

# NPN Silicon Power Transistor

## High Voltage SWITCHMODE™ Series

Designed for use in electronic ballast (light ballast) and in Switchmode Power supplies up to 50 Watts. Main features include:

- 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  $t_{si} = 3.2$   $\mu$ s (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

### 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	$I_C$	5.0	Adc
— Peak(1)	$I_{CM}$	10	
Base Current	$I_B$	2.0	Adc
Total Device Dissipation (T <sub>C</sub> = 25°C)	$P_D$	75	Watts
Derate above 25°C		0.6	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	$R_{\theta JC}$	1.65	°C/W
— Junction to Ambient	$R_{\theta JA}$	62.5	

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

Characteristic	Symbol	Min	Typ	Max	Unit
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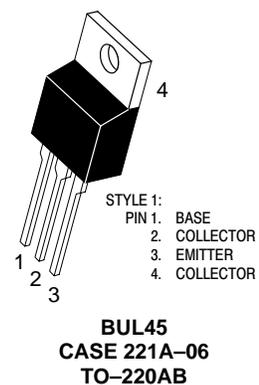
### OFF CHARACTERISTICS

Collector–Emitter Sustaining Voltage ( $I_C = 100$ mA, $L = 25$ mH)	$V_{CEO(sus)}$	400	—	—	Vdc
Collector Cutoff Current ( $V_{CE} = \text{Rated } V_{CEO}$ , $I_B = 0$ )	$I_{CEO}$	—	—	100	$\mu$ Adc
Collector Cutoff Current ( $V_{CE} = \text{Rated } V_{CES}$ , $V_{EB} = 0$ )	$I_{CES}$	—	—	10	$\mu$ Adc
(T <sub>C</sub> = 125°C)		—	—	100	
Emitter Cutoff Current ( $V_{EB} = 9.0$ Vdc, $I_C = 0$ )	$I_{EBO}$	—	—	100	$\mu$ Adc

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

## BUL45

**POWER TRANSISTOR**  
**5.0 AMPERES**  
**700 VOLTS**  
**35 and 75 WATTS**



# BUL45

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

Characteristic	Symbol	Min	Typ	Max	Unit
<b>ON CHARACTERISTICS</b>					
Base-Emitter Saturation Voltage ( $I_C = 1.0 \text{ Adc}$ , $I_B = 0.2 \text{ Adc}$ ) ( $I_C = 2.0 \text{ Adc}$ , $I_B = 0.4 \text{ Adc}$ )	$V_{BE(\text{sat})}$	— —	0.84 0.89	1.2 1.25	Vdc
Collector-Emitter Saturation Voltage ( $I_C = 1.0 \text{ Adc}$ , $I_B = 0.2 \text{ Adc}$ )  ( $T_C = 125^\circ\text{C}$ )	$V_{CE(\text{sat})}$	— —	0.175 0.150	0.25 —	Vdc
Collector-Emitter Saturation Voltage ( $I_C = 2.0 \text{ Adc}$ , $I_B = 0.4 \text{ Adc}$ )  ( $T_C = 125^\circ\text{C}$ )	$V_{CE(\text{sat})}$	— —	0.25 0.275	0.4 —	Vdc
DC Current Gain ( $I_C = 0.3 \text{ Adc}$ , $V_{CE} = 5.0 \text{ Vdc}$ )  ( $I_C = 2.0 \text{ Adc}$ , $V_{CE} = 1.0 \text{ Vdc}$ )  ( $I_C = 10 \text{ mAdc}$ , $V_{CE} = 5.0 \text{ Vdc}$ )  ( $T_C = 125^\circ\text{C}$ )	$h_{FE}$	14 — 7.0 5.0 10	— 32 14 12 22	34 — — — —	—

## DYNAMIC CHARACTERISTICS

Current Gain Bandwidth ( $I_C = 0.5 \text{ Adc}$ , $V_{CE} = 10 \text{ Vdc}$ , $f = 1.0 \text{ MHz}$ )				$f_T$	—	12	—	MHz
Output Capacitance ( $V_{CB} = 10 \text{ Vdc}$ , $I_E = 0$ , $f = 1.0 \text{ MHz}$ )				$C_{ob}$	—	50	75	pF
Input Capacitance ( $V_{EB} = 8.0 \text{ Vdc}$ )				$C_{ib}$	—	920	1200	pF
Dynamic Saturation Voltage:  Determined 1.0 $\mu\text{s}$ and 3.0 $\mu\text{s}$ respectively after rising $I_{B1}$ reaches 90% of final $I_{B1}$ (see Figure 18)	( $I_C = 1.0 \text{ Adc}$ $I_{B1} = 100 \text{ mAdc}$ $V_{CC} = 300 \text{ V}$ )	1.0 $\mu\text{s}$	( $T_C = 125^\circ\text{C}$ )	$V_{CE}$ (Dyn sat)	—	1.75	—	Vdc
		3.0 $\mu\text{s}$	( $T_C = 125^\circ\text{C}$ )		—	0.5	—	
	( $I_C = 2.0 \text{ Adc}$ $I_{B1} = 400 \text{ mAdc}$ $V_{CC} = 300 \text{ V}$ )	1.0 $\mu\text{s}$	( $T_C = 125^\circ\text{C}$ )		—	1.85	—	
		3.0 $\mu\text{s}$	( $T_C = 125^\circ\text{C}$ )		—	0.5	—	

# BUL45

## SWITCHING CHARACTERISTICS: Resistive Load

Turn-On Time	(I <sub>C</sub> = 2.0 Adc, I <sub>B1</sub> = I <sub>B2</sub> = 0.4 Adc Pulse Width = 20 μs, Duty Cycle < 20% V <sub>CC</sub> = 300 V) (T <sub>C</sub> = 125°C)	t <sub>on</sub>	— —	75 120	110 —	ns
Turn-Off Time		t <sub>off</sub>	— —	2.8 3.5	3.5 —	μs

## SWITCHING CHARACTERISTICS: Inductive Load (V<sub>CC</sub> = 15 Vdc, L<sub>C</sub> = 200 μH, V<sub>clamp</sub> = 300 Vdc)

Fall Time	(I <sub>C</sub> = 2.0 Adc, I <sub>B1</sub> = 0.4 Adc I <sub>B2</sub> = 0.4 Adc) (T <sub>C</sub> = 125°C)	t <sub>fi</sub>	70 —	— 200	170 —	ns
Storage Time		t <sub>si</sub>	2.6 —	— 4.2	3.8 —	μs
Crossover Time		t <sub>c</sub>	— —	230 400	350 —	ns
Fall Time	(I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 100 mAdc I <sub>B2</sub> = 0.5 Adc) (T <sub>C</sub> = 125°C)	t <sub>fi</sub>	— —	110 100	150 —	ns
Storage Time		t <sub>si</sub>	— —	1.1 1.5	1.7 —	μs
Crossover Time		t <sub>c</sub>	— —	170 170	250 —	ns
Fall Time	(I <sub>C</sub> = 2.0 Adc, I <sub>B1</sub> = 250 mAdc I <sub>B2</sub> = 2.0 Adc) (T <sub>C</sub> = 125°C)	t <sub>fi</sub>	— —	80	120	ns
Storage Time		t <sub>si</sub>	— —	0.6	0.9	μs
Crossover Time		t <sub>c</sub>	— —	175	300	ns

# BUL45

## TYPICAL STATIC CHARACTERISTICS

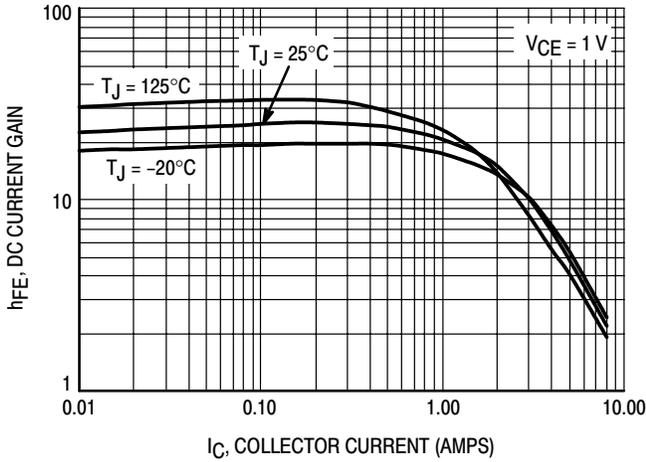


Figure 1. DC Current Gain @ 1 Volt

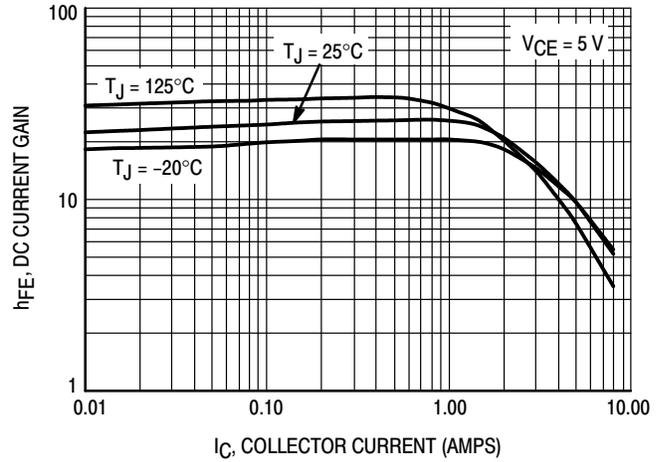


Figure 2. DC Current Gain at @ 5 Volts

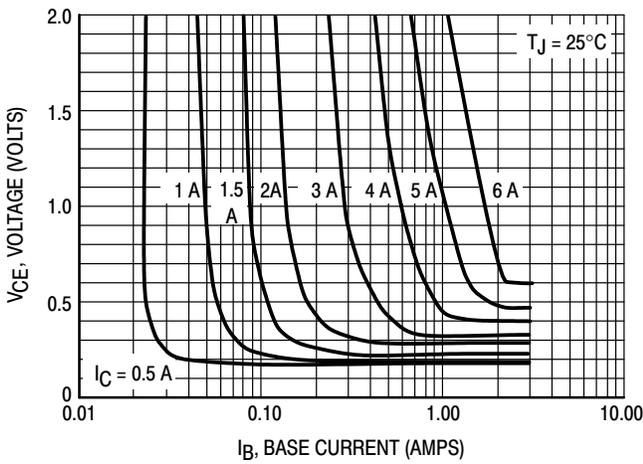


Figure 3. Collector-Emitter Saturation Region

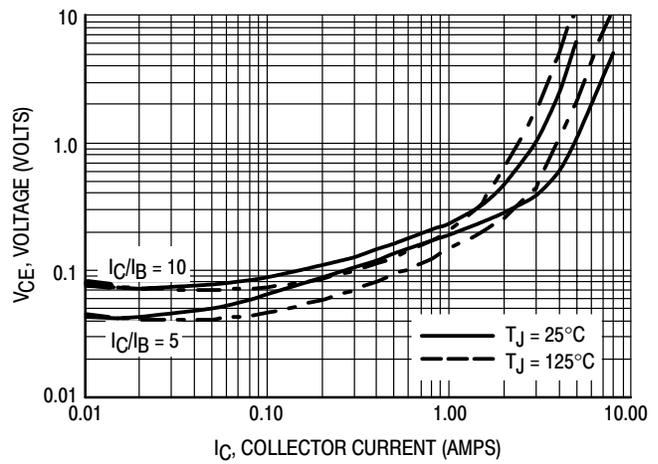


Figure 4. Collector-Emitter Saturation Voltage

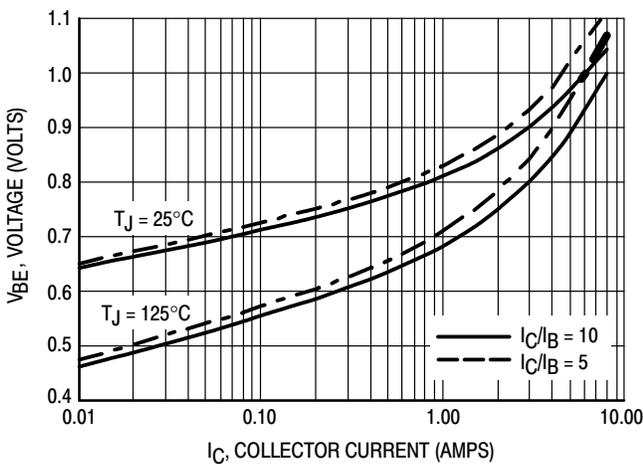


Figure 5. Base-Emitter Saturation Region

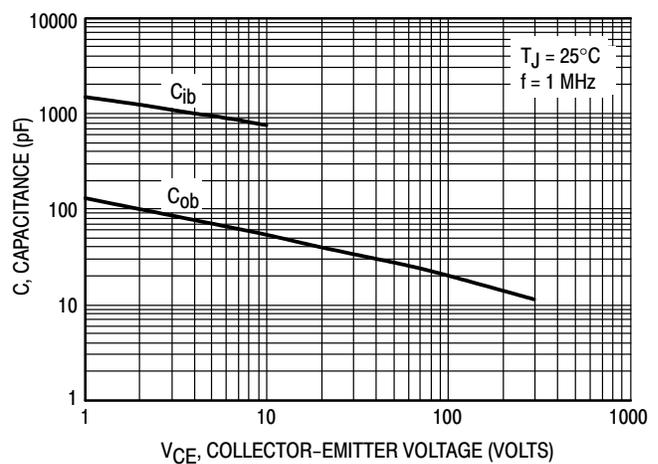


Figure 6. Capacitance

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

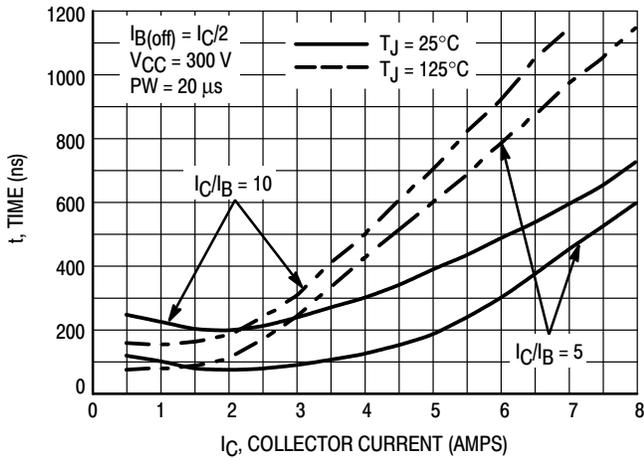


Figure 7. Resistive Switching,  $t_{on}$

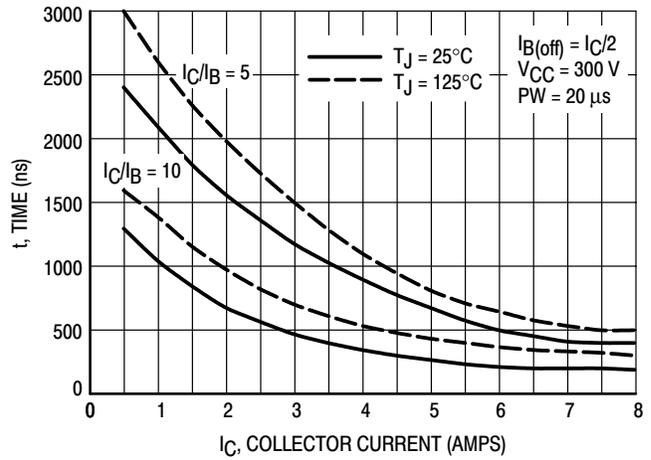


Figure 8. Resistive Switching,  $t_{off}$

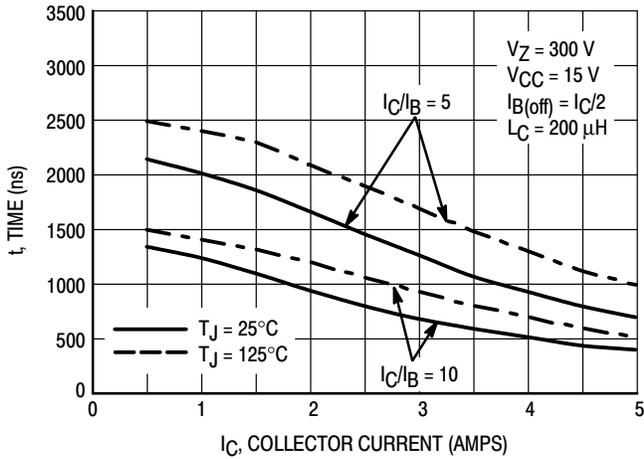


Figure 9. Inductive Storage Time,  $t_{si}$

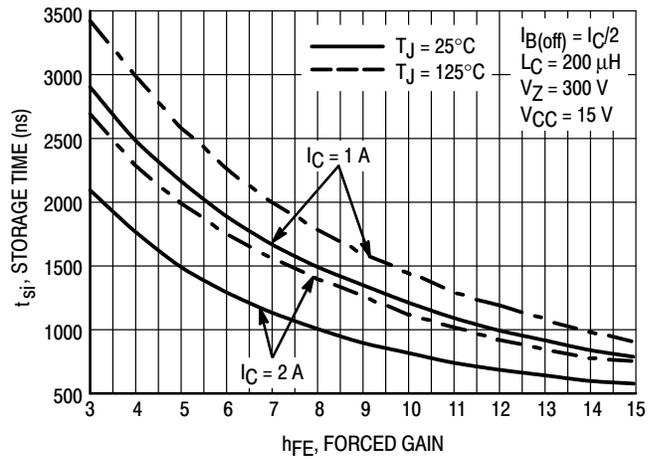


Figure 10. Inductive Storage Time,  $t_{si}(h_{FE})$

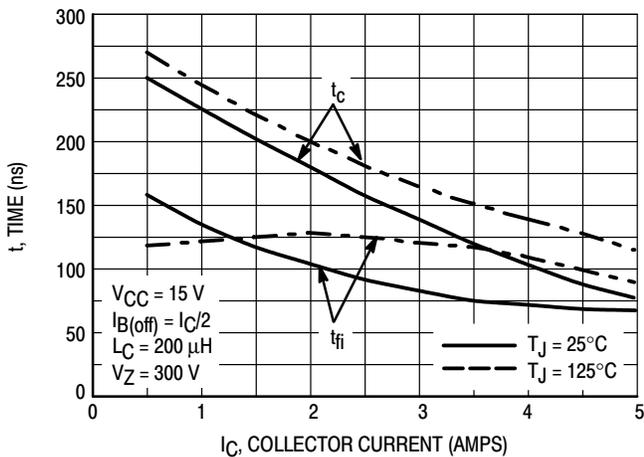


Figure 11. Inductive Switching,  $t_c$  &  $t_{fi}$ ,  $I_C/I_B = 5$

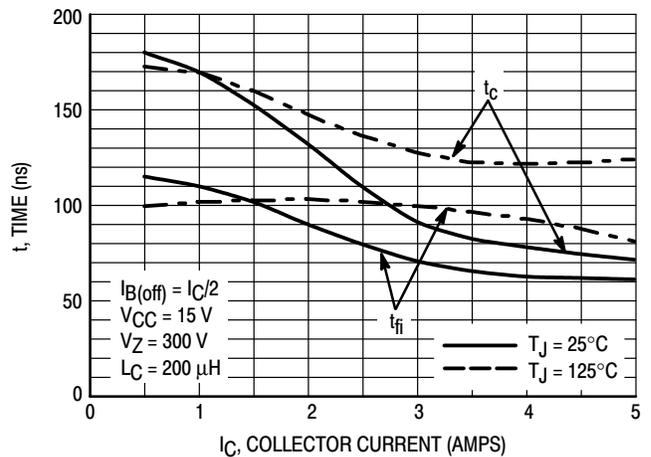


Figure 12. Inductive Switching,  $t_c$  &  $t_{fi}$ ,  $I_C/I_B = 10$

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

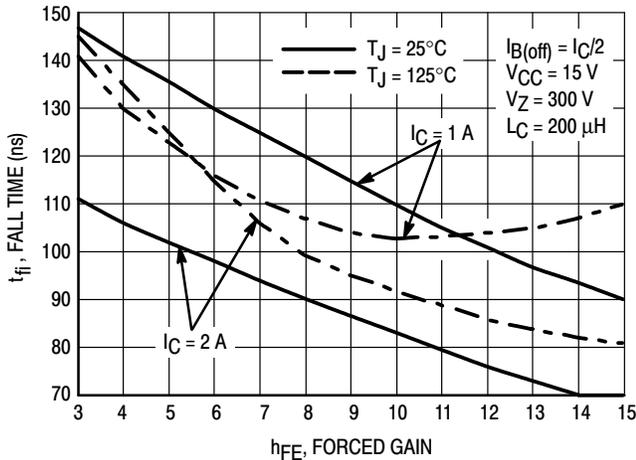


Figure 13. Inductive Fall Time,  $t_{fi}(h_{FE})$

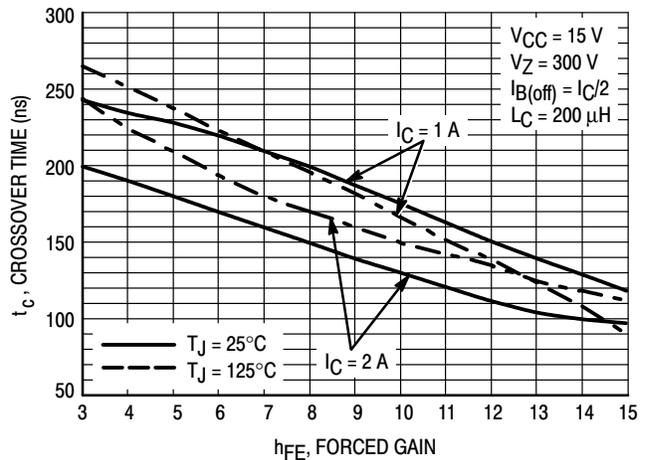


Figure 14. Crossover Time

GUARANTEED SAFE OPERATING AREA INFORMATION

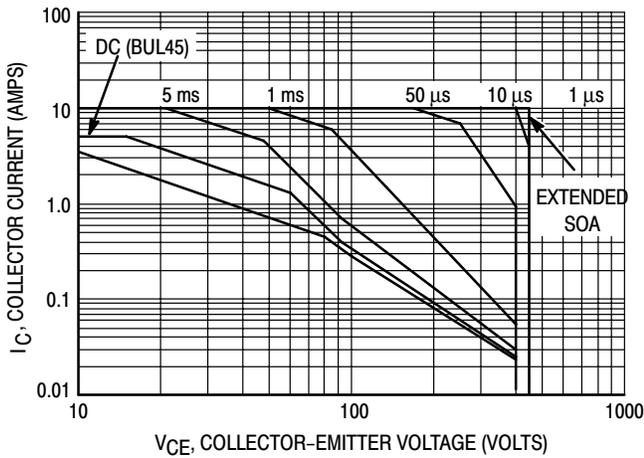


Figure 15. Forward Bias Safe Operating Area

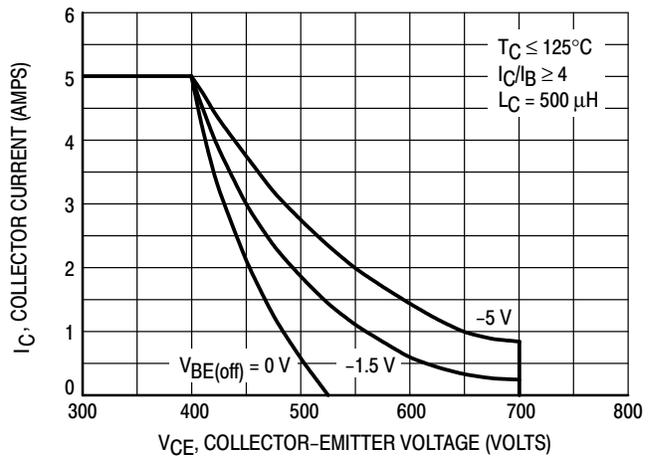


Figure 16. Reverse Bias Switching Safe Operating Area

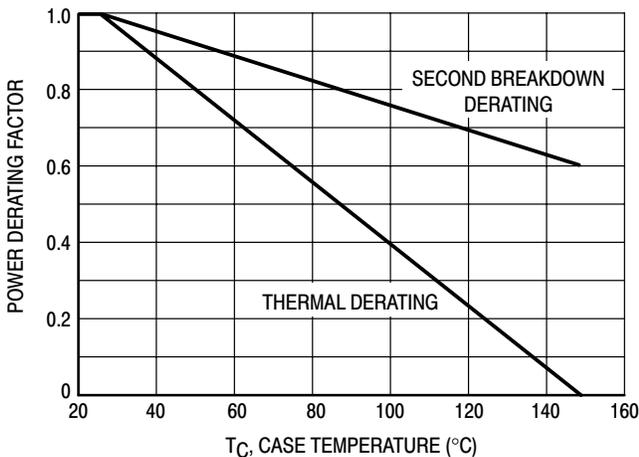


Figure 17. Forward Bias Power Derating

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  $T_C = 25^\circ\text{C}$ ;  $T_{J(\text{pk})}$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ\text{C}$ . 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.  $T_{J(\text{pk})}$  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.

# BUL45

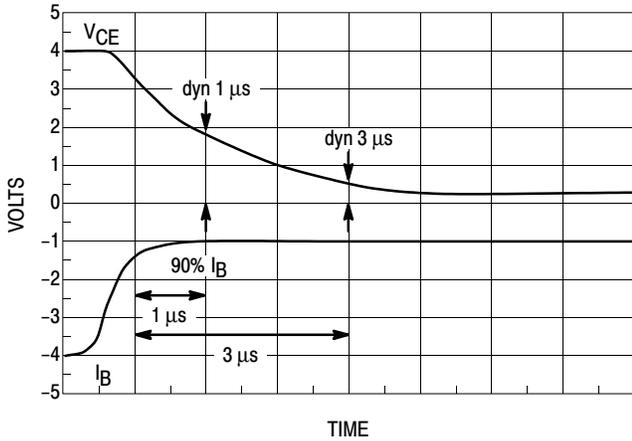


Figure 18. Dynamic Saturation Voltage Measurements

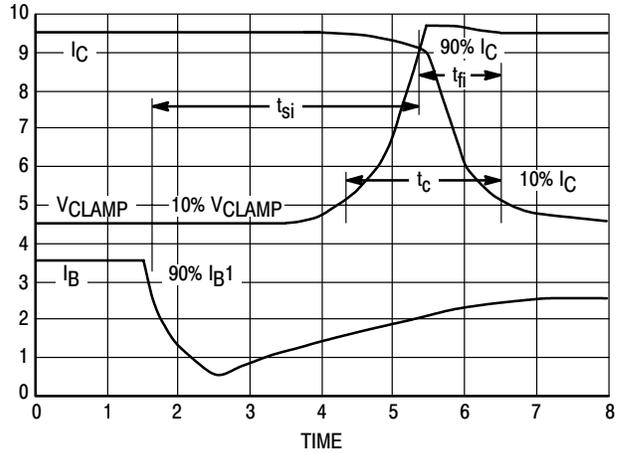
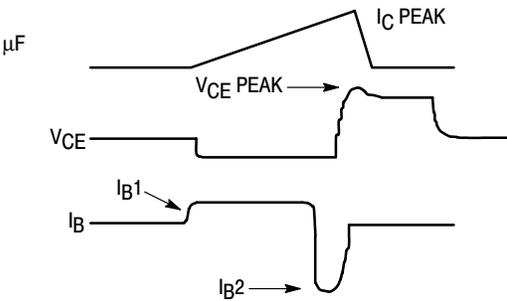
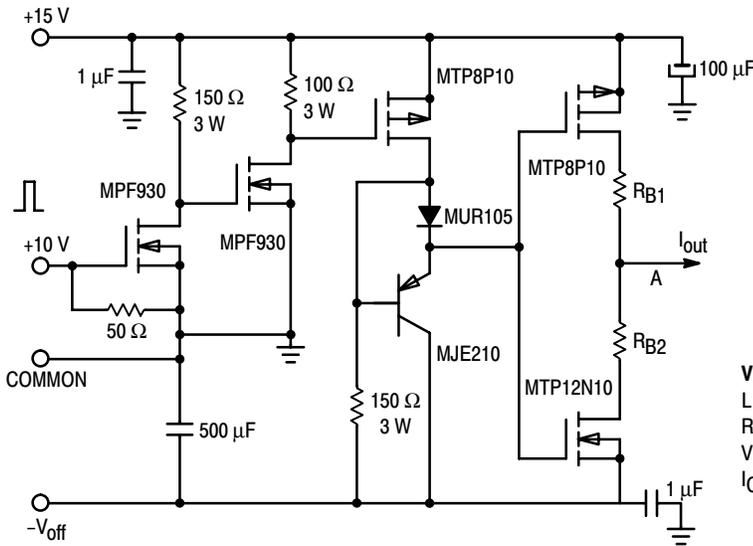


Figure 19. Inductive Switching Measurements



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

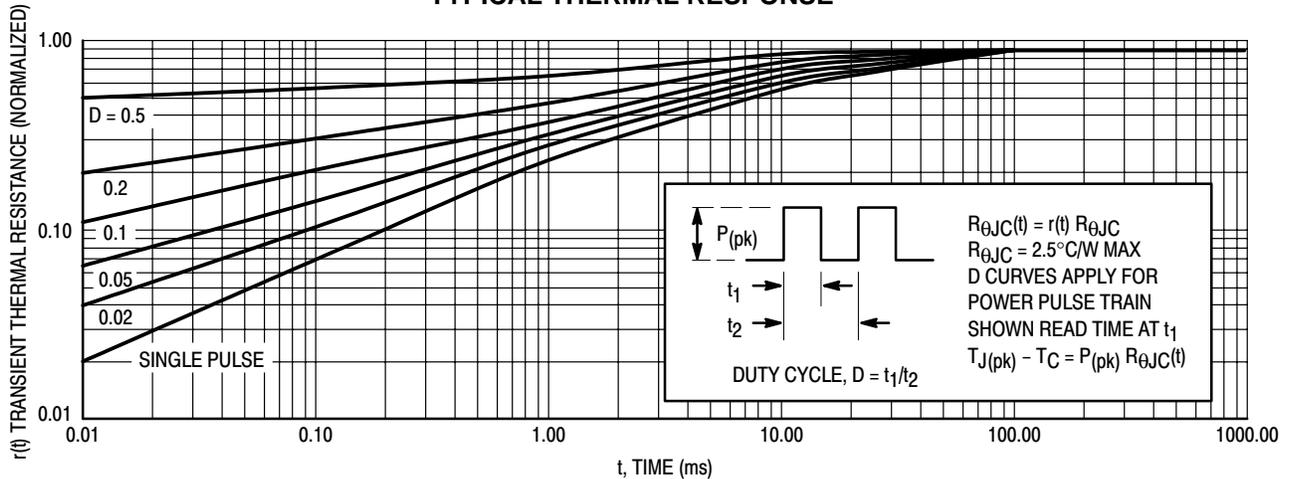
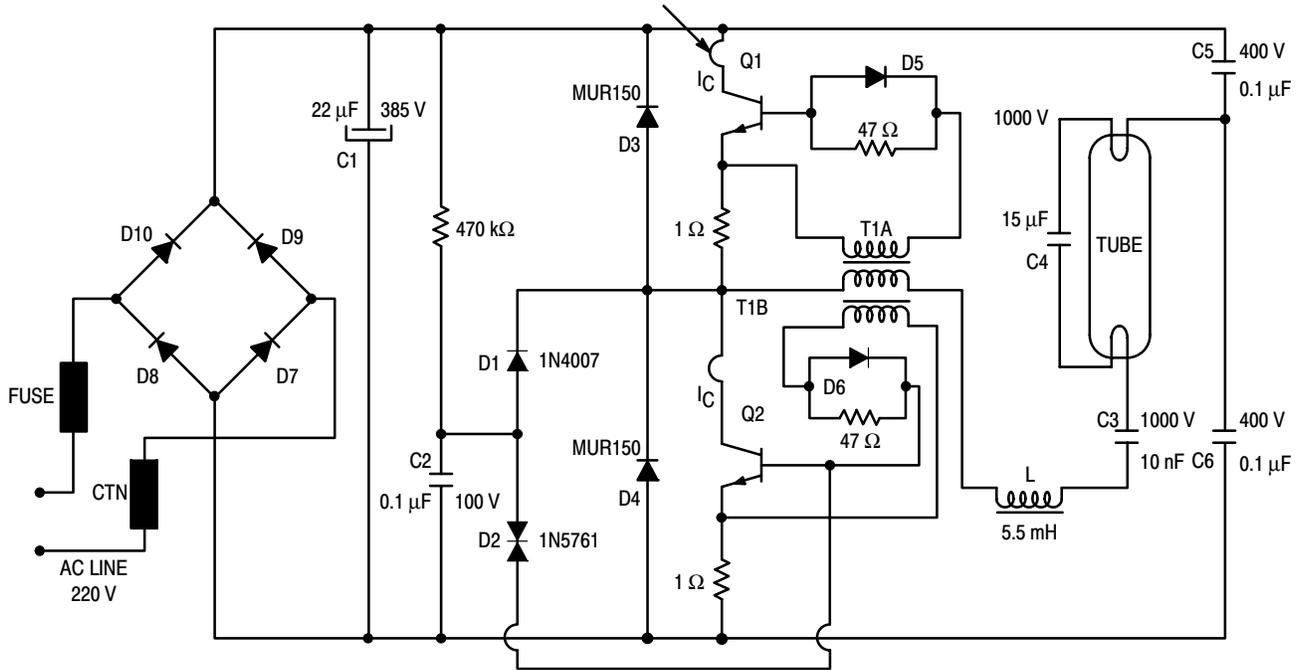


Figure 20. Typical Thermal Response ( $Z_{\theta JC}(t)$ ) for BUL45

## 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  $\varnothing$  = 0.6 mm  
 T1 = FT10 toroid, T4A (LCC)  
 Primary: 4 turns  
 Secondaries: T1A: 4 turns  
 T1B: 4 turns

All resistors are 1/4 Watt,  $\pm 5\%$   
 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:

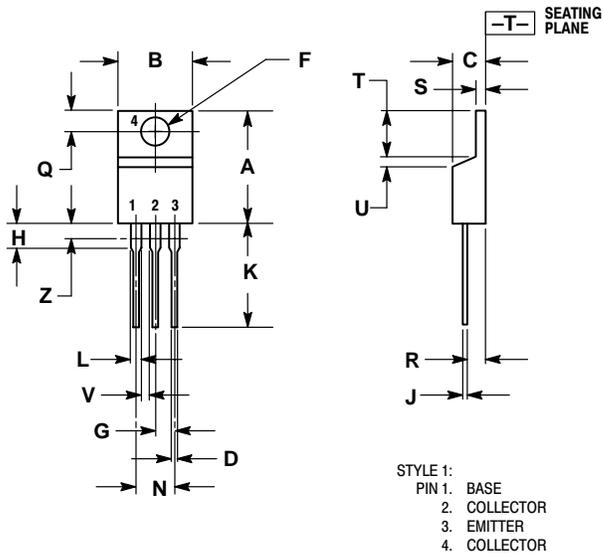
1. Since this design does not include the line input filter, it cannot be used "as-is" in a practical industrial circuit.
2. The windings are given for a 55 Watt load. For proper operation they must be re-calculated with any other loads.

Figure 21. Application Example

# BUL45

## 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

**Notes**

**Notes**

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