 | Vdc |

| | | | | | | |
|---|---|---|---|---|---|---|
| Collector Emitter Sustaining Voltage<br>$R_{coil} = 0.05\Omega$, $L_{coil} = 180\mu H$<br>$V_{clamp}$ = rated $V_{CEX}$<br>$V_{BE\ (off)} = -5$Vdc<br>$T_C = 100^\circ C$<br>$\frac{I_C}{I_{B1}} = 20$ | | | | | | Vdc |
| | $I_C$ = 24Adc | $V_{CEX1\ (sus)}$ | 400 | – | – | |
| | $I_C$ = 12Adc | $V_{CEX2\ (sus)}$ | 425 | – | – | |
| | $I_C$ = 4Adc | $V_{CEX3\ (sus)}$ | 700 | – | – | |

## SWITCHING CHARACTERISTICS
### RESISTIVE LOAD

| | | | | | | |
|---|---|---|---|---|---|---|
| Turn-on Time | ($V_{CC}$ = 250 Vdc, $I_C$ = 12 A, $I_{B1}$ = 0.6 A, $V_{BE(off)}$ = 5 Vdc, $t_p$ = 25 µs Duty Cycle ≤ 2%). | $t_{on}$ | – | 0.3 | 1.2 | µs |
| Storage Time | | $t_s$ | – | 0.8 | 3.3 | µs |
| Fall Time | | $t_f$ | – | 0.4 | 1.2 | µs |

[1] The internal Collector-to-Emitter diode can eliminate the need for an external diode to clamp inductive loads. Tests have shown that the Forward Recovery Voltage ($V_f$) of this diode is comparable to that of typical fast recovery rectifiers.

[2] Pulse Test. PW = 300 µs, Duty Cycle ≤ 2%.

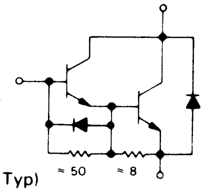
# MOTOROLA

# BUT 36

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

The BUT36 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
  1.7 uS Inductive Fall Time at 100°C (Typ)
  4.5 uS Inductive Storage Time at 100°C (Typ)
- Operating Temperature Range −65 to 175°C



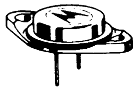

**24 AMPERES**

**NPN SILICON POWER DARLINGTON TRANSISTORS**

**1400 VOLTS**
**250 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.



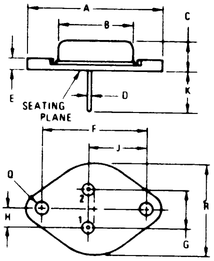
### MAXIMUM RATINGS

| Rating | Symbol | | Unit |
|---|---|---|---|
| Collector-Emitter Voltage | $V_{CEO(sus)}$ | 1000 | Vdc |
| Collector-Emitter Voltage | $V_{CEV}$ | 1400 | Vdc |
| Emitter Base Voltage | $V_{EB}$ | 10 | Vdc |
| Collector Current – Continuous – Peak (1) | $I_C$ $I_{CM}$ | 24 40 | Adc |
| Base Current – Continuous – Peak (1) | $I_B$ $I_{BM}$ | 15 20 | Adc |
| Free Wheel Diode: Forward current – Continuous – Peak | $I_F$ $I_{FM}$ | 24 40 | Adc |
| Total Power Dissipation @ $T_C$ = 25°C @ $T_C$ = 100°C Derate above 25°C | $P_D$ | 250 125 | 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 | $R\theta_{JC}$ | 0.6 | °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%.




STYLE 1
PIN 1. BASE
2. EMITTER
CASE COLLECTOR

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | – | 39 37 | – | 1 550 |
| B | – | 21 08 | – | 0.830 |
| C | 6.35 | 7.62 | 0.250 | 0.300 |
| D | 0.99 | 1 09 | 0.039 | 0.043 |
| E | – | 3.43 | – | 0.135 |
| F | 29.90 | 30.40 | 1 177 | 1 197 |
| G | 10.67 | 11 18 | 0.420 | 0.440 |
| H | 5.33 | 5.59 | 0.210 | 0.220 |
| J | 16.64 | 17.15 | 0.655 | 0.675 |
| K | 11 18 | 12 19 | 0 440 | 0.480 |
| Q | 3.84 | 4.09 | 0 151 | 0 161 |
| R | – | 26.67 | – | 1 050 |

**CASE 197-01**
MODIFIED TO-3

**ELECTRICAL CHARACTERISTICS** ($T_C$ = 25°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) | $V_{CEO(sus)}$ | 1000 | – | – | Vdc |
| Collector Cutoff Current ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc) | $I_{CEV}$ | – | – | 0.2 | mAdc |
| ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C$ = 100 °C) | | – | – | 4.0 | |
| Emitter Cutoff Current ($V_{EB}$ = 2.0 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 ($I_C$ = 8 A, $V_{CE}$ = 5 V) | $h_{FE}$ | 20 | – | – | |
| ($I_C$ = 16 A, $V_{CE}$ = 5 V) | | 5 | – | – | |
| Collector-Emitter Saturation Voltage ($I_C$ = 24 A, $I_B$ = 12 A) | $V_{CE(sat)}$ | – | – | 5.0 | Vdc |
| Base-Emitter Saturation Voltage ($I_C$ = 16 A, $I_B$ = 3.2 A) | $V_{BE(sat)}$ | – | – | 3.3 | Vdc |
| Diode Forward Voltage ($I_F$ = 24 A) | $V_f$ | – | – | 4.0 | Vdc |

**SWITCHING CHARACTERISTICS**
Inductive Load, Clamped (Table 1)

| | | | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Storage Time | $T_C$ = 25°C | See Table 1 | $t_s$ | – | – | 6.0 | μs |
| Fall Time | | $I_C$ = 16 A | $t_f$ | – | – | 2.5 | μs |
| Storage Time | $T_C$ = 100°C | $I_{B1}$ = 3.2 A | $t_s$ | – | 4.5 | – | μs |
| Fall Time | | $V_{BE(off)}$ = 5 V | $t_f$ | – | 1.7 | – | μs |

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

## TYPICAL CHARACTERISTICS

FIGURE 1 — DC CURRENT GAIN

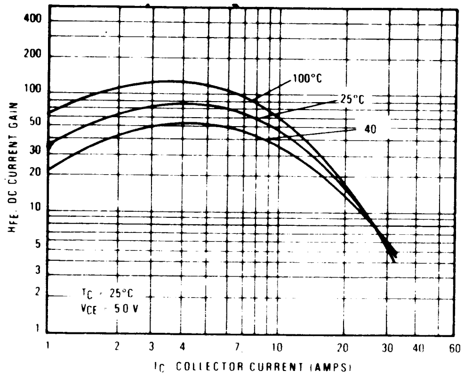



FIGURE 2 — COLLECTOR SATURATION REGION

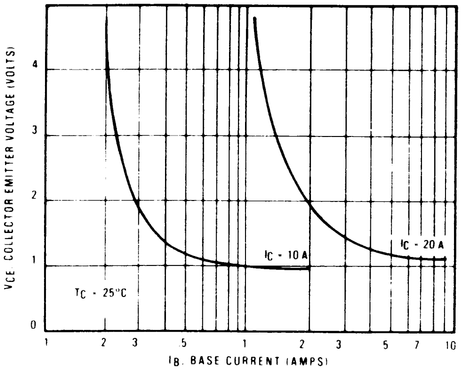



FIGURE 3 — COLLECTOR-EMITTER SATURATION VOLTAGE

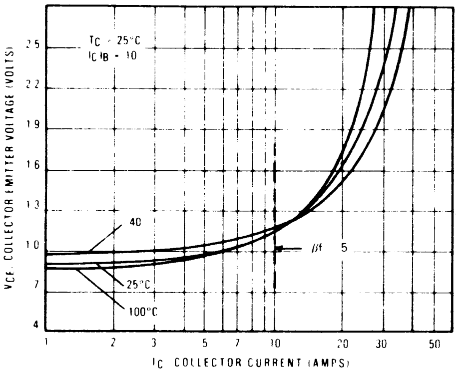



FIGURE 4 — BASE-EMITTER VOLTAGE

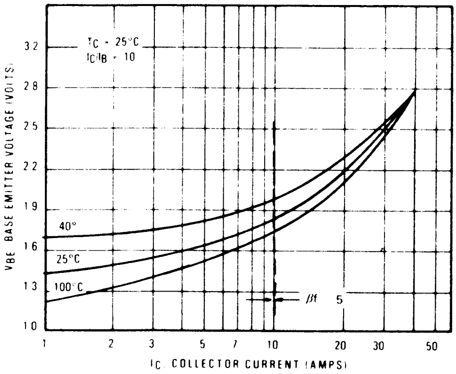



FIGURE 5 — THERMAL RESPONSE

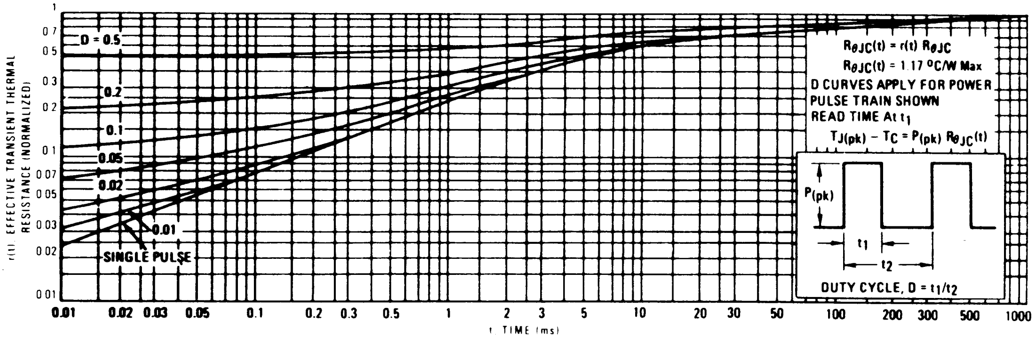


**TABLE 1 – TEST CONDITIONS FOR DYNAMIC PERFORMANCE**

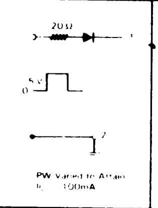
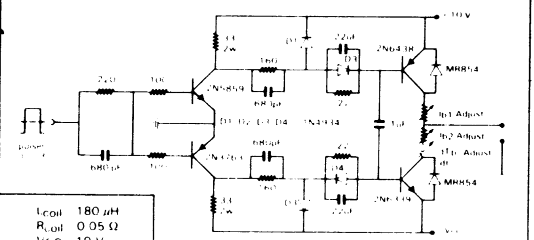
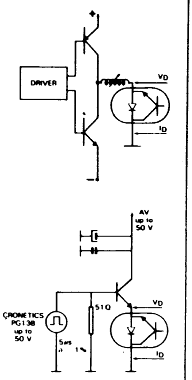
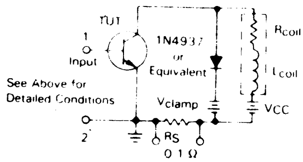
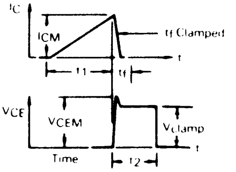
| | VCEO(sus) | RBSOA AND INDUCTIVE SWITCHING | TEST CIRCUIT for FREE-WHEEL DIODE |
|---|---|---|---|
| INPUT CONDITIONS |  |  |  |
| CIRCUIT VALUES | $L_{coil}$ = 10 mH VCC = 10V<br>$R_{coil}$ = 0.7 Ω<br>$V_{clamp}$ = VCEO(sus) | $L_{coil}$ = 180 μH<br>$R_{coil}$ = 0.05 Ω<br>VCC = 10 V | |
| TEST CIRCUITS | **INDUCTIVE TEST CIRCUIT**<br> | **OUTPUT WAVEFORMS**<br><br>t1 Adjusted to Obtain IC<br>$t_1 \approx \frac{L_{coil}(I_{CM})}{V_{CC}}$<br>$t_2 \approx \frac{L_{coil}(I_{CM})}{V_{clamp}}$<br>Test Equipment<br>Scope – Tektronix 475 or Equivalent | |

**FIGURE 6 – FALL TIME vs IB2/IB1**

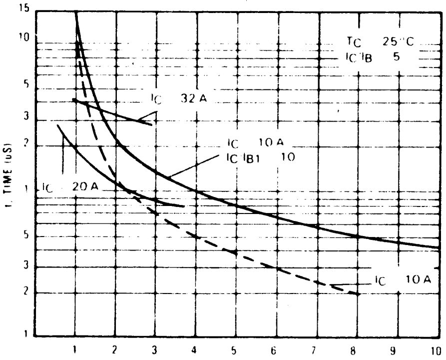



**FIGURE 7 – TURN-OFF TIME vs Ic**

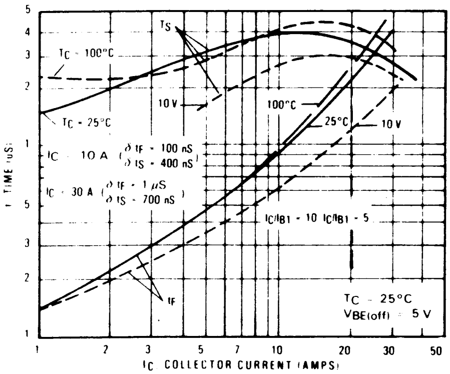



**FIGURE 8 – STORAGE TIME vs FORCED GAIN**

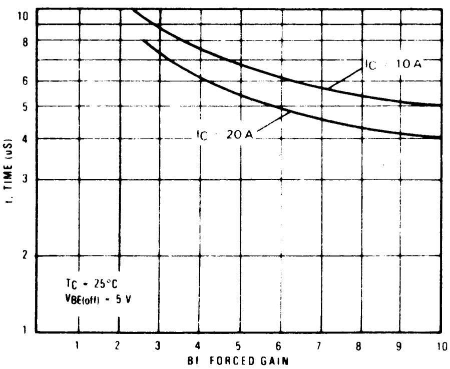
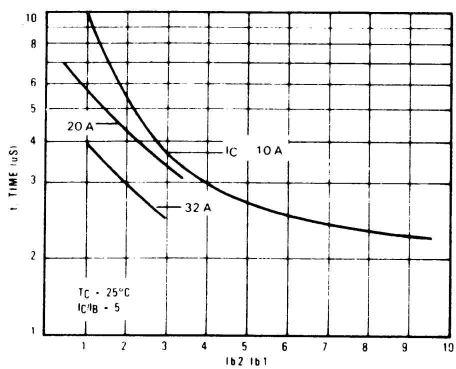



**FIGURE 9 – STORAGE TIME vs Ib2/Ib1**



## FREE-WHEEL DIODE CHARACTERISTICS

FIGURE 10 – FREE WHEEL DIODE MEASUREMENTS

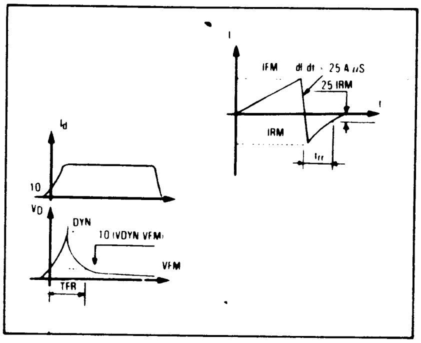



FIGURE 11 – FORWARD VOLTAGE

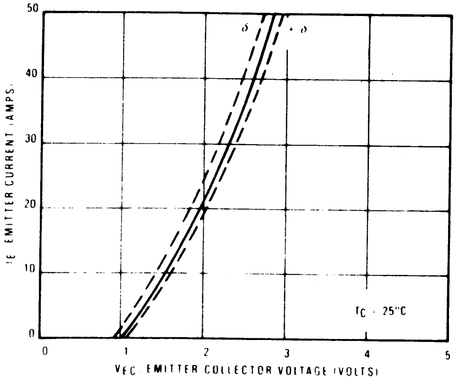



FIGURE 12 – FORWARD MODULATION VOLTAGE

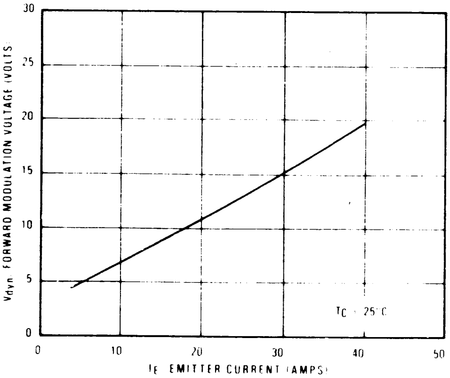



FIGURE 13 – PEAK REVERSE RECOVERY CURRENT

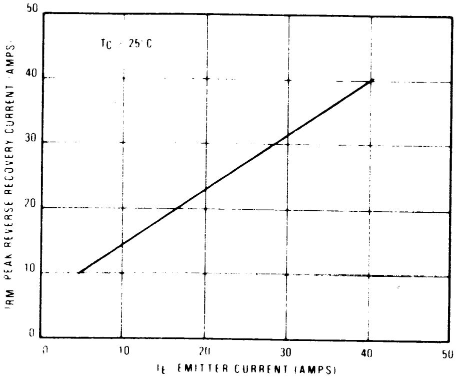



FIGURE 14 – FORWARD RECOVERY TIME

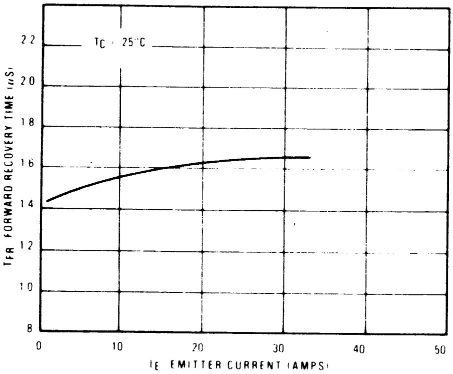
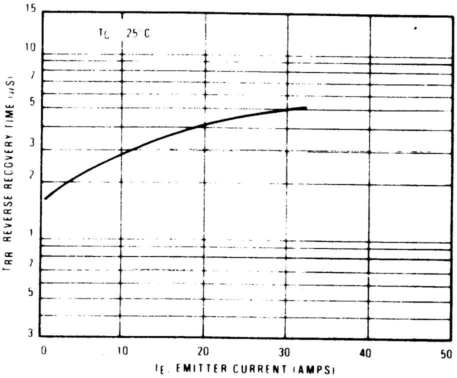



FIGURE 15 – REVERSE RECOVERY TIME



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

FIGURE 16 – SAFE OPERATING AREA

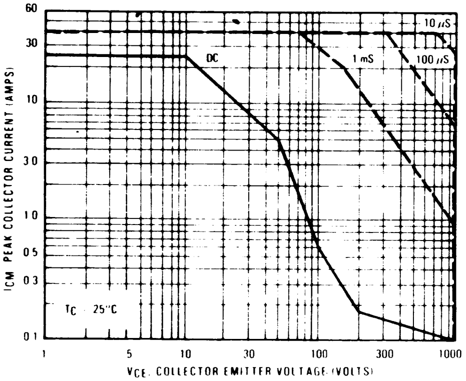
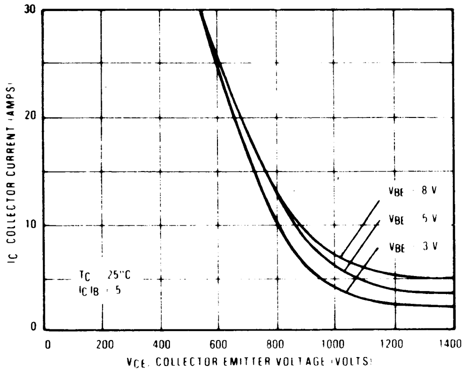



FIGURE 17 – REVERSE BIAS SAFE OPERATING AREA




## 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 grater dissipation than the curves indicate.

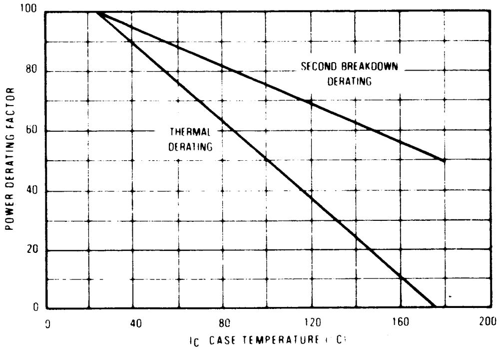
The data of Figure 16 is based on $T_C = 25°C$; $T_{J(pk)}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_C \geqq 25°C$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at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

FIGURE 18 – POWER DERATING



# MOTOROLA

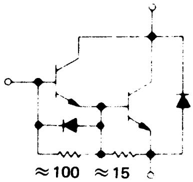
# BUT 50P

**ADVANCE INFORMATION**

## SWITCHMODE▲ SERIES
## NPN SILICON POWER DARLINGTON TRANSISTORS

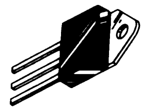
The BUT50P darlington transistor is designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. It is particularly suited for line operated switch-mode applications such as :

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




**8 AMPERES**
**NPN SILICON**
**POWER DARLINGTON TRANSISTORS**

**500 VOLTS-$V_{ceo(sus)}$**
**100 WATTS**
**850 VOLTS-$V_{ces}$**



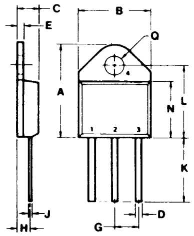
## MAXIMUM RATINGS

| Rating | Symbol | BUT50P | Unit |
|---|---|---|---|
| Collector-Emiter Voltage | $V_{CEO(sus)}$ | 500 | Vdc |
| Collector-Emitter Voltage | $V_{CEX(sus)}$ | 850 | Vdc |
| Collector-Emitter Voltage | $V_{CEV}$ | 850 | Vdc |
| Emitter Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector Current — Continuous<br>— Peak (1) | $I_C$<br>$I_{CM}$ | 8<br>16 | Adc |
| Base Current — Continuous<br>— Peak (1) | $I_B$<br>$I_{BM}$ | 2<br>4 | Adc |
| Free Wheel Diode :<br>Forward Current — continous<br>— peak | <br>$I_F$<br>$I_{FM}$ | <br>8<br>16 | Adc |
| Total Power Dissipation @ $T_C$=25°C<br>@ $T_C$=100°C<br>Derate above 25°C | $P_D$ | 100<br>40<br>.8 | Watts<br><br>W/°C |
| Operating and Storage Junction Temperature Range | $T_J$, $T_{stg}$ | -65 to + 150 | °C |

## THERMAL CHARACTERISTICS

| Characteristic | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Case | $R_{\theta JC}$ | 1.25 | °C/W |

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




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

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 20.32 | 21.08 | 0.800 | 0.830 |
| B | 15.49 | 15.90 | 0.610 | 0.626 |
| C | 4.19 | 5.08 | 0.165 | 0.200 |
| D | 1.02 | 1.65 | 0.040 | 0.065 |
| E | 1.35 | 1.65 | 0.053 | 0.065 |
| G | 5.21 | 5.72 | 0.205 | 0.225 |
| H | 2.41 | 3.20 | 0.095 | 0.126 |
| J | 0.38 | 0.64 | 0.015 | 0.025 |
| K | 12.70 | 15.49 | 0.500 | 0.610 |
| L | 15.88 | 16.51 | 0.625 | 0.650 |
| N | 12.19 | 12.70 | 0.480 | 0.500 |
| Q | 3.94 | 4.19 | 0.155 | 0.165 |

**Case 340-01**
**TO-218AC**

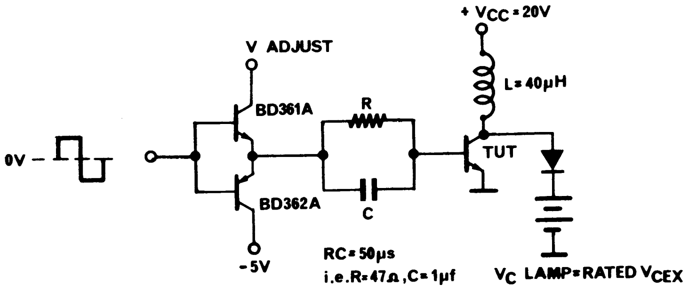
## ELECTRICAL CHARACTERISTICS ($T_C$ = 25°C unless otherwise noted)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO(sus)}$ | 500 | – | – | Vdc |
| Collector Cutoff Current | $I_{CEV}$ | | | | mAdc |
| ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc) | | – | – | 0.25 | |
| ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C$ = 100°C | | – | – | 2.5 | |
| Emitter Cutoff Current ($V_{EB}$ = 8.0 V, $I_C$ = 0) | $I_{EBO}$ | – | – | 175 | mAdc |
| **ON CHARACTERISTICS (1)** | | | | | |
| DC Current Gain ($I_c$ = 2 Adc, $V_{ce}$ = 5 V) | $h_{FE}$ | 30 | – | – | – |
| Collector-Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_c$ = 5 Adc, $I_b$ = 0.25 Adc) | | – | – | 2.0 | |
| ($I_c$ = 8 Adc, $I_b$ = 1 Adc) | | – | – | 3.0 | |
| ($I_c$ = 5 Adc, $I_b$ = 0.25 Adc, $T_c$ = 100°C) | | – | – | 2.5 | |
| Base-Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_c$ = 5 Adc, $I_b$ = 0.25 Adc) | | – | – | 2.5 | |
| ($I_c$ = 5 Adc, $I_b$ = 0.25 Adc, $T_c$ = 100°C) | | – | – | 2.5 | |
| Diode Forward Voltage ($I_F$ = 5 Adc) | $V_f$ | – | – | 4.0 | Vdc |

**SWITCHING CHARACTERISTICS**
Inductive Load, Clamped

| | Conditions | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Storage Time | ($I_c$ = 5 A, $Ib_1$ = 0.25 A, Vbe(off) = 5 V) | $t_s$ | – | 0.75 | – | μs |
| Fall Time | | $t_f$ | – | 0.10 | – | μs |

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




SWITCHING TIMES TEST CIRCUIT

ADVANCE INFORMATION

## SWITCHMODE▲ SERIES
## NPN SILICON POWER DARLINGTON TRANSISTORS

The BUT51P darlington transistor is designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. It is particularly suited for line operated switch-mode applications such as :

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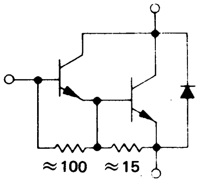
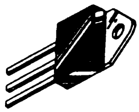
- Inverters
- Solenoid and Relay Drivers
- Motor Controls
- Deflection Circuits




15 AMPERES
NPN SILICON
POWER DARLINGTON
TRANSISTORS

500 VOLTS-$V_{ceo(sus)}$
100 WATTS
850 VOLTS–$V_{ces}$



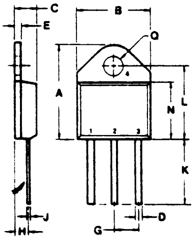
## MAXIMUM RATINGS

| Rating | Symbol | BUT51P | Unit |
|---|---|---|---|
| Collector-Emiter Voltage | $V_{CEO(sus)}$ | 500 | Vdc |
| Collector-Emitter Voltage | $V_{CEX(sus)}$ | 850 | Vdc |
| Collector-Emitter Voltage | $V_{CEV}$ | 850 | Vdc |
| Emitter Base Voltage | $V_{EB}$ | 8 | Vdc |
| Collector Current – Continuous<br>– Peak (1) | $I_C$<br>$I_{CM}$ | 15<br>25 | Adc |
| Base Current – Continuous<br>– Peak (1) | $I_B$<br>$I_{BM}$ | 2.5<br>5 | Adc |
| Free Wheel Diode :<br>Forward Current – continous<br>– peak | <br>$I_F$<br>$I_{FM}$ | <br>15<br>25 | Adc |
| Total Power Dissipation @$T_C$=25°C<br>@$T_C$=100°C<br>Derate above 25°C | $P_D$ | 125<br>50<br>1 | Watts<br><br>W/°C |
| Operating and Storage Junction Temperature Range | $T_J$, $T_{stg}$ | -65 to + 150 | °C |

## THERMAL CHARACTERISTICS

| Characteristic | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Case | $R_{\theta JC}$ | 1 | °C/W |

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




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

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 20.32 | 21.08 | 0.800 | 0.830 |
| B | 15.49 | 15.90 | 0.610 | 0.626 |
| C | 4.19 | 5.08 | 0.165 | 0.200 |
| D | 1.02 | 1.65 | 0.040 | 0.065 |
| E | 1.35 | 1.65 | 0.053 | 0.065 |
| G | 5.21 | 5.72 | 0.205 | 0.225 |
| H | 2.41 | 3.20 | 0.095 | 0.126 |
| J | 0.38 | 0.64 | 0.015 | 0.025 |
| K | 12.70 | 15.49 | 0.500 | 0.610 |
| L | 15.88 | 16.51 | 0.625 | 0.650 |
| N | 12.19 | 12.70 | 0.480 | 0.500 |
| Q | 3.94 | 4.19 | 0.155 | 0.165 |

**Case 340-01**
**TO-218AC**

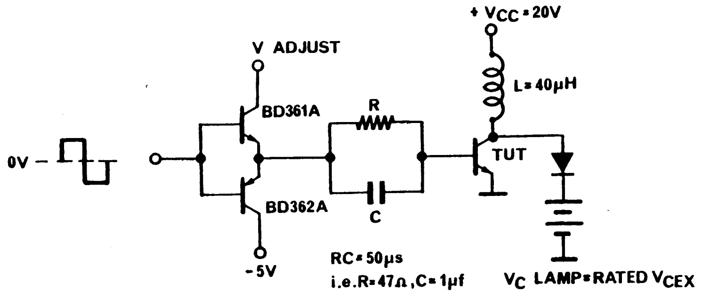
## ELECTRICAL CHARACTERISTICS ($T_C$ = 25°C unless otherwise noted)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector-Emitter Sustaining Voltage ($I_C$ = 100 mA, $I_B$ = 0) | $V_{CEO(sus)}$ | 500 | – | – | Vdc |
| Collector Cutoff Current ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc)<br>($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C$ = 100°C) | $I_{CEV}$ | 0.25<br>2.5 | –<br>– | –<br>– | mAdc |
| Emitter Cutoff Current ($V_{EB}$ = 8.0 V, $I_C$ = 0) | $I_{EBO}$ | – | – | 175 | mAdc |
| **ON CHARACTERISTICS** (1) | | | | | |
| DC Current Gain ($I_c$ = 5 Adc, $V_{ce}$ = 5 V) | $h_{FE}$ | 40 | – | – | – |
| Collector-Emitter Saturation Voltage ($I_c$ = 10 Adc, $I_b$ = 0.5 Adc)<br>($I_c$ = 15 Adc, $I_b$ = 1.5 Adc)<br>($I_c$ = 10 Adc, $I_b$ = 0.55 Adc, $T_c$ = 100°C) | $V_{CE(sat)}$ | –<br>–<br>– | –<br>–<br>– | 2.0<br>3.0<br>2.5 | Vdc |
| Base-Emitter Saturation Voltage ($I_c$ = 10 Adc, $I_b$ = 0.5 Adc)<br>($I_c$ = 10 Adc, $I_b$ = 0.55 Adc, $T_c$ = 100°C) | $V_{BE(sat)}$ | –<br>– | –<br>– | 2.5<br>2.5 | Vdc |
| Diode Forward Voltage ($I_F$ = 10 Adc) | $V_f$ | – | – | 4.0 | Vdc |

**SWITCHING CHARACTERISTICS**
Inductive Load, Clamped

| | Conditions | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Storage Time | ($I_c$ = 10 A, $I_{b1}$ = 0.5 A, $V_{be(off)}$ = 5 V) | $t_s$ | – | 1.1 | – | μs |
| Fall Time | | $t_f$ | – | 0.16 | – | μs |

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




SWITCHING TIMES TEST CIRCUIT