

# BUL146, BUL146F

## SWITCHMODE™

### NPN Bipolar Power Transistor For Switching Power Supply Applications

The BUL146 / BUL146F have an applications specific state-of-the-art die designed for use in fluorescent electric lamp ballasts to 130 W and in Switchmode Power supplies for all types of electronic equipment.

#### Features

- 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)
- Full Characterization at 125°C
- Two Packages Choices: Standard TO-220 or Isolated TO-220
- Parametric Distributions are Tight and Consistent Lot-to-Lot
- BUL146F, Case 221D, is UL Recognized to 3500 V<sub>RMS</sub>: File # E69369
- Pb-Free Packages are Available\*

#### MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Sustaining Voltage	V <sub>CEO</sub>	400	Vdc
Collector-Base Breakdown Voltage	V <sub>CES</sub>	700	Vdc
Emitter-Base Voltage	V <sub>EBO</sub>	9.0	Vdc
Collector Current – Continuous	I <sub>C</sub>	6.0	Adc
– Peak (Note 1)	I <sub>CM</sub>	15	
Base Current – Continuous	I <sub>B</sub>	4.0	Adc
– Peak (Note 1)	I <sub>BM</sub>	8.0	
RMS Isolation Voltage (Note 2) (for 1 sec, R.H. < 30%, T <sub>C</sub> = 25°C)	V <sub>ISOL1</sub> V <sub>ISOL2</sub> V <sub>ISOL3</sub>	<b>BUL146F</b> 4500 3500 1500	V
Total Device Dissipation @ T <sub>C</sub> = 25°C	P <sub>D</sub>		W
BUL146		100	W/°C
BUL146F		40	
Derate above 25°C			
BUL146		0.8	
BUL146F		0.32	
Operating and Storage Temperature	T <sub>J</sub> , T <sub>stg</sub>	-65 to 150	°C

#### THERMAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction-to-Case BUL146 BUL146F	R <sub>θJC</sub>	1.25 3.125	°C/W
Thermal Resistance, Junction-to-Ambient	R <sub>θJA</sub>	62.5	°C/W
Maximum Lead Temperature for Soldering Purposes 1/8" from Case for 5 Seconds	T <sub>L</sub>	260	°C

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

1. Pulse Test: Pulse Width = 5 ms, Duty Cycle ≤ 10%.
2. Proper strike and creepage distance must be provided.

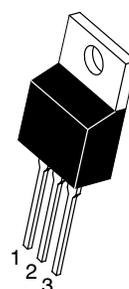


**ON Semiconductor®**

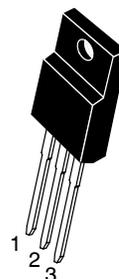
<http://onsemi.com>

**POWER TRANSISTOR  
8.0 AMPERES  
1000 VOLTS  
45 and 125 WATTS**

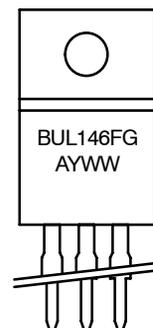
#### MARKING DIAGRAMS



TO-220AB  
CASE 221A-09  
STYLE 1



TO-220 FULLPACK  
CASE 221D  
STYLE 2  
UL RECOGNIZED



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

#### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 8 of this data sheet.

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

# BUL146, BUL146F

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

Characteristic	Symbol	Min	Typ	Max	Unit
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### OFF CHARACTERISTICS

Collector-Emitter Sustaining Voltage ( $I_C = 100\text{ mA}$ , $L = 25\text{ mH}$ )	$V_{CEO(sus)}$	400	-	-	Vdc	
Collector Cutoff Current ( $V_{CE} = \text{Rated } V_{CEO}$ , $I_B = 0$ )	$I_{CEO}$	-	-	100	$\mu\text{Adc}$	
Collector Cutoff Current ( $V_{CE} = \text{Rated } V_{CES}$ , $V_{EB} = 0$ )	$I_{CES}$	-	-	100	$\mu\text{Adc}$	
$(V_{CE} = 500\text{ V}$ , $V_{EB} = 0)$		$(T_C = 125^\circ\text{C})$	-	-		500
		$(T_C = 125^\circ\text{C})$	-	-		100
Emitter Cutoff Current ( $V_{EB} = 9.0\text{ Vdc}$ , $I_C = 0$ )	$I_{EBO}$	-	-	100	$\mu\text{Adc}$	

### ON CHARACTERISTICS

Base-Emitter Saturation Voltage ( $I_C = 1.3\text{ Adc}$ , $I_B = 0.13\text{ Adc}$ ) ( $I_C = 3.0\text{ Adc}$ , $I_B = 0.6\text{ Adc}$ )	$V_{BE(sat)}$	-	0.82	1.1	Vdc	
		-	0.93	1.25		
Collector-Emitter Saturation Voltage ( $I_C = 1.3\text{ Adc}$ , $I_B = 0.13\text{ Adc}$ ) ( $T_C = 125^\circ\text{C}$ ) ( $I_C = 3.0\text{ Adc}$ , $I_B = 0.6\text{ Adc}$ ) ( $T_C = 125^\circ\text{C}$ )	$V_{CE(sat)}$	-	0.22	0.5	Vdc	
		-	0.20	0.5		
		-	0.30	0.7		
		-	0.30	0.7		
DC Current Gain ( $I_C = 0.5\text{ Adc}$ , $V_{CE} = 5.0\text{ Vdc}$ )  ( $I_C = 1.3\text{ Adc}$ , $V_{CE} = 1.0\text{ Vdc}$ )  ( $I_C = 3.0\text{ Adc}$ , $V_{CE} = 1.0\text{ Vdc}$ )  ( $I_C = 10\text{ mAdc}$ , $V_{CE} = 5.0\text{ Vdc}$ )	$h_{FE}$	14	-	34	-	
		$(T_C = 125^\circ\text{C})$	-	30		-
		$(T_C = 125^\circ\text{C})$	12	20		-
		$(T_C = 125^\circ\text{C})$	12	20		-
		$(T_C = 125^\circ\text{C})$	8.0	13		-
	$(T_C = 125^\circ\text{C})$	7.0	12	-		
	$(T_C = 125^\circ\text{C})$	10	20	-		

### DYNAMIC CHARACTERISTICS

Current Gain Bandwidth ( $I_C = 0.5\text{ Adc}$ , $V_{CE} = 10\text{ Vdc}$ , $f = 1.0\text{ MHz}$ )	$f_T$	-	14	-	MHz		
Output Capacitance ( $V_{CB} = 10\text{ Vdc}$ , $I_E = 0$ , $f = 1.0\text{ MHz}$ )	$C_{OB}$	-	95	150	pF		
Input Capacitance ( $V_{EB} = 8.0\text{ V}$ )	$C_{IB}$	-	1000	1500	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)	$(I_C = 1.3\text{ Adc}$ $I_{B1} = 300\text{ mAdc}$ $V_{CC} = 300\text{ V}$ )	1.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	2.5	-	V
		3.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	6.5	-	
	$(I_C = 3.0\text{ Adc}$ $I_{B1} = 0.6\text{ Adc}$ $V_{CC} = 300\text{ V}$ )	1.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	0.6	-	
		3.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	2.5	-	
		1.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	3.0	-	
		3.0 $\mu\text{s}$	$(T_C = 125^\circ\text{C})$	-	7.0	-	
				-	0.75	-	
				-	1.4	-	

# BUL146, BUL146F

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

Characteristic	Symbol	Min	Typ	Max	Unit
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### SWITCHING CHARACTERISTICS: Resistive Load (D.C. $\leq 10\%$ , Pulse Width = 20 $\mu\text{s}$ )

Turn-On Time	$(I_C = 1.3 \text{ Adc}, I_{B1} = 0.13 \text{ Adc}$ $I_{B2} = 0.65 \text{ Adc}, V_{CC} = 300 \text{ V})$	$(T_C = 125^\circ\text{C})$	$t_{on}$	–	100	200	ns
Turn-Off Time			$t_{off}$	–	1.35	2.5	$\mu\text{s}$
Turn-On Time	$(I_C = 3.0 \text{ Adc}, I_{B1} = 0.6 \text{ Adc}$ $I_{B1} = 1.5 \text{ Adc}, V_{CC} = 300 \text{ V})$	$(T_C = 125^\circ\text{C})$	$t_{on}$	–	90	150	ns
Turn-Off Time			$t_{off}$	–	1.7	2.5	$\mu\text{s}$
		$(T_C = 125^\circ\text{C})$		–	2.1	–	

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

Fall Time	$(I_C = 1.3 \text{ Adc}, I_{B1} = 0.13 \text{ Adc}$ $I_{B2} = 0.65 \text{ Adc})$	$(T_C = 125^\circ\text{C})$	$t_{fi}$	–	115	200	ns
Storage Time			$t_{si}$	–	1.35	2.5	$\mu\text{s}$
Crossover Time			$t_c$	–	200	350	ns
		$(T_C = 125^\circ\text{C})$		–	210	–	
Fall Time	$(I_C = 3.0 \text{ Adc}, I_{B1} = 0.6 \text{ Adc}$ $I_{B2} = 1.5 \text{ Adc})$	$(T_C = 125^\circ\text{C})$	$t_{fi}$	–	85	150	ns
Storage Time			$t_{si}$	–	1.75	2.5	$\mu\text{s}$
Crossover Time			$t_c$	–	175	300	ns
		$(T_C = 125^\circ\text{C})$		–	200	–	
Fall Time	$(I_C = 3.0 \text{ Adc}, I_{B1} = 0.6 \text{ Adc}$ $I_{B2} = 0.6 \text{ Adc})$	$(T_C = 125^\circ\text{C})$	$t_{fi}$	80	–	180	ns
Storage Time			$t_{si}$	2.6	–	3.8	$\mu\text{s}$
Crossover Time			$t_c$	–	230	350	ns
		$(T_C = 125^\circ\text{C})$		–	400	–	

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## TYPICAL STATIC CHARACTERISTICS

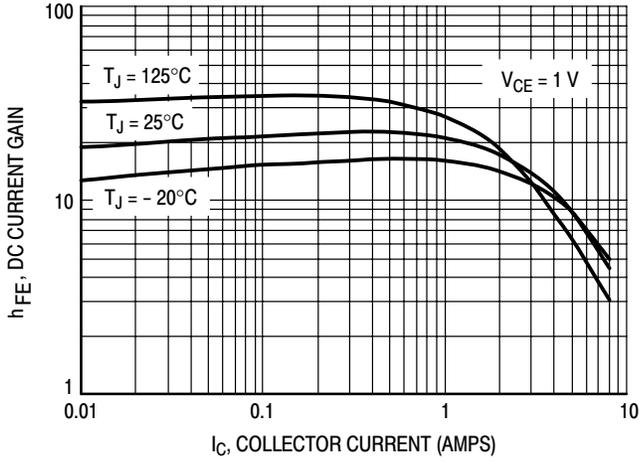


Figure 1. DC Current Gain @ 1 Volt

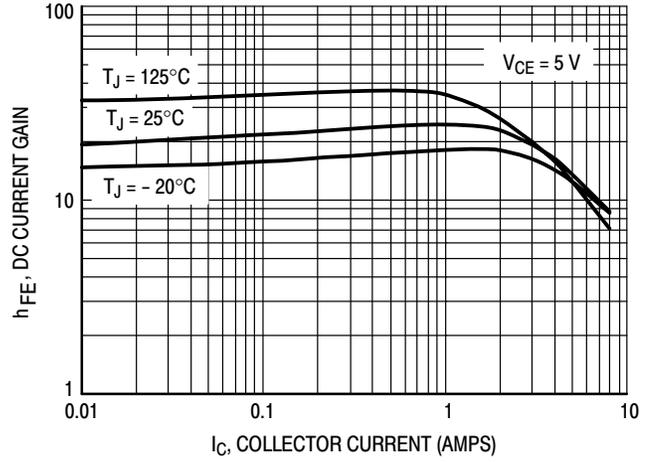


Figure 2. DC Current Gain @ 5 Volts

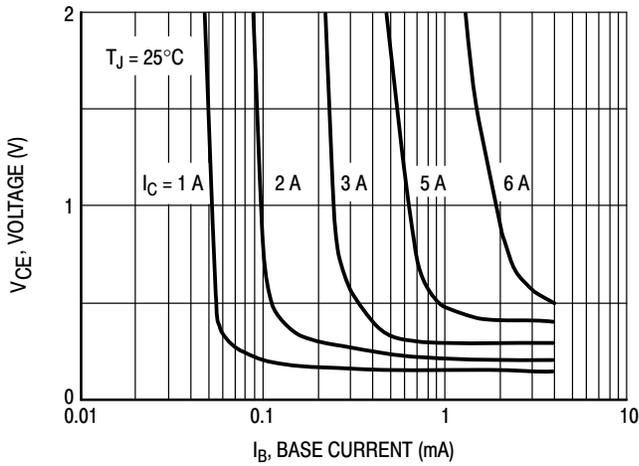


Figure 3. Collector Saturation Region

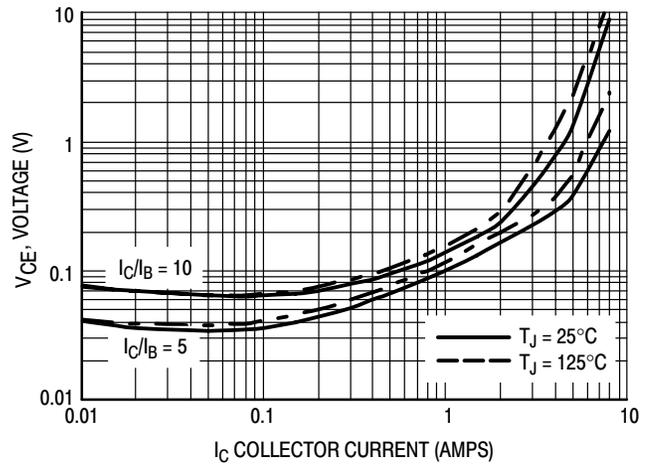


Figure 4. Collector-Emitter Saturation Voltage

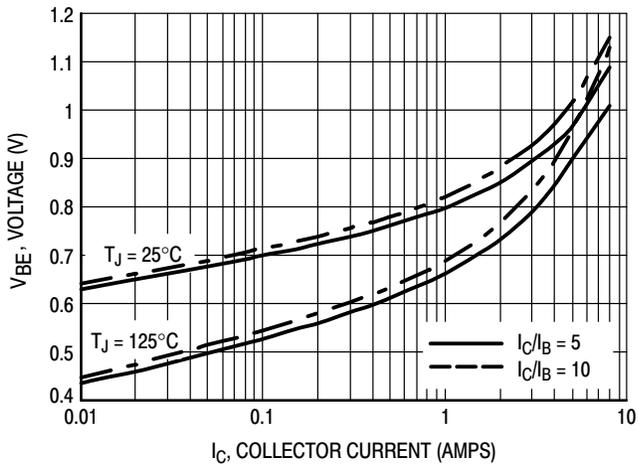


Figure 5. Base-Emitter Saturation Region

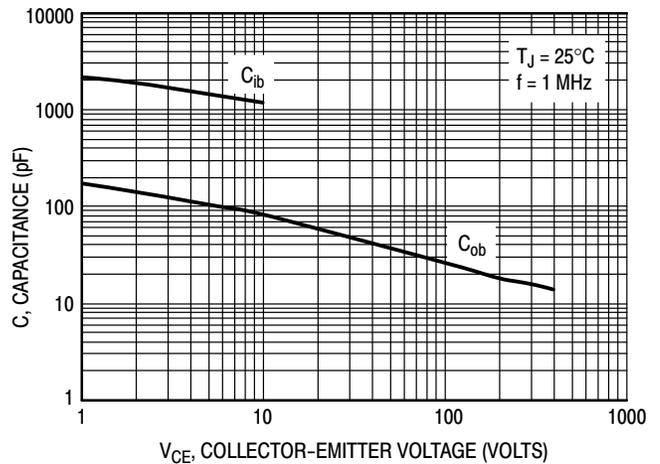


Figure 6. Capacitance

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

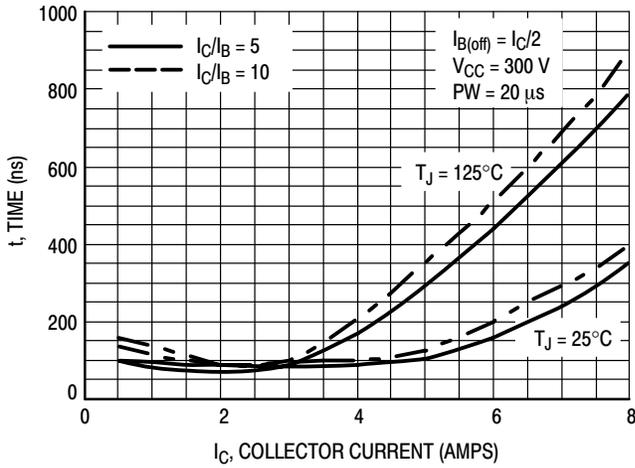


Figure 7. Resistive Switching,  $t_{on}$

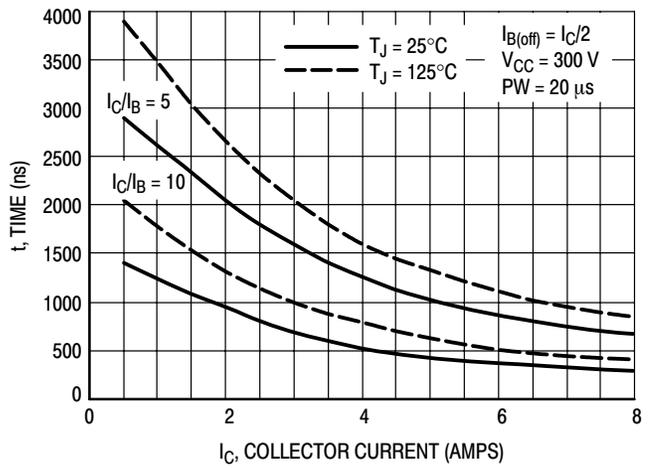


Figure 8. Resistive Switching,  $t_{off}$

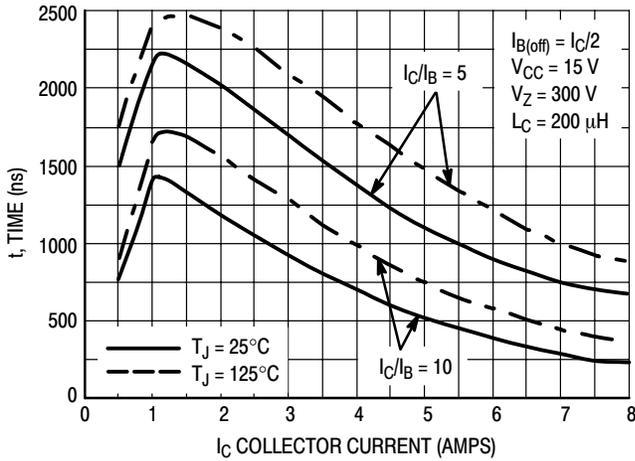


Figure 9. Inductive Storage Time,  $t_{si}$

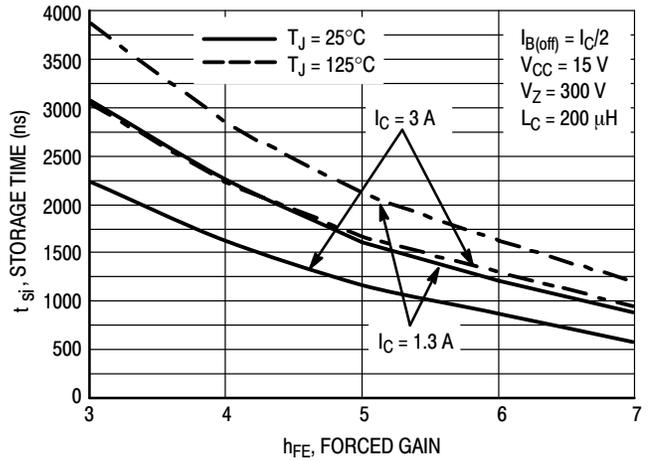


Figure 10. Inductive Storage Time,  $t_{si}(h_{FE})$

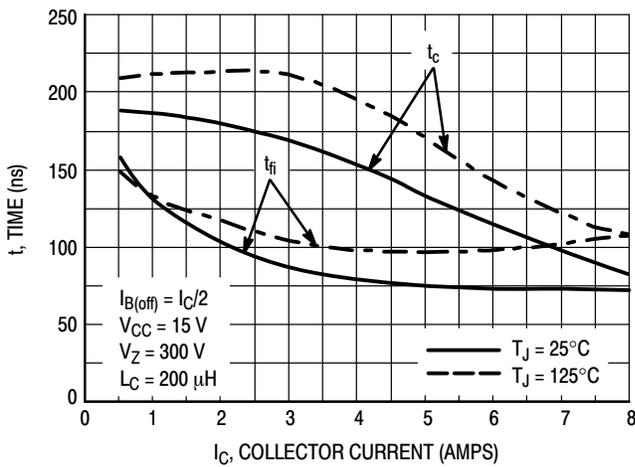


Figure 11. Inductive Switching,  $t_c$  and  $t_{fi}$   
 $I_C/I_B = 5$

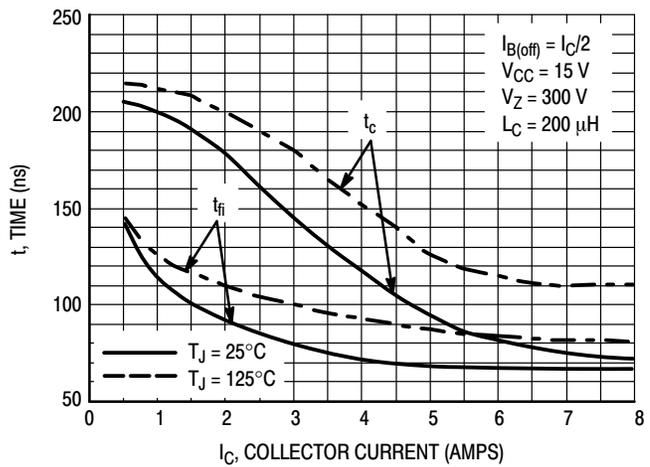


Figure 12. Inductive Switching,  $t_c$  and  $t_{fi}$   
 $I_C/I_B = 10$

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

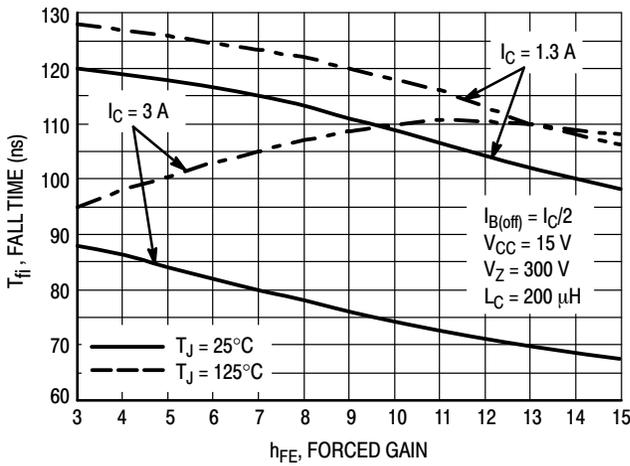


Figure 13. Inductive Fall Time

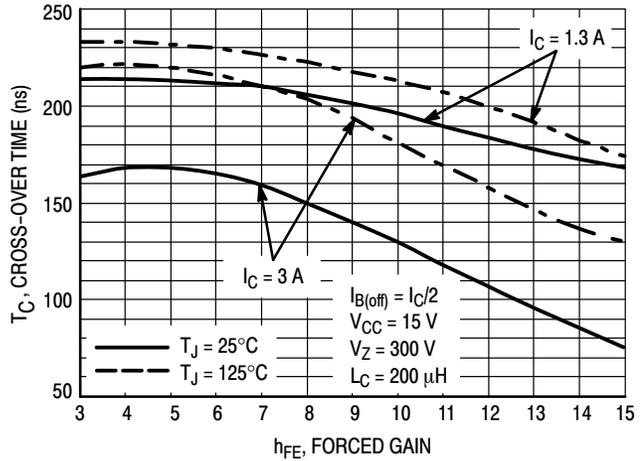


Figure 14. Inductive Cross-Over Time

**GUARANTEED SAFE OPERATING AREA INFORMATION**

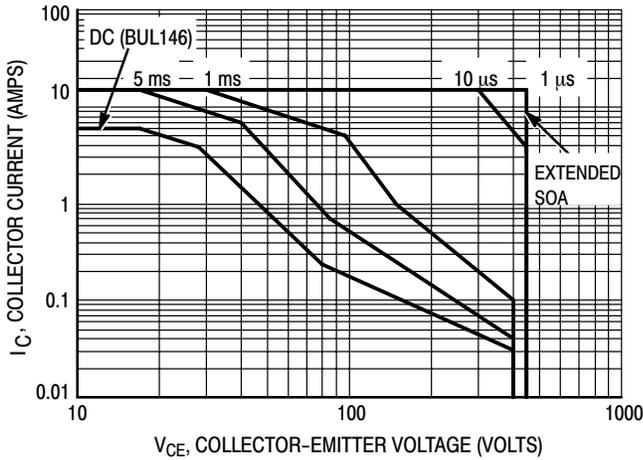


Figure 15. Forward Bias Safe Operating Area

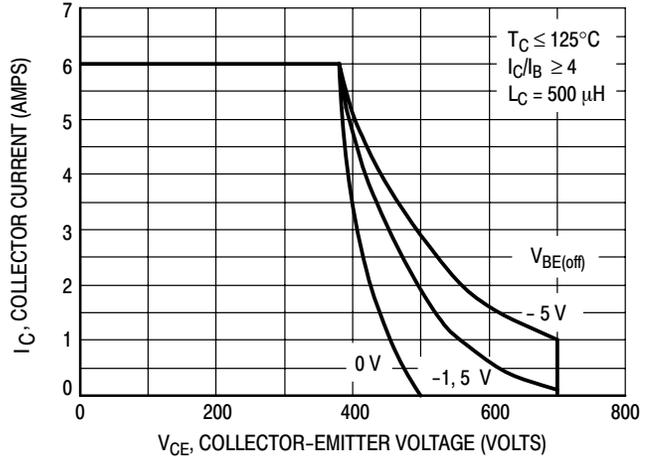


Figure 16. Reverse Bias Switching Safe Operating Area

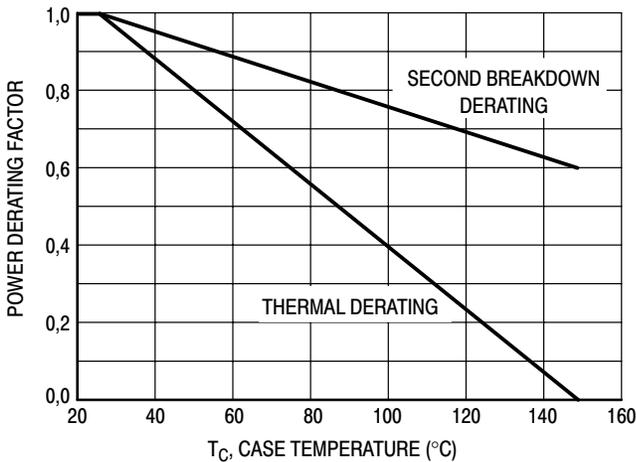


Figure 17. Forward Bias Power Derating

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  $T_C = 25^\circ\text{C}$ ;  $T_{J(pk)}$  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 in Figure 15 may be found at any case temperature by using the appropriate curve as Figure 17.  $T_{J(pk)}$  may be calculated from the data in Figure 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.

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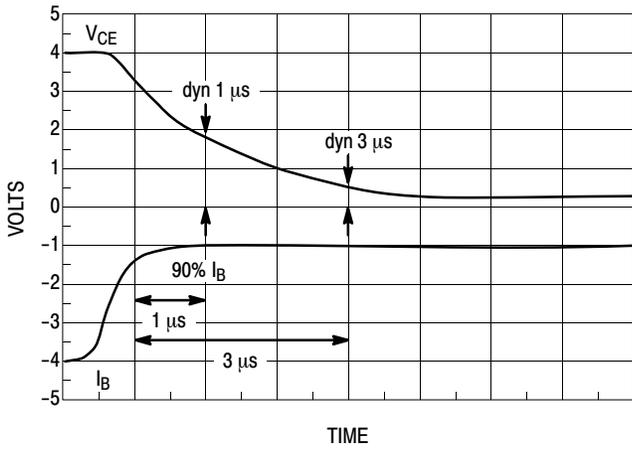


Figure 18. Dynamic Saturation Voltage Measurements

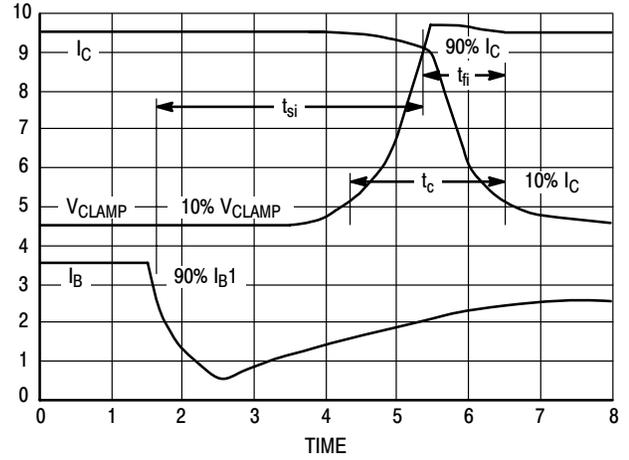
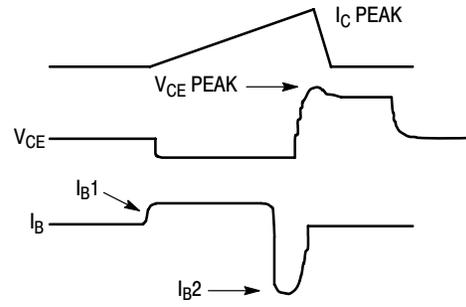
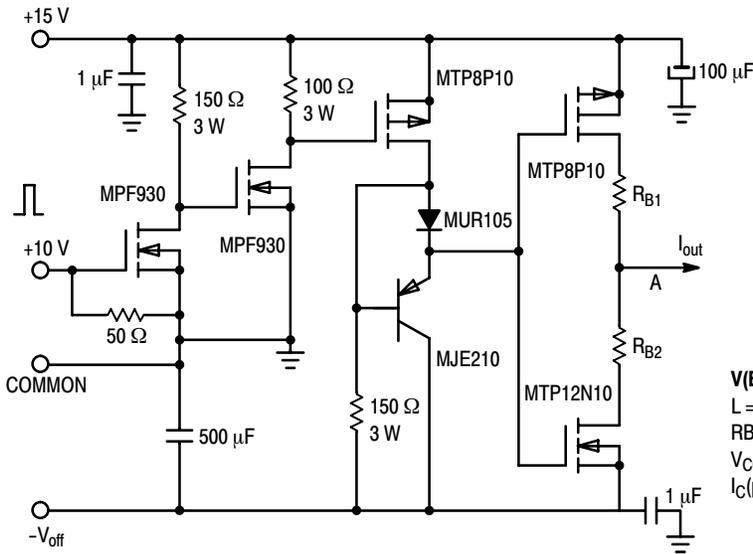


Figure 19. Inductive Switching Measurements



$V(BR)CEO(sus)$	INDUCTIVE SWITCHING	RBSOA
$L = 10 \text{ mH}$	$L = 200 \mu\text{H}$	$L = 500 \mu\text{H}$
$RB2 = \infty$	$RB2 = 0$	$RB2 = 0$
$V_{CC} = 20 \text{ VOLTS}$	$V_{CC} = 15 \text{ VOLTS}$	$V_{CC} = 15 \text{ VOLTS}$
$I_C(pk) = 100 \text{ mA}$	$RB1 \text{ SELECTED FOR DESIRED } I_{B1}$	$RB1 \text{ SELECTED FOR DESIRED } I_{B1}$

Table 1. Inductive Load Switching Drive Circuit

# BUL146, BUL146F

## TYPICAL THERMAL RESPONSE

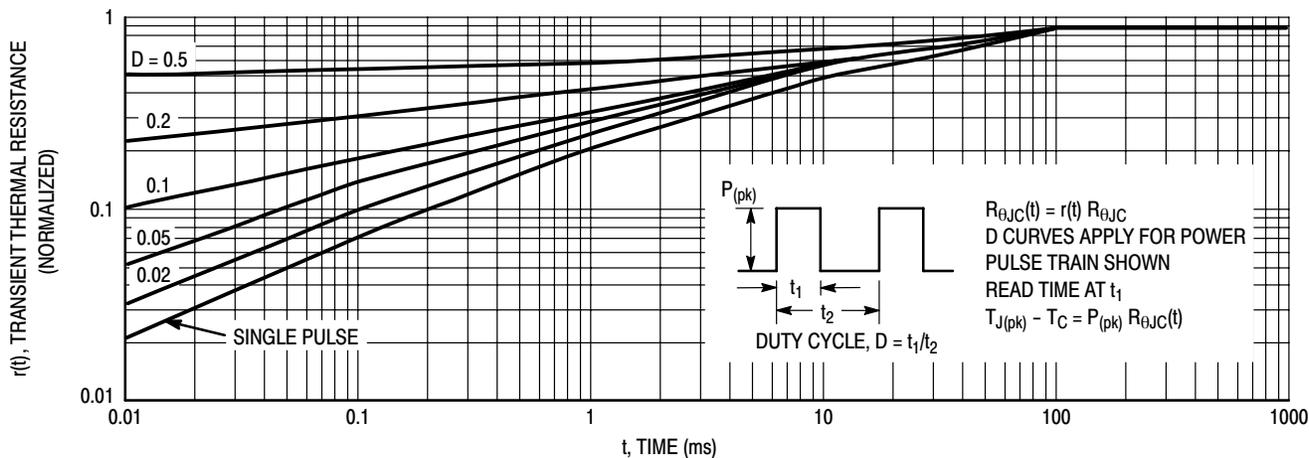


Figure 20. Typical Thermal Response ( $Z_{\theta JC}(t)$ ) for BUL146

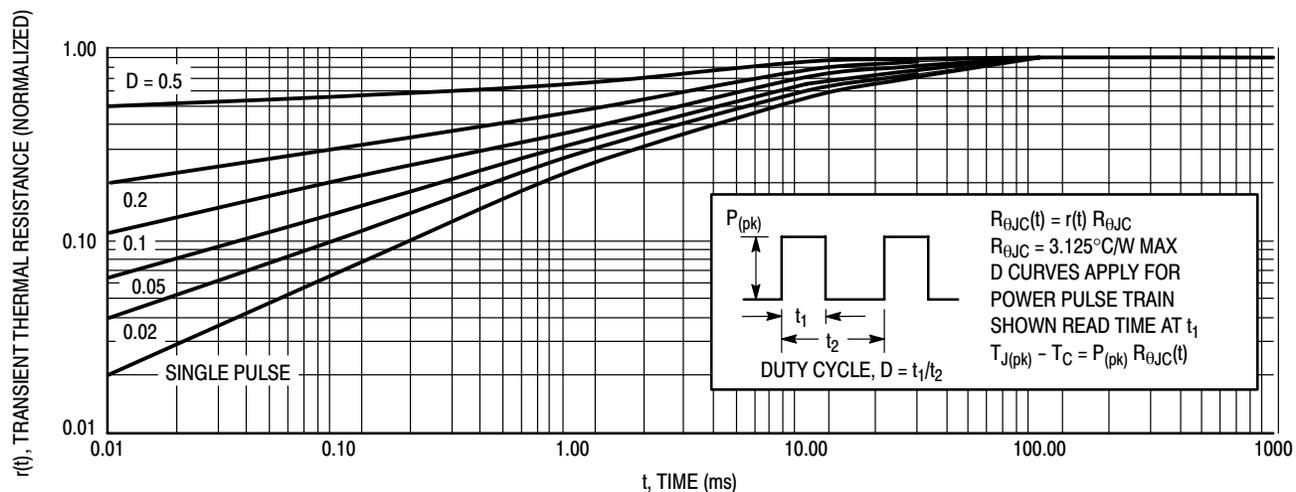


Figure 21. Typical Thermal Response for BUL146F

### ORDERING INFORMATION

Device	Package	Shipping
BUL146	TO-220AB	50 Units / Rail
BUL146G	TO-220AB (Pb-Free)	50 Units / Rail
BUL146F	TO-220 (Fullpack)	50 Units / Rail
BUL146FG	TO-220 (Fullpack) (Pb-Free)	50 Units / Rail

TEST CONDITIONS FOR ISOLATION TESTS\*

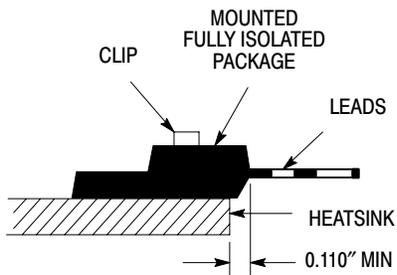


Figure 22a. Screw or Clip Mounting Position for Isolation Test Number 1

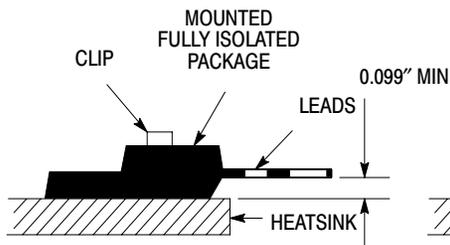


Figure 22b. Clip Mounting Position for Isolation Test Number 2

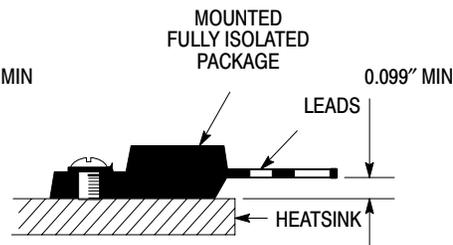


Figure 22c. Screw Mounting Position for Isolation Test Number 3

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

MOUNTING INFORMATION\*\*

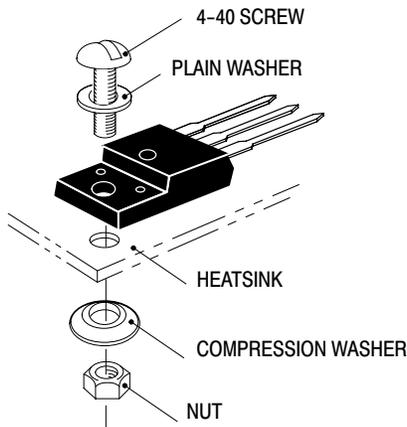


Figure 23a. Screw-Mounted

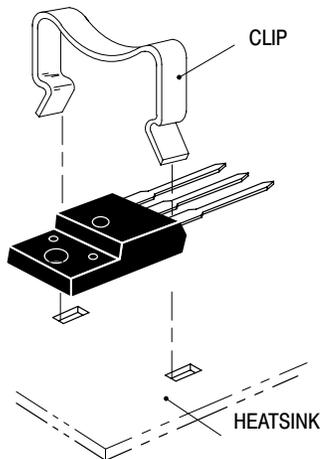


Figure 23b. Clip-Mounted

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.

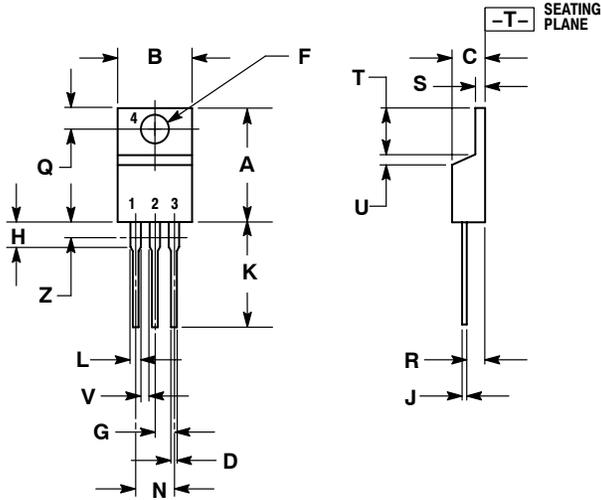
Additional tests on slotted 4-40 screws indicate that the screw slot fails between 15 to 20 in · lbs without adversely affecting the package. However, in order to positively ensure the package integrity of the fully isolated device, ON Semiconductor does not recommend exceeding 10 in · lbs of mounting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

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

# BUL146, BUL146F

## PACKAGE DIMENSIONS

### TO-220AB CASE 221A-09 ISSUE AA

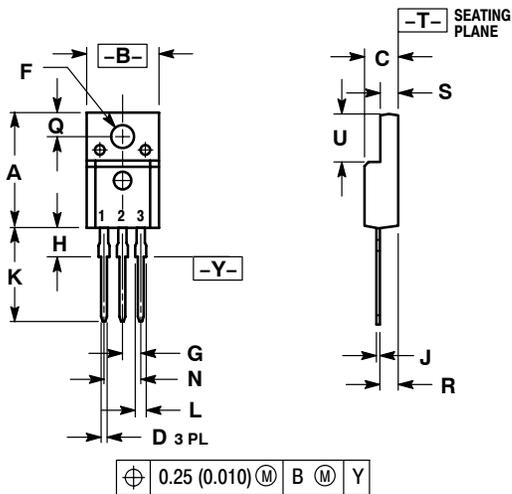


- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: INCH.
  3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

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

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

### TO-220 FULLPAK CASE 221D-03 ISSUE G



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: INCH
  3. 221D-01 THRU 221D-02 OBSOLETE, NEW STANDARD 221D-03.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.625	0.635	15.88	16.12
B	0.408	0.418	10.37	10.63
C	0.180	0.190	4.57	4.83
D	0.026	0.031	0.65	0.78
F	0.116	0.119	2.95	3.02
G	0.100 BSC		2.54 BSC	
H	0.125	0.135	3.18	3.43
J	0.018	0.025	0.45	0.63
K	0.530	0.540	13.47	13.73
L	0.048	0.053	1.23	1.36
N	0.200 BSC		5.08 BSC	
Q	0.124	0.128	3.15	3.25
R	0.099	0.103	2.51	2.62
S	0.101	0.113	2.57	2.87
U	0.238	0.258	6.06	6.56

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

# BUL146, BUL146F

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