Designer's™ Data Sheet
SWITCHMODE Series NPN Silicon Power Transistors

MJE16002*
MJE16004*

*Motorola Preferred Device

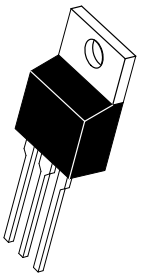
5.0 AMPERE
NPN SILICON
POWER TRANSISTORS
450 VOLTS
80 WATTS

These transistors are designed for high–voltage, high–speed switching of inductive circuits where fall time and RBSOA are critical. They are particularly well–suited for line–operated switchmode applications.

The MJE16004 is a high–gain version of the MJE16002 and MJH16002 for applications where drive current is limited.

Typical Applications:

- Switching Regulators
- High Resolution Deflection Circuits
- Inverters
- Motor Drives
- Fast Switching Speeds
  - 50 ns Inductive Fall Time @ 75°C (Typ)
  - 70 ns Crossover Time @ 75°C (Typ)
- 100°C Performance Specified for:
  - Reverse–Biased SOA
  - Inductive Switching Times
  - Saturation Voltages
  - Leakage Currents



CASE 221A–06
TO–220AB

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	$V_{CEO(sus)}$	450	Vdc
Collector–Emitter Voltage	V_{CEV}	850	Vdc
Emitter–Base Voltage	V_{EB}	6.0	Vdc
Collector Current — Continuous — Peak (1)	I_C I_{CM}	5.0 10	Adc
Base Current — Continuous — Peak (1)	I_B I_{BM}	4.0 8.0	Adc
Total Power Dissipation @ T_C = 25°C @ T_C = 100°C Derate above T_C = 25°C	P_D	80 32 0.64	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.56	°C/W
Lead Temperature for Soldering Purposes: 1/8″ from Case for 5 Seconds	T_L	275	°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.

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

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REV 2

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

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS (1)						
Collector–Emitter Sustaining Voltage (Table 2) (I_C = 100 mA, I_B = 0)		$V_{CEO(sus)}$	450	—	—	Vdc
Collector Cutoff Current (V_{CEV} = 850 Vdc, $V_{BE(off)}$ = 1.5 Vdc) (V_{CEV} = 850 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 100°C)		I_{CEV}	 — —	 — —	 0.25 1.5	mAdc
Collector Cutoff Current (V_{CE} = 850 Vdc, R_{BE} = 50 Ω, T_C = 100°C)		I_{CER}	—	—	2.5	mAdc
Emitter Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)		I_{EBO}	—	—	1.0	mAdc
SECOND BREAKDOWN						
Second Breakdown Collector Current with Base Forward Biased		$I_{S/b}$	See Figure 17 or 18			
Clamped Inductive SOA with Base Reverse Biased		RBSOA	See Figure 19			
ON CHARACTERISTICS (1)						
Collector–Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 1.5 Adc, I_B = 0.2 Adc)	MJE16002		—	—	1.0	
(I_C = 1.5 Adc, I_B = 0.15 Adc)	MJE16004		—	—	1.0	
(I_C = 3.0 Adc, I_B = 0.4 Adc)	MJE16002		—	—	2.5	
(I_C = 3.0 Adc, I_B = 0.3 Adc)	MJE16004		—	—	2.5	
(I_C = 3.0 Adc, I_B = 0.4 Adc, T_C = 100°C)	MJE16002		—	—	2.5	
(I_C = 3.0 Adc, I_B = 0.3 Adc, T_C = 100°C)	MJE16004		—	—	2.5	
Base–Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 3.0 Adc, I_B = 0.4 Adc)	MJE16002		—	—	1.5	
(I_C = 3.0 Adc, I_B = 0.3 Adc)	MJE16004		—	—	1.5	
(I_C = 3.0 Adc, I_S = 0.4 Adc, T_C = 100°C)	MJE16002		—	—	1.5	
(I_C = 3.0 Adc, I_B = 0.3 Adc, T_C = 100°C)	MJE16004		—	—	1.5	
DC Current Gain		h_{FE}				—
(I_C = 5.0 Adc, V_{CE} = 5.0 Vdc)	MJE16002		5.0	—	—	
	MJE16004		7.0	—	—	
DYNAMIC CHARACTERISTICS						
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f_{test} = 1.0 kHz)		C_{ob}	—	—	200	pF
SWITCHING CHARACTERISTICS						
Resistive Load (Table 1) MJE16002/MJH10002						
Delay Time	(I_C = 3.0 Adc, V_{CC} = 250 Vdc, I_{B1} = 0.4 Adc, PW = 30 μs, Duty Cycle ≤ 2.0%)	(I_{B2} = 0.8 Adc, R_{B2} = 8.0 Ω)	t_d	—	30	100	ns
Rise Time			t_r	—	100	300	
Storage Time			t_s	—	1000	3000	
Fall Time			t_f	—	60	300	
Storage Time		($V_{BE(off)}$ = 5.0 Vdc)	t_s	—	400	—	
Fall Time			t_f	—	130	—	
Resistive Load (Table 1) MJE16004/MJH16004						
Delay Time	(I_C = 3.0 Adc, V_{CC} = 250 Vdc, I_{B1} = 0.3 Adc, PW = 30 μs, Duty Cycle ≤ 2.0%)	(I_{B2} = 0.6 Adc, R_{B2} = 8.0 Ω)	t_d	—	30	100	ns
Rise Time			t_r	—	130	300	
Storage Time			t_s	—	800	2700	
Fall Time			t_f	—	80	350	
Storage Time		($V_{BE(off)}$ = 5.0 Vdc)	t_s	—	250	—	
Fall Time			t_f	—	60	—	

(1) Pulse Test: PW = 300 μs, Duty Cycle ≤ 2%.

$$*\beta_f = \frac{I_C}{I_{B1}}$$

SWITCHING CHARACTERISTICS (continued)

Characteristics			Symbol	Min	Typ	Max	Unit
Inductive Load (Table 2) MJE16002							
Storage Time	(I_C = 3.0 Adc, I_{B1} = 0.4 Adc, $V_{BE(off)}$ = 5.0 Vdc, $V_{CE(pk)}$ = 400 Vdc)	(T_J = 100°C)	t_{sv}	—	500	1600	ns
Fall Time			t_{fi}	—	100	200	
Crossover Time			t_c	—	120	250	
Storage Time		(T_J = 150°C)	t_{sv}	—	600	—	
Fall Time			t_{fi}	—	120	—	
Crossover Time			t_c	—	160	—	
Inductive Load (Table 2) MJE16004							
Storage Time	(I_C = 3.0 Adc, I_{B1} = 0.3 Adc, $V_{BE(off)}$ = 5.0 Vdc, $V_{CE(pk)}$ = 400 Vdc)	(T_J = 100°C)	t_{sv}	—	400	1300	ns
Fall Time			t_{fi}	—	80	150	
Crossover Time			t_c	—	90	200	
Storage Time		(T_J = 150°C)	t_{sv}	—	450	—	
Fall Time			t_{fi}	—	100	—	
Crossover Time			t_c	—	110	—	

(1) Pulse Test: PW = 300 μs, Duty Cycle ≤ 2%.

$$^*\beta_f = \frac{I_C}{I_{B1}}$$

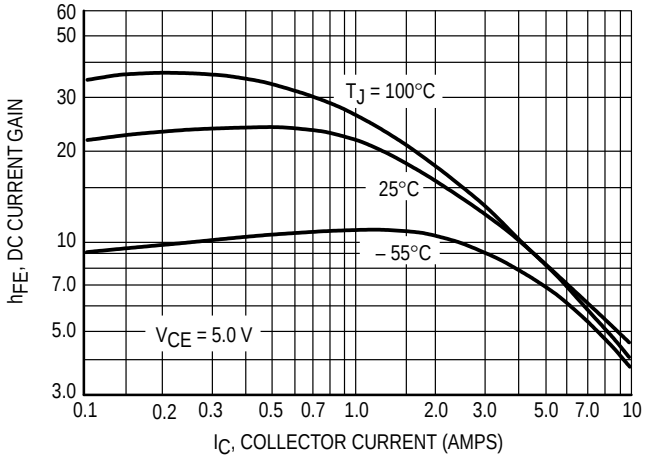


Figure 1. DC Current Gain

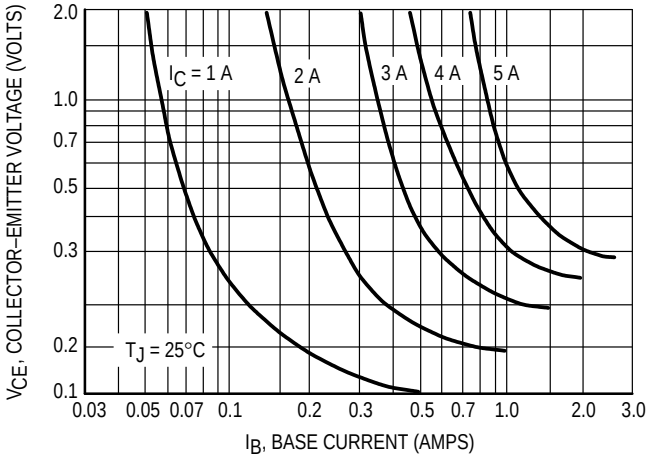


Figure 2. Collector Saturation Region

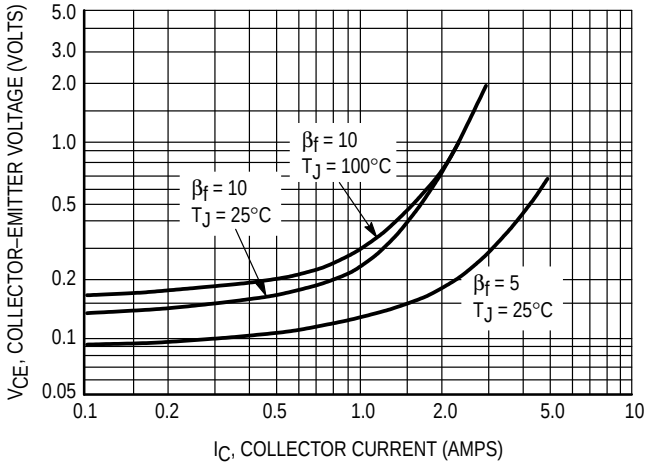


Figure 3. Collector–Emitter Saturation Region

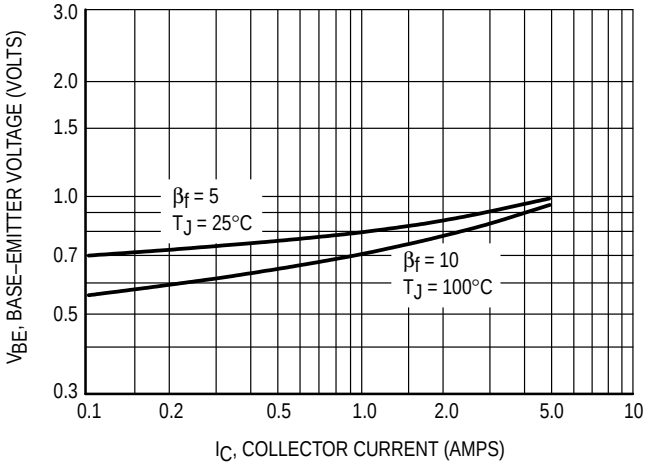


Figure 4. Base–Emitter Voltage

TYPICAL STATIC CHARACTERISTICS (continued)

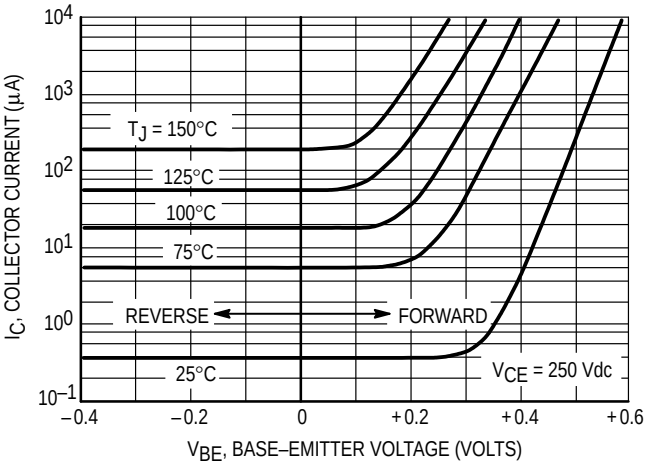


Figure 5. Collector Cutoff Region

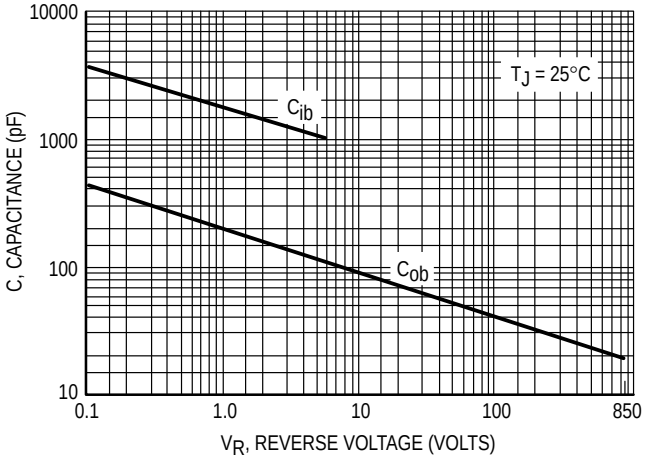


Figure 6. Capacitance

TYPICAL DYNAMIC CHARACTERISTICS

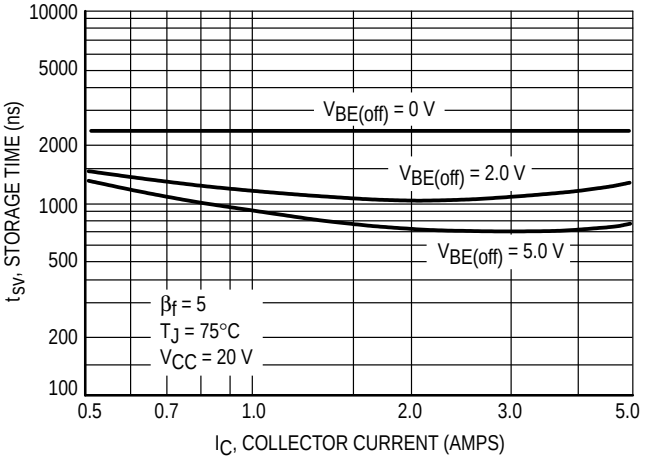


Figure 7. Storage Time

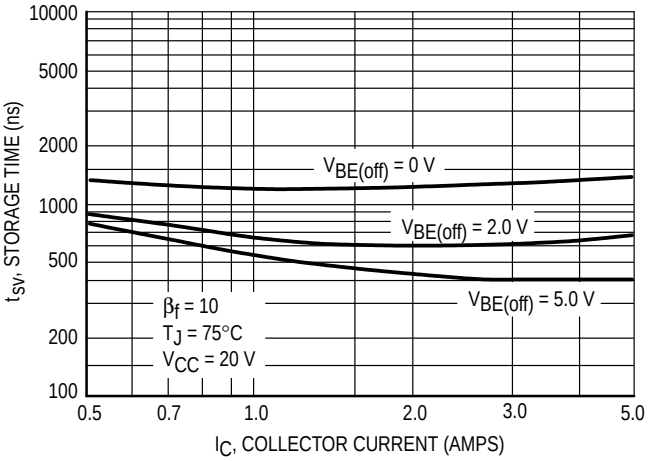


Figure 8. Storage Time

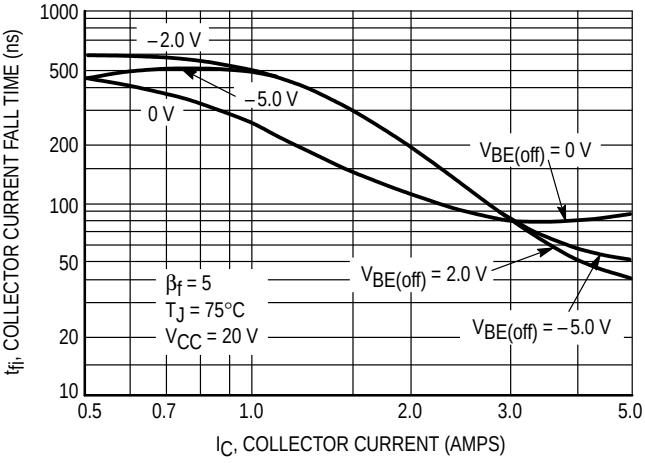


Figure 9. Collector Current Fall Time

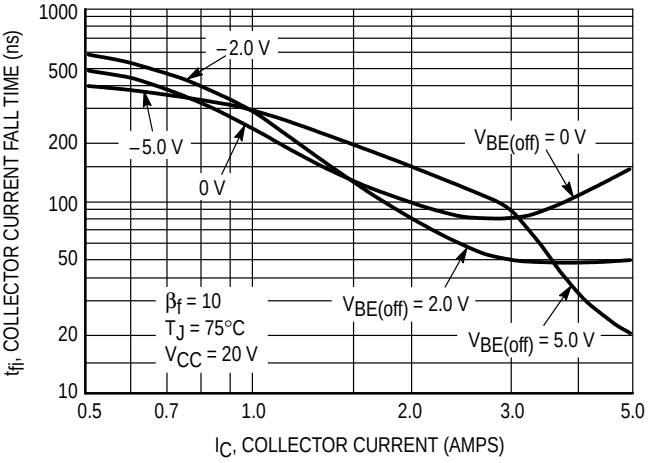


Figure 10. Collector Current Fall Time

TYPICAL DYNAMIC CHARACTERISTICS (continued)

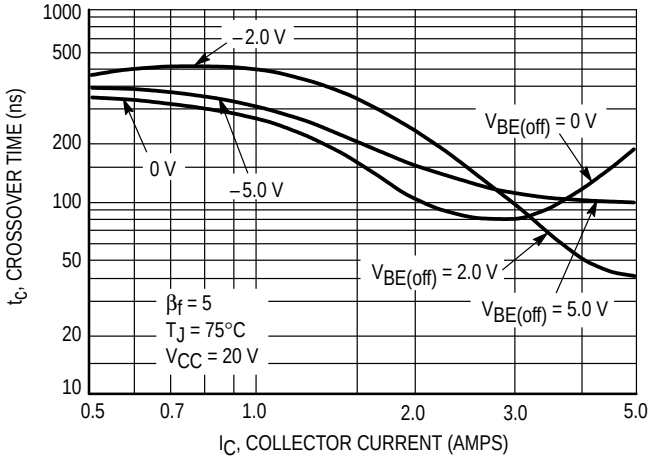


Figure 11. Crossover Time

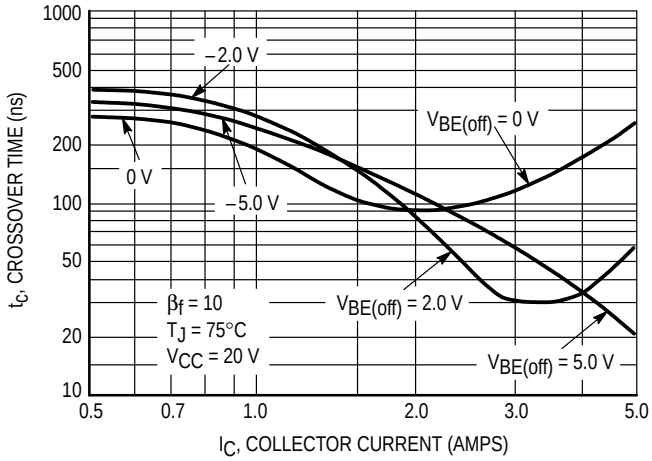


Figure 12. Crossover Time

TYPICAL ELECTRICAL CHARACTERISTICS

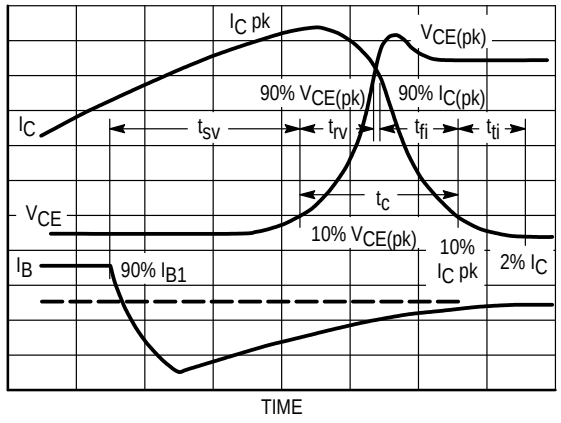


Figure 13. Inductive Switching Measurements

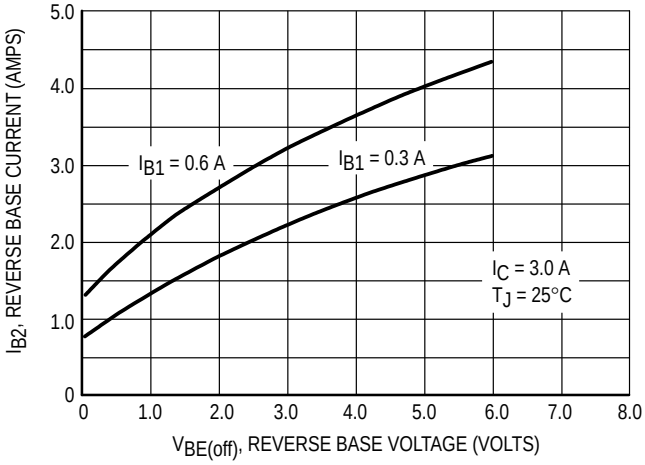


Figure 14. Peak Reverse Base Current

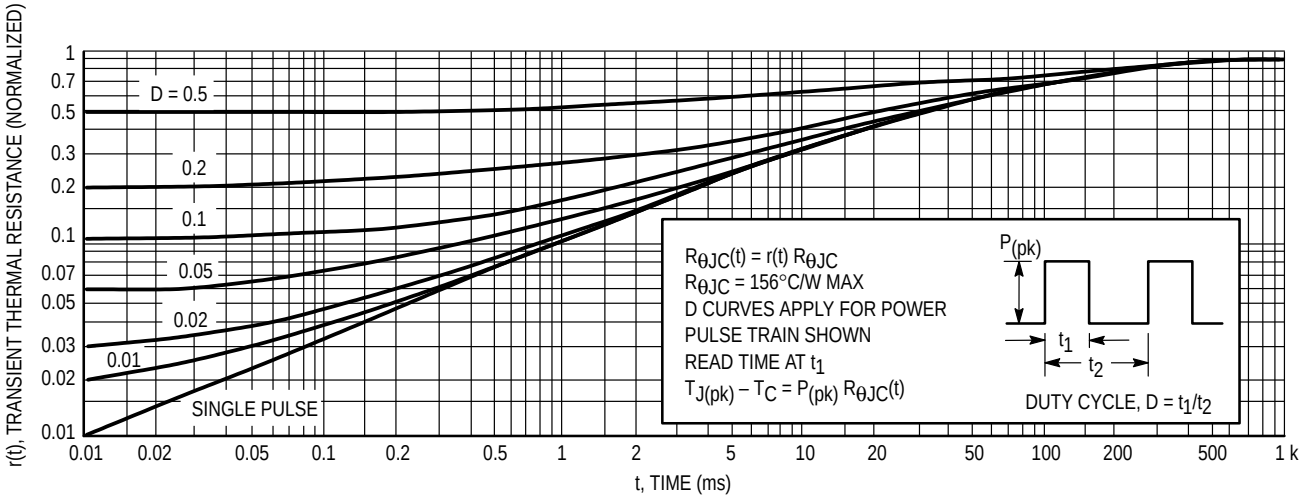


Figure 15. Thermal Response (MJE16002 and MJE16004)

SAFE OPERATING AREA INFORMATION

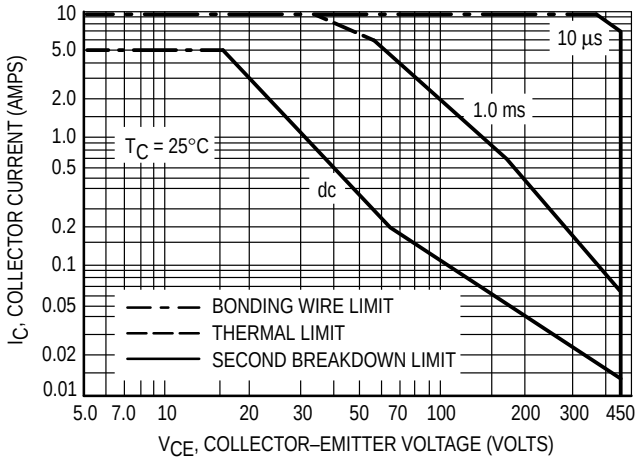


Figure 16. Maximum Rated Forward Bias Safe Operating Area (MJE16002 and MJE16004)

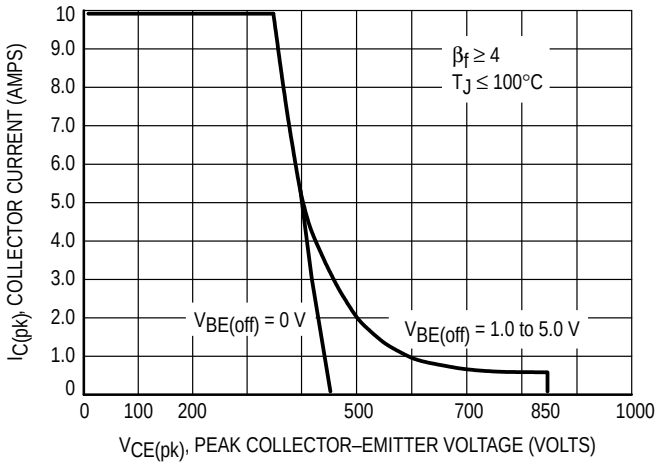


Figure 17. Maximum Rated Reverse Bias Safe Operating Area

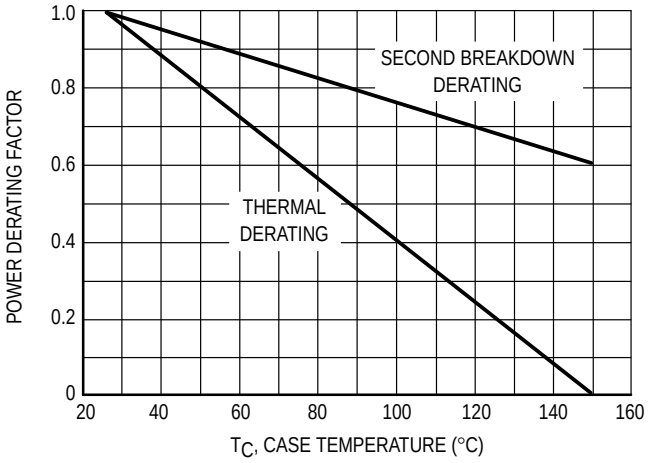


Figure 18. Power Derating

SAFE OPERATING AREA INFORMATION

FORWARD BIAS

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 16 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 $T_C \geq 25°C$. Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figures 17 and 18 may be found at any case temperature by using the appropriate curve on Figure 20.

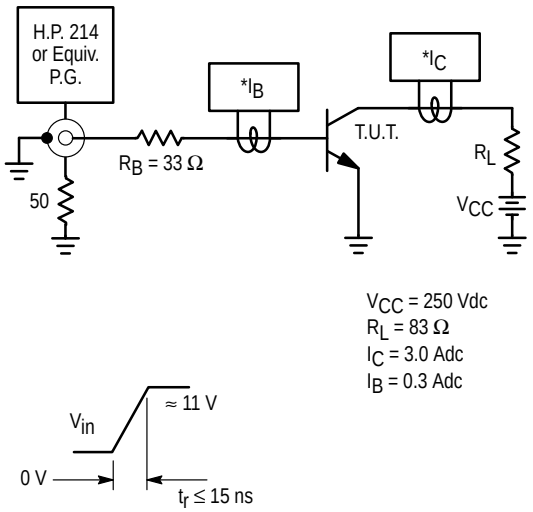
$T_{J(pk)}$ may be calculated from the data in Figure 15. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

REVERSE BIAS

For inductive loads, high voltage and high current must be sustained simultaneously during turn–off, in most cases, with the base–to–emitter junction reverse biased. Under these conditions the collector voltage must be held to a safe level at or below a specific value of collector current. This can be accomplished by several means such as active clamping, RC snubbing, load line shaping, etc. The safe level for these devices is specified as Reverse Bias Safe 0perating Area and represents the voltage–current condition allowable pulling reverse biased turn–off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 17 gives the RBSOA characteristics.

Table 1. Resistive Load Switching

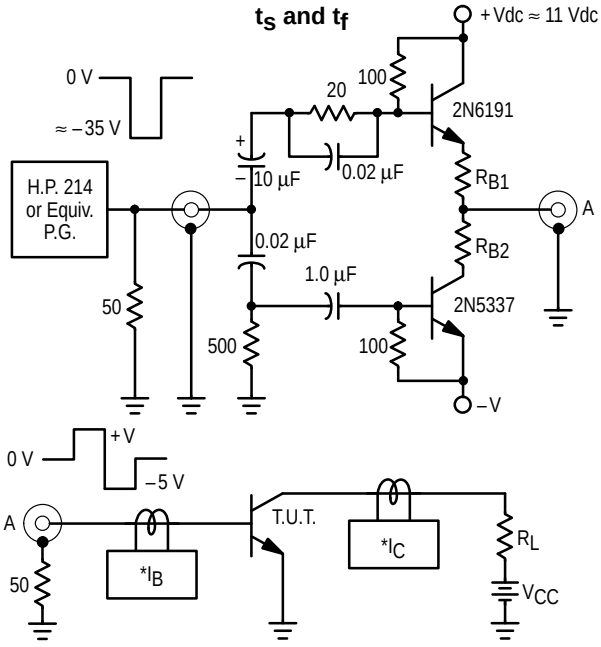
t_d and t_r



V_{CC} = 250 Vdc
R_L = 83 Ω
I_C = 3.0 Adc
I_B = 0.3 Adc

*Tektronix
P–6042 or
Equivalent

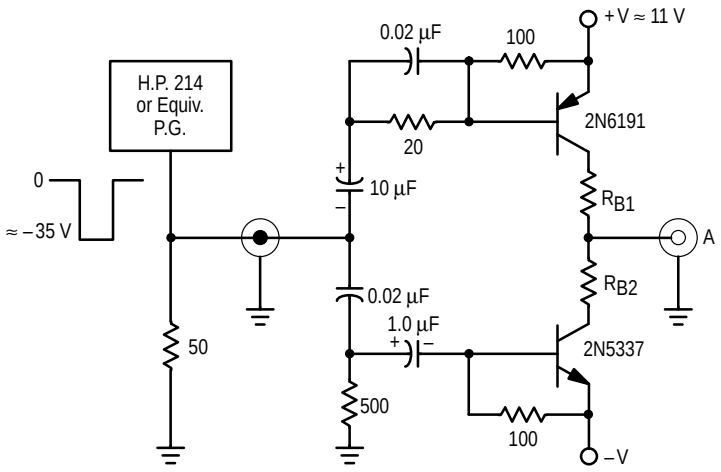
t_s and t_f

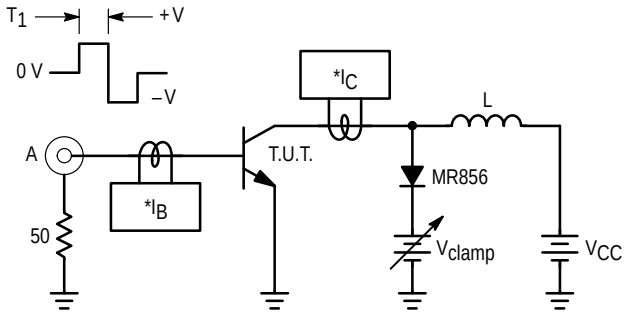


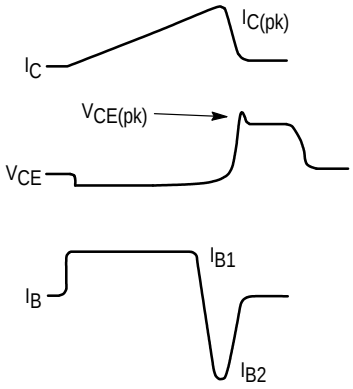
V_{CC} = 250	I_{B1} = 0.3 Adc	R_{B1} = 33 Ω
R_L = 83 Ω	I_{B2} = 0.6 Adc	R_{B2} = 8.0 Ω
I_C = 3.0 Adc	For $V_{BE(off)}$ = 5.0 V	R_{B2} = 0 Ω

Note: Adjust –V to obtain desired $V_{BE(off)}$ at Point A.

Table 2. Inductive Load Switching







$$T_1 \approx \frac{L_{coil}\ (I_{Cpk})}{V_{CC}}$$

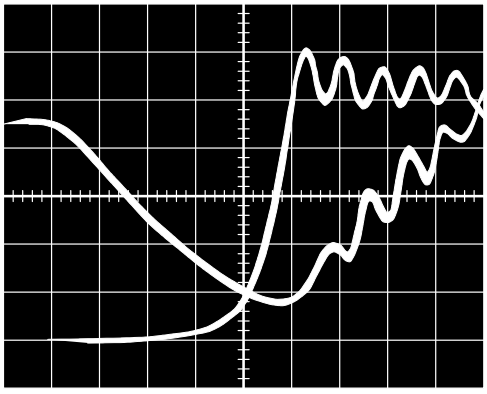
T_1 adjusted to obtain $I_{C(pk)}$

$V_{CEO(sus)}$	**Inductive Switching**	**RBSOA**
L = 10 mH	L = 200 µH	L = 200 µH
R_{B2} = ∞	R_{B2} = 0	R_{B2} = 0
V_{CC} = 20 Volts	V_{CC} = 20 Volts	V_{CC} = 20 Volts
	R_{B1} selected for desired I_{B1}	R_{B1} selected for desired I_{B1}
*Tektronix P–6042 or Equivalent	Scope — Tektronix 7403 or Equivalent	

Note: Adjust –V to obtain desired $V_{BE(off)}$ at Point A.

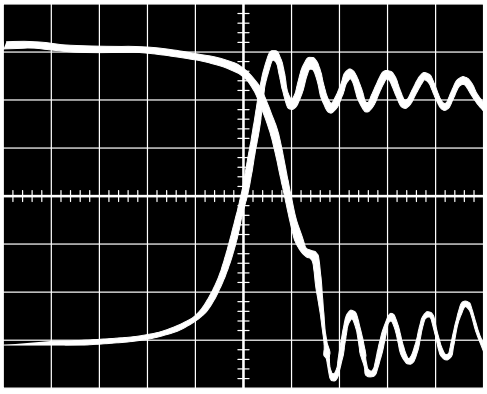
TYPICAL INDUCTIVE SWITCHING WAVEFORMS

t_{sv}



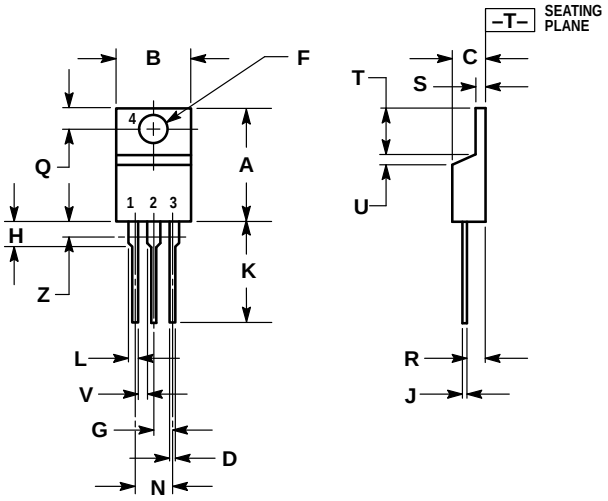
$I_{C(pk)}$ = 3.0 Amps
I_{B1} = 0.3 Amp
$V_{BE(off)}$ = 5.0 Volts
$V_{CE(pk)}$ = 300 Volts
T_C = 25°C
Time Base =
20 ns/cm

t_{fi}, t_c



$I_{C(pk)}$ = 3.0 Amps
I_{B1} = 0.3 Amp
$V_{BE(off)}$ = 5.0 Volts
$V_{CE(pk)}$ = 300 Volts
T_C = 25°C
Time Base =
20 ns/cm

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.

	INCHES		MILLIMETERS	
DIM	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

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