# BUL45G

## NPN Silicon Power Transistor

### High Voltage Switch-mode Series

Designed for use in electronic ballast (light ballast) and in switch-mode power supplies up to 50 W.

**Features**

- Improved Efficiency Due to:
  - ♦ Low Base Drive Requirements (High and Flat DC Current Gain $h_{FE}$)
  - ♦ Low Power Losses (On-State and Switching Operations)
  - ♦ Fast Switching: $t_{fi}$ = 100 ns (typ) and $t_{si}$ = 3.2 μs (typ)
  - ♦ @ $I_C$ = 2.0 A, $I_{B1}$ = $I_{B2}$ = 0.4 A
- Full Characterization at 125°C
- Tight Parametric Distributions Consistent Lot-to-Lot
- These Devices are Pb-Free and are RoHS Compliant*

**MAXIMUM RATINGS**

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector-Emitter Sustaining Voltage | $V_{CEO}$ | 400 | Vdc |
| Collector-Base Breakdown Voltage | $V_{CES}$ | 700 | Vdc |
| Emitter-Base Voltage | $V_{EBO}$ | 9.0 | Vdc |
| Collector Current – Continuous<br>– Peak (Note 1) | $I_C$<br>$I_{CM}$ | 5.0<br>10 | Adc |
| Base Current | $I_B$ | 2.0 | Adc |
| Total Device Dissipation @ $T_C$ = 25°C<br>Derate above 25°C | $P_D$ | 75<br>0.6 | W<br>W/°C |
| Operating and Storage Temperature | $T_J$, $T_{stg}$ | -65 to 150 | °C |

**THERMAL CHARACTERISTICS**

| Characteristics | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction-to-Case | $R_{\theta JC}$ | 1.65 | °C/W |
| Thermal Resistance, Junction-to-Ambient | $R_{\theta JA}$ | 62.5 | °C/W |

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

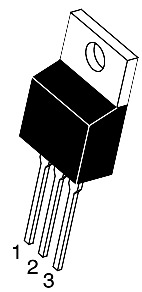
1. Pulse Test: Pulse Width = 5 ms, Duty Cycle ≤ 10%.

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

**ON Semiconductor®**

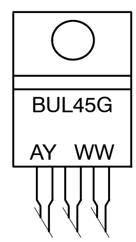
**http://onsemi.com**

**POWER TRANSISTOR**
**5.0 AMPERES, 700 VOLTS,**
**35 AND 75 WATTS**




**TO-220AB**
**CASE 221A-09**
**STYLE 1**

**MARKING DIAGRAM**




BUL45 = Device Code
A = Assembly Location
Y = Year
WW = Work Week
G = Pb-Free Package

**ORDERING INFORMATION**

| Device | Package | Shipping |
|---|---|---|
| BUL45G | TO-220<br>(Pb-Free) | 50 Units / Rail |

**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, L = 25 mH) | $V_{CEO(sus)}$ | 400 | – | – | Vdc |
| Collector Cutoff Current ($V_{CE}$ = Rated $V_{CEO}$, $I_B$ = 0) | $I_{CEO}$ | – | – | 100 | μAdc |
| Collector Cutoff Current ($V_{CE}$ = Rated $V_{CES}$, $V_{EB}$ = 0)<br>($T_C$ = 125°C) | $I_{CES}$ | –<br>– | –<br>– | 10<br>100 | μAdc |
| Emitter Cutoff Current ($V_{EB}$ = 9.0 Vdc, $I_C$ = 0) | $I_{EBO}$ | – | – | 100 | μAdc |
| **ON CHARACTERISTICS** | | | | | |
| Base-Emitter Saturation Voltage<br>($I_C$ = 1.0 Adc, $I_B$ = 0.2 Adc)<br>($I_C$ = 2.0 Adc, $I_B$ = 0.4 Adc) | $V_{BE(sat)}$ | <br>–<br>– | <br>0.84<br>0.89 | <br>1.2<br>1.25 | Vdc |
| Collector-Emitter Saturation Voltage ($I_C$ = 1.0 Adc, $I_B$ = 0.2 Adc)<br>($T_C$ = 125°C) | $V_{CE(sat)}$ | –<br>– | 0.175<br>0.150 | 0.25<br>– | Vdc |
| Collector-Emitter Saturation Voltage ($I_C$ = 2.0 Adc, $I_B$ = 0.4 Adc)<br>($T_C$ = 125°C) | $V_{CE(sat)}$ | –<br>– | 0.25<br>0.275 | 0.4<br>– | Vdc |
| DC Current Gain ($I_C$ = 0.3 Adc, $V_{CE}$ = 5.0 Vdc)<br>($T_C$ = 125°C)<br>($I_C$ = 2.0 Adc, $V_{CE}$ = 1.0 Vdc)<br>($T_C$ = 125°C)<br>($I_C$ = 10 mAdc, $V_{CE}$ = 5.0 Vdc) | $h_{FE}$ | 14<br>–<br>7.0<br>5.0<br>10 | –<br>32<br>14<br>12<br>22 | 34<br>–<br>–<br>–<br>– | – |
| **DYNAMIC CHARACTERISTICS** | | | | | |
| Current Gain Bandwidth ($I_C$ = 0.5 Adc, $V_{CE}$ = 10 Vdc, f = 1.0 MHz) | $f_T$ | – | 12 | — | MHz |
| Output Capacitance ($V_{CB}$ = 10 Vdc, $I_E$ = 0, f = 1.0 MHz) | $C_{ob}$ | – | 50 | 75 | pF |
| Input Capacitance ($V_{EB}$ = 8.0 Vdc) | $C_{ib}$ | – | 920 | 1200 | pF |
| Dynamic Saturation Voltage: Determined 1.0 μs and 3.0 μs respectively after rising $I_{B1}$ reaches 90% of final $I_{B1}$ (see Figure 18); ($I_C$ = 1.0 Adc, $I_{B1}$ = 100 mAdc, $V_{CC}$ = 300 V); 1.0 μs<br>($T_C$ = 125°C) | $V_{CE}$ (Dyn sat) | –<br>– | 1.75<br>4.4 | –<br>– | Vdc |
| ($I_C$ = 1.0 Adc, $I_{B1}$ = 100 mAdc, $V_{CC}$ = 300 V); 3.0 μs<br>($T_C$ = 125°C) | | –<br>– | 0.5<br>1.0 | –<br>– | |
| ($I_C$ = 2.0 Adc, $I_{B1}$ = 400 mAdc, $V_{CC}$ = 300 V); 1.0 μs<br>($T_C$ = 125°C) | | –<br>– | 1.85<br>6.0 | –<br>– | |
| ($I_C$ = 2.0 Adc, $I_{B1}$ = 400 mAdc, $V_{CC}$ = 300 V); 3.0 μs<br>($T_C$ = 125°C) | | –<br>– | 0.5<br>1.0 | –<br>– | |
| **SWITCHING CHARACTERISTICS: Resistive Load** | | | | | |
| Turn-On Time ($I_C$ = 2.0 Adc, $I_{B1}$ = $I_{B2}$ = 0.4 Adc, Pulse Width = 20 μs, Duty Cycle < 20% $V_{CC}$ = 300 V)<br>($T_C$ = 125°C) | $t_{on}$ | –<br>– | 75<br>120 | 110<br>– | ns |
| Turn-Off Time<br>($T_C$ = 125°C) | $t_{off}$ | –<br>– | 2.8<br>3.5 | 3.5<br>– | μs |
| **SWITCHING CHARACTERISTICS: Inductive Load** ($V_{CC}$ = 15 Vdc, $L_C$ = 200 μH, $V_{clamp}$ = 300 Vdc) | | | | | |
| Fall Time ($I_C$ = 2.0 Adc, $I_{B1}$ = 0.4 Adc, $I_{B2}$ = 0.4 Adc)<br>($T_C$ = 125°C) | $t_{fi}$ | 70<br>– | –<br>200 | 170<br>– | ns |
| Storage Time<br>($T_C$ = 125°C) | $t_{si}$ | 2.6<br>– | –<br>4.2 | 3.8<br>– | μs |
| Crossover Time<br>($T_C$ = 125°C) | $t_c$ | –<br>– | 230<br>400 | 350<br>– | ns |
| Fall Time ($I_C$ = 1.0 Adc, $I_{B1}$ = 100 mAdc, $I_{B2}$ = 0.5 Adc)<br>($T_C$ = 125°C) | $t_{fi}$ | –<br>– | 110<br>100 | 150<br>– | ns |
| Storage Time<br>($T_C$ = 125°C) | $t_{si}$ | –<br>– | 1.1<br>1.5 | 1.7<br>– | μs |
| Crossover Time<br>($T_C$ = 125°C) | $t_c$ | –<br>– | 170<br>170 | 250<br>– | ns |
| Fall Time ($I_C$ = 2.0 Adc, $I_{B1}$ = 250 mAdc, $I_{B2}$ = 2.0 Adc)<br>($T_C$ = 125°C) | $t_{fi}$ | – | 80 | 120 | ns |
| Storage Time ($T_C$ = 125°C) | $t_{si}$ | – | 0.6 | 0.9 | μs |
| Crossover Time ($T_C$ = 125°C) | $t_c$ | – | 175 | 300 | ns |

## TYPICAL STATIC CHARACTERISTICS

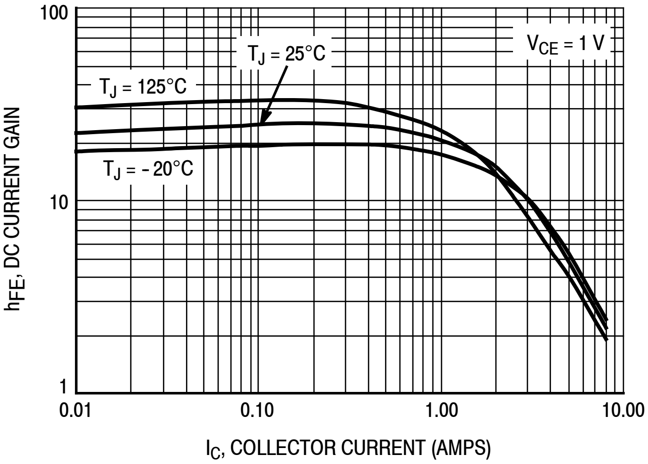



**Figure 1. DC Current Gain @ 1 Volt**

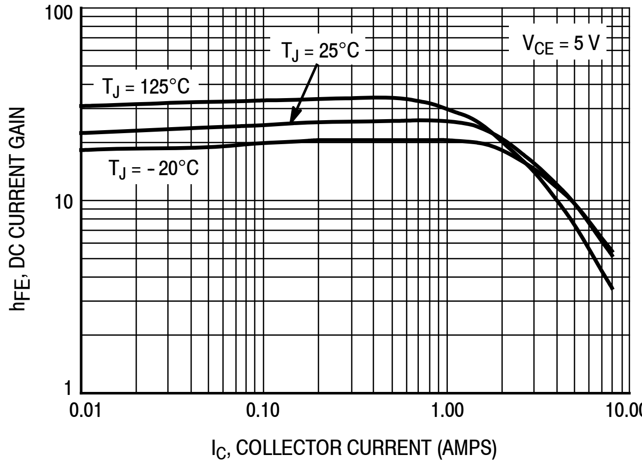



**Figure 2. DC Current Gain at @ 5 Volts**

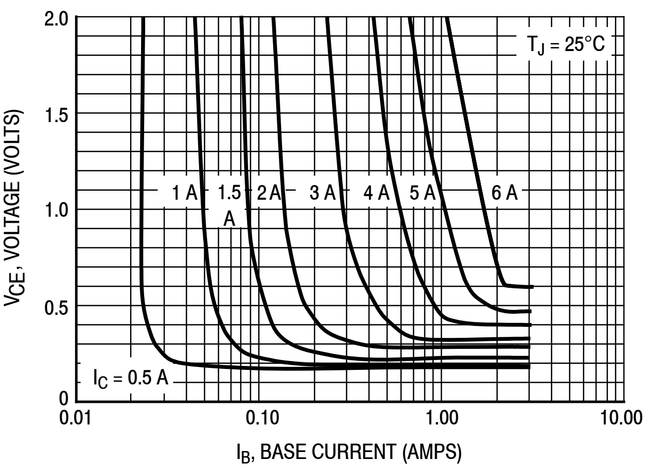



**Figure 3. Collector-Emitter Saturation Region**

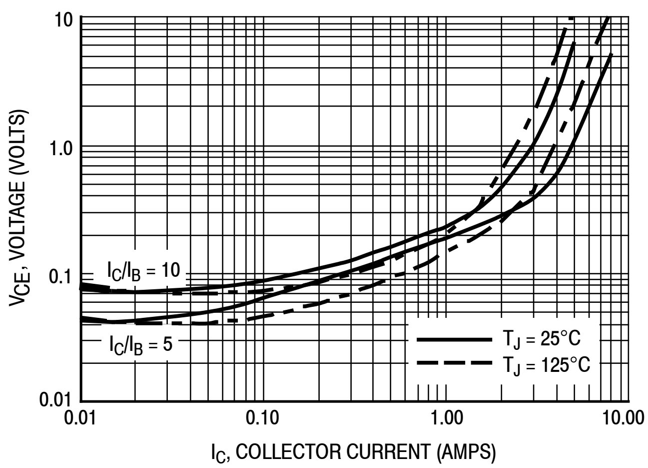



**Figure 4. Collector-Emitter Saturation Voltage**

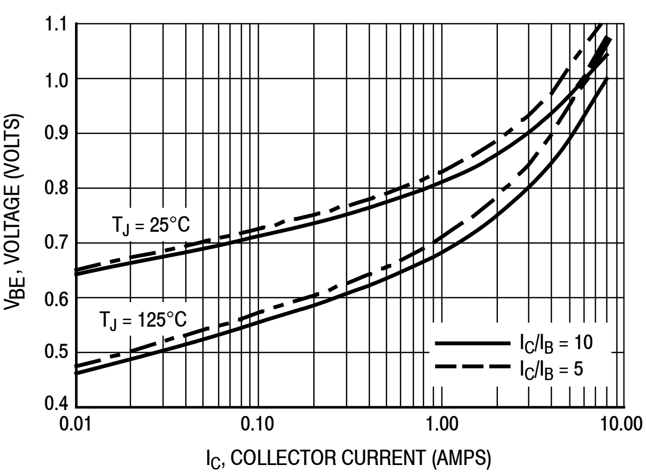



**Figure 5. Base-Emitter Saturation Region**

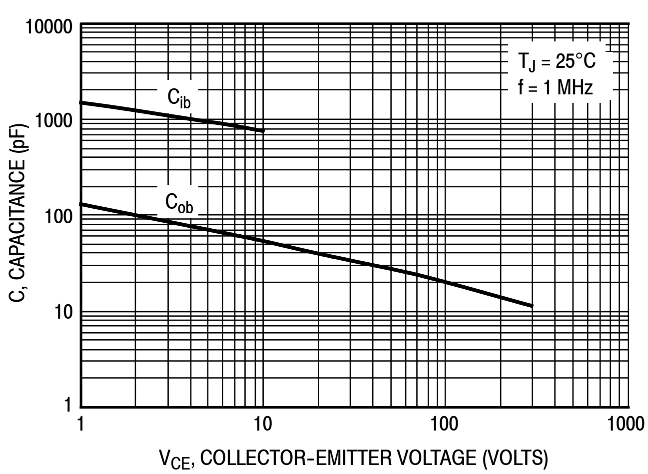



**Figure 6. Capacitance**

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

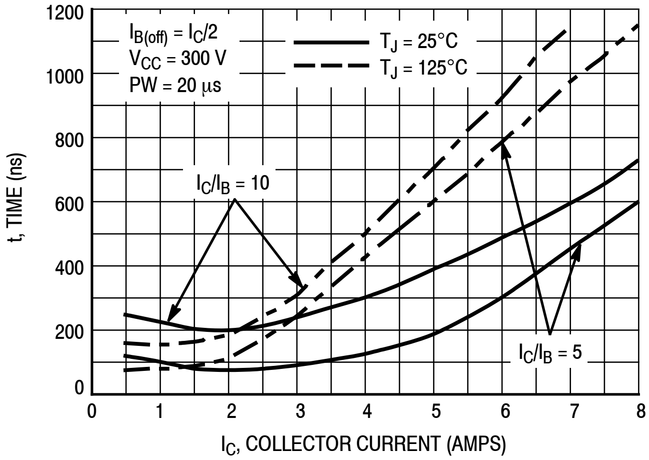



**Figure 7. Resistive Switching, $t_{on}$**

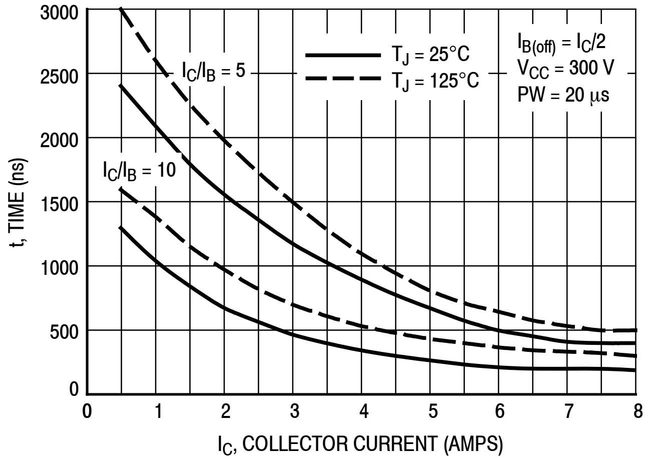



**Figure 8. Resistive Switching, $t_{off}$**

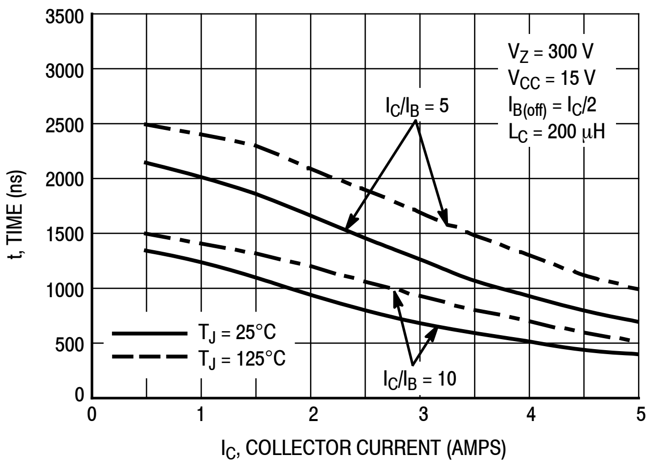



**Figure 9. Inductive Storage Time, $t_{si}$**

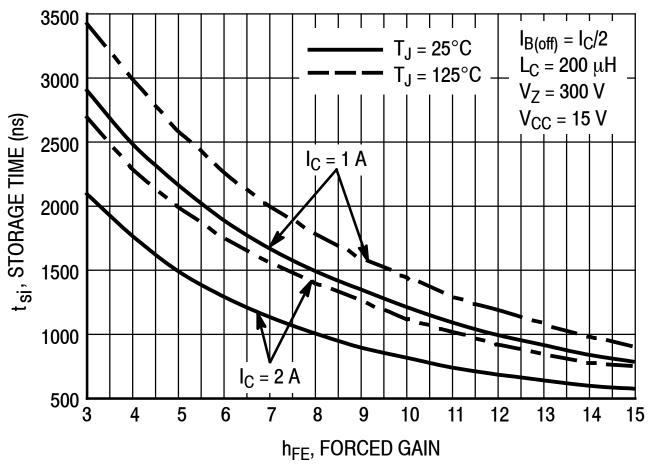



**Figure 10. Inductive Storage Time, $t_{si}(h_{FE})$**

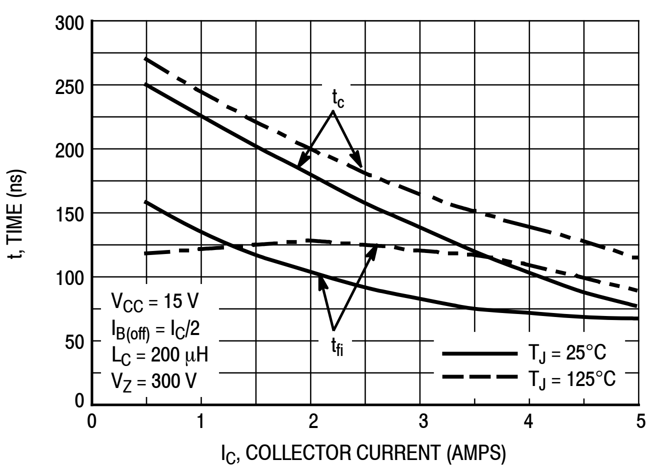



**Figure 11. Inductive Switching, $t_c$ & $t_{fi}$, $I_C/I_B = 5$**

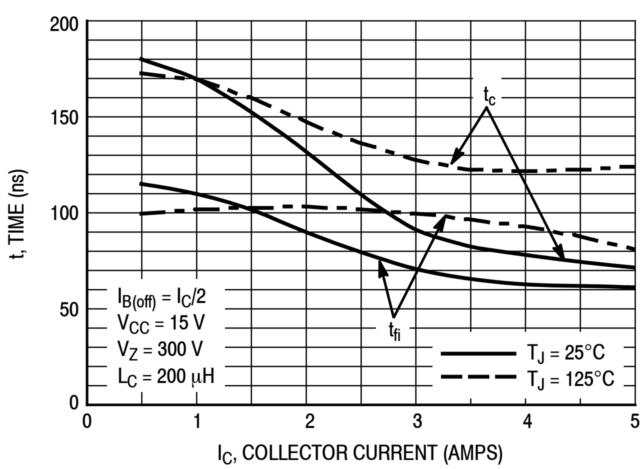



**Figure 12. Inductive Switching, $t_c$ & $t_{fi}$, $I_C/I_B = 10$**

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

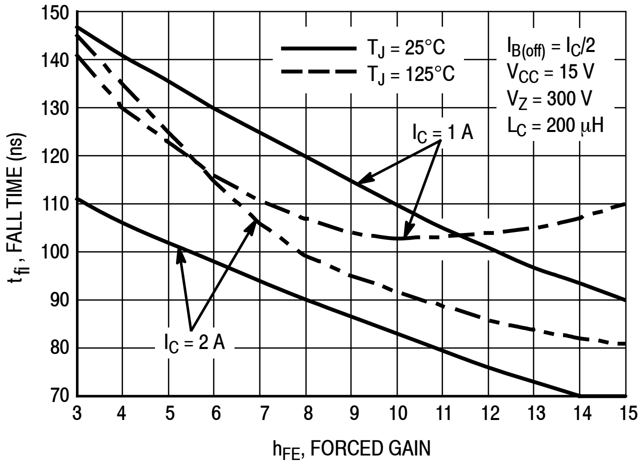



**Figure 13. Inductive Fall Time, $t_{fi}(h_{FE})$**

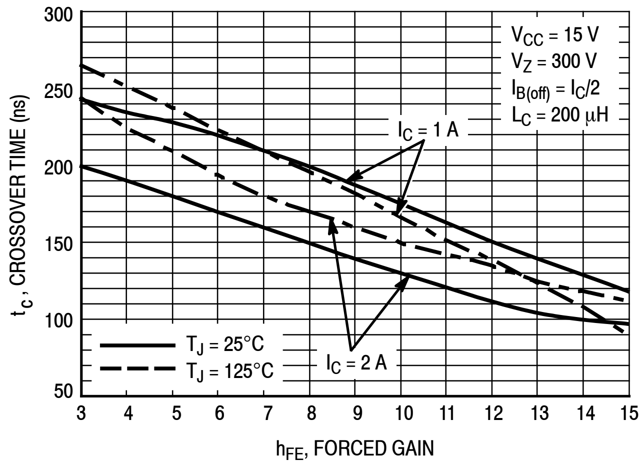



**Figure 14. Crossover Time**

## GUARANTEED SAFE OPERATING AREA INFORMATION

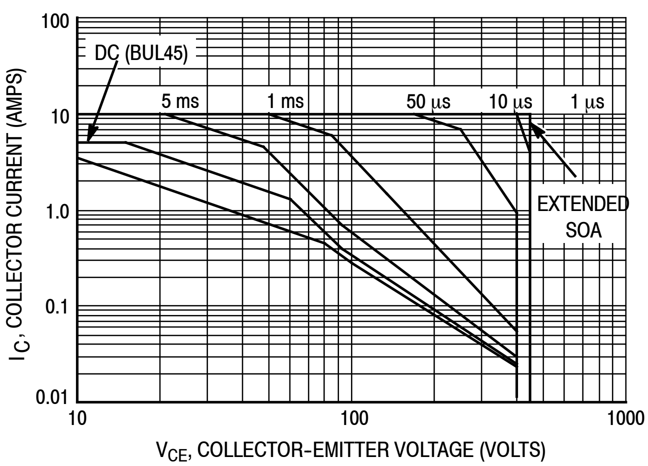



**Figure 15. Forward Bias Safe Operating Area**

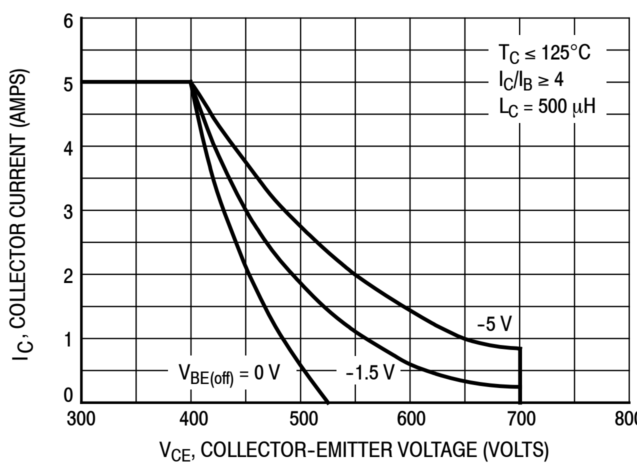



**Figure 16. Reverse Bias Switching Safe Operating Area**

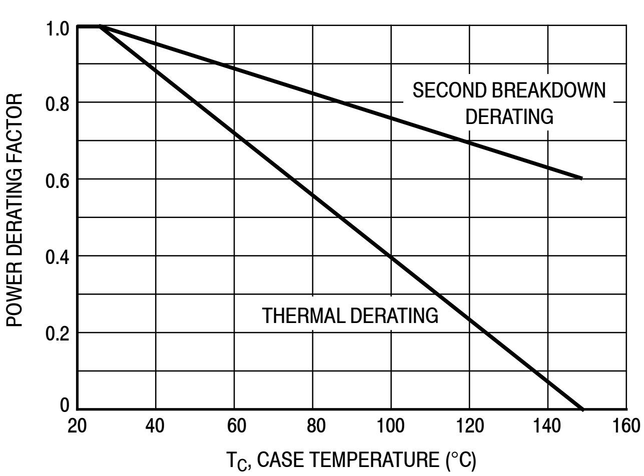



**Figure 17. Forward Bias Power Derating**

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 $T_C = 25°C$; $T_{J(pk)}$ 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 in Figure 15 may be found at any case temperature by using the appropriate curve on Figure 17. $T_{J(pk)}$ may be calculated from the data in Figures 20. 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 16). This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode.

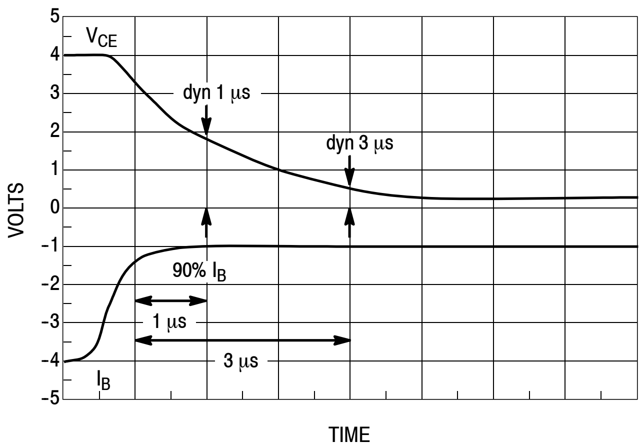



**Figure 18. Dynamic Saturation Voltage Measurements**

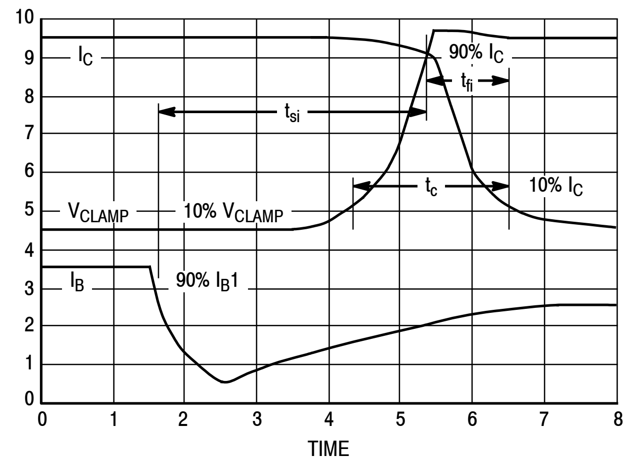
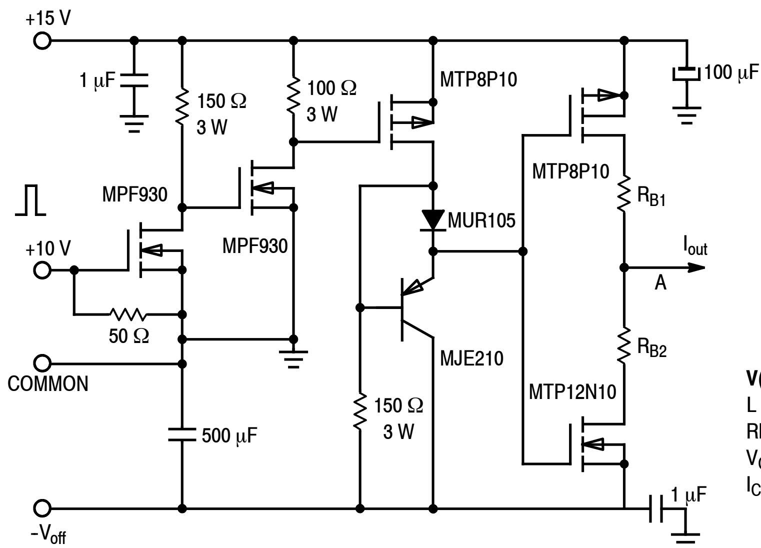
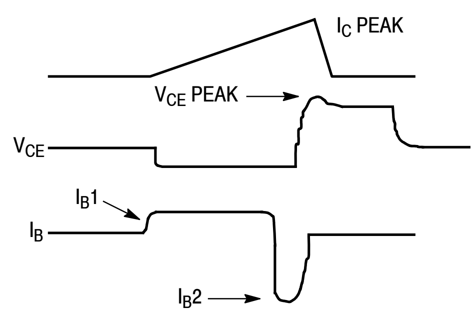



**Figure 19. Inductive Switching Measurements**




| V(BR)CEO(sus) | INDUCTIVE SWITCHING | RBSOA |
|---|---|---|
| L = 10 mH | L = 200 μH | L = 500 μH |
| RB2 = ∞ | RB2 = 0 | RB2 = 0 |
| $V_{CC}$ = 20 VOLTS | $V_{CC}$ = 15 VOLTS | $V_{CC}$ = 15 VOLTS |
| $I_C$(pk) = 100 mA | RB1 SELECTED FOR DESIRED $I_{B1}$ | RB1 SELECTED FOR DESIRED $I_{B1}$ |

**Table 1. Inductive Load Switching Drive Circuit**

## TYPICAL THERMAL RESPONSE

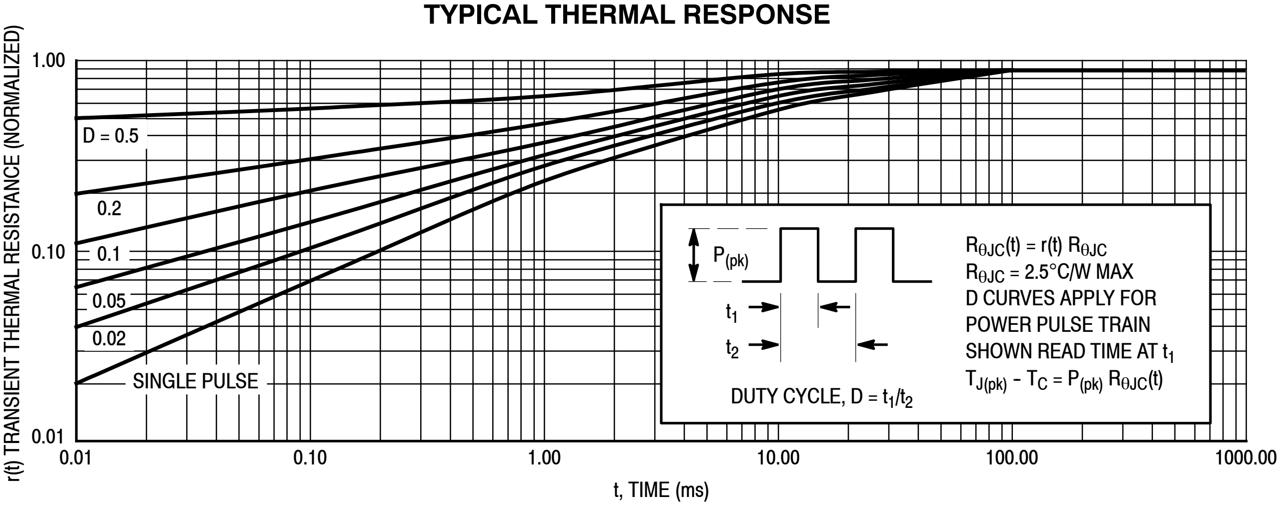
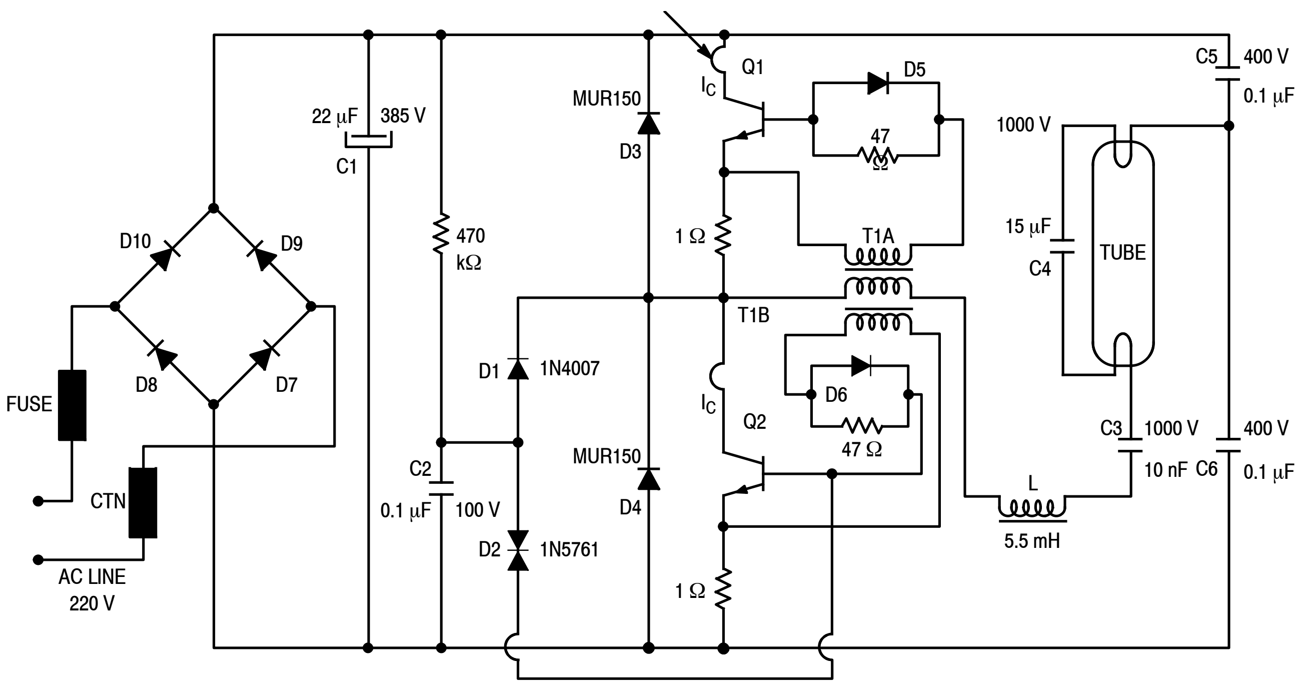



**Figure 20. Typical Thermal Response ($Z_{\theta JC}(t)$) for BUL45**

The BUL45 Bipolar Power Transistors were specially designed for use in electronic lamp ballasts. A circuit designed by ON Semiconductor applications was built to demonstrate how well these devices operate. The circuit and detailed component list are provided below.




**Components Lists**

Q1 = Q2 = BUL45 Transistor
D1 = 1N4007 Rectifier
D2 = 1N5761 Rectifier
D3 = D4 = MUR150
D5 = D6 = MUR105
D7 = D8 = D9 = D10 = 1N400
CTN = 47 Ω @ 25°C
L = RM10 core, A1 = 400, B51 (LCC) 75 turns, wire ∅ = 0.6 mm
T1 = FT10 toroid, T4A (LCC)
Primary: 4 turns
Secondaries: T1A: 4 turns
T1B: 4 turns

All resistors are 1/4 Watt, ±5%
R1 = 470 kΩ
R2 = R3 = 47 Ω
R4 = R5 = 1 Ω (these resistors are optional, and might be replaced by a short circuit)
C1 = 22 μF/385 V
C2 = 0.1 μF
C3 = 10 nF/1000 V
C4 = 15 nF/1000 V
C5 = C6 = 0.1 μF/400 V

NOTES:
1. Since this design does not include the line input filter, it cannot be used “as-is” in a practical industrial circuit.
2. The windings are given for a 55 Watt load. For proper operation they must be re-calculated with any other loads.

**Figure 21. Application Example**

## ADDITIONAL INFORMATION

**TECHNICAL PUBLICATIONS**:
**Technical Library:** www.onsemi.com/design/resources/technical−documentation
**onsemi Website:** www.onsemi.com

**ONLINE SUPPORT:** www.onsemi.com/support
**For additional information, please contact your local Sales Representative at** www.onsemi.com/support/sales

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