

# SWITCHMODE™

## NPN Bipolar Power Transistor

### For Switching Power Supply Applications

The BUL44 have an applications specific state-of-the-art die designed for use in 220 V line operated Switchmode Power supplies and electronic light ballasts. These high voltage/high speed transistors offer the following:

- Improved Efficiency Due to Low Base Drive Requirements:
  - High and Flat DC Current Gain  $h_{FE}$
  - Fast Switching
  - No Coil Required in Base Circuit for Turn-Off (No Current Tail)
- Full Characterization at 125°C
- Tight Parametric Distributions are Consistent Lot-to-Lot

#### MAXIMUM RATINGS

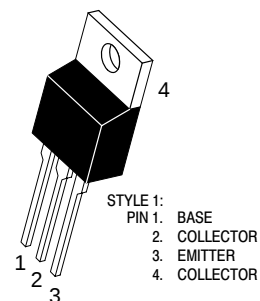
| Rating                                           | Symbol                            | Value       | Unit  |
|--------------------------------------------------|-----------------------------------|-------------|-------|
| Collector-Emitter Sustaining Voltage             | $V_{CEO}$                         | 400         | Vdc   |
| Collector-Emitter Breakdown Voltage              | $V_{CES}$                         | 700         | Vdc   |
| Emitter-Base Voltage                             | $V_{EBO}$                         | 9.0         | Vdc   |
| Collector Current — Continuous                   | $I_C$                             | 2.0         | Adc   |
| — Peak(1)                                        | $I_{CM}$                          | 5.0         |       |
| Base Current — Continuous                        | $I_B$                             | 1.0         | Adc   |
| — Peak(1)                                        | $I_{BM}$                          | 2.0         |       |
| Total Device Dissipation (T <sub>C</sub> = 25°C) | $P_D$                             | 50          | Watts |
| Derate above 25°C                                |                                   | 0.4         | W/°C  |
| Operating and Storage Temperature                | T <sub>J</sub> , T <sub>stg</sub> | – 65 to 150 | °C    |

#### THERMAL CHARACTERISTICS

| Rating                                                                           | Symbol          | Max  | Unit |
|----------------------------------------------------------------------------------|-----------------|------|------|
| Thermal Resistance — Junction to Case                                            | $R_{\theta JC}$ | 2.5  | °C/W |
| — Junction to Ambient                                                            | $R_{\theta JA}$ | 62.5 |      |
| Maximum Lead Temperature for Soldering<br>Purposes: 1/8" from Case for 5 Seconds | T <sub>L</sub>  | 260  | °C   |

## BUL44

POWER TRANSISTOR  
2.0 AMPERES  
700 VOLTS  
40 and 100 WATTS



**BUL44**  
**CASE 221A-06**  
**TO-220AB**

# BUL44

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

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

### OFF CHARACTERISTICS

|                                                                                                                       |                       |     |   |     |      |
|-----------------------------------------------------------------------------------------------------------------------|-----------------------|-----|---|-----|------|
| Collector–Emitter Sustaining Voltage (I <sub>C</sub> = 100 mA, L = 25 mH)                                             | V <sub>CEO(sus)</sub> | 400 | — | —   | Vdc  |
| Collector Cutoff Current (V <sub>CE</sub> = Rated V <sub>CEO</sub> , I <sub>B</sub> = 0)                              | I <sub>CEO</sub>      | —   | — | 100 | μAdc |
| Collector Cutoff Current (V <sub>CE</sub> = Rated V <sub>CES</sub> , V <sub>EB</sub> = 0)<br>(T <sub>C</sub> = 125°C) | I <sub>CES</sub>      | —   | — | 100 | μAdc |
| (V <sub>CE</sub> = 500 V, V <sub>EB</sub> = 0) (T <sub>C</sub> = 125°C)                                               |                       | —   | — | 500 |      |
|                                                                                                                       |                       | —   | — | 100 |      |
| Emitter Cutoff Current (V <sub>EB</sub> = 9.0 Vdc, I <sub>C</sub> = 0)                                                | I <sub>EBO</sub>      | —   | — | 100 | μAdc |

### ON CHARACTERISTICS

|                                                                                                                                                                                                                                                                                                                                                                     |                      |                                         |                                       |                                  |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------------------------|---------------------------------------|----------------------------------|-----|
| Base–Emitter Saturation Voltage (I <sub>C</sub> = 0.4 Adc, I <sub>B</sub> = 40 mAdc)<br>(I <sub>C</sub> = 1.0 Adc, I <sub>B</sub> = 0.2 Adc)                                                                                                                                                                                                                        | V <sub>BE(sat)</sub> | —<br>—                                  | 0.85<br>0.92                          | 1.1<br>1.25                      | Vdc |
| Collector–Emitter Saturation Voltage<br>(I <sub>C</sub> = 0.4 Adc, I <sub>B</sub> = 40 mAdc)<br>(I <sub>C</sub> = 1.0 Adc, I <sub>B</sub> = 0.2 Adc)<br>(T <sub>C</sub> = 125°C)<br>(T <sub>C</sub> = 125°C)                                                                                                                                                        | V <sub>CE(sat)</sub> | —<br>—<br>—<br>—                        | 0.20<br>0.20<br>0.25<br>0.25          | 0.5<br>0.5<br>0.6<br>0.6         | Vdc |
| DC Current Gain<br>(I <sub>C</sub> = 0.2 Adc, V <sub>CE</sub> = 5.0 Vdc)<br>(I <sub>C</sub> = 0.4 Adc, V <sub>CE</sub> = 1.0 Vdc)<br>(I <sub>C</sub> = 1.0 Adc, V <sub>CE</sub> = 1.0 Vdc)<br>(I <sub>C</sub> = 10 mAdc, V <sub>CE</sub> = 5.0 Vdc)<br>(T <sub>C</sub> = 125°C)<br>(T <sub>C</sub> = 125°C)<br>(T <sub>C</sub> = 125°C)<br>(T <sub>C</sub> = 125°C) | h <sub>FE</sub>      | 14<br>—<br>12<br>12<br>8.0<br>7.0<br>10 | —<br>32<br>20<br>20<br>14<br>13<br>22 | 34<br>—<br>—<br>—<br>—<br>—<br>— | —   |

### DYNAMIC CHARACTERISTICS

|                                                                                                                                                    |                                                                                     |                   |                             |                |   |      |     |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------|-----------------------------|----------------|---|------|-----|----------|
| Current Gain Bandwidth ( $I_C = 0.5 \text{ Adc}$ , $V_{CE} = 10 \text{ Vdc}$ , $f = 1.0 \text{ MHz}$ )                                             |                                                                                     |                   |                             | $f_T$          | — | 13   | —   | MHz      |
| Output Capacitance ( $V_{CB} = 10 \text{ Vdc}$ , $I_E = 0$ , $f = 1.0 \text{ MHz}$ )                                                               |                                                                                     |                   |                             | $C_{OB}$       | — | 38   | 60  | pF       |
| Input Capacitance ( $V_{EB} = 8.0 \text{ V}$ )                                                                                                     |                                                                                     |                   |                             | $C_{IB}$       | — | 380  | 600 | pF       |
| Dynamic Saturation Voltage:<br>Determined 1.0 $\mu\text{s}$ and 3.0 $\mu\text{s}$ respectively after rising $I_{B1}$ reaches 90% of final $I_{B1}$ | $(I_C = 0.4 \text{ Adc}$<br>$I_{B1} = 40 \text{ mAdc}$<br>$V_{CC} = 300 \text{ V})$ | 1.0 $\mu\text{s}$ | $(T_C = 125^\circ\text{C})$ | $V_{CE(dsat)}$ | — | 2.5  | —   | $V_{dc}$ |
|                                                                                                                                                    |                                                                                     | 3.0 $\mu\text{s}$ | $(T_C = 125^\circ\text{C})$ |                | — | 1.3  | —   |          |
|                                                                                                                                                    | $(I_C = 1.0 \text{ Adc}$<br>$I_{B1} = 0.2 \text{ Adc}$<br>$V_{CC} = 300 \text{ V})$ | 1.0 $\mu\text{s}$ | $(T_C = 125^\circ\text{C})$ |                | — | 3.2  | —   |          |
|                                                                                                                                                    |                                                                                     | 3.0 $\mu\text{s}$ | $(T_C = 125^\circ\text{C})$ |                | — | 1.25 | —   |          |

(1) Pulse Test: Pulse Width = 5.0 ms, Duty Cycle ≤ 10%.

(continued)

# BUL44

## SWITCHING CHARACTERISTICS: Resistive Load (D.C. $\leq 10\%$ , Pulse Width = 20 $\mu\text{s}$ )

|               |                                                                                                                                      |                  |   |      |     |               |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------|------------------|---|------|-----|---------------|
| Turn-On Time  | (I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc<br>I <sub>B2</sub> = 0.2 Adc, V <sub>CC</sub> = 300 V) (T <sub>C</sub> = 125°C) | t <sub>on</sub>  | — | 40   | 100 | ns            |
| Turn-Off Time |                                                                                                                                      | t <sub>off</sub> | — | 40   | —   | —             |
| Turn-On Time  | (I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc<br>I <sub>B2</sub> = 0.2 Adc, V <sub>CC</sub> = 300 V) (T <sub>C</sub> = 125°C) | t <sub>on</sub>  | — | 1.5  | 2.5 | $\mu\text{s}$ |
| Turn-Off Time |                                                                                                                                      | t <sub>off</sub> | — | 2.0  | —   | —             |
| Turn-On Time  | (I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc<br>I <sub>B1</sub> = 0.5 Adc, V <sub>CC</sub> = 300 V) (T <sub>C</sub> = 125°C) | t <sub>on</sub>  | — | 85   | 150 | ns            |
| Turn-Off Time |                                                                                                                                      | t <sub>off</sub> | — | 85   | —   | —             |
| Turn-On Time  | (I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc<br>I <sub>B2</sub> = 0.5 Adc, V <sub>CC</sub> = 300 V) (T <sub>C</sub> = 125°C) | t <sub>on</sub>  | — | 1.75 | 2.5 | $\mu\text{s}$ |
| Turn-Off Time |                                                                                                                                      | t <sub>off</sub> | — | 2.10 | —   | —             |

## SWITCHING CHARACTERISTICS: Inductive Load (V<sub>clamp</sub> = 300 V, V<sub>CC</sub> = 15 V, L = 200 $\mu\text{H}$ )

|                |                                                                                                               |                 |     |      |      |               |
|----------------|---------------------------------------------------------------------------------------------------------------|-----------------|-----|------|------|---------------|
| Fall Time      | (I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc<br>I <sub>B2</sub> = 0.2 Adc) (T <sub>C</sub> = 125°C)   | t <sub>fi</sub> | —   | 125  | 200  | ns            |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 120  | —    | —             |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 0.7  | 1.25 | $\mu\text{s}$ |
| Fall Time      | (I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc<br>I <sub>B2</sub> = 0.2 Adc) (T <sub>C</sub> = 125°C)   | t <sub>fi</sub> | —   | 0.8  | —    | —             |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 110  | 200  | ns            |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 110  | —    | —             |
| Fall Time      | (I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc<br>I <sub>B2</sub> = 0.5 Adc) (T <sub>C</sub> = 125°C)   | t <sub>fi</sub> | —   | 110  | 175  | ns            |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 120  | —    | —             |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 1.7  | 2.75 | $\mu\text{s}$ |
| Fall Time      | (I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc<br>I <sub>B2</sub> = 0.5 Adc) (T <sub>C</sub> = 125°C)   | t <sub>fi</sub> | —   | 2.25 | —    | —             |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 180  | 300  | ns            |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 210  | —    | —             |
| Fall Time      | (I <sub>C</sub> = 0.8 Adc, I <sub>B1</sub> = 160 mAdc<br>I <sub>B2</sub> = 160 mAdc) (T <sub>C</sub> = 125°C) | t <sub>fi</sub> | 70  | —    | 170  | ns            |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 180  | —    | —             |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 2.6  | 3.8  | $\mu\text{s}$ |
| Fall Time      | (I <sub>C</sub> = 0.8 Adc, I <sub>B1</sub> = 160 mAdc<br>I <sub>B2</sub> = 160 mAdc) (T <sub>C</sub> = 125°C) | t <sub>fi</sub> | 2.6 | —    | —    | —             |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | 4.2  | —    | —             |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | 190  | 300  | ns            |
| Fall Time      | (I <sub>C</sub> = 0.8 Adc, I <sub>B1</sub> = 160 mAdc<br>I <sub>B2</sub> = 160 mAdc) (T <sub>C</sub> = 125°C) | t <sub>fi</sub> | —   | 350  | —    | —             |
| Storage Time   |                                                                                                               | t <sub>si</sub> | —   | —    | —    | —             |
| Crossover Time |                                                                                                               | t <sub>c</sub>  | —   | —    | —    | —             |

TYPICAL STATIC CHARACTERISTICS

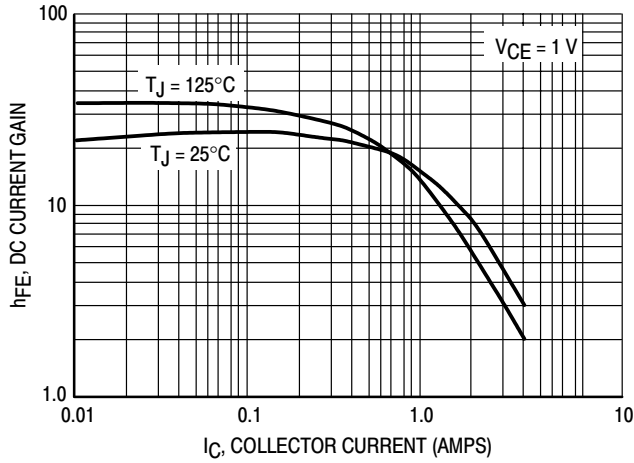


Figure 1. DC Current Gain at 1 Volt

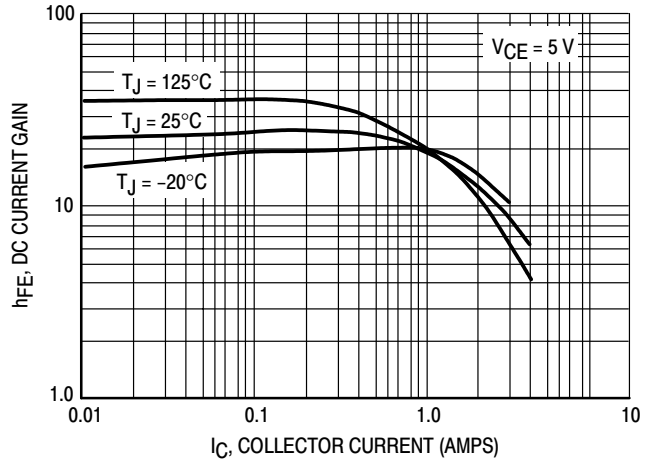


Figure 2. DC Current Gain at 5 Volts

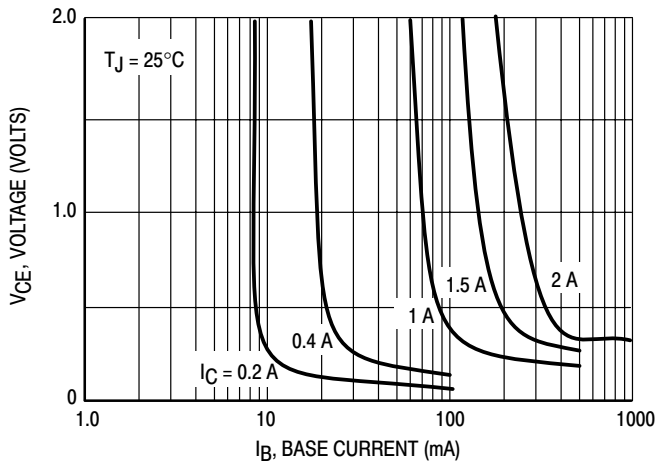


Figure 3. Collector Saturation Region

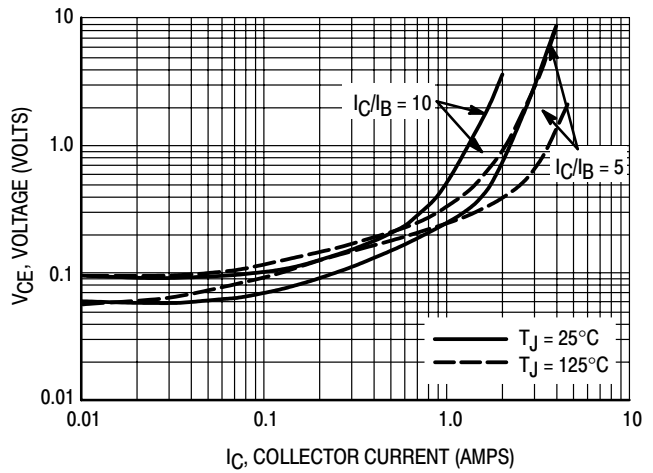


Figure 4. Collector-Emitter Saturation Voltage

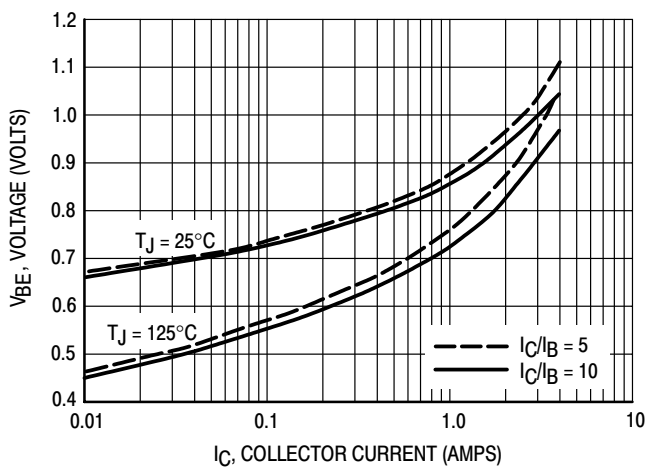


Figure 5. Base-Emitter Saturation Region

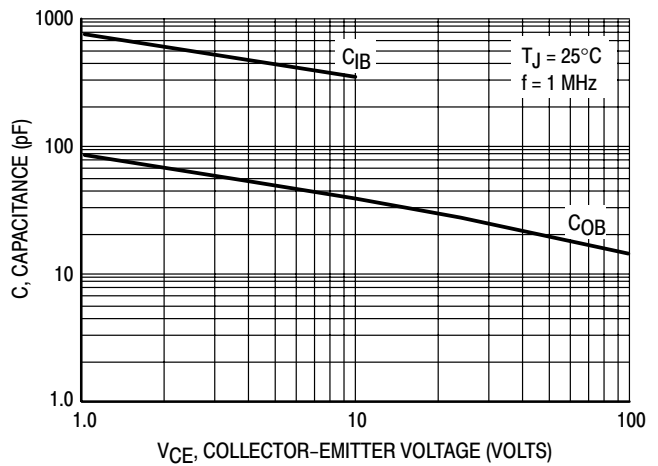


Figure 6. Capacitance

TYPICAL SWITCHING CHARACTERISTICS  
( $I_{B2} = I_C/2$  for all switching)

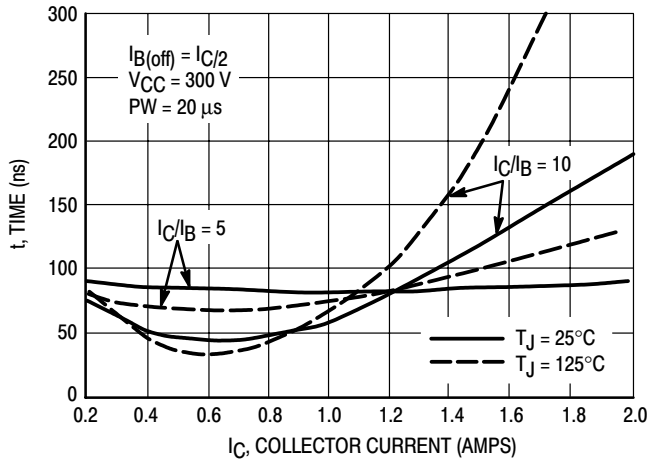


Figure 7. Resistive Switching,  $t_{on}$

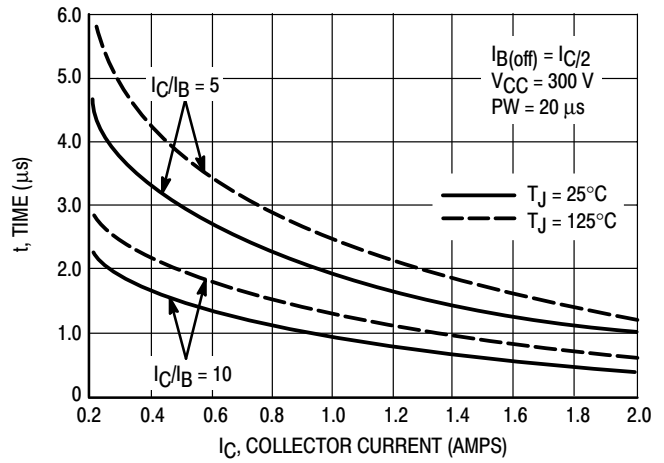


Figure 8. Resistive Switching,  $t_{off}$

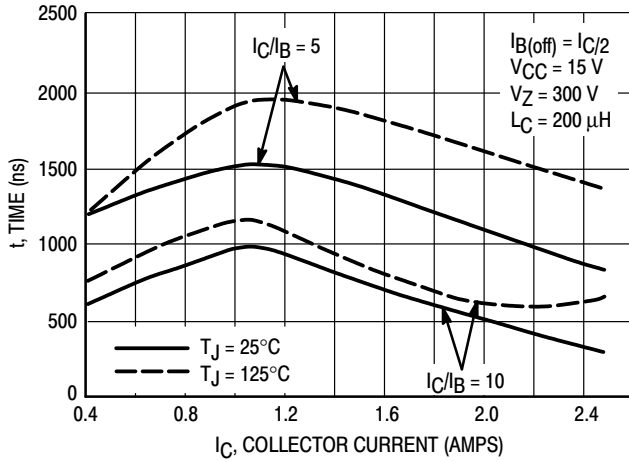


Figure 9. Inductive Storage Time,  $t_{si}$

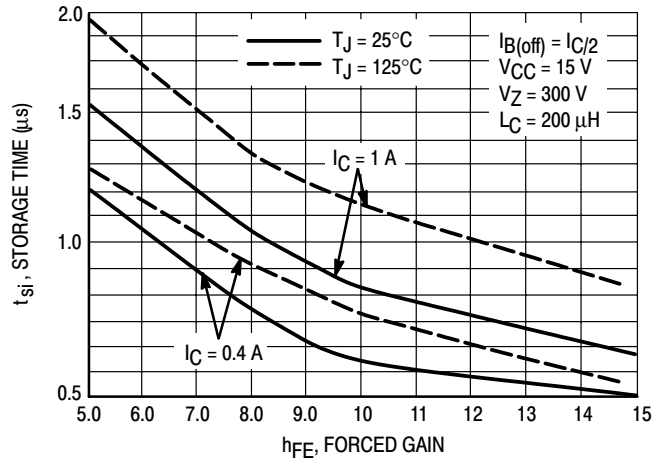


Figure 10. Inductive Storage Time

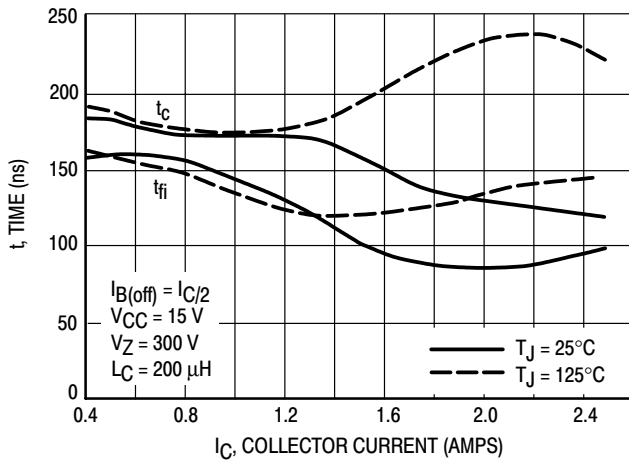


Figure 11. Inductive Switching,  $t_c$  and  $t_{fi}$   $I_C/I_B = 5$

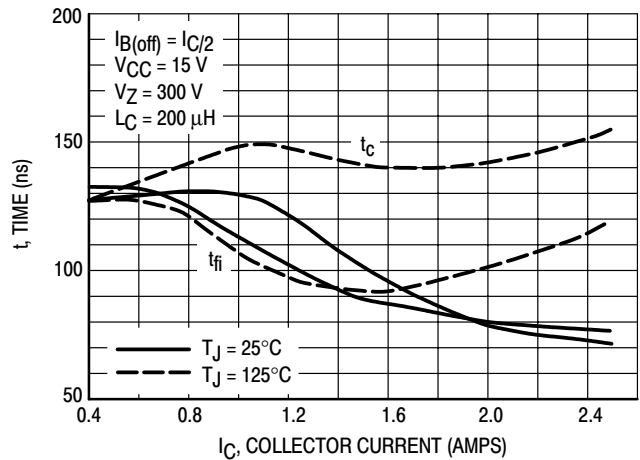


Figure 12. Inductive Switching,  $t_c$  and  $t_{fi}$   $I_C/I_B = 10$

### TYPICAL SWITCHING CHARACTERISTICS ( $I_{B2} = I_C/2$ for all switching)

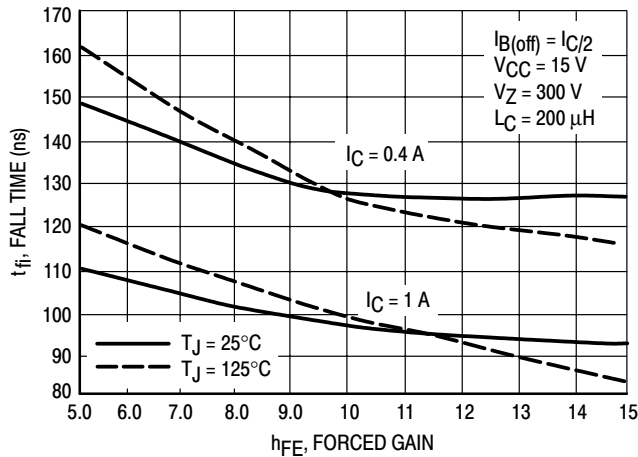


Figure 13. Inductive Fall Time

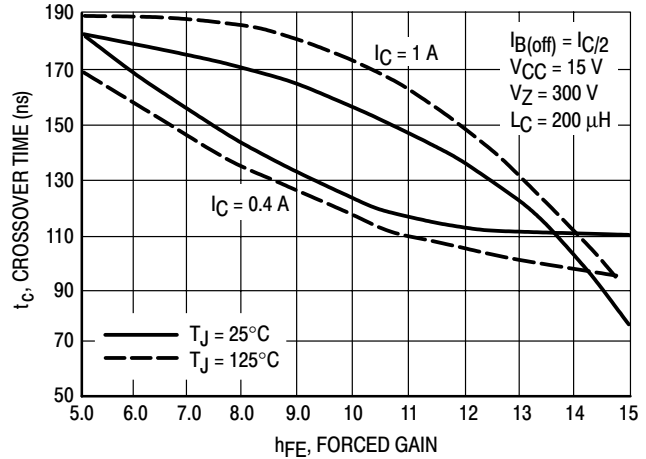


Figure 14. Inductive Crossover Time

### GUARANTEED SAFE OPERATING AREA INFORMATION

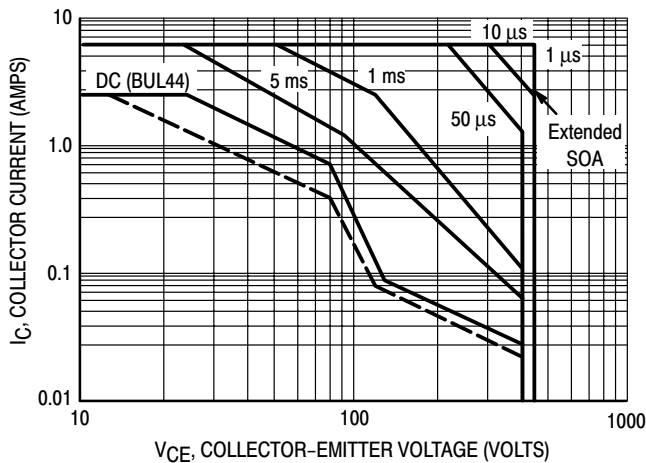


Figure 15. Forward Bias Safe Operating Area

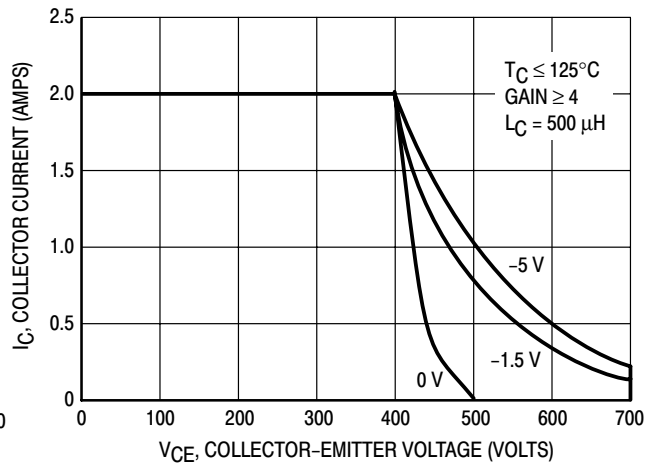


Figure 16. Reverse Bias Switching Safe Operating Area

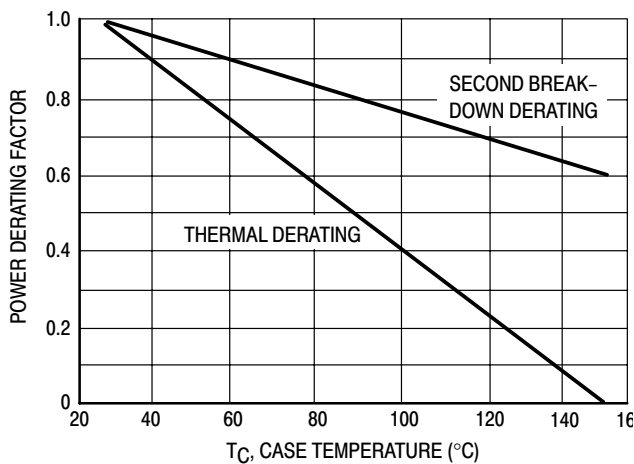


Figure 17. Forward Bias Power Derating

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 subjected to greater dissipation than the curves indicate. The data of figure 15 is based on  $T_C = 25^\circ\text{C}$ ;  $T_J(\text{PK})$  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 15 may be found at any case temperature by using the appropriate curve on figure 17.  $T_J(\text{PK})$  may be calculated from the data in figure 20. At any case temperatures, thermal limitations will reduce the power than can be handled to values less than the limitations imposed by second breakdown. For inductive loads, high voltage and current must be sustained simultaneously during turn-off with the base-to-emitter junction reverse-biased. The safe level is specified as a reverse-biased safe operating area (Figure 16). This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode.

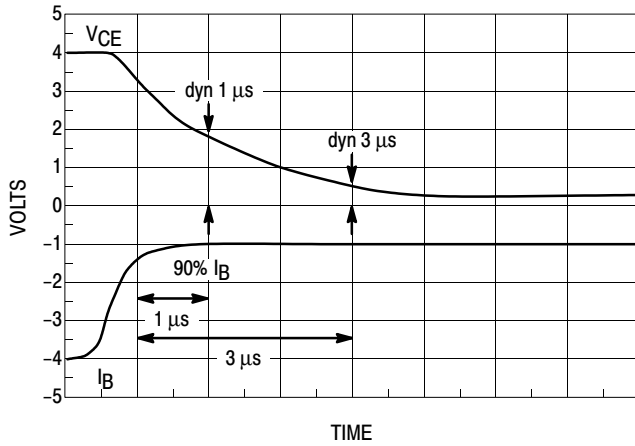


Figure 18. Dynamic Saturation Voltage Measurements

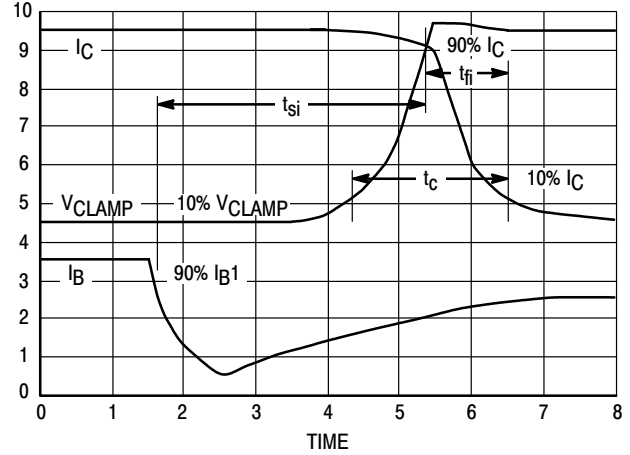
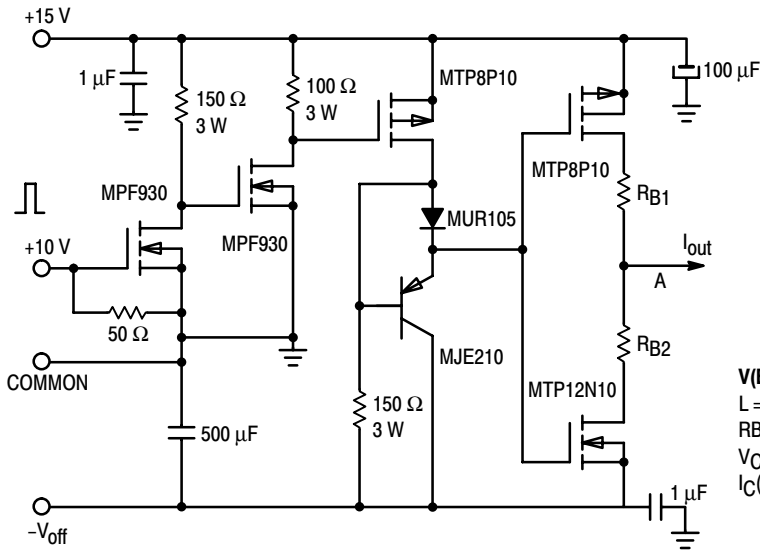


Figure 19. Inductive Switching Measurements



| V(BR)CEO(sus)   | INDUCTIVE SWITCHING          | RBSOA                        |
|-----------------|------------------------------|------------------------------|
| L = 10 mH       | L = 200 μH                   | L = 500 μH                   |
| RB2 = ∞         | RB2 = 0                      | RB2 = 0                      |
| VCC = 20 VOLTS  | VCC = 15 VOLTS               | VCC = 15 VOLTS               |
| IC(pk) = 100 mA | RB1 SELECTED FOR DESIRED IB1 | RB1 SELECTED FOR DESIRED IB1 |

Table 1. Inductive Load Switching Drive Circuit

### TYPICAL THERMAL RESPONSE

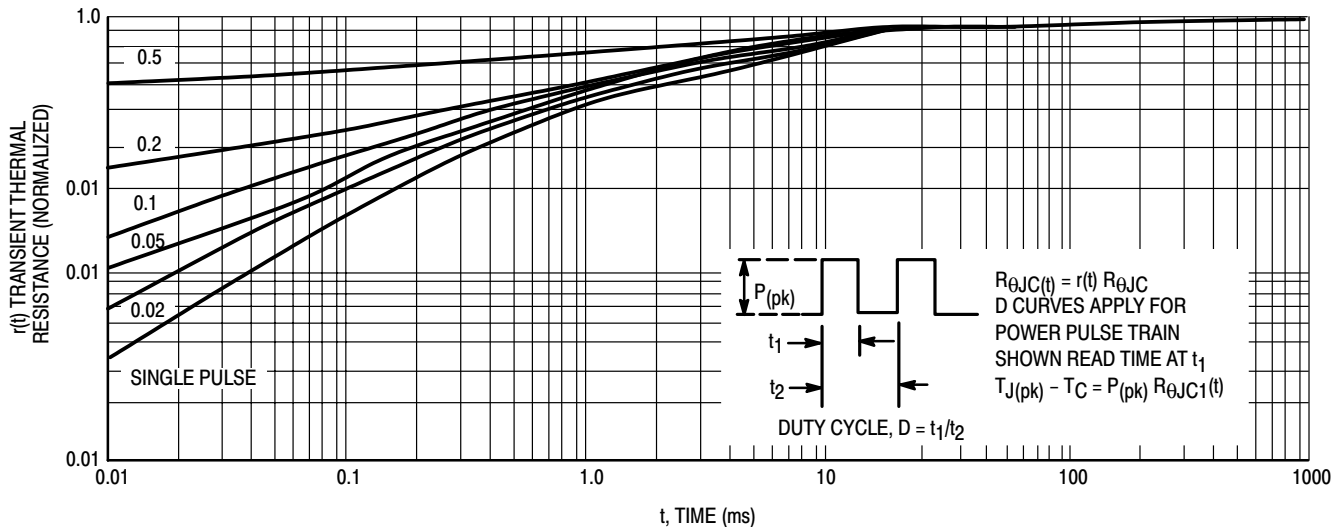
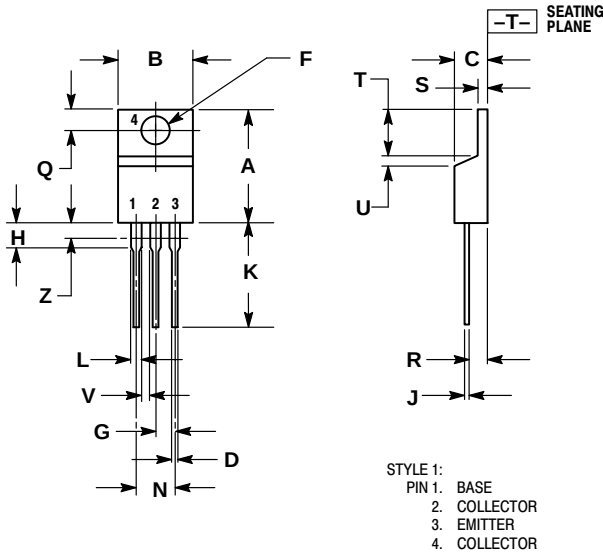


Figure 20. Typical Thermal Response ( $Z_{\theta JC}(t)$ ) for BUL44

# BUL44

## PACKAGE DIMENSIONS

### TO-220AB CASE 221A-09 ISSUE AA



#### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

| DIM | INCHES |       | MILLIMETERS |       |
|-----|--------|-------|-------------|-------|
|     | MIN    | MAX   | MIN         | MAX   |
| A   | 0.570  | 0.620 | 14.48       | 15.75 |
| B   | 0.380  | 0.405 | 9.66        | 10.28 |
| C   | 0.160  | 0.190 | 4.07        | 4.82  |
| D   | 0.025  | 0.035 | 0.64        | 0.88  |
| F   | 0.142  | 0.147 | 3.61        | 3.73  |
| G   | 0.095  | 0.105 | 2.42        | 2.66  |
| H   | 0.110  | 0.155 | 2.80        | 3.93  |
| J   | 0.018  | 0.025 | 0.46        | 0.64  |
| K   | 0.500  | 0.562 | 12.70       | 14.27 |
| L   | 0.045  | 0.060 | 1.15        | 1.52  |
| N   | 0.190  | 0.210 | 4.83        | 5.33  |
| Q   | 0.100  | 0.120 | 2.54        | 3.04  |
| R   | 0.080  | 0.110 | 2.04        | 2.79  |
| S   | 0.045  | 0.055 | 1.15        | 1.39  |
| T   | 0.235  | 0.255 | 5.97        | 6.47  |
| U   | 0.000  | 0.050 | 0.00        | 1.27  |
| V   | 0.045  | ---   | 1.15        | ---   |
| Z   | ---    | 0.080 | ---         | 2.04  |

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