

# 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

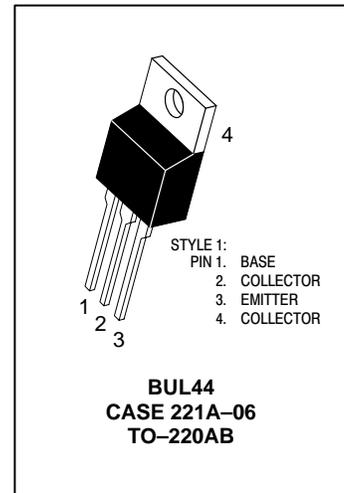
Rating	Symbol	Value	Unit
Collector-Emitter Sustaining Voltage	$V_{CEO}$	400	Vdc
Collector-Emitter Breakdown Voltage	$V_{CES}$	700	Vdc
Emitter-Base Voltage	$V_{EBO}$	9.0	Vdc
Collector Current — Continuous	$I_C$	2.0	Adc
— Peak(1)	$I_{CM}$	5.0	
Base Current — Continuous	$I_B$	1.0	Adc
— Peak(1)	$I_{BM}$	2.0	
Total Device Dissipation Derate above 25°C	$P_D$	50 0.4	Watts W/°C
Operating and Storage Temperature	$T_J, T_{stg}$	- 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 Purposes: 1/8" from Case for 5 Seconds	$T_L$	260	°C

**BUL44**

**POWER TRANSISTOR**  
**2.0 AMPERES**  
**700 VOLTS**  
**40 and 100 WATTS**



# BUL44

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

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

## DYNAMIC CHARACTERISTICS

Current Gain Bandwidth (I <sub>C</sub> = 0.5 Adc, V <sub>CE</sub> = 10 Vdc, f = 1.0 MHz)	f <sub>T</sub>	—	13	—	MHz	
Output Capacitance (V <sub>CB</sub> = 10 Vdc, I <sub>E</sub> = 0, f = 1.0 MHz)	C <sub>OB</sub>	—	38	60	pF	
Input Capacitance (V <sub>EB</sub> = 8.0 V)	C <sub>IB</sub>	—	380	600	pF	
Dynamic Saturation Voltage: Determined 1.0 μs and 3.0 μs respectively after rising I <sub>B1</sub> reaches 90% of final I <sub>B1</sub>	(I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc, V <sub>CC</sub> = 300 V)	1.0 μs (T <sub>C</sub> = 125°C)	—	2.5	—	Vdc
		3.0 μs (T <sub>C</sub> = 125°C)	—	2.7	—	
	(I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc, V <sub>CC</sub> = 300 V)	1.0 μs (T <sub>C</sub> = 125°C)	—	1.3	—	
		3.0 μs (T <sub>C</sub> = 125°C)	—	1.15	—	
		1.0 μs (T <sub>C</sub> = 125°C)	—	3.2	—	
		3.0 μs (T <sub>C</sub> = 125°C)	—	7.5	—	
			—	1.25	—	
			—	1.6	—	

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

(continued)

# BUL44

## SWITCHING CHARACTERISTICS: Resistive Load (D.C. ≤ 10%, Pulse Width = 20 μs)

Turn-On Time	(I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc 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 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	μs
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 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 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	μs
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 μH)

Fall Time	(I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc 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	μs
Fall Time	(I <sub>C</sub> = 0.4 Adc, I <sub>B1</sub> = 40 mAdc 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 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	μs
Fall Time	(I <sub>C</sub> = 1.0 Adc, I <sub>B1</sub> = 0.2 Adc 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 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	μs
Fall Time	(I <sub>C</sub> = 0.8 Adc, I <sub>B1</sub> = 160 mAdc I <sub>B2</sub> = 160 mAdc) (T <sub>C</sub> = 125°C)	t <sub>fi</sub>	—	4.2	—	—
Storage Time		t <sub>si</sub>	—	190	300	ns
Crossover Time		t <sub>c</sub>	—	350	—	—

TYPICAL STATIC CHARACTERISTICS

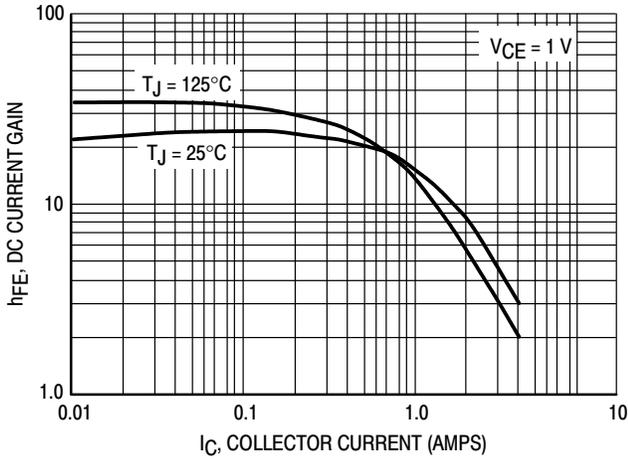


Figure 1. DC Current Gain at 1 Volt

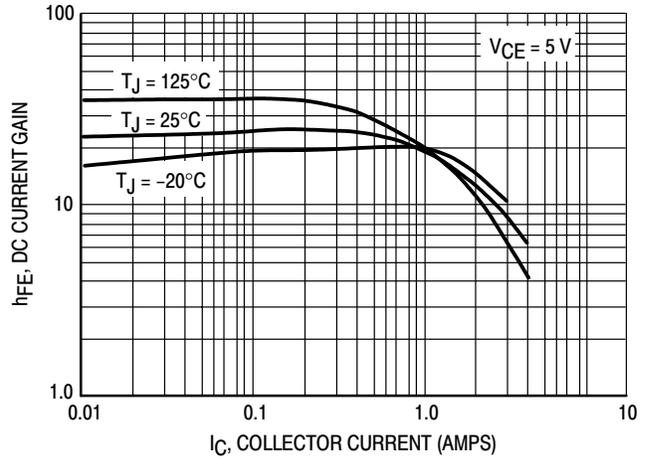


Figure 2. DC Current Gain at 5 Volts

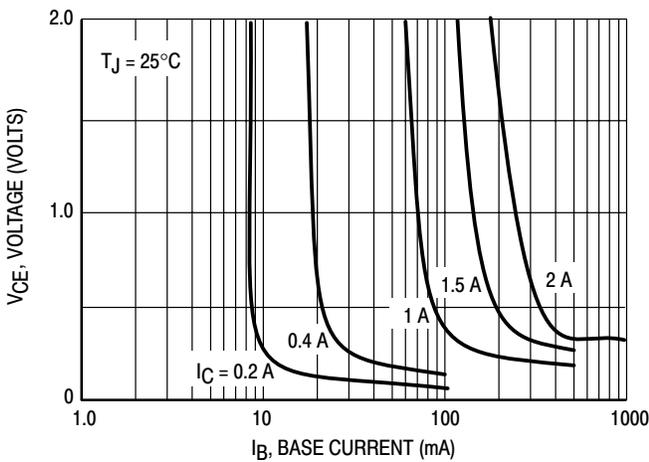


Figure 3. Collector Saturation Region

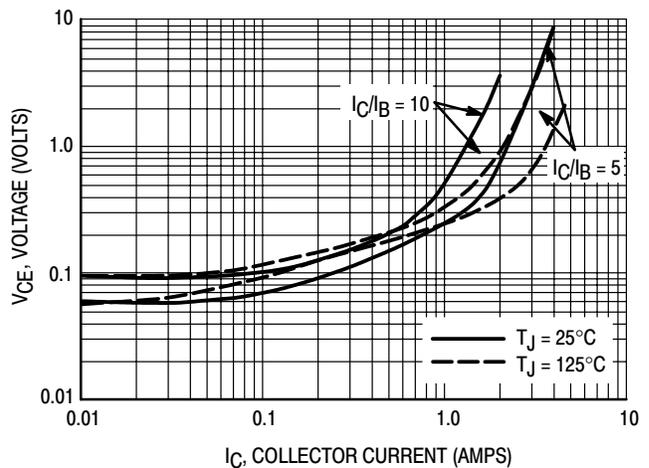


Figure 4. Collector-Emitter Saturation Voltage

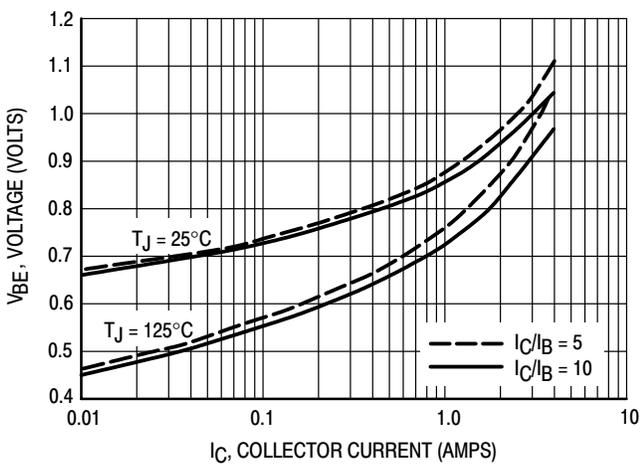


Figure 5. Base-Emitter Saturation Region

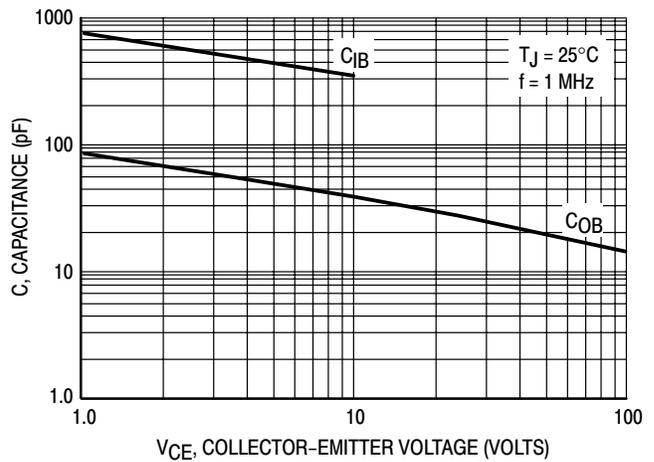


Figure 6. Capacitance

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

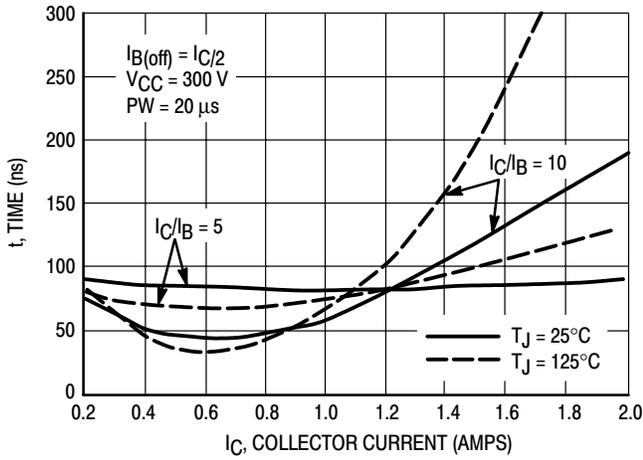


Figure 7. Resistive Switching,  $t_{on}$

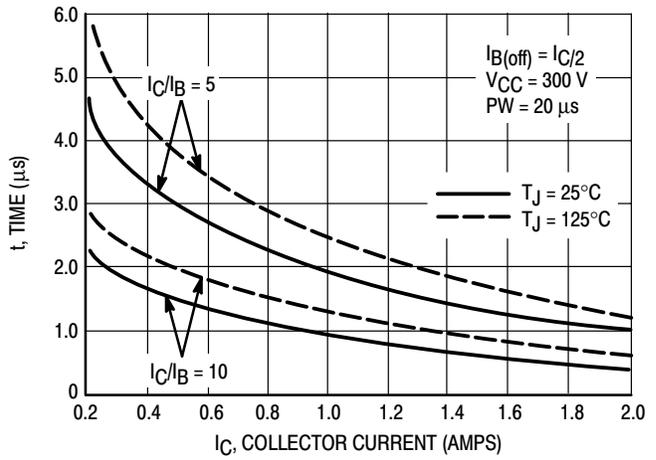


Figure 8. Resistive Switching,  $t_{off}$

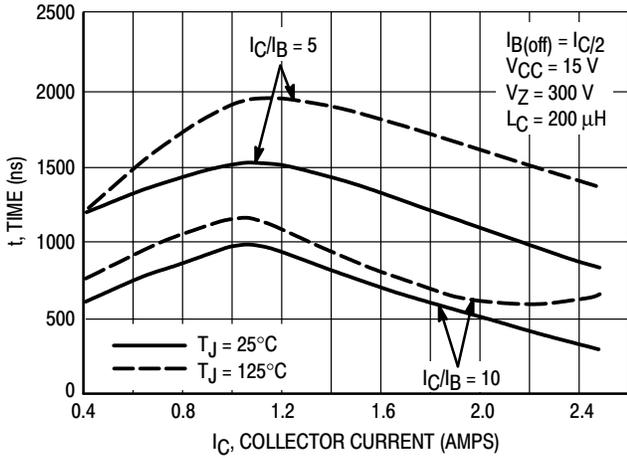


Figure 9. Inductive Storage Time,  $t_{sj}$

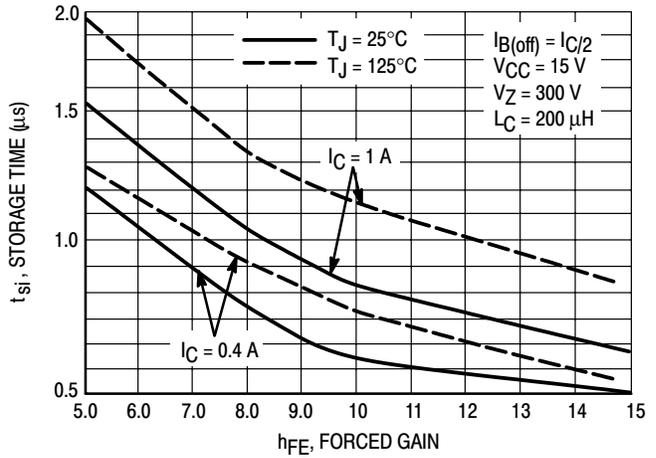


Figure 10. Inductive Storage Time

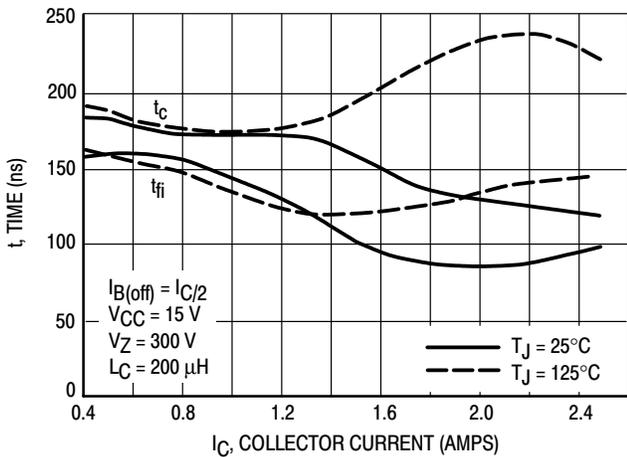


Figure 11. Inductive Switching,  $t_c$  and  $t_{fi}$   $I_C/I_B = 5$

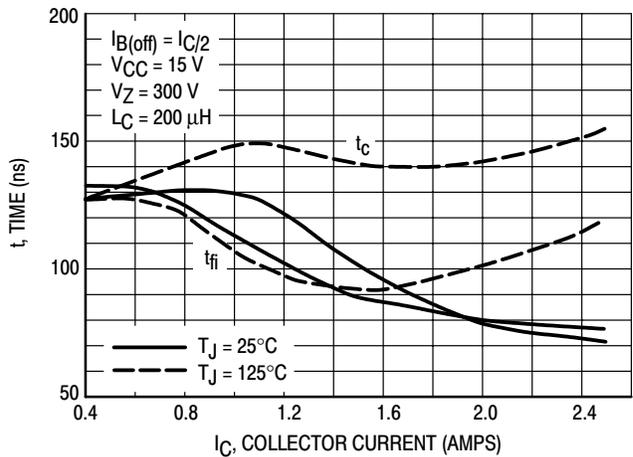


Figure 12. Inductive Switching,  $t_c$  and  $t_{fi}$   $I_C/I_B = 10$

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

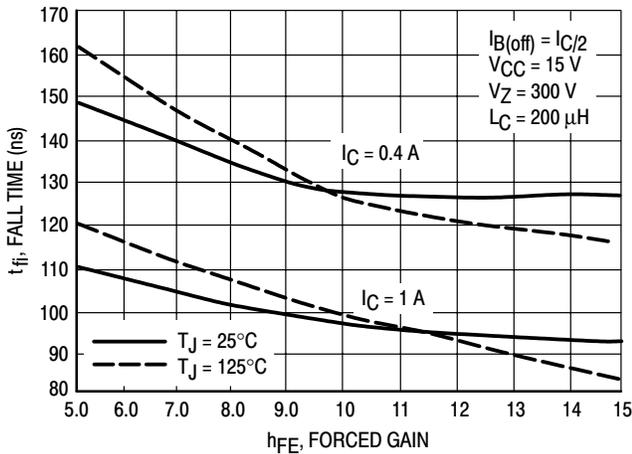


Figure 13. Inductive Fall Time

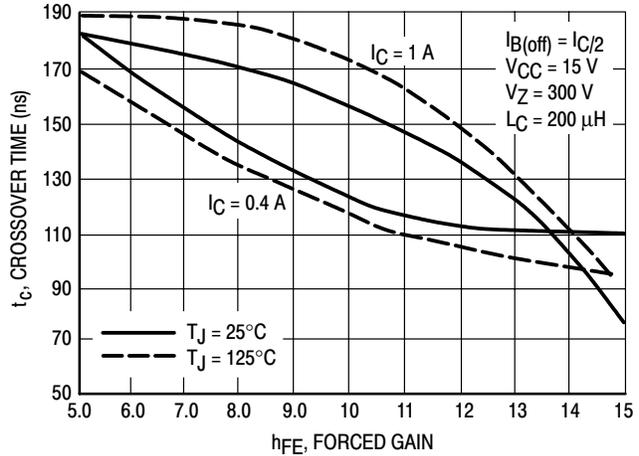


Figure 14. Inductive Crossover Time

GUARANTEED SAFE OPERATING AREA INFORMATION

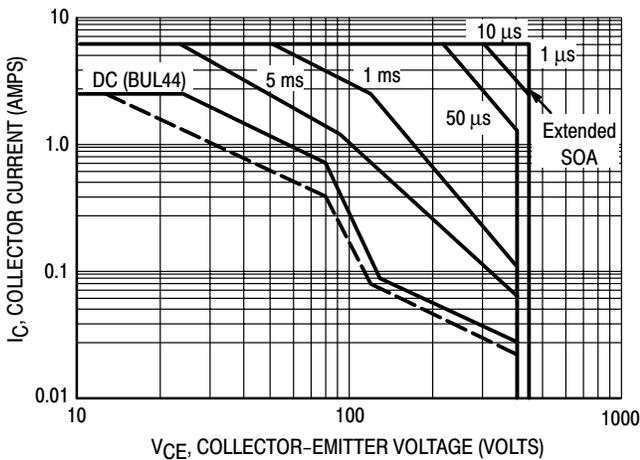


Figure 15. Forward Bias Safe Operating Area

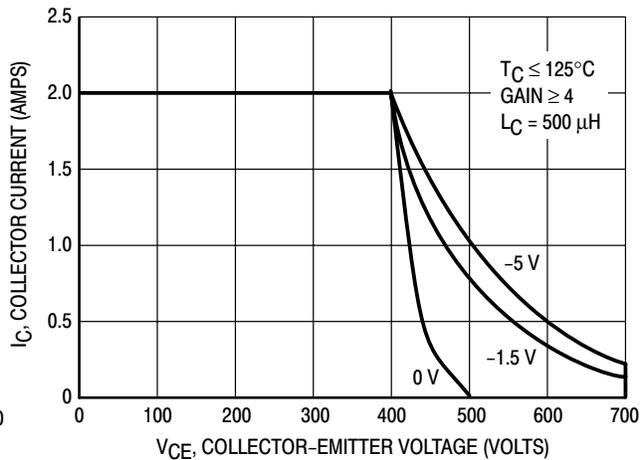


Figure 16. Reverse Bias Switching Safe Operating Area

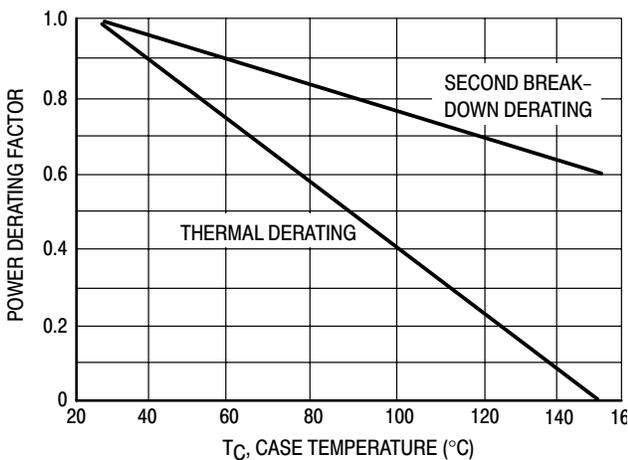


Figure 17. Forward Bias Power Derating

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.

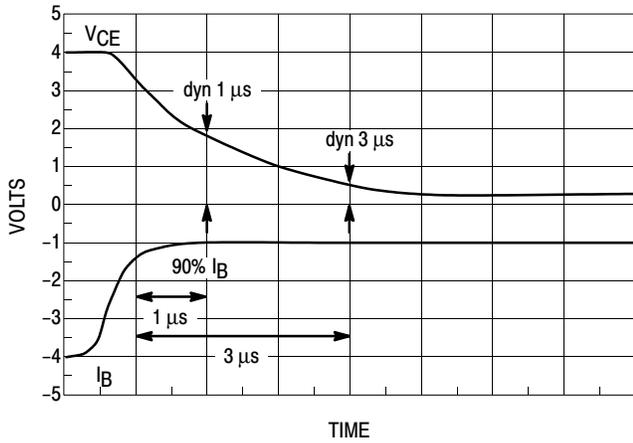


Figure 18. Dynamic Saturation Voltage Measurements

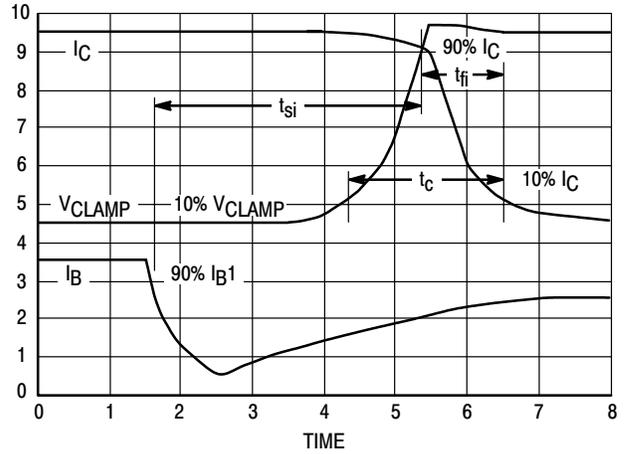


Figure 19. Inductive Switching Measurements

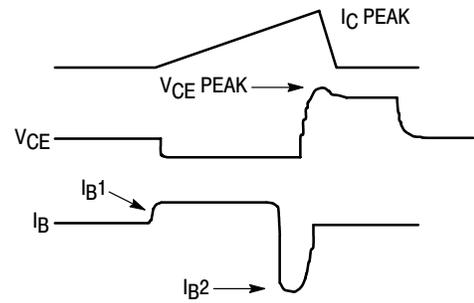
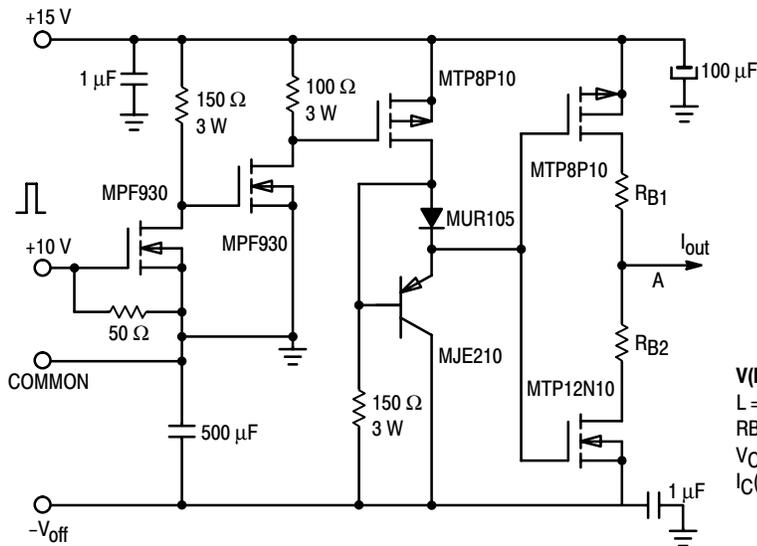


Table 1. Inductive Load Switching Drive Circuit

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

TYPICAL THERMAL RESPONSE

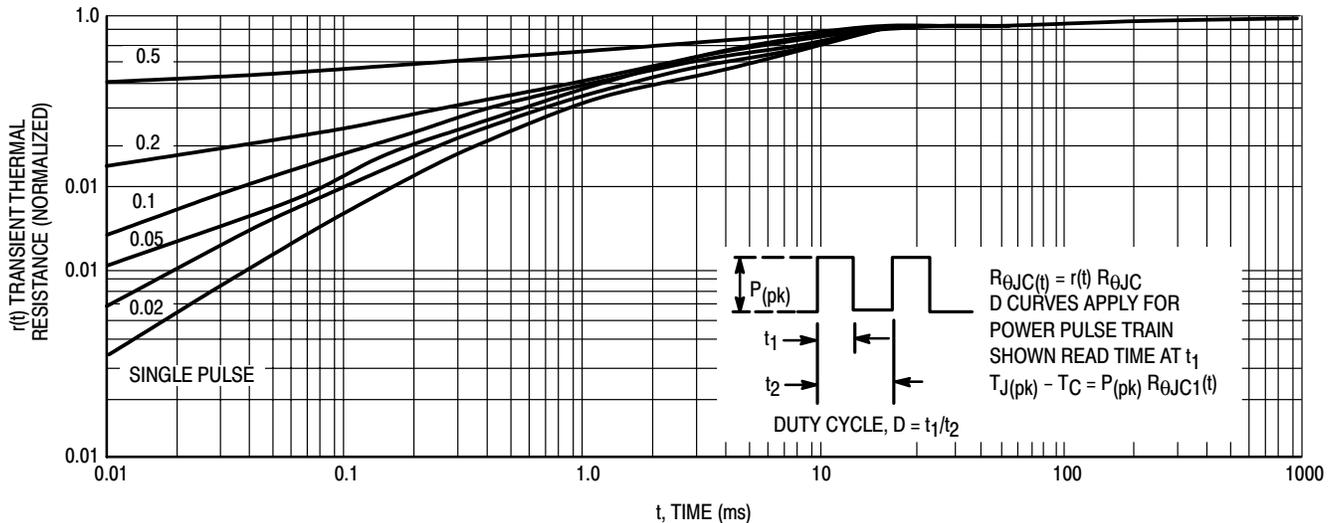
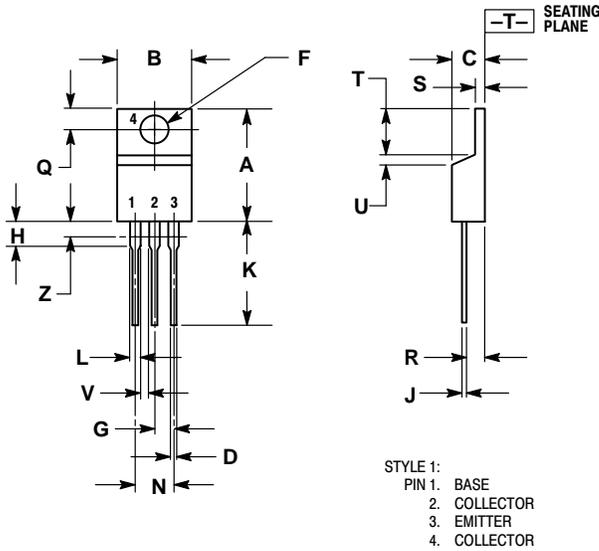


Figure 20. Typical Thermal Response ( $Z_{\theta JC}(t)$ ) for BUL44

# 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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