Designer's™ Data Sheet
SWITCHMODE™
NPN Bipolar Power Transistor
For Switching Power Supply Applications

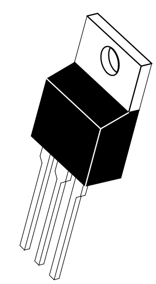
BUL147*
BUL147F*

*Motorola Preferred Device

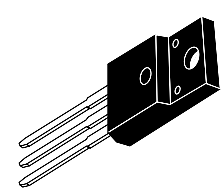
POWER TRANSISTOR
8.0 AMPERES
700 VOLTS
45 and 125 WATTS

The BUL147/BUL147F have an applications specific state–of–the–art die designed for use in electric fluorescent lamp ballasts to 180 Watts and in Switchmode Power supplies for all types of electronic equipment. These high–voltage/high–speed transistors offer the following:

- Improved Efficiency Due to Low Base Drive Requirements:
  - — High and Flat DC Current Gain
  - — Fast Switching
  - — No Coil Required in Base Circuit for Turn–Off (No Current Tail)
- Parametric Distributions are Tight and Consistent Lot–to–Lot
- Two Package Choices: Standard TO–220 or Isolated TO–220
- BUL147F, Isolated Case 221D, is UL Recognized to 3500 V_{RMS}: File #E69369



BUL147
CASE 221A–06
TO–220AB



BUL147F
CASE 221D–02
ISOLATED TO–220 TYPE
UL RECOGNIZED

MAXIMUM RATINGS

Rating		Symbol	BUL147	BUL147F	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 — Peak(1)		I_C I_{CM}	8.0 16		Adc
Base Current — Continuous — Peak(1)		I_B I_{BM}	4.0 8.0		Adc
RMS Isolated Voltage(2) (for 1 sec, R.H. < 30%, T_C = 25°C)	Test No. 1 Per Fig. 22a Test No. 2 Per Fig. 22b Test No. 3 Per Fig. 22c	V_{ISOL}	— — —	4500 3500 1500	Volts
Total Device Dissipation Derate above 25°C	(T_C = 25°C)	P_D	125 1.0	45 0.36	Watts W/°C
Operating and Storage Temperature		T_J, T_{stg}	– 65 to 150		°C

THERMAL CHARACTERISTICS

Rating	Symbol	BUL44	BUL44F	Unit
Thermal Resistance — Junction to Case — Junction to Ambient	$R_{\theta JC}$ $R_{\theta JA}$	1.0 62.5	2.78 62.5	°C/W
Maximum Lead Temperature for Soldering Purposes: 1/8″ from Case for 5 Seconds	T_L	260		°C

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) (T_C = 125°C) (V_{CE} = 500 V, V_{EB} = 0) (T_C = 125°C)	I_{CES}	— — —	— — —	100 500 100	µAdc
Emitter Cutoff Current (V_{EB} = 9.0 Vdc, I_C = 0)	I_{EBO}	—	—	100	µAdc

(1) Pulse Test: Pulse Width = 5.0 ms, Duty Cycle ≤ 10%.
(2) Proper strike and creepage distance must be provided.

(continued)

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.

Preferred devices are Motorola recommended choices for future use and best overall value.

REV 1

ELECTRICAL CHARACTERISTICS — continued (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS					
Base–Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 0.2 Adc)	$V_{BE(sat)}$	—	0.82	1.1	Vdc
(I_C = 4.5 Adc, I_B = 0.9 Adc)		—	0.92	1.25	
Collector–Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 2.0 Adc, I_B = 0.2 Adc)		—	0.25	0.5	
(T_C = 125°C)		—	0.3	0.5	
(I_C = 4.5 Adc, I_B = 0.9 Adc)		—	0.35	0.7	
(T_C = 125°C)		—	0.35	0.8	
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)	h_{FE}	14	—	34	—
(T_C = 125°C)		—	30	—	
(I_C = 4.5 Adc, V_{CE} = 1.0 Vdc)		8.0	12	—	
(T_C = 125°C)		7.0	11	—	
(I_C = 2.0 Adc, V_{CE} = 1.0 Vdc) (T_C = 25°C to 125°C)		10	18	—	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)		10	20	—	
DYNAMIC CHARACTERISTICS					
Current Gain Bandwidth (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	—	14	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	—	100	175	pF
Input Capacitance (V_{EB} = 8.0 V)	C_{ib}	—	1750	2500	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 = 2.0 Adc, I_{B1} = 200 mAdc, V_{CC} = 300 V) 1.0 µs	$V_{CE(dsat)}$	—	3.0	—	Volts
(T_C = 125°C)		—	5.5	—	
3.0 µs		—	0.8	—	
(T_C = 125°C)		—	1.4	—	
(I_C = 5.0 Adc, I_{B1} = 0.9 Adc, V_{CC} = 300 V) 1.0 µs		—	3.3	—	
(T_C = 125°C)		—	8.5	—	
3.0 µs		—	0.4	—	
(T_C = 125°C)		—	1.0	—	
SWITCHING CHARACTERISTICS: Resistive Load (D.C. ≤ 10%, Pulse Width = 20 µs)					
Turn–On Time (I_C = 2.0 Adc, I_{B1} = 0.2 Adc, I_{B2} = 1.0 Adc, V_{CC} = 300 V)	t_{on}	—	200	350	ns
(T_C = 125°C)		—	190	—	
Turn–Off Time	t_{off}	—	1.0	2.5	µs
(T_C = 125°C)		—	1.6	—	
Turn–On Time (I_C = 4.5 Adc, I_{B1} = 0.9 Adc, I_{B1} = 2.25 Adc, V_{CC} = 300 V)	t_{on}	—	85	150	ns
(T_C = 125°C)		—	100	—	
Turn–Off Time	t_{off}	—	1.5	2.5	µs
(T_C = 125°C)		—	2.0	—	
SWITCHING CHARACTERISTICS: Inductive Load (V_{clamp} = 300 V, V_{CC} = 15 V, L = 200 µH)					
Fall Time (I_C = 2.0 Adc, I_{B1} = 0.2 Adc, I_{B2} = 1.0 Adc)	t_{fi}	—	100	180	ns
(T_C = 125°C)		—	120	—	
Storage Time	t_{si}	—	1.3	2.5	µs
(T_C = 125°C)		—	1.9	—	
Crossover Time	t_c	—	210	350	ns
(T_C = 125°C)		—	230	—	
Fall Time (I_C = 4.5 Adc, I_{B1} = 0.9 Adc, I_{B2} = 2.25 Adc)	t_{fi}	—	80	150	ns
(T_C = 125°C)		—	100	—	
Storage Time	t_{si}	—	1.6	3.2	µs
(T_C = 125°C)		—	2.1	—	
Crossover Time	t_c	—	170	300	ns
(T_C = 125°C)		—	200	—	
Fall Time (I_C = 4.5 Adc, I_{B1} = 0.9 Adc, I_{B2} = 0.9 Adc)	t_{fi}	60	—	180	ns
(T_C = 125°C)		—	150	—	
Storage Time	t_{si}	2.6	—	3.8	µs
(T_C = 125°C)		—	4.3	—	
Crossover Time	t_c	—	200	350	ns
(T_C = 125°C)		—	330	—	

TYPICAL STATIC CHARACTERISTICS

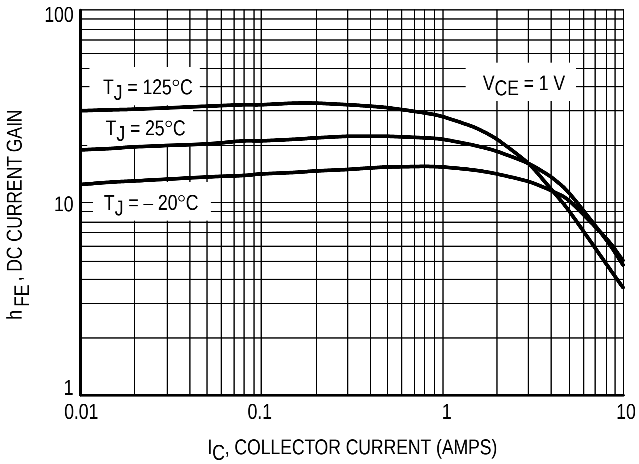


Figure 1. DC Current Gain @ 1 Volt

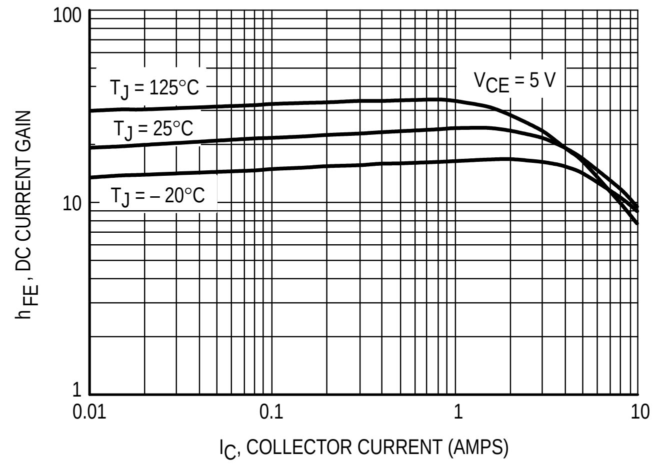


Figure 2. DC Current Gain @ 5 Volts

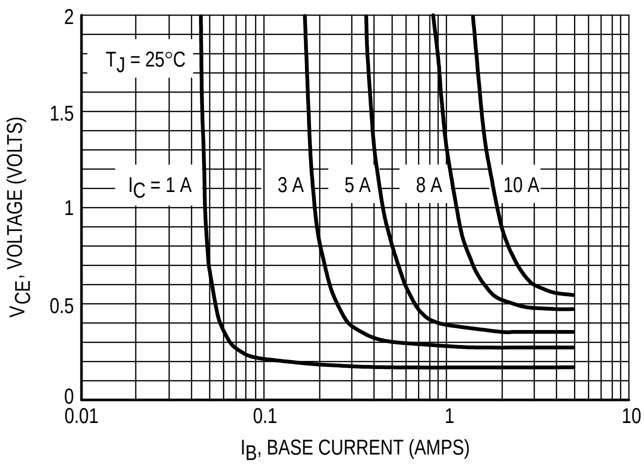


Figure 3. Collector Saturation Region

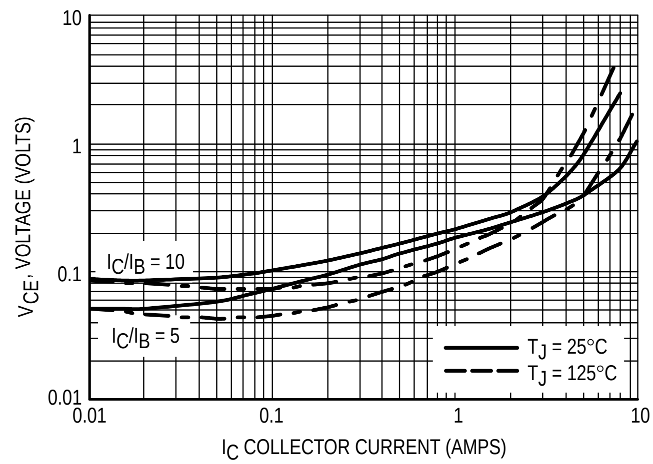


Figure 4. Collector–Emitter Saturation Voltage

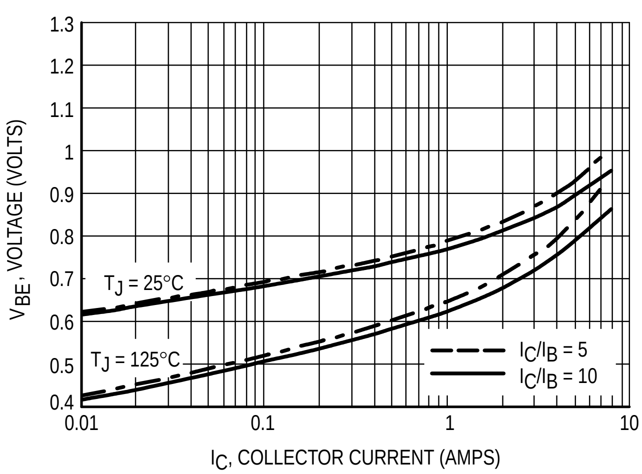


Figure 5. Base–Emitter Saturation Region

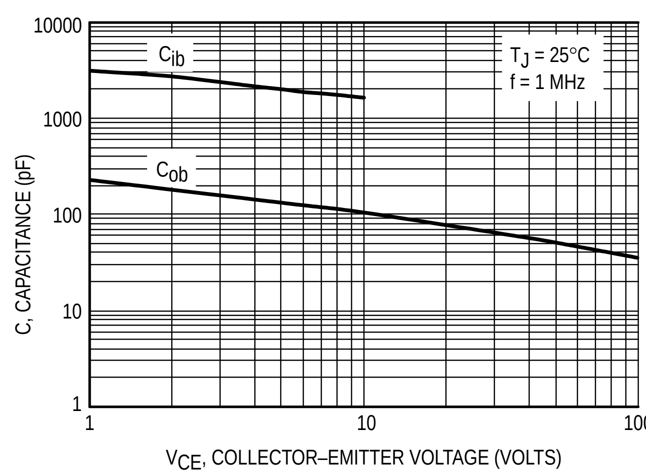


Figure 6. Capacitance

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

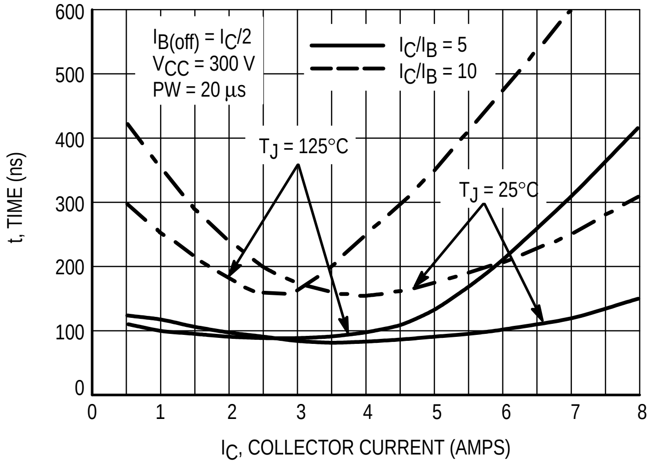


Figure 7. Resistive Switching, t_{on}

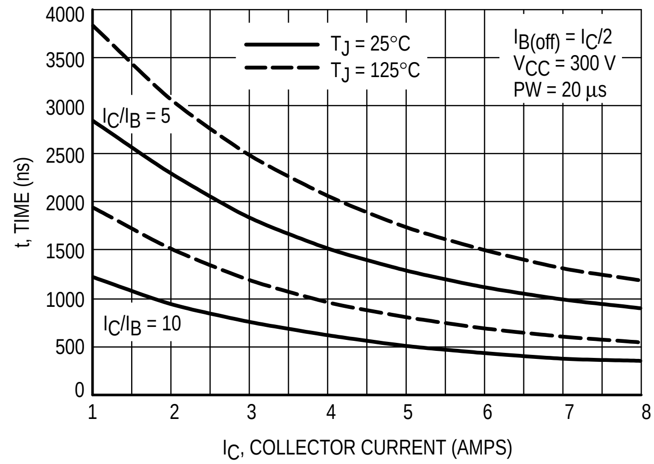


Figure 8. Resistive Switching, t_{off}

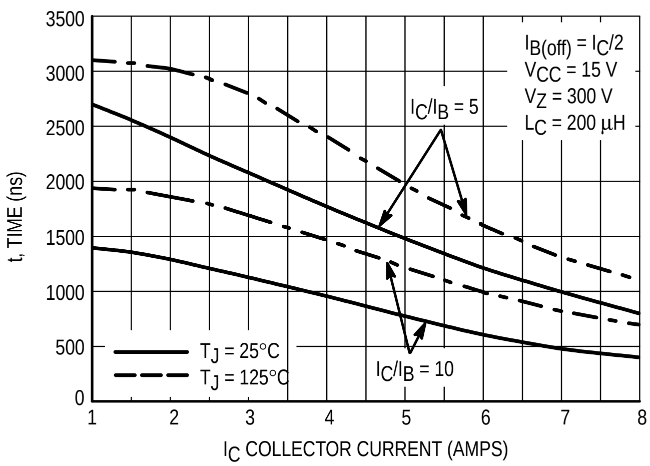


Figure 9. Inductive Storage Time, t_{si}

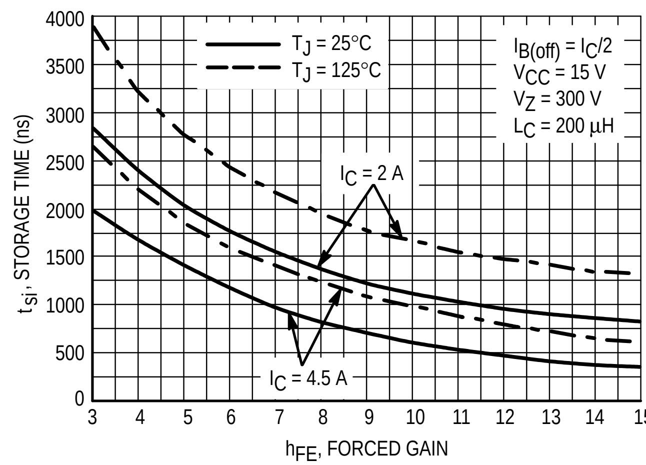


Figure 10. Inductive Storage Time, $t_{si}(h_{FE})$

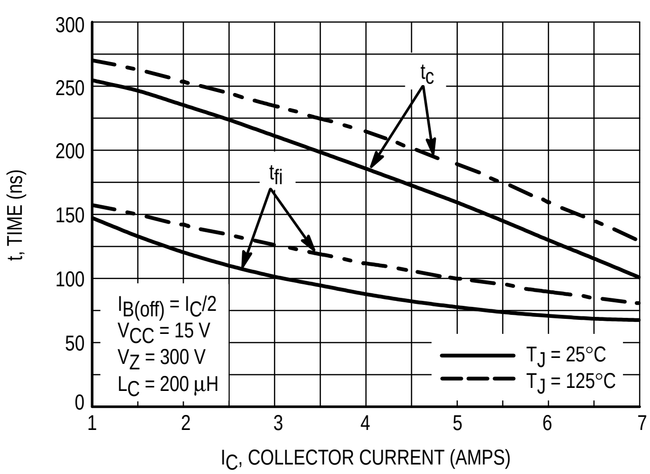


Figure 11. Inductive Switching, t_c and t_{fi}
$I_C/I_B = 5$

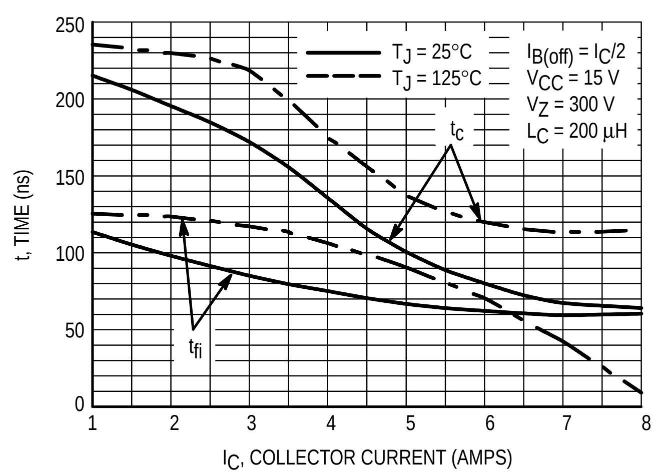


Figure 12. Inductive Switching, t_c and t_{fi}
$I_C/I_B = 10$

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

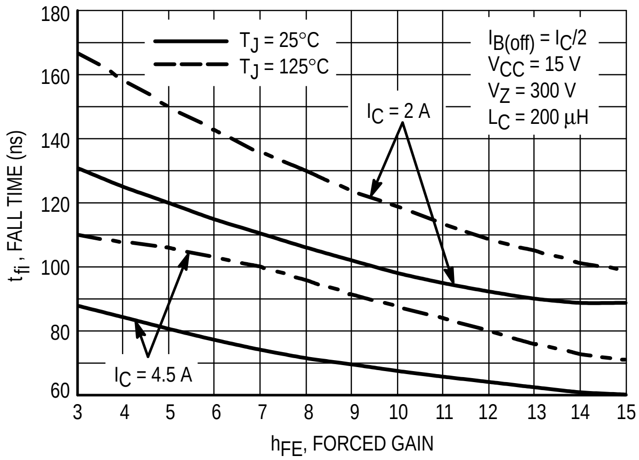


Figure 13. Inductive Fall Time

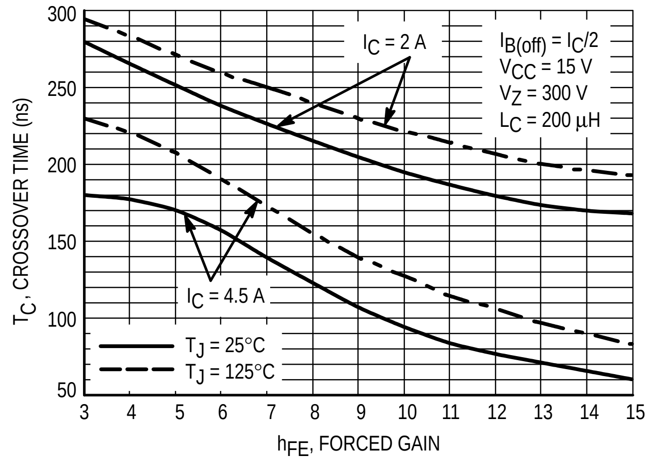


Figure 14. Inductive Crossover Time

GUARANTEED SAFE OPERATING AREA INFORMATION

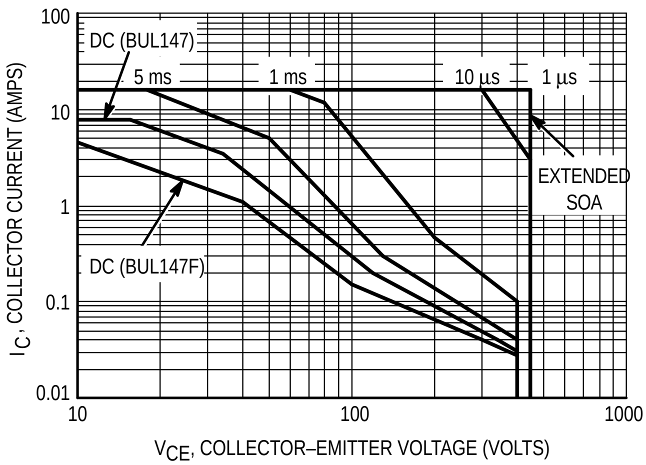


Figure 15. Forward Bias Safe Operating Area

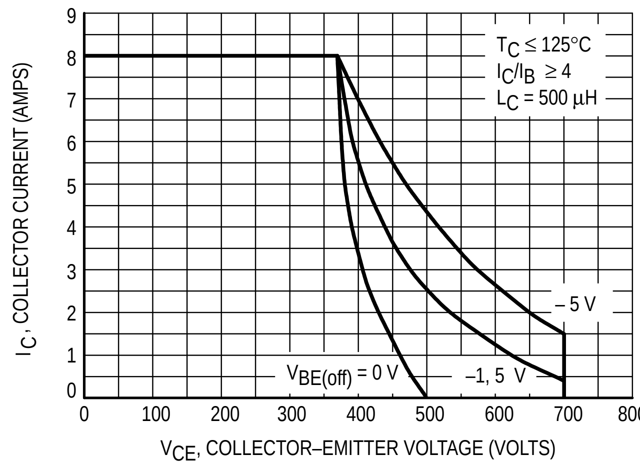


Figure 16. Reverse Bias Switching Safe Operating Area

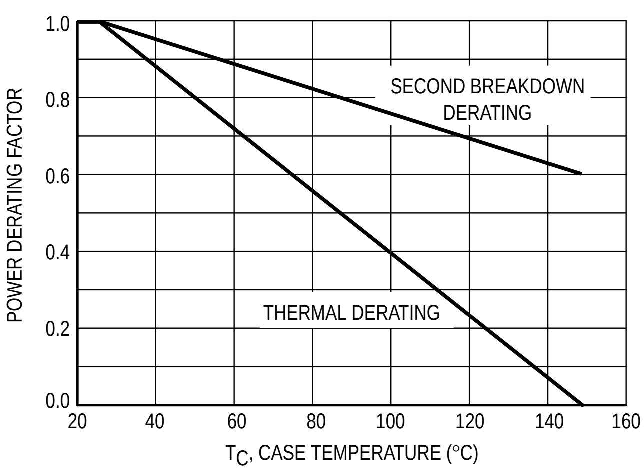


Figure 17. Forward Bias Power Derating

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°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°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 Figure 20 and 21. 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.

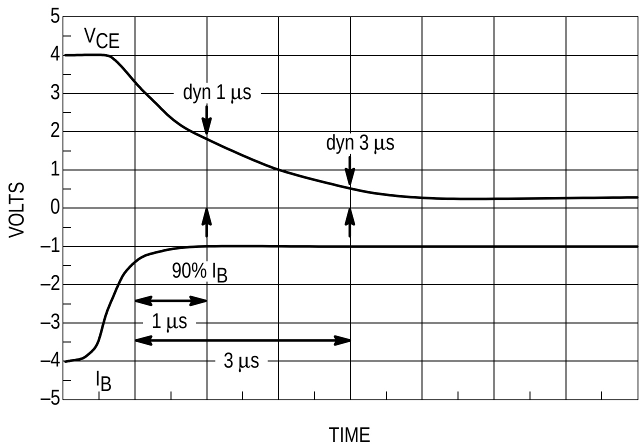


Figure 18. Dynamic Saturation Voltage Measurements

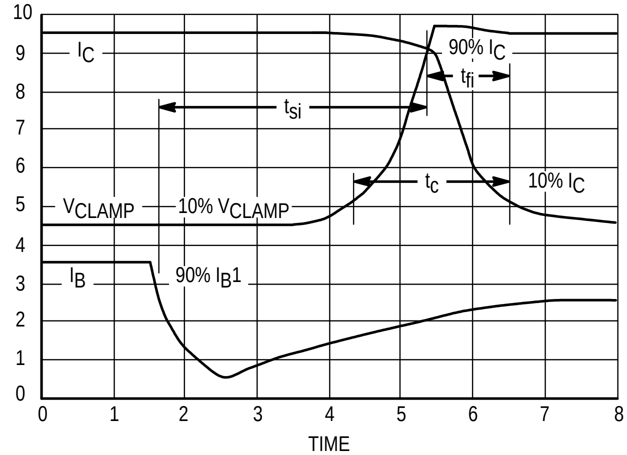
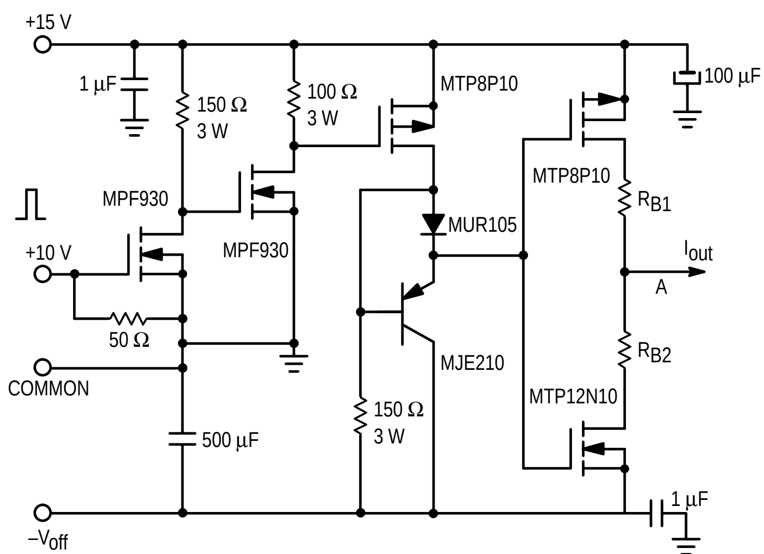
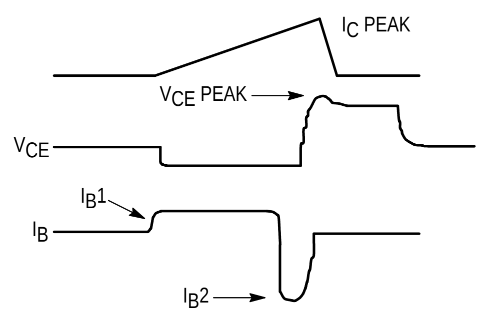


Figure 19. Inductive Switching Measurements





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

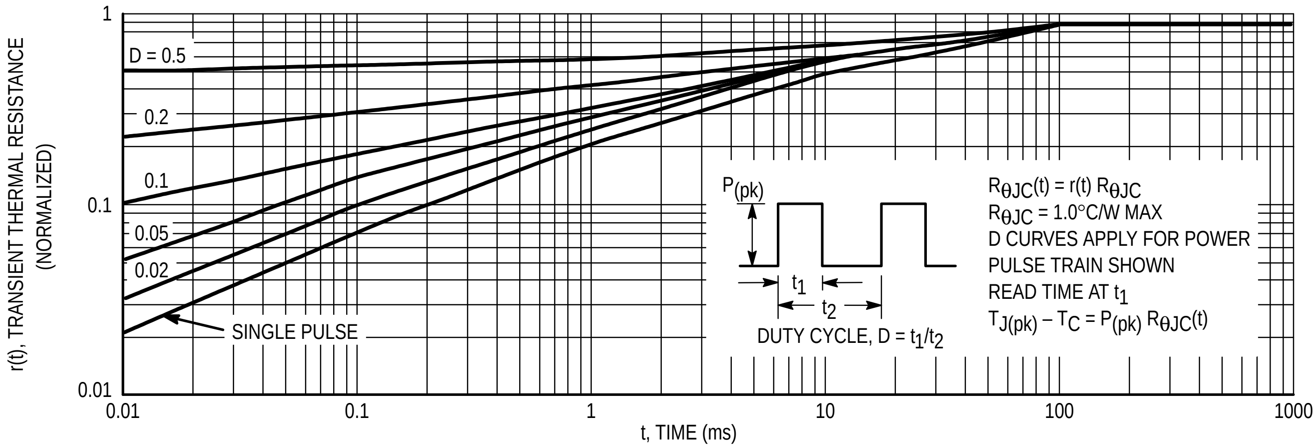


Figure 20. Typical Thermal Response ($Z_{\theta JC}(t)$) for BUL147

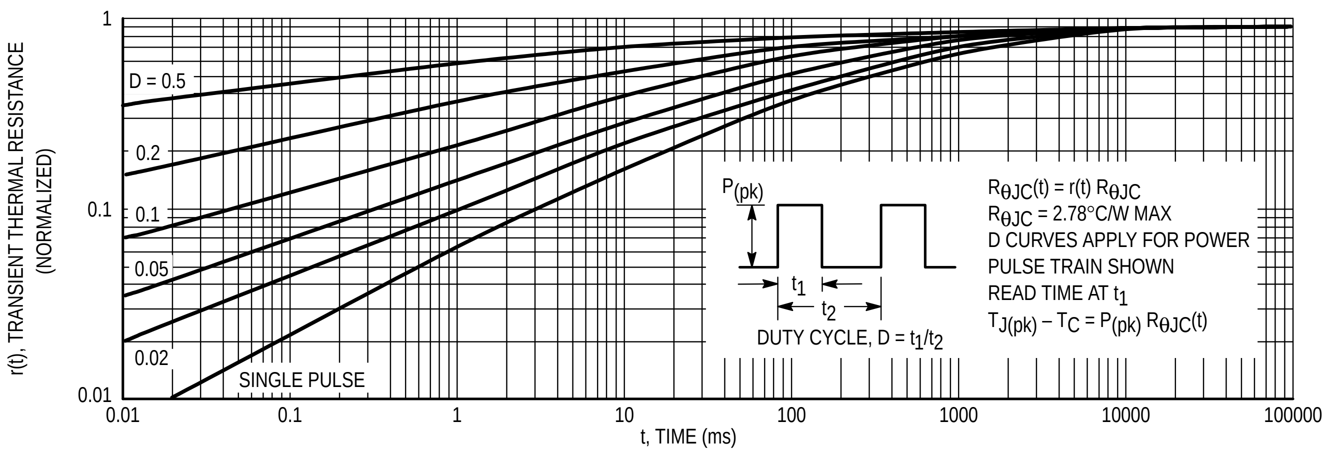


Figure 21. Typical Thermal Response ($Z_{\theta JC}(t)$) for BUL147F

TEST CONDITIONS FOR ISOLATION TESTS*

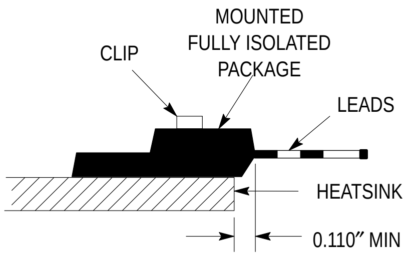


Figure 22a. Screw or Clip Mounting Position for Isolation Test Number 1

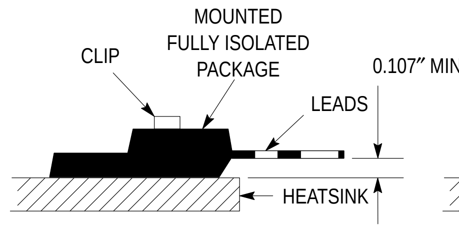


Figure 22b. Clip Mounting Position for Isolation Test Number 2

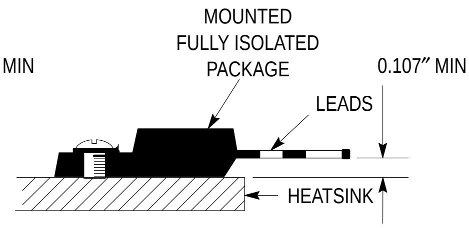


Figure 22c. Screw Mounting Position for Isolation Test Number 3

* Measurement made between leads and heatsink with all leads shorted together.

MOUNTING INFORMATION**

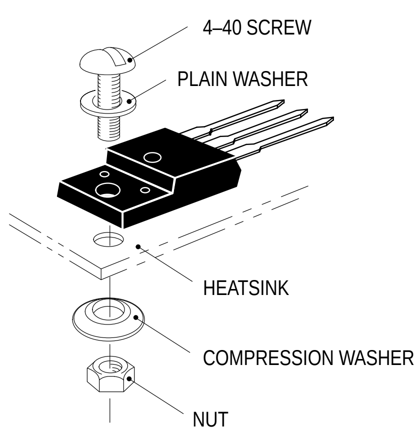


Figure 23a. Screw–Mounted

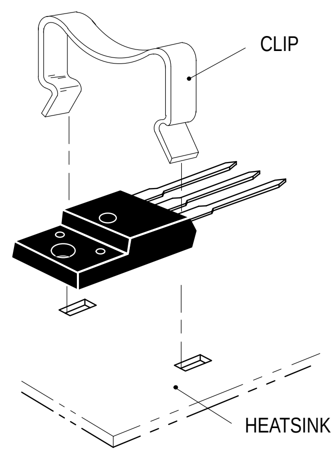


Figure 23b. Clip–Mounted

Figure 23. Typical Mounting Techniques for Isolated Package

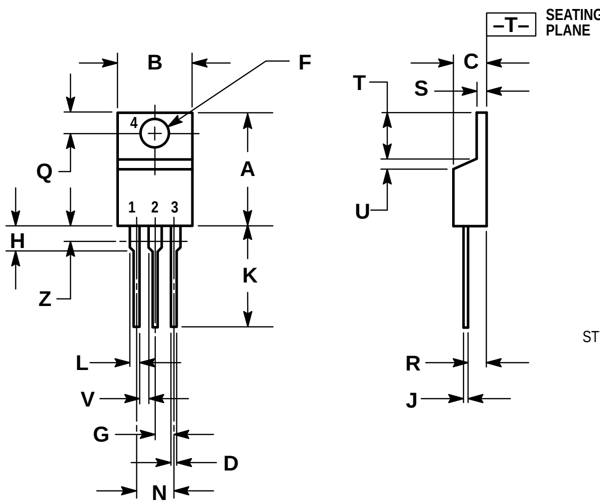
Laboratory tests on a limited number of samples indicate, when using the screw and compression washer mounting technique, a screw torque of 6 to 8 in · lbs is sufficient to provide maximum power dissipation capability. The compression washer helps to maintain a constant pressure on the package over time and during large temperature excursions.

Destructive laboratory tests show that using a hex head 4–40 screw, without washers, and applying a torque in excess of 20 in · lbs will cause the plastic to crack around the mounting hole, resulting in a loss of isolation capability.

Additional tests on slotted 4–40 screws indicate that the screw slot fails between 15 to 20 in · lbs without adversely affecting the package. However, in order to positively ensure the package integrity of the fully isolated device, Motorola does not recommend exceeding 10 in · lbs of mounting torque under any mounting conditions.

** For more information about mounting power semiconductors see Application Note AN1040.

PACKAGE DIMENSIONS

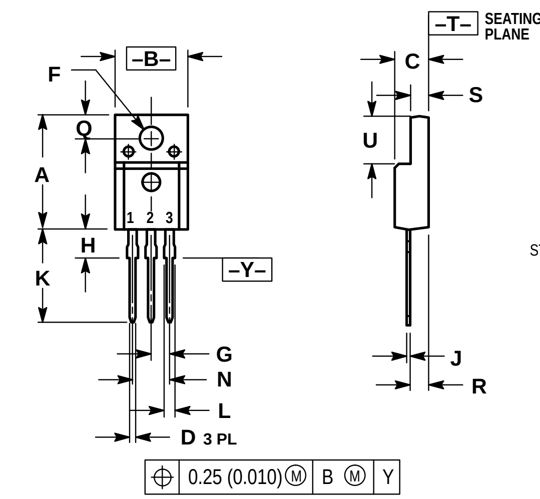


STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

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

BUL44
CASE 221A–06
TO–220AB
ISSUE Y



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

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.621	0.629	15.78	15.97
B	0.394	0.402	10.01	10.21
C	0.181	0.189	4.60	4.80
D	0.026	0.034	0.67	0.86
F	0.121	0.129	3.08	3.27
G	0.100 BSC		2.54 BSC	
H	0.123	0.129	3.13	3.27
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.14	1.52
N	0.200 BSC		5.08 BSC	
Q	0.126	0.134	3.21	3.40
R	0.107	0.111	2.72	2.81
S	0.096	0.104	2.44	2.64
U	0.259	0.267	6.58	6.78

BUL44F
CASE 221D–02
(ISOLATED TO–220 TYPE)
ISSUE D

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