

BUL45D2

Designer's™ Data Sheet
**High Speed, High Gain Bipolar
NPN Power Transistor with
Integrated Collector-Emitter
Diode and Built-in Efficient
Antisaturation Network**

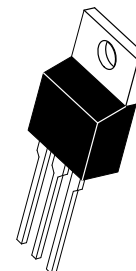
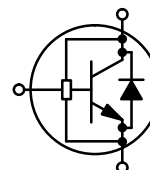
The BUL45D2 is state-of-art High Speed High gain BIPolar transistor (H2BIP). High dynamic characteristics and lot to lot minimum spread (± 150 ns on storage time) make it ideally suitable for light ballast applications. Therefore, there is no need to guarantee an h_{FE} window.

Main features:

- Low Base Drive Requirement
- High Peak DC Current Gain (55 Typical) @ $I_C = 100$ mA
- **Extremely Low Storage Time Min/Max Guarantees Due to the H2BIP Structure which Minimizes the Spread**
- Integrated Collector-Emitter Free Wheeling Diode
- Fully Characterized and Guaranteed Dynamic $V_{CE(sat)}$
- "6 Sigma" Process Providing Tight and Reproducible Parameter Spreads

It's characteristics make it also suitable for PFC application.

POWER TRANSISTORS
5 AMPERES
700 VOLTS
75 WATTS



CASE 221A-06
TO-220AB

MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|--|----------------|------------|---------------------|
| Collector-Emitter Sustaining Voltage | V_{CEO} | 400 | Vdc |
| Collector-Base Breakdown Voltage | V_{CBO} | 700 | Vdc |
| Collector-Emitter Breakdown Voltage | V_{CES} | 700 | Vdc |
| Emitter-Base Voltage | V_{EBO} | 12 | Vdc |
| Collector Current — Continuous | I_C | 5 | Adc |
| — Peak (1) | I_{CM} | 10 | |
| Base Current — Continuous | I_B | 2 | Adc |
| — Peak (1) | I_{BM} | 4 | |
| *Total Device Dissipation @ $T_C = 25^\circ\text{C}$ | P_D | 75 | Watt |
| *Derate above 25°C | | 0.6 | W/ $^\circ\text{C}$ |
| Operating and Storage Temperature | T_J, T_{stg} | -65 to 150 | $^\circ\text{C}$ |

THERMAL CHARACTERISTICS

| | | | |
|--|-----------------|------|---------------------------|
| Thermal Resistance | | | $^\circ\text{C}/\text{W}$ |
| — Junction to Case | $R_{\theta JC}$ | 1.65 | |
| — Junction to Ambient | $R_{\theta JA}$ | 62.5 | |
| Maximum Lead Temperature for Soldering Purposes: 1/8" from case for 5 seconds | T_L | 260 | $^\circ\text{C}$ |

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

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

BUL45D2

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|--|----------------|--|------|-------------------|-----------------|
| OFF CHARACTERISTICS | | | | | |
| Collector–Emitter Sustaining Voltage ($I_C = 100\text{ mA}$, $L = 25\text{ mH}$) | $V_{CEQ(sus)}$ | 400 | 450 | | Vdc |
| Collector–Base Breakdown Voltage ($I_{CBO} = 1\text{ mA}$) | V_{CBO} | 700 | 910 | | Vdc |
| Emitter–Base Breakdown Voltage ($I_{EBO} = 1\text{ mA}$) | V_{EBO} | 12 | 14.1 | | Vdc |
| Collector Cutoff Current ($V_{CE} = \text{Rated } V_{CE0}$, $I_B = 0$) | I_{CEO} | | | 100 | μAdc |
| Collector Cutoff Current ($V_{CE} = \text{Rated } V_{CES}$, $V_{EB} = 0$) ($V_{CE} = 500\text{ V}$, $V_{EB} = 0$) | I_{CES} | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | | 100 500 100 | μAdc |
| Emitter–Cutoff Current ($V_{EB} = 10\text{ Vdc}$, $I_C = 0$) | I_{EBO} | | | 100 | μAdc |

ON CHARACTERISTICS

| | | | | | | |
|---|---|---------------|-------------------------|--|---|-----|
| Base–Emitter Saturation Voltage ($I_C = 0.8\text{ Adc}$, $I_B = 80\text{ mAdc}$) ($I_C = 2\text{ Adc}$, $I_B = 0.4\text{ Adc}$) | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | $V_{BE(sat)}$ | | 0.8 0.7 0.89 0.79 | 1 0.9 1 0.9 | Vdc |
| Collector–Emitter Saturation Voltage ($I_C = 0.8\text{ Adc}$, $I_B = 80\text{ mAdc}$) ($I_C = 2\text{ Adc}$, $I_B = 0.4\text{ Adc}$) ($I_C = 0.8\text{ Adc}$, $I_B = 40\text{ mAdc}$) | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | $V_{CE(sat)}$ | | 0.28 0.32 0.32 0.38 0.46 0.62 | 0.4 0.5 0.5 0.6 0.75 1 | Vdc |
| DC Current Gain ($I_C = 0.8\text{ Adc}$, $V_{CE} = 1\text{ Vdc}$) ($I_C = 2\text{ Adc}$, $V_{CE} = 1\text{ Vdc}$) | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | h_{FE} | 22 20 10 7 | 34 29 14 9.5 | | — |

DIODE CHARACTERISTICS

| | | | | | | |
|---|---|----------|--|--|---------------------------|----|
| Forward Diode Voltage ($I_{EC} = 1\text{ Adc}$) ($I_{EC} = 2\text{ Adc}$) ($I_{EC} = 0.4\text{ Adc}$) | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | V_{EC} | | 1.04 0.7 1.2 0.85 0.62 | 1.5 1.6 1.2 | V |
| Forward Recovery Time (see Figure 27) ($I_F = 1\text{ Adc}$, $di/dt = 10\text{ A}/\mu\text{s}$) ($I_F = 2\text{ Adc}$, $di/dt = 10\text{ A}/\mu\text{s}$) ($I_F = 0.4\text{ Adc}$, $di/dt = 10\text{ A}/\mu\text{s}$) | @ $T_C = 25^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ @ $T_C = 25^\circ\text{C}$ | T_{fr} | | 330 360 320 | | ns |

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|----------|-----|-----|-----|------|
| DYNAMIC CHARACTERISTICS | | | | | |
| Current Gain Bandwidth ($I_C = 0.5 \text{ Adc}$, $V_{CE} = 10 \text{ Vdc}$, $f = 1 \text{ MHz}$) | f_T | | 13 | | MHz |
| Output Capacitance ($V_{CB} = 10 \text{ Vdc}$, $I_E = 0$, $f = 1 \text{ MHz}$) | C_{ob} | | 50 | 75 | pF |
| Input Capacitance ($V_{EB} = 8 \text{ Vdc}$) | C_{ib} | | 340 | 500 | pF |

DYNAMIC SATURATION VOLTAGE

| | | | | | | | | |
|--|--|-------------------|---|----------------|--|-------------|--|---|
| Dynamic Saturation Voltage: Determined 1 μs and 3 μs respectively after rising I_{B1} reaches 90% of final I_{B1} | $I_C = 1 \text{ A}$ $I_{B1} = 100 \text{ mA}$ $V_{CC} = 300 \text{ V}$ | @ 1 μs | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | $V_{CE(dsat)}$ | | 3.7 9.4 | | V |
| | | @ 3 μs | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | | | 0.35 2.7 | | V |
| | $I_C = 2 \text{ A}$ $I_{B1} = 0.8 \text{ A}$ $V_{CC} = 300 \text{ V}$ | @ 1 μs | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | | | 3.9 12 | | V |
| | | @ 3 μs | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | | | 0.4 1.5 | | V |

SWITCHING CHARACTERISTICS: Resistive Load (D.C. $\leq 10\%$, Pulse Width = 20 μs)

| | | | | | | | |
|---------------|--|---|-----------|-----|-------------|-----|---------------|
| Turn-on Time | $I_C = 2 \text{ Adc}$, $I_{B1} = 0.4 \text{ Adc}$ $I_{B2} = 1 \text{ Adc}$ $V_{CC} = 300 \text{ Vdc}$ | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_{on} | | 90 105 | 150 | ns |
| Turn-off Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_{off} | | 1.15 1.5 | 1.3 | μs |
| Turn-on Time | $I_C = 2 \text{ Adc}$, $I_{B1} = 0.4 \text{ Adc}$ $I_{B2} = 0.4 \text{ Adc}$ $V_{CC} = 300 \text{ Vdc}$ | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_{on} | | 90 110 | 150 | ns |
| Turn-off Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_{off} | 2.1 | 3.1 | 2.4 | μs |

SWITCHING CHARACTERISTICS: Inductive Load ($V_{clamp} = 300 \text{ V}$, $V_{CC} = 15 \text{ V}$, $L = 200 \mu\text{H}$)

| | | | | | | | |
|----------------|---|---|-------|------|--------------|------|---------------|
| Fall Time | $I_C = 1 \text{ Adc}$ $I_{B1} = 100 \text{ mAdc}$ $I_{B2} = 500 \text{ mAdc}$ | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_f | | 90 93 | 150 | ns |
| Storage Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_s | | 0.72 1.05 | 0.9 | μs |
| Crossover Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_c | | 95 95 | 150 | ns |
| Fall Time | $I_C = 2 \text{ Adc}$ $I_{B1} = 0.4 \text{ Adc}$ $I_{B2} = 0.4 \text{ Adc}$ | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_f | | 80 105 | 150 | ns |
| Storage Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_s | 1.95 | 2.9 | 2.25 | μs |
| Crossover Time | | @ $T_C = 25^\circ\text{C}$ @ $T_C = 125^\circ\text{C}$ | t_c | | 225 450 | 300 | ns |

TYPICAL STATIC CHARACTERISTICS

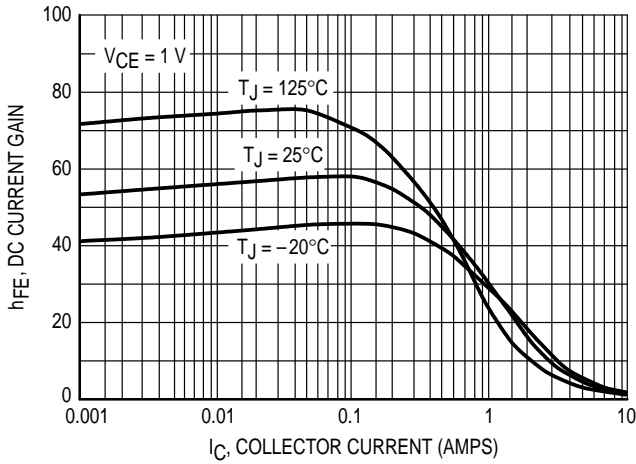


Figure 1. DC Current Gain @ 1 Volt

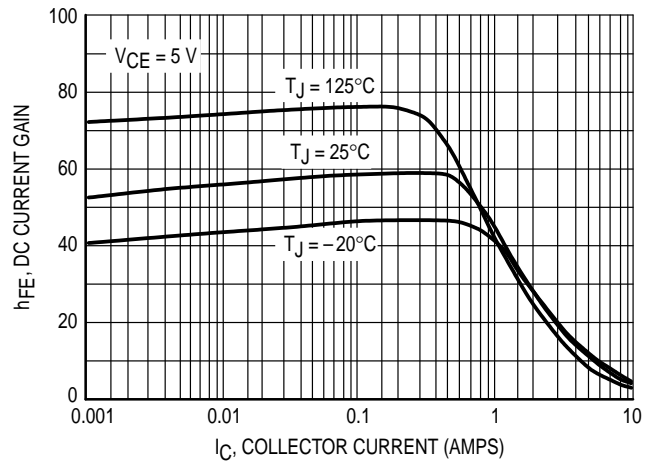


Figure 2. DC Current Gain @ 5 Volt

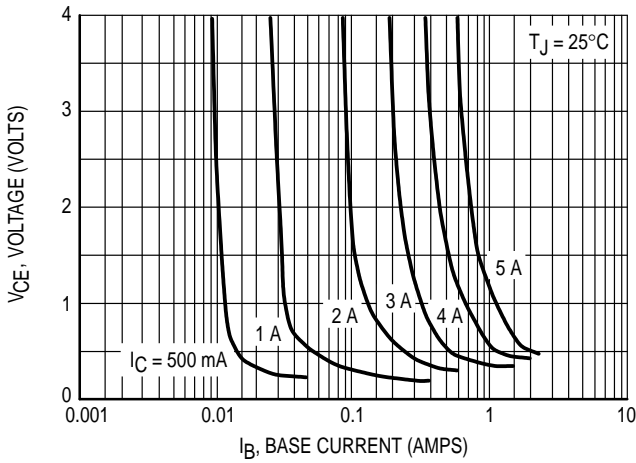


Figure 3. Collector Saturation Region

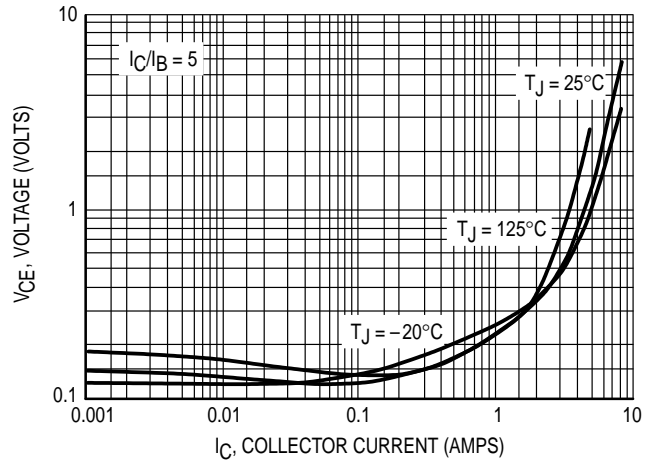


Figure 4. Collector-Emitter Saturation Voltage

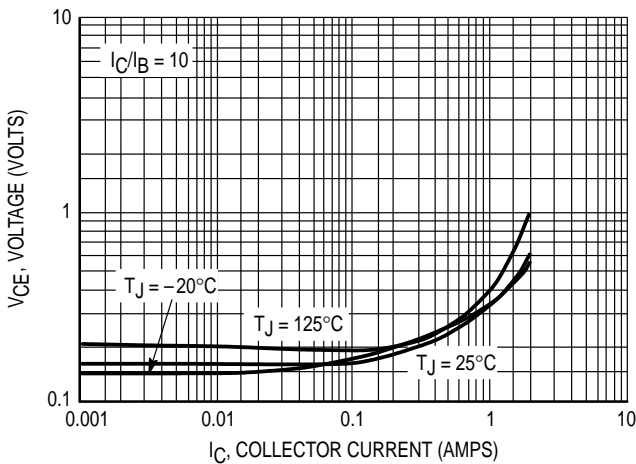


Figure 5. Collector-Emitter Saturation Voltage

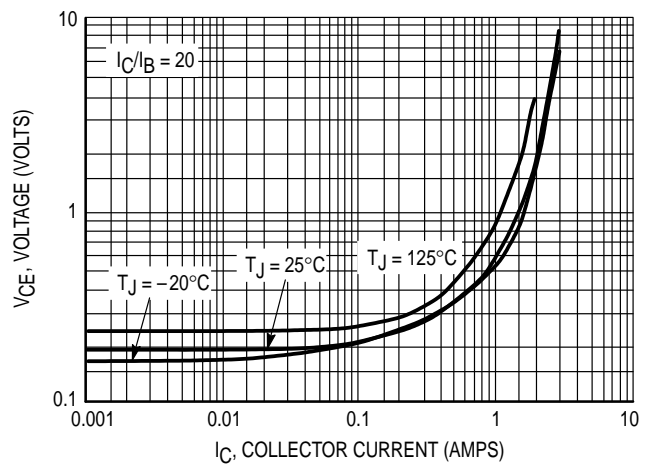


Figure 6. Collector-Emitter Saturation Voltage

TYPICAL STATIC CHARACTERISTICS

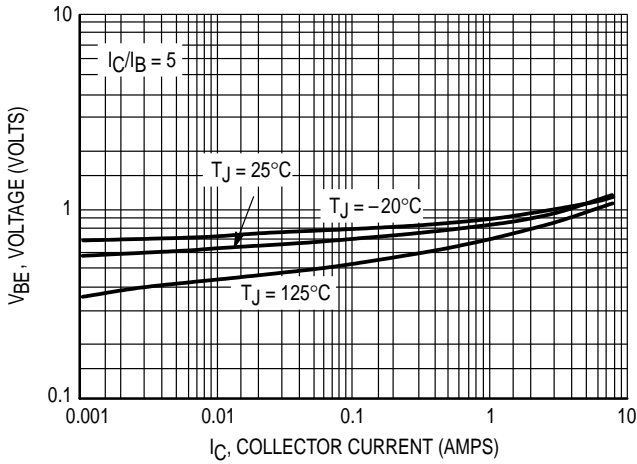


Figure 7. Base-Emitter Saturation Region

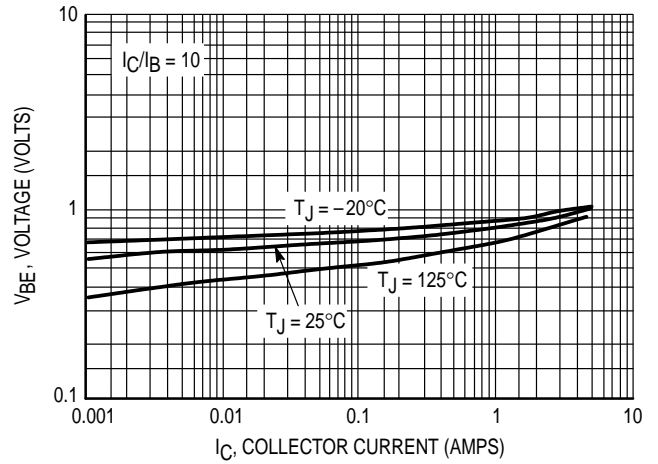


Figure 8. Base-Emitter Saturation Region

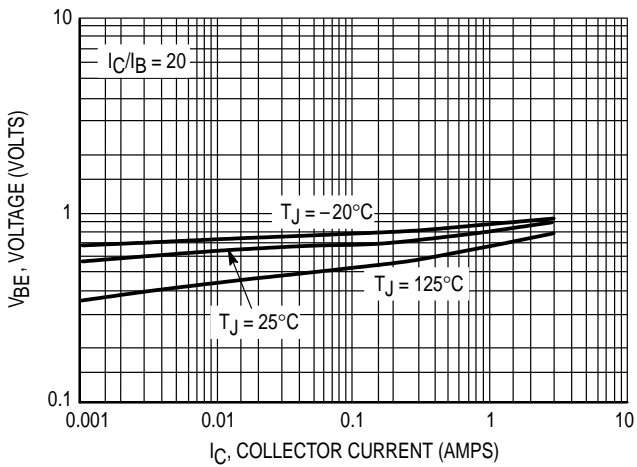


Figure 9. Base-Emitter Saturation Region

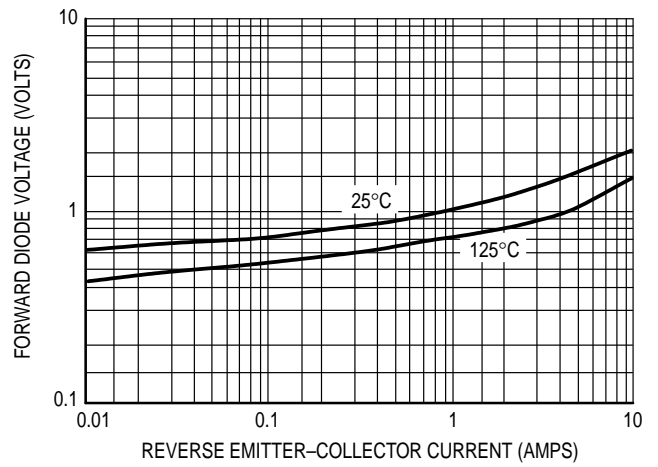


Figure 10. Forward Diode Voltage

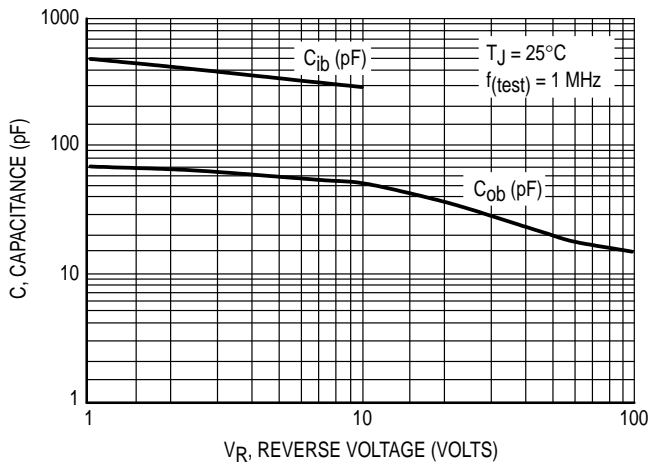


Figure 11. Capacitance

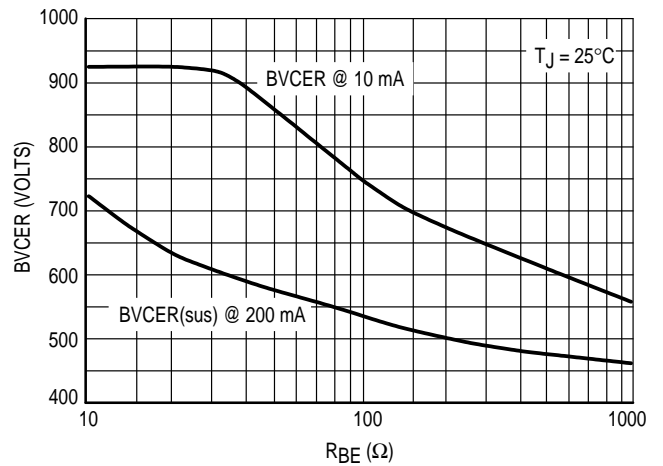


Figure 12. $BVCER = f(I_{CER})$

TYPICAL SWITCHING CHARACTERISTICS

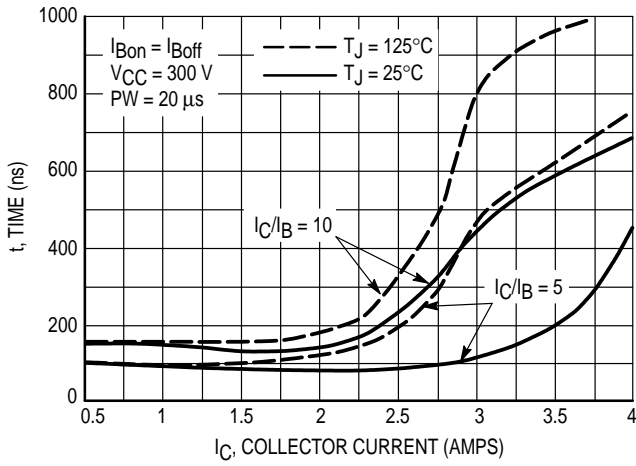


Figure 13. Resistive Switch Time, t_{on}

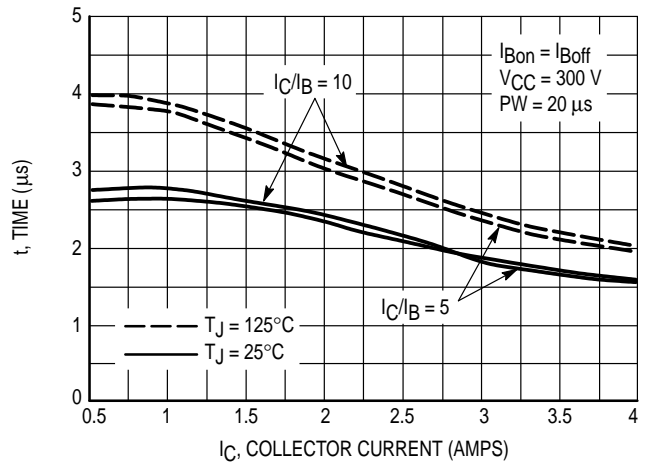


Figure 14. Resistive Switch Time, t_{off}

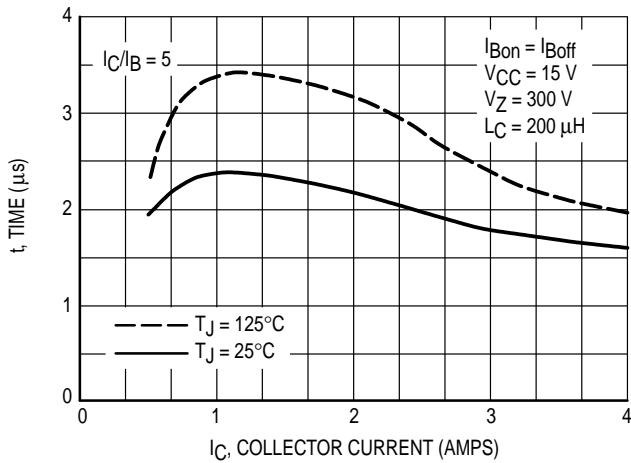


Figure 15. Inductive Storage Time, t_{si} @ $I_C/I_B = 5$

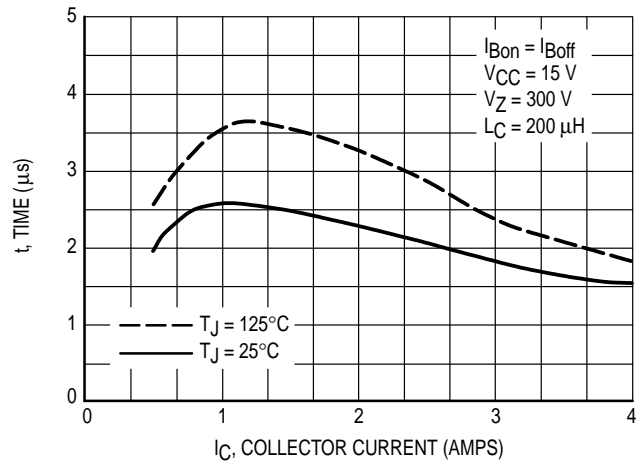


Figure 16. Inductive Storage Time, t_{si} @ $I_C/I_B = 10$

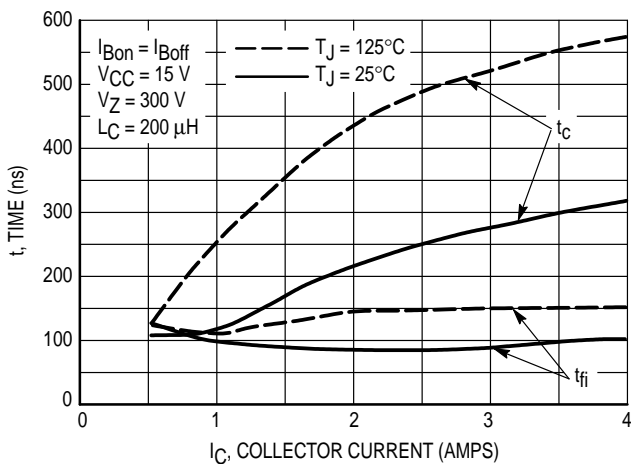


Figure 17. Inductive Switching, t_c & t_{fi} @ $I_C/I_B = 5$

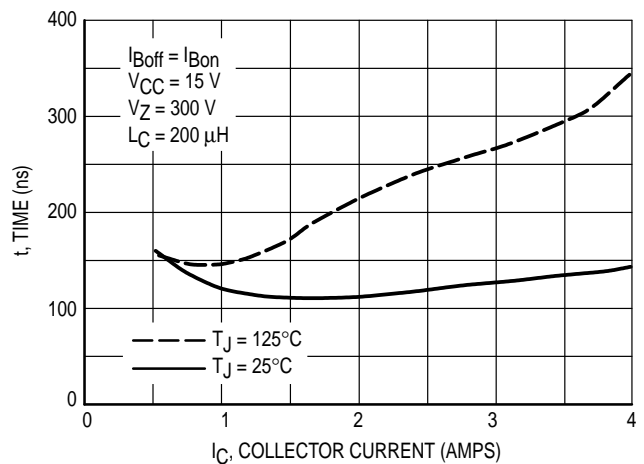


Figure 18. Inductive Switching, t_{fi} @ $I_C/I_B = 10$

TYPICAL SWITCHING CHARACTERISTICS

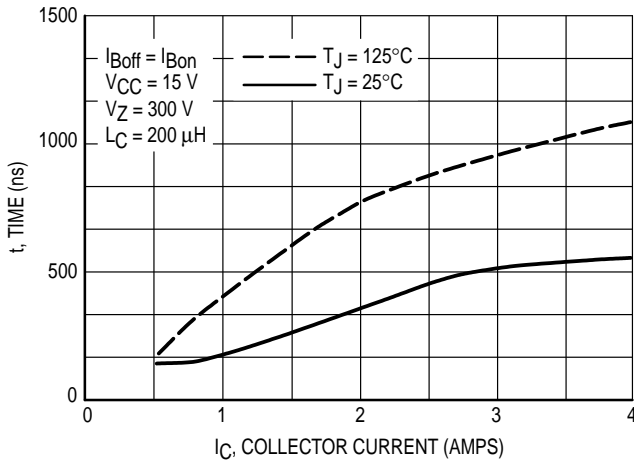


Figure 19. Inductive Switching, t_c @ $I_C/I_B = 10$

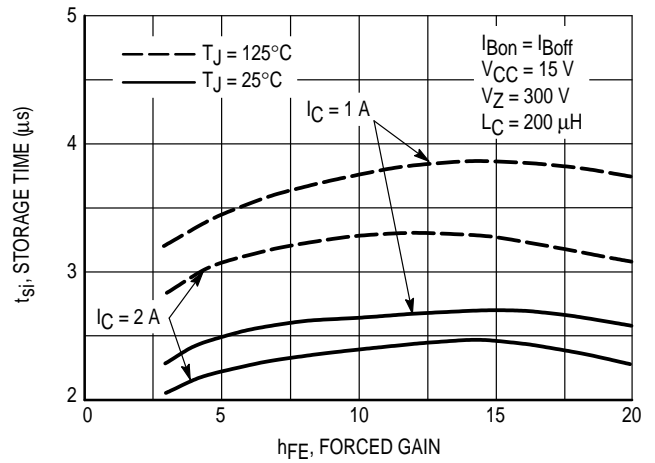


Figure 20. Inductive Storage Time

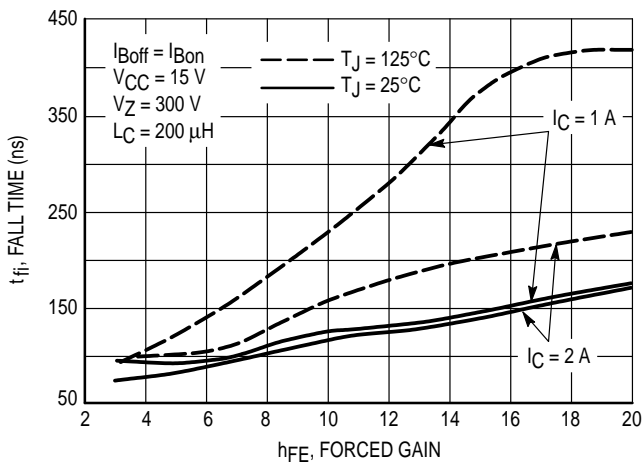


Figure 21. Inductive Fall Time

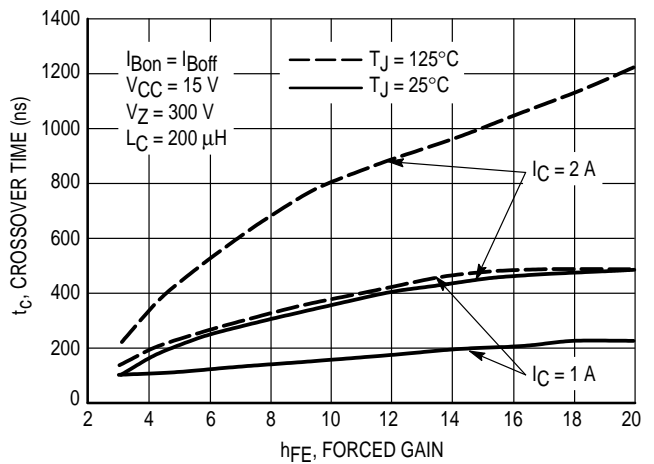


Figure 22. Inductive Crossover Time

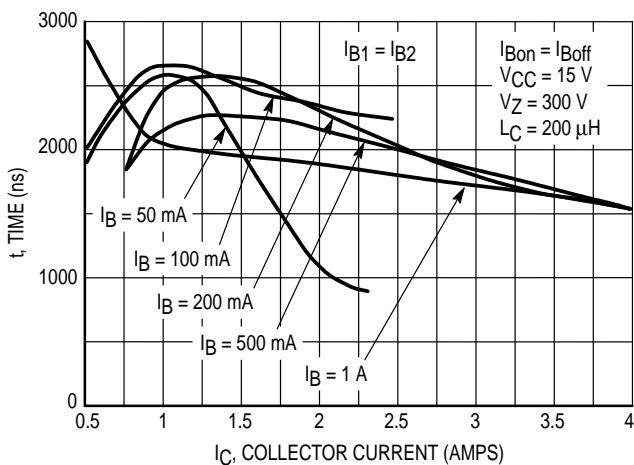


Figure 23. Inductive Storage Time, t_{sj}

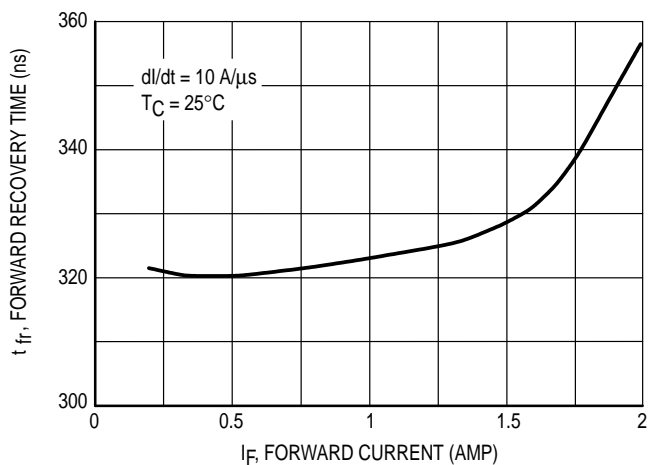


Figure 24. Forward Recovery Time t_{fr}

TYPICAL SWITCHING CHARACTERISTICS

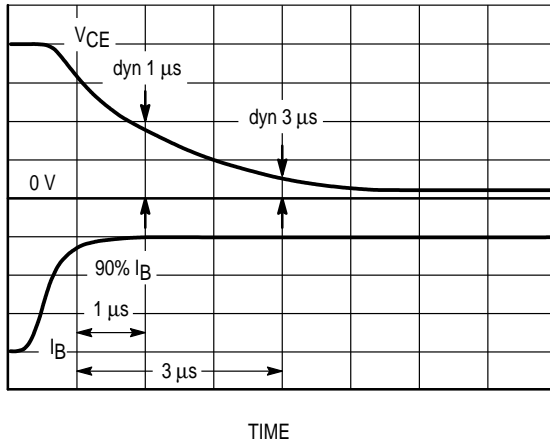


Figure 25. Dynamic Saturation Voltage Measurements

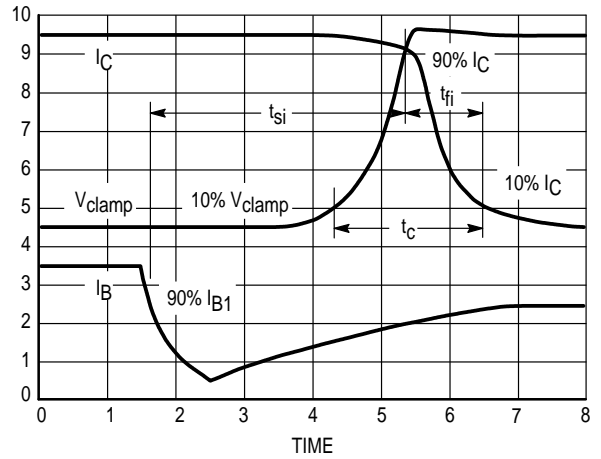


Figure 26. Inductive Switching Measurements

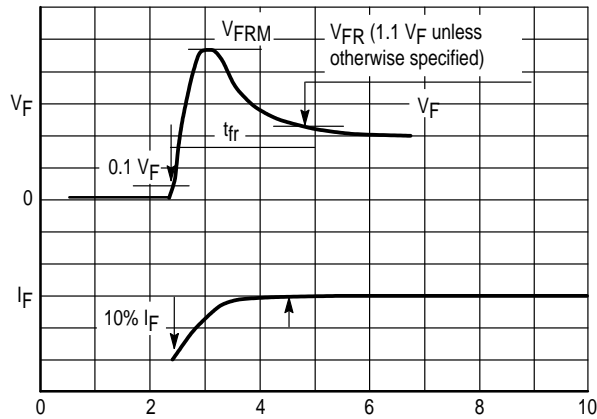
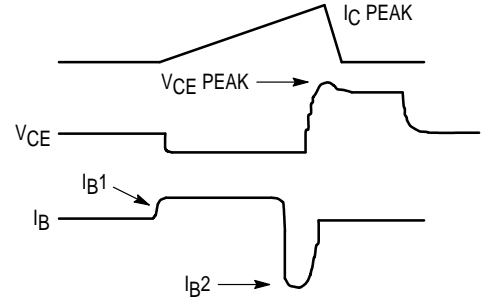
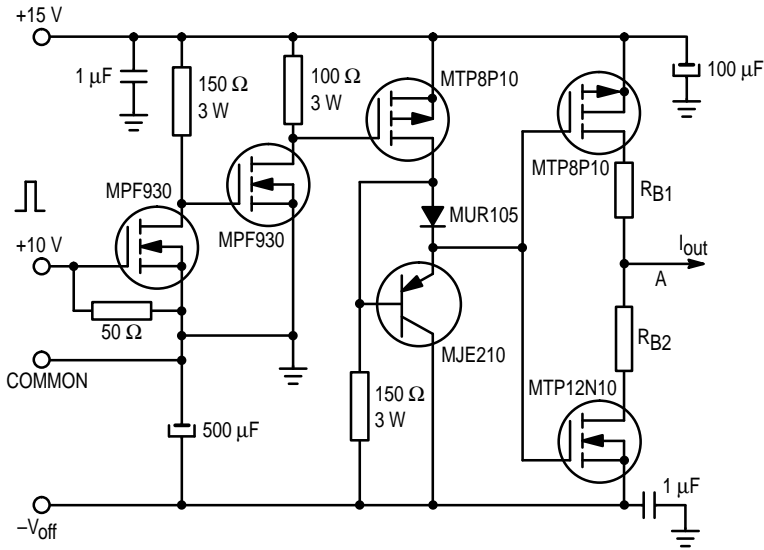


Figure 27. t_{fr} Measurements

TYPICAL SWITCHING CHARACTERISTICS

Table 1. Inductive Load Switching Drive Circuit



$V_{(BR)CEO(sus)}$
 $L = 10 \text{ mH}$
 $R_{B2} = \infty$
 $V_{CC} = 20 \text{ Volts}$
 $I_{C(pk)} = 100 \text{ mA}$

Inductive Switching
 $L = 200 \mu\text{H}$
 $R_{B2} = 0$
 $V_{CC} = 15 \text{ Volts}$
 R_{B1} selected for desired I_{B1}

RBSOA
 $L = 500 \mu\text{H}$
 $R_{B2} = 0$
 $V_{CC} = 15 \text{ Volts}$
 R_{B1} selected for desired I_{B1}

TYPICAL CHARACTERISTICS

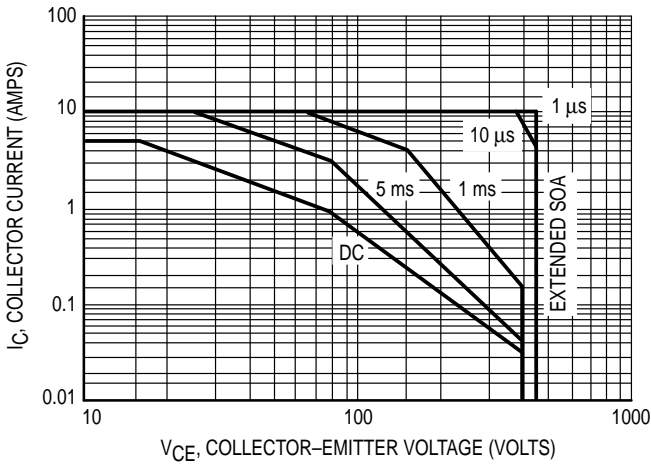


Figure 28. Forward Bias Safe Operating Area

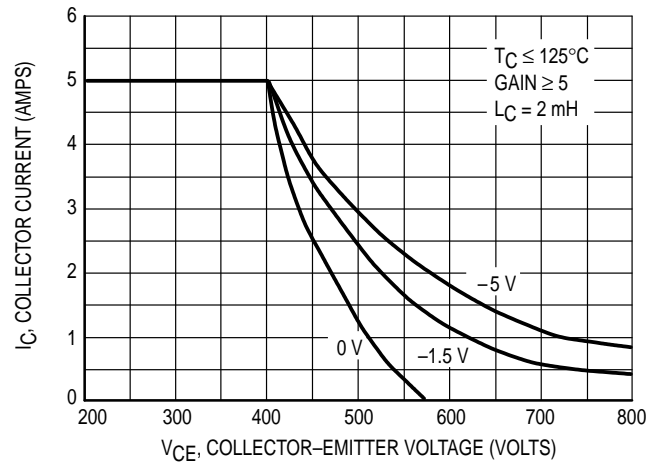


Figure 29. Reverse Bias Safe Operating Area

TYPICAL CHARACTERISTICS

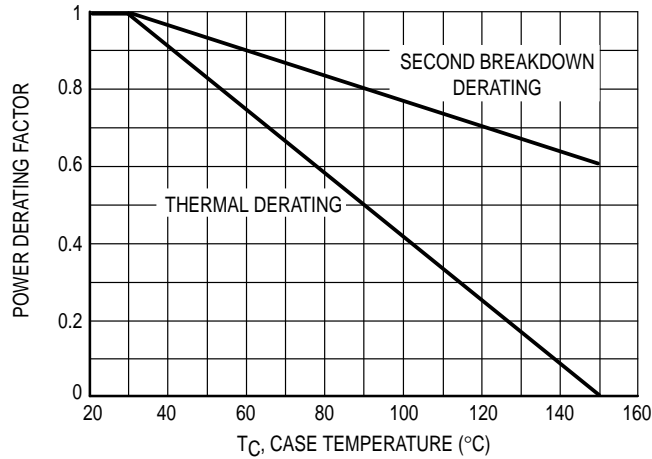


Figure 30. Forward Bias Power Derating

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 28 is based on $T_C = 25^\circ\text{C}$; $T_{J(pk)}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_C > 25^\circ\text{C}$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figure 28 may be found at any case temperature by using the appropriate curve on Figure 30.

$T_{J(pk)}$ may be calculated from the data in Figure 31. At any case temperatures, thermal limitations will reduce the power that 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 29). This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode.

TYPICAL THERMAL RESPONSE

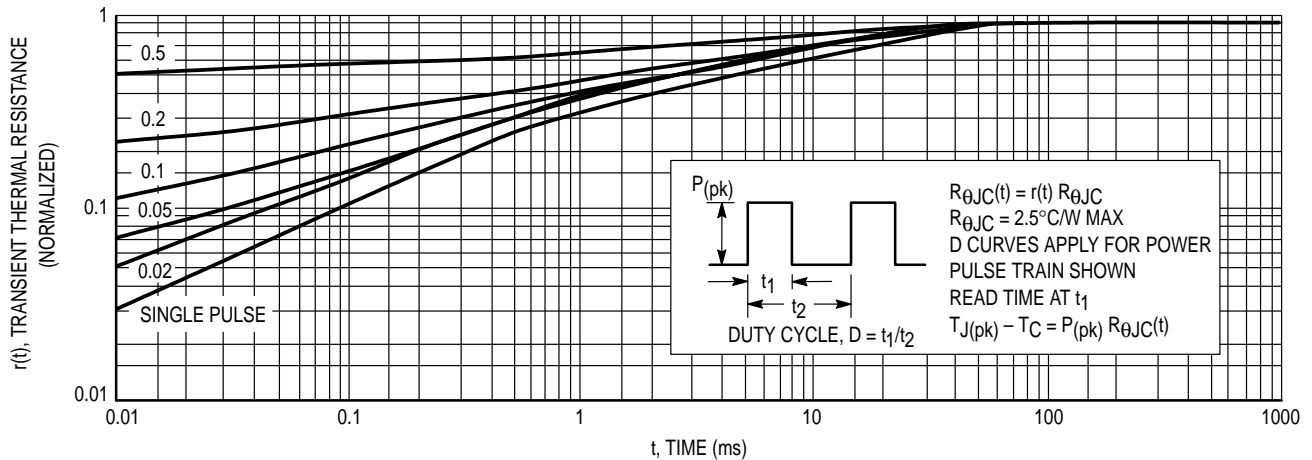
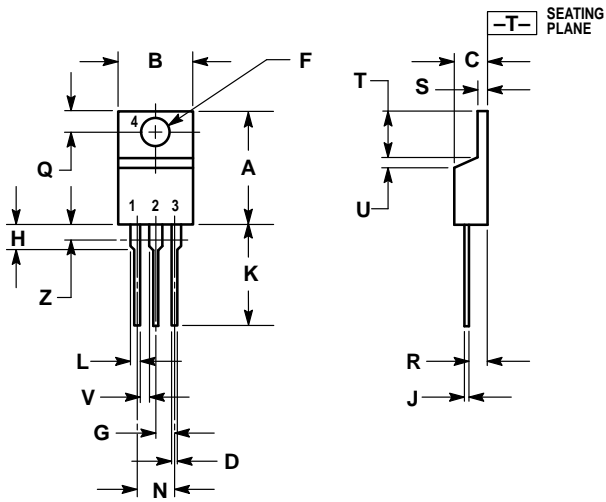


Figure 31. Typical Thermal Response ($Z_{\theta JC}(t)$) for BUL45D2

PACKAGE DIMENSIONS




- 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 |

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

CASE 221A-06
 TO-220AB
 ISSUE Y

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