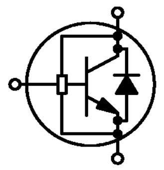
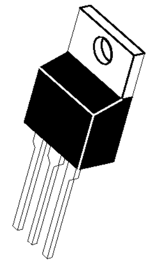
MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by BUL45D2/D

BUL45D2

POWER TRANSISTORS
5 AMPERES
700 VOLTS
75 WATTS





CASE 221A–06
TO–220AB

Designer's™ Data Sheet

High Speed, High Gain Bipolar NPN Power Transistor with Integrated Collector-Emitter Diode and Built-in Efficient Antisaturation Network

The BUL45D2 is state–of–art High Speed High gain BIPolar transistor (H2BIP). High dynamic characteristics and lot to lot minimum spread (±150 ns on storage time) make it ideally suitable for light ballast applications. Therefore, there is no need to guarantee an h_{FE} window.

Main features:

- Low Base Drive Requirement
- High Peak DC Current Gain (55 Typical) @ I_C = 100 mA
- **Extremely Low Storage Time Min/Max Guarantees Due to the H2BIP Structure which Minimizes the Spread**
- Integrated Collector–Emitter Free Wheeling Diode
- Fully Characterized and Guaranteed Dynamic $V_{CE(sat)}$
- "6 Sigma" Process Providing Tight and Reproductible Parameter Spreads

It's characteristics make it also suitable for PFC application.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Sustaining Voltage	V_{CEO}	400	Vdc
Collector–Base Breakdown Voltage	V_{CBO}	700	Vdc
Collector–Emitter Breakdown Voltage	V_{CES}	700	Vdc
Emitter–Base Voltage	V_{EBO}	12	Vdc
Collector Current — Continuous — Peak (1)	I_C I_{CM}	5 10	Adc
Base Current — Continuous — Peak (1)	I_B I_{BM}	2 4	Adc
*Total Device Dissipation @ T_C = 25°C *Derate above 25°C	P_D	75 0.6	Watt W/°C
Operating and Storage Temperature	T_J, T_{stg}	–65 to 150	°C

THERMAL CHARACTERISTICS

Thermal Resistance — Junction to Case — Junction to Ambient	 $R_{\theta JC}$ $R_{\theta JA}$	 1.65 62.5	°C/W
Maximum Lead Temperature for Soldering Purposes: 1/8″ from case for 5 seconds	T_L	260	°C

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

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.

MOTOROLA

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	450		Vdc
Collector–Base Breakdown Voltage (I_{CBO} = 1 mA)		V_{CBO}	700	910		Vdc
Emitter–Base Breakdown Voltage (I_{EBO} = 1 mA)		V_{EBO}	12	14.1		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 = 25°C @ T_C = 125°C	I_{CES}			100 500	µAdc
(V_{CE} = 500 V, V_{EB} = 0)	@ T_C = 125°C				100	
Emitter–Cutoff Current (V_{EB} = 10 Vdc, I_C = 0)		I_{EBO}			100	µAdc
ON CHARACTERISTICS						
Base–Emitter Saturation Voltage (I_C = 0.8 Adc, I_B = 80 mAdc)	@ T_C = 25°C @ T_C = 125°C	$V_{BE(sat)}$		0.8 0.7	1 0.9	Vdc
(I_C = 2 Adc, I_B = 0.4 Adc)	@ T_C = 25°C @ T_C = 125°C			0.89 0.79	1 0.9	
Collector–Emitter Saturation Voltage (I_C = 0.8 Adc, I_B = 80 mAdc)	@ T_C = 25°C @ T_C = 125°C	$V_{CE(sat)}$		0.28 0.32	0.4 0.5	Vdc
(I_C = 2 Adc, I_B = 0.4 Adc)	@ T_C = 25°C @ T_C = 125°C			0.32 0.38	0.5 0.6	
(I_C = 0.8 Adc, I_B = 40 mAdc)	@ T_C = 25°C @ T_C = 125°C			0.46 0.62	0.75 1	
DC Current Gain (I_C = 0.8 Adc, V_{CE} = 1 Vdc)	@ T_C = 25°C @ T_C = 125°C	h_{FE}	22 20	34 29		—
(I_C = 2 Adc, V_{CE} = 1 Vdc)	@ T_C = 25°C @ T_C = 125°C		10 7	14 9.5		
DIODE CHARACTERISTICS						
Forward Diode Voltage (I_{EC} = 1 Adc)	@ T_C = 25°C @ T_C = 125°C	V_{EC}		1.04 0.7	1.5	V
(I_{EC} = 2 Adc)	@ T_C = 25°C @ T_C = 125°C			1.2	1.6	
(I_{EC} = 0.4 Adc)	@ T_C = 25°C @ T_C = 125°C			0.85 0.62	1.2	
Forward Recovery Time (see Figure 27) (I_F = 1 Adc, di/dt = 10 A/µs)	@ T_C = 25°C	T_{fr}		330		ns
(I_F = 2 Adc, di/dt = 10 A/µs)	@ T_C = 25°C			360		
(I_F = 0.4 Adc, di/dt = 10 A/µs)	@ T_C = 25°C			320		

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

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Current Gain Bandwidth (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1 MHz)	f_T		13		MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}		50	75	pF
Input Capacitance (V_{EB} = 8 Vdc)	C_{ib}		340	500	pF

DYNAMIC SATURATION VOLTAGE

Characteristic				Symbol	Min	Typ	Max	Unit
Dynamic Saturation Voltage: Determined 1 µs and 3 µs respectively after rising I_{B1} reaches 90% of final I_{B1}	I_C = 1 A I_{B1} = 100 mA V_{CC} = 300 V	@ 1 µs	@ T_C = 25°C @ T_C = 125°C	$V_{CE(dsat)}$		3.7 9.4		V
		@ 3 µs	@ T_C = 25°C @ T_C = 125°C			0.35 2.7		V
	I_C = 2 A I_{B1} = 0.8 A V_{CC} = 300 V	@ 1 µs	@ T_C = 25°C @ T_C = 125°C			3.9 12		V
		@ 3 µs	@ T_C = 25°C @ T_C = 125°C			0.4 1.5		V

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

Characteristic			Symbol	Min	Typ	Max	Unit
Turn–on Time	I_C = 2 Adc, I_{B1} = 0.4 Adc I_{B2} = 1 Adc V_{CC} = 300 Vdc	@ T_C = 25°C @ T_C = 125°C	t_{on}		90 105	150	ns
Turn–off Time		@ T_C = 25°C @ T_C = 125°C	t_{off}		1.15 1.5	1.3	µs
Turn–on Time	I_C = 2 Adc, I_{B1} = 0.4 Adc I_{B2} = 0.4 Adc V_{CC} = 300 Vdc	@ T_C = 25°C @ T_C = 125°C	t_{on}		90 110	150	ns
Turn–off Time		@ T_C = 25°C @ T_C = 125°C	t_{off}	2.1	 3.1	2.4	µs

SWITCHING CHARACTERISTICS: Inductive Load (V_{clamp} = 300 V, V_{CC} = 15 V, L = 200 µH)

Characteristic			Symbol	Min	Typ	Max	Unit
Fall Time	I_C = 1 Adc I_{B1} = 100 mAdc I_{B2} = 500 mAdc	@ T_C = 25°C @ T_C = 125°C	t_f		90 93	150	ns
Storage Time		@ T_C = 25°C @ T_C = 125°C	t_s		0.72 1.05	0.9	µs
Crossover Time		@ T_C = 25°C @ T_C = 125°C	t_c		95 95	150	ns
Fall Time	I_C = 2 Adc I_{B1} = 0.4 Adc I_{B2} = 0.4 Adc	@ T_C = 25°C @ T_C = 125°C	t_f		80 105	150	ns
Storage Time		@ T_C = 25°C @ T_C = 125°C	t_s	1.95	 2.9	2.25	µs
Crossover Time		@ T_C = 25°C @ T_C = 125°C	t_c		225 450	300	ns

TYPICAL STATIC CHARACTERISTICS

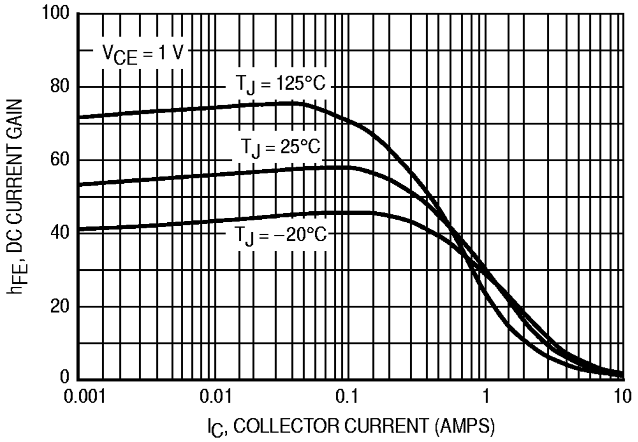


Figure 1. DC Current Gain @ 1 Volt

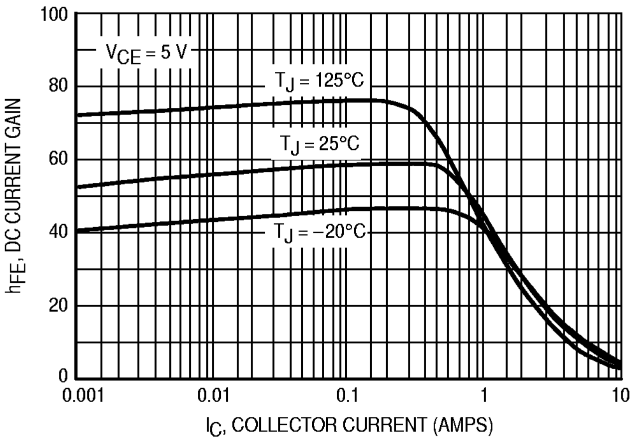


Figure 2. DC Current Gain @ 5 Volt

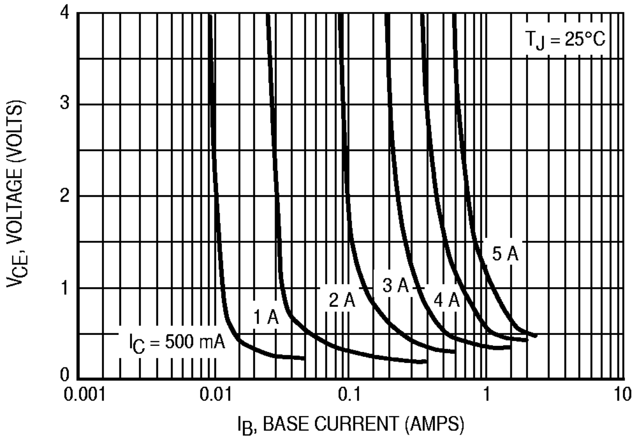


Figure 3. Collector Saturation Region

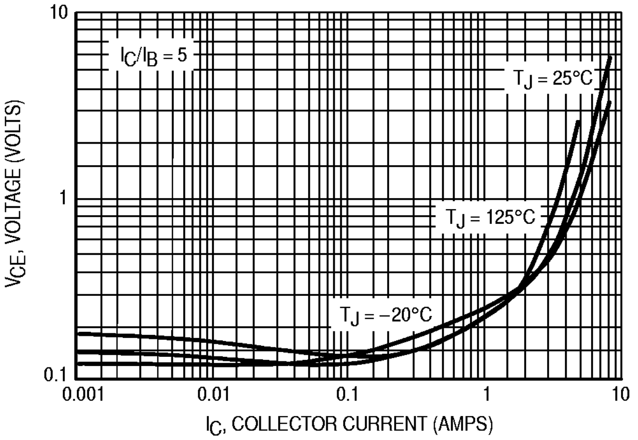


Figure 4. Collector–Emitter Saturation Voltage

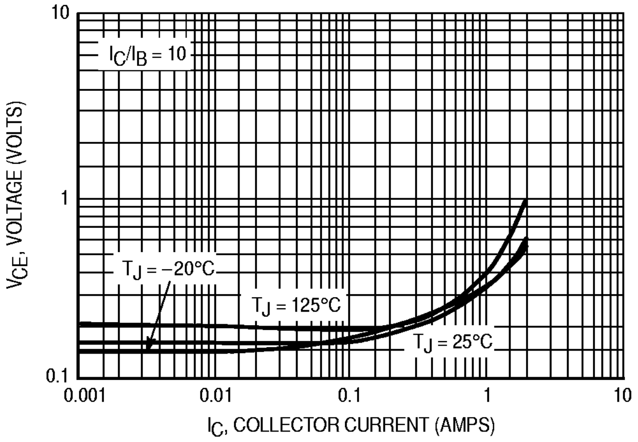


Figure 5. Collector–Emitter Saturation Voltage

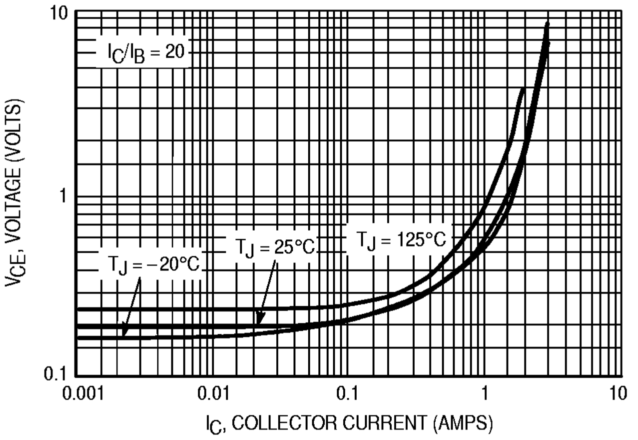


Figure 6. Collector–Emitter Saturation Voltage

TYPICAL STATIC CHARACTERISTICS

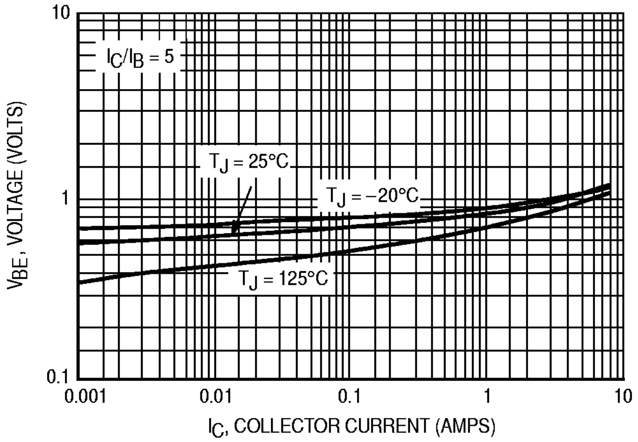


Figure 7. Base–Emitter Saturation Region

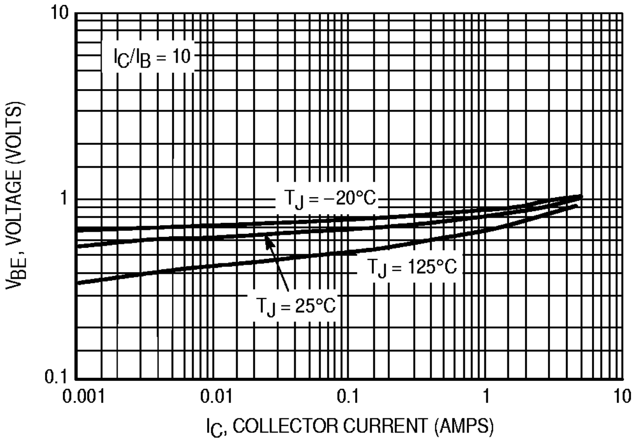


Figure 8. Base–Emitter Saturation Region

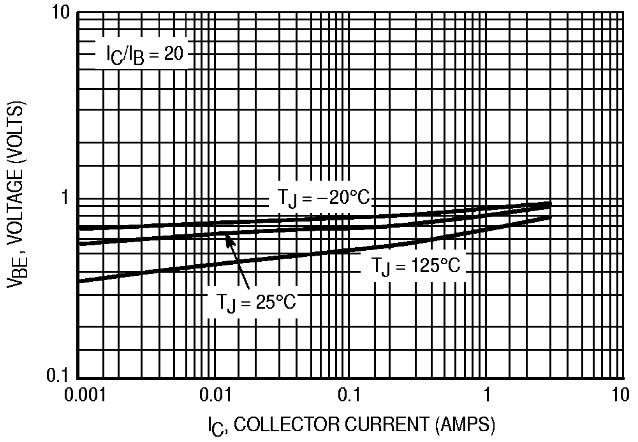


Figure 9. Base–Emitter Saturation Region

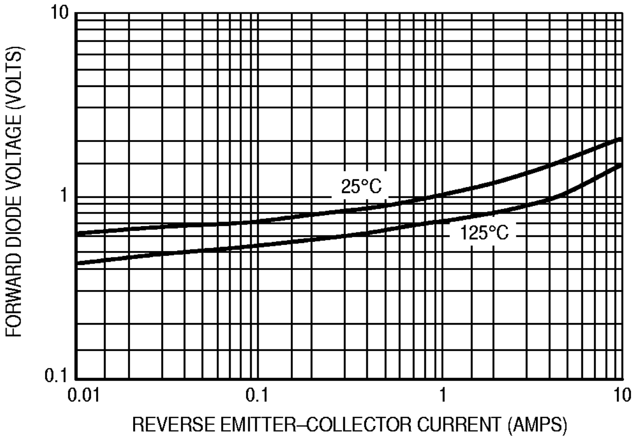


Figure 10. Forward Diode Voltage

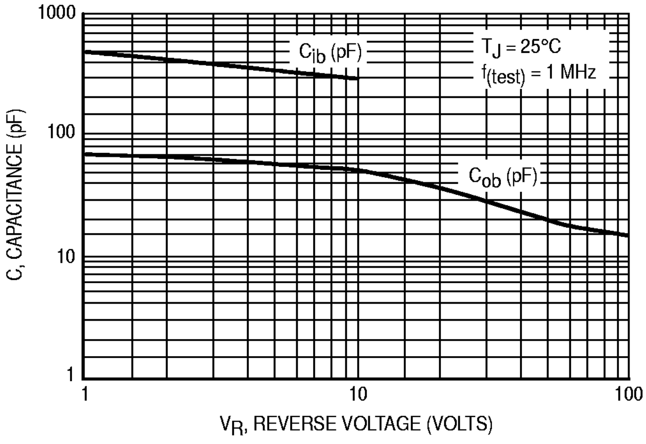


Figure 11. Capacitance

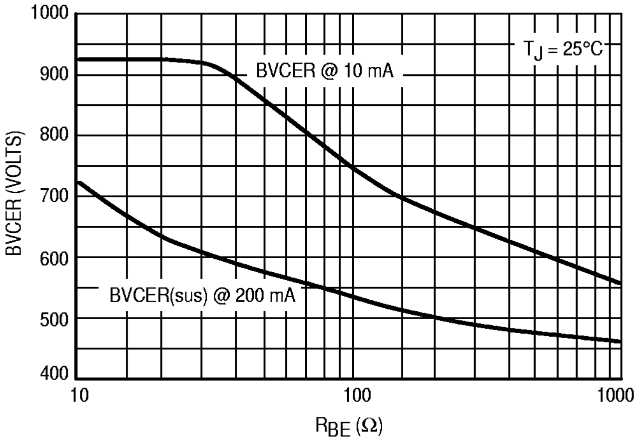


Figure 12. BVCER = f(ICER)

TYPICAL SWITCHING CHARACTERISTICS

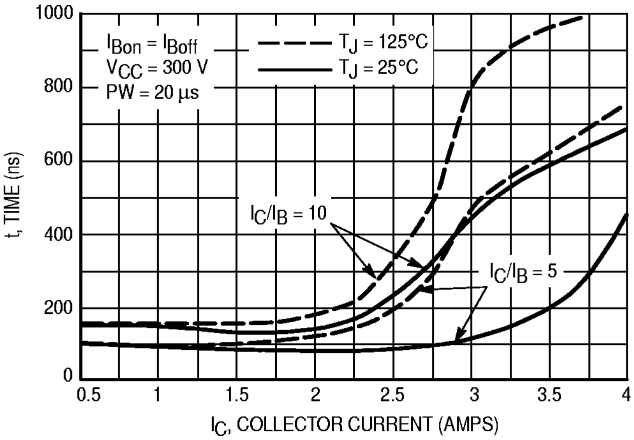


Figure 13. Resistive Switch Time, t_{on}

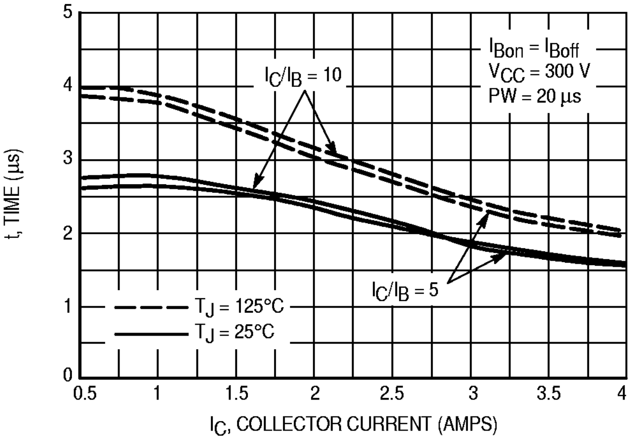


Figure 14. Resistive Switch Time, t_{off}

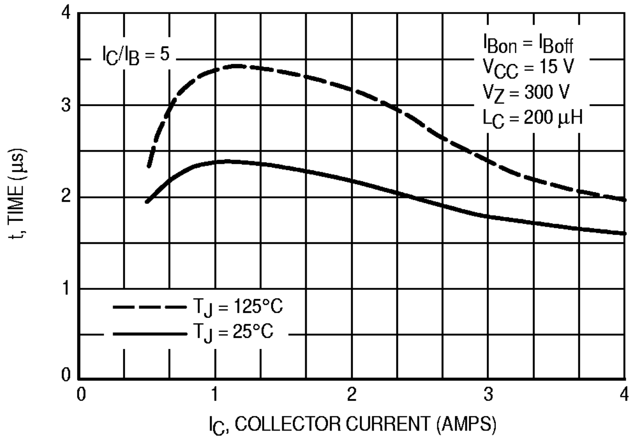


Figure 15. Inductive Storage Time, t_{si} @ I_C/I_B = 5

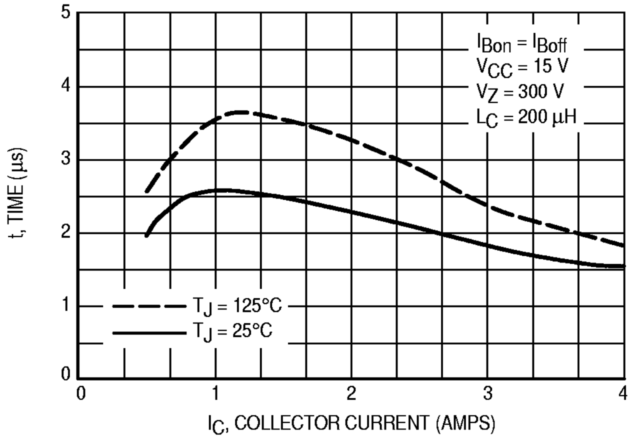


Figure 16. Inductive Storage Time, t_{si} @ I_C/I_B = 10

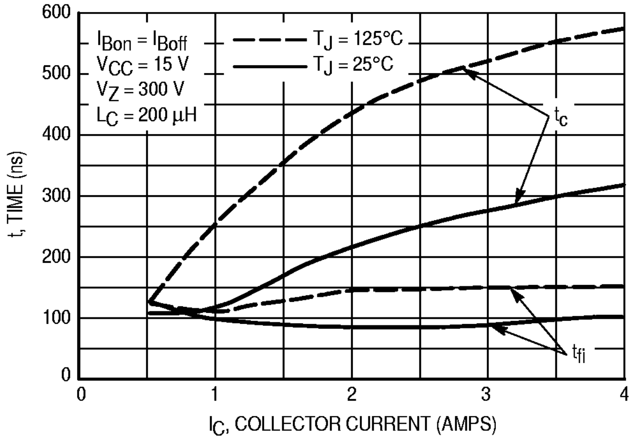


Figure 17. Inductive Switching, t_c & t_{fi} @ I_C/I_B = 5

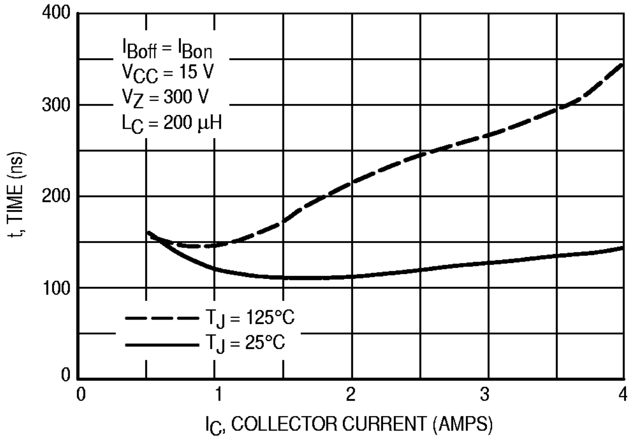


Figure 18. Inductive Switching, t_{fi} @ I_C/I_B = 10

TYPICAL SWITCHING CHARACTERISTICS

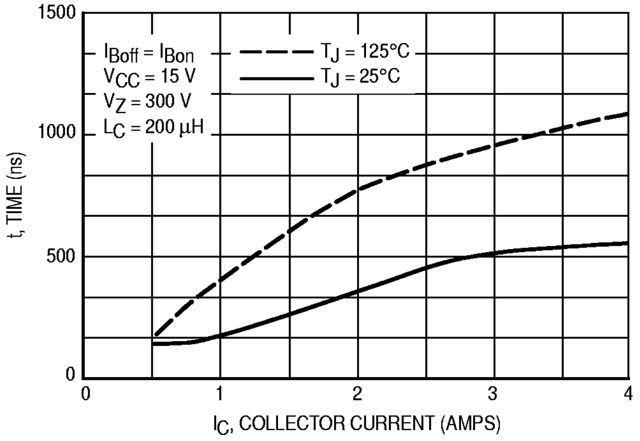


Figure 19. Inductive Switching, t_c @ $I_C/I_B = 10$

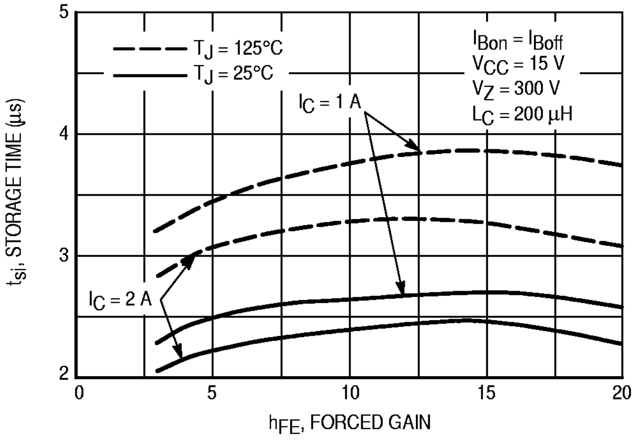


Figure 20. Inductive Storage Time

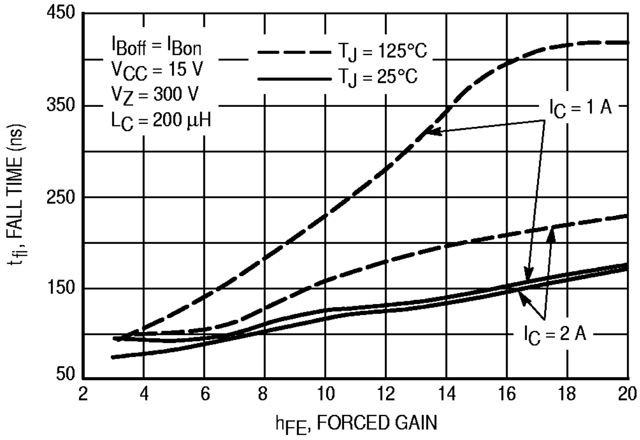


Figure 21. Inductive Fall Time

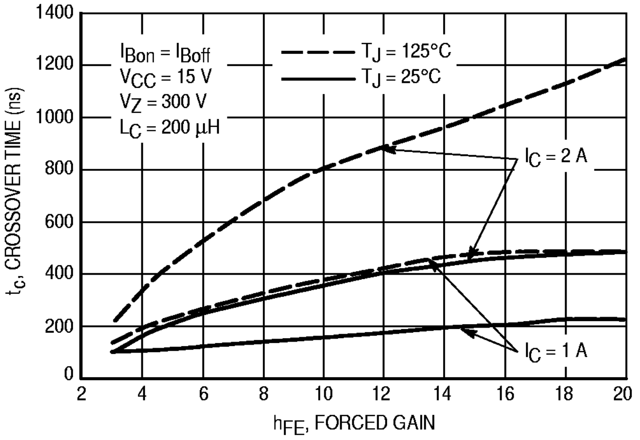


Figure 22. Inductive Crossover Time

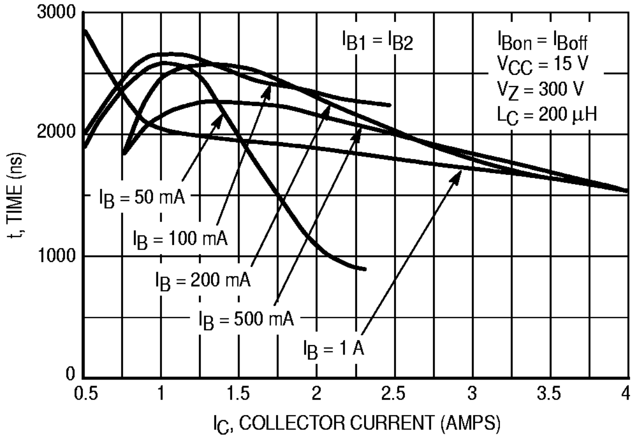


Figure 23. Inductive Storage Time, t_{si}

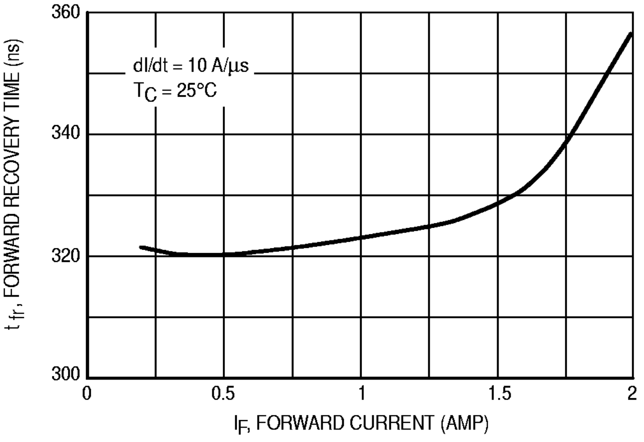


Figure 24. Forward Recovery Time t_{fr}

TYPICAL SWITCHING CHARACTERISTICS

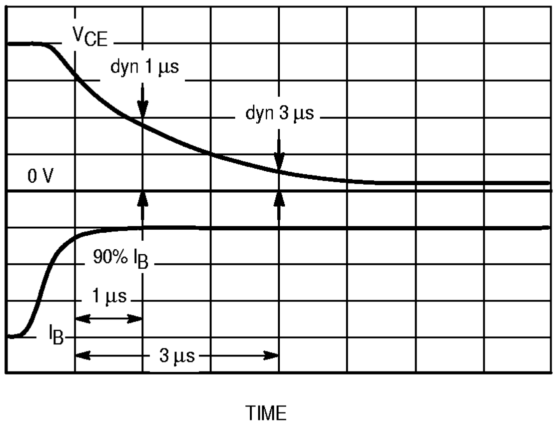


Figure 25. Dynamic Saturation Voltage Measurements

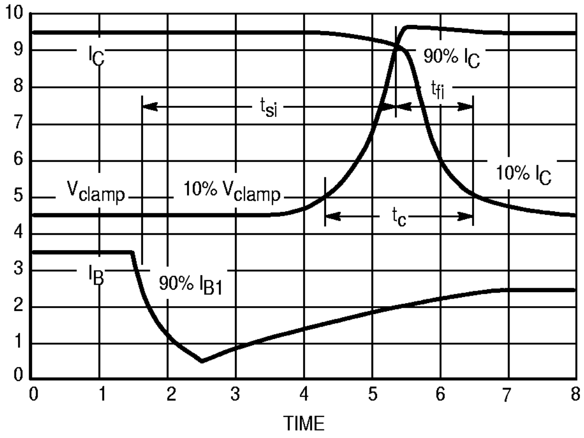


Figure 26. Inductive Switching Measurements

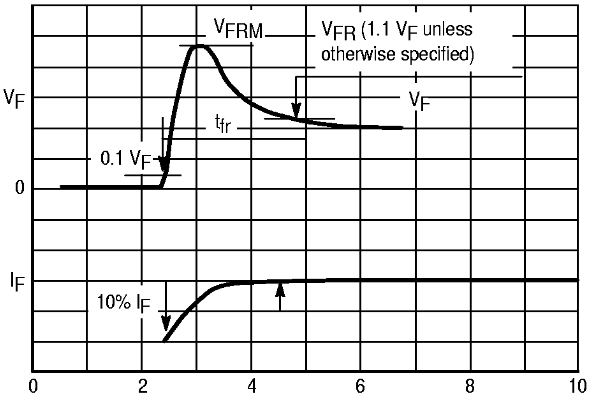
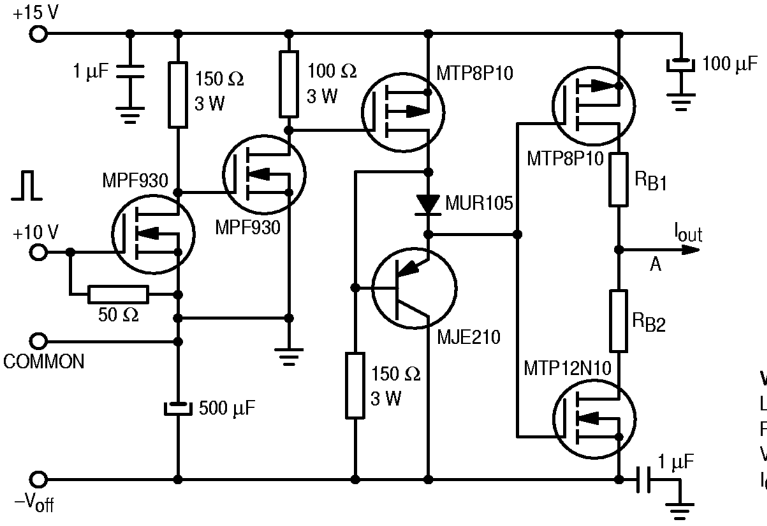
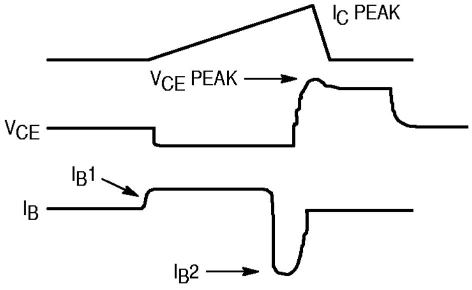


Figure 27. t_{fr} Measurements

TYPICAL SWITCHING CHARACTERISTICS

Table 1. Inductive Load Switching Drive Circuit





$V_{(BR)CEO(sus)}$	**Inductive Switching**	**RBSOA**
L = 10 mH	L = 200 µH	L = 500 µH
$R_{B2} = \infty$	$R_{B2} = 0$	$R_{B2} = 0$
V_{CC} = 20 Volts	V_{CC} = 15 Volts	V_{CC} = 15 Volts
$I_{C(pk)}$ = 100 mA	R_{B1} selected for desired I_{B1}	R_{B1} selected for desired I_{B1}

TYPICAL CHARACTERISTICS

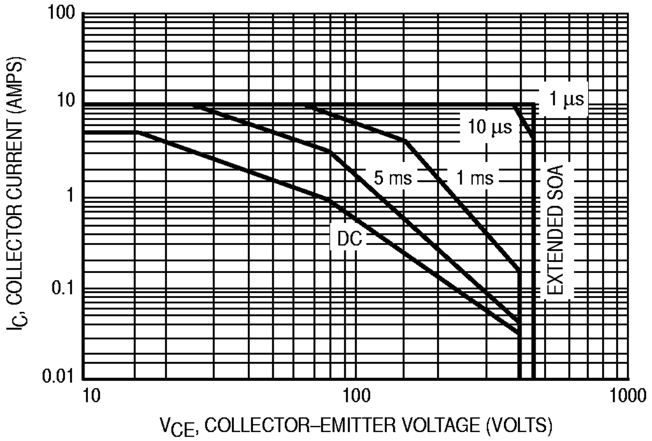


Figure 28. Forward Bias Safe Operating Area

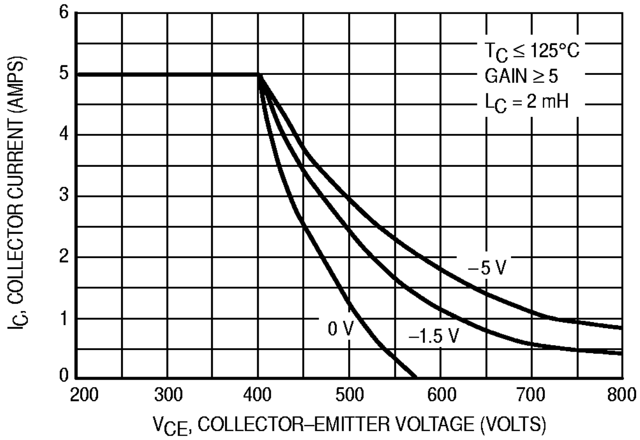


Figure 29. Reverse Bias Safe Operating Area

TYPICAL CHARACTERISTICS

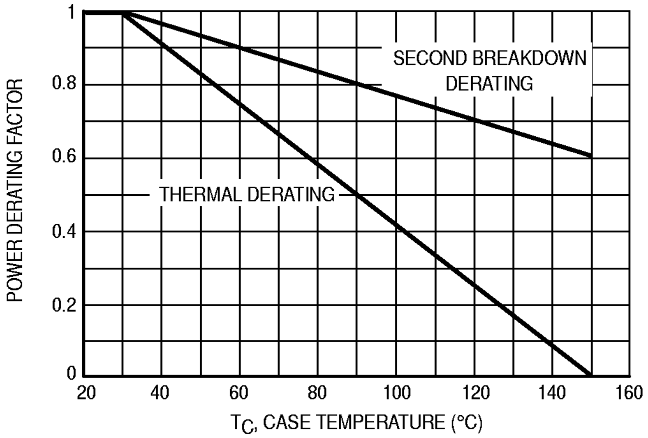


Figure 30. Forward Bias Power Derating

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 28 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 on Figure 28 may be found at any case temperature by using the appropriate curve on Figure 30.

$T_{J(pk)}$ may be calculated from the data in Figure 31. 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 29). This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode.

TYPICAL THERMAL RESPONSE

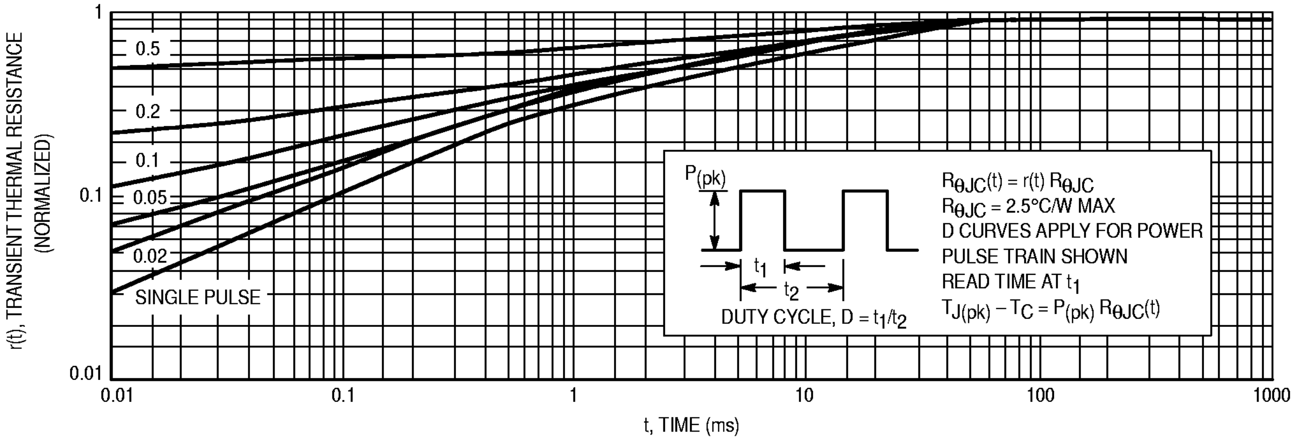
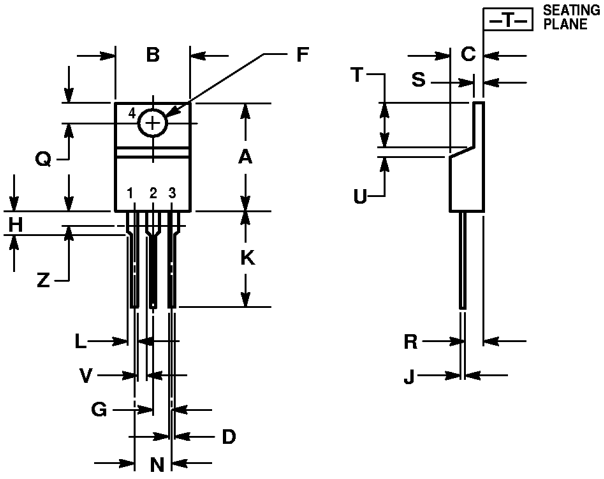


Figure 31. Typical Thermal Response ($Z_{\theta JC}(t)$) for BUL45D2

PACKAGE DIMENSIONS



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

CASE 221A–06
TO–220AB
ISSUE Y