

# NPN Silicon Power Transistor

## 1 kV SWITCHMODE™ Series

These transistors are designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line-operated SWITCHMODE applications.

**Typical Applications:**

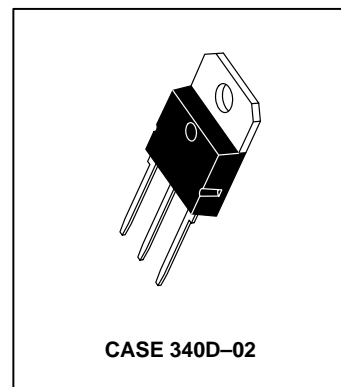
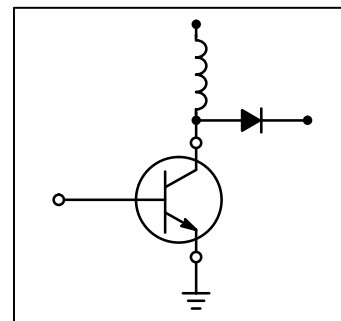
- Switching Regulators
- Inverters
- Solenoids
- Relay Drivers
- Motor Controls
- Deflection Circuits

**Features:**

- Collector-Emitter Voltage —  $V_{CEV} = 1000 \text{ Vdc}$
- Fast Turn-Off Times
- 80 ns Inductive Fall Time —  $100^\circ\text{C}$  (Typ)
- 120 ns Inductive Crossover Time —  $100^\circ\text{C}$  (Typ)
- 800 ns Inductive Storage Time —  $100^\circ\text{C}$  (Typ)
- $100^\circ\text{C}$  Performance Specified for:
  - Reverse-Biased SOA with Inductive Load
  - Switching Times with Inductive Loads
  - Saturation Voltages
  - Leakage Currents
- Extended FBSOA Rating Using Ultra-fast Rectifiers
- Extremely High RBSOA Capability

**MJH16006A**

**POWER TRANSISTORS**  
**8 AMPERES**  
**500 VOLTS**  
**150 WATTS**

**CASE 340D-02**

**Preferred** devices are ON Semiconductor recommended choices for future use and best overall value.

# MJH16006A

## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	$V_{CEO}$	500	Vdc
Collector–Emitter Voltage	$V_{CEV}$	1000	Vdc
Emitter–Base Voltage	$V_{EB}$	6	Vdc
Collector Current — Continuous — Peak <sup>(1)</sup>	$I_C$ $I_{CM}$	8 16	Adc
Base Current — Continuous — Peak <sup>(1)</sup>	$I_B$ $I_{BM}$	6 12	Adc
Total Power Dissipation @ $T_C = 25^\circ\text{C}$ @ $T_C = 100^\circ\text{C}$ Derate above $T_C = 25^\circ\text{C}$	$P_D$	125 50 1	Watts  W/ $^\circ\text{C}$
Operating and Storage Junction Temperature Range	$T_J, T_{stg}$	–55 to 150	$^\circ\text{C}$

## THERMAL CHARACTERISTICS

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

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

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

Characteristic	Symbol	Min	Typ	Max	Unit
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### OFF CHARACTERISTICS<sup>(1)</sup>

Collector–Emitter Sustaining Voltage (Table 1) ( $I_C = 100\text{ mA}$ , $I_B = 0$ )	$V_{CEO(sus)}$	500	—	—	Vdc
Collector Cutoff Current ( $V_{CEV} = 1000\text{ Vdc}$ , $V_{BE(off)} = 1.5\text{ Vdc}$ ) ( $V_{CEV} = 1000\text{ Vdc}$ , $V_{BE(off)} = 1.5\text{ Vdc}$ , $T_C = 100^\circ\text{C}$ )	$I_{CEV}$	— —	0.003 0.020	0.15 1.0	mAdc
Collector Cutoff Current ( $V_{CE} = 1000\text{ Vdc}$ , $R_{BE} = 50\ \Omega$ , $T_C = 100^\circ\text{C}$ )	$I_{CER}$	—	0.020	1.0	mAdc
Emitter Cutoff Current ( $V_{EB} = 6\text{ Vdc}$ , $I_C = 0$ )	$I_{EBO}$	—	0.005	0.15	mAdc

### SECOND BREAKDOWN

Second Breakdown Collector Current with Base Forward Biased	$I_{S/b}$	See Figure 14a or 14b			
Clamped Inductive SOA with Base Reverse Biased	RBSOA	See Figure 15			

### ON CHARACTERISTICS<sup>(1)</sup>

Collector–Emitter Saturation Voltage ( $I_C = 3\text{ Adc}$ , $I_B = 0.6\text{ Adc}$ ) ( $I_C = 5\text{ Adc}$ , $I_B = 1\text{ Adc}$ ) ( $I_C = 5\text{ Adc}$ , $I_B = 1\text{ Adc}$ , $T_C = 100^\circ\text{C}$ )	$V_{CE(sat)}$	— — —	0.35 0.50 0.60	0.7 1 1.5	Vdc
Base–Emitter Saturation Voltage ( $I_C = 5\text{ Adc}$ , $I_B = 1\text{ Adc}$ ) ( $I_C = 5\text{ Adc}$ , $I_B = 1\text{ Adc}$ , $T_C = 100^\circ\text{C}$ )	$V_{BE(sat)}$	— —	1 1	1.5 1.5	Vdc
DC Current Gain ( $I_C = 8\text{ Adc}$ , $V_{CE} = 5\text{ Vdc}$ )	$h_{FE}$	5	8	—	—

### DYNAMIC CHARACTERISTICS

Output Capacitance ( $V_{CB} = 10\text{ Vdc}$ , $I_E = 0$ , $f_{test} = 1\text{ kHz}$ )	$C_{ob}$	—	—	350	pF
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### SWITCHING CHARACTERISTICS

Inductive Load (Table 1)							
Storage Time	$(I_C = 5\text{ Adc},$ $I_{B1} = 0.66\text{ Adc},$ $V_{BE(off)} = 5\text{ Vdc},$ $V_{CE(pk)} = 400\text{ Vdc})$	$(T_J = 100^{\circ}\text{C})$	$t_{sv}$	—	800	2000	ns
Fall Time			$t_{fi}$	—	80	200	
Crossover Time			$t_c$	—	120	300	
Storage Time		$(T_J = 150^{\circ}\text{C})$	$t_{sv}$	—	1000	—	
Fall Time			$t_{fi}$	—	90	—	
Crossover Time			$t_c$	—	150	—	
Resistive Load (Table 2)							
Delay Time	$(I_C = 5\text{ Adc},$ $V_{CC} = 250\text{ Vdc},$ $I_{B1} = 0.66\text{ Adc},$ $PW = 30\text{ }\mu\text{s},$ $\text{Duty Cycle} \leq 2\%)$	$(I_{B2} = 1.3\text{ Adc},$ $R_{B1} = R_{B2} = 4\text{ }\Omega)$	$t_d$	—	25	100	ns
Rise Time			$t_r$	—	400	700	
Storage Time			$t_s$	—	1400	3000	
Fall Time			$t_f$	—	175	400	
Storage Time		$(V_{BE(off)} = 5\text{ Vdc})$	$t_s$	—	475	—	
Fall Time			$t_f$	—	100	—	

(1) Pulse Test:  $PW = 300\ \mu\text{s}$ , Duty Cycle  $\leq 2\%$ .

TYPICAL STATIC CHARACTERISTICS

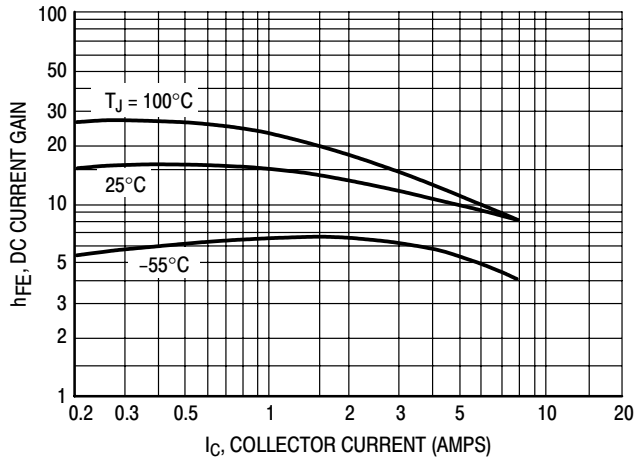


Figure 6. DC Current Gain

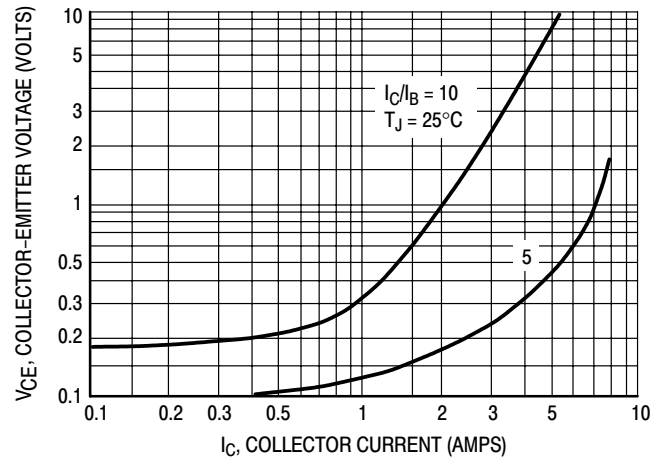


Figure 7. Collector–Emitter Saturation Region

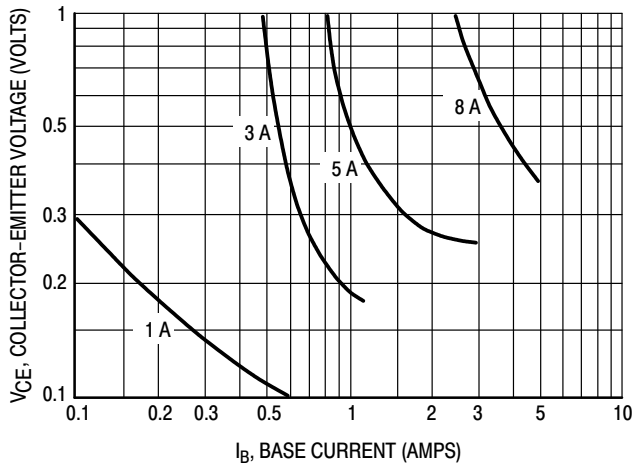


Figure 8. Collector–Emitter Saturation Region

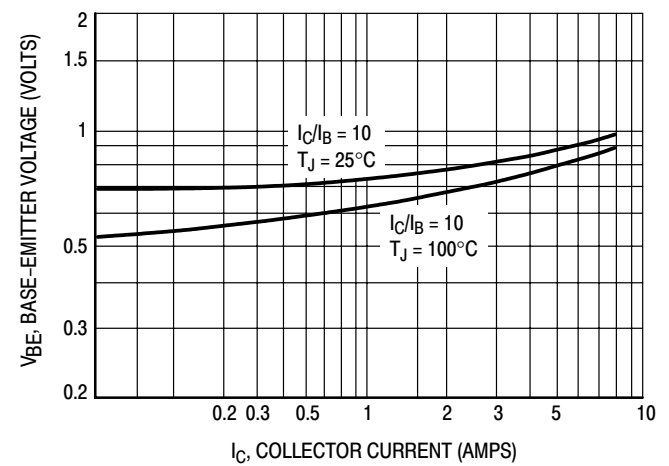


Figure 9. Base–Emitter Saturation Region

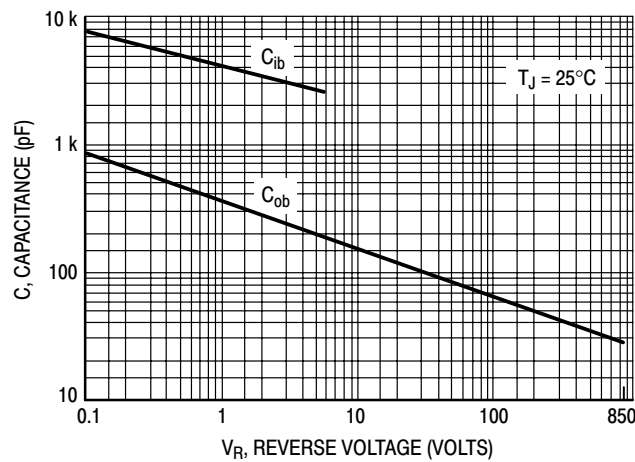


Figure 10. Capacitance

TYPICAL INDUCTIVE SWITCHING CHARACTERISTICS

$I_C/I_{B1} = 5$ ,  $T_C = 75^\circ\text{C}$ ,  $V_{CE(pk)} = 400\text{ V}$

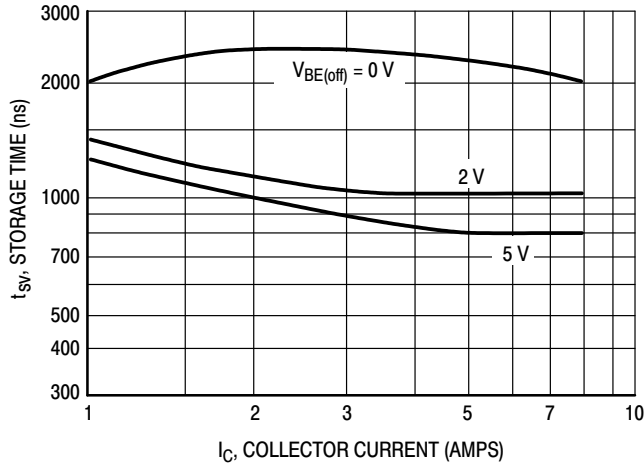


Figure 11. Storage Time

$I_C/I_{B1} = 10$ ,  $T_C = 75^\circ\text{C}$ ,  $V_{CE(pk)} = 400\text{ V}$

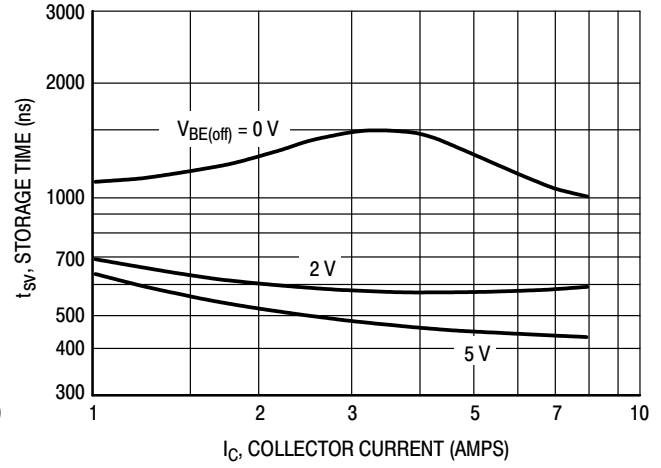


Figure 12. Storage Time

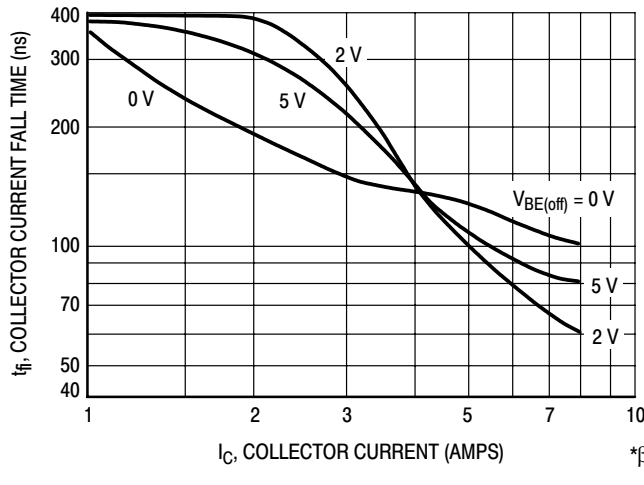


Figure 13. Collector Current Fall Time

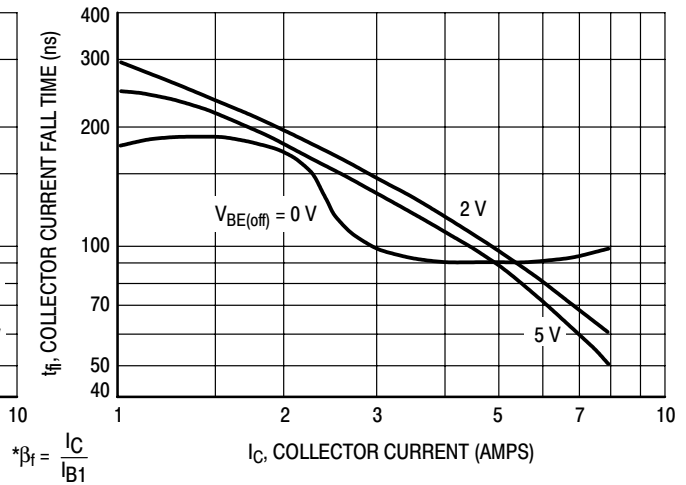


Figure 14. Collector Current Fall Time

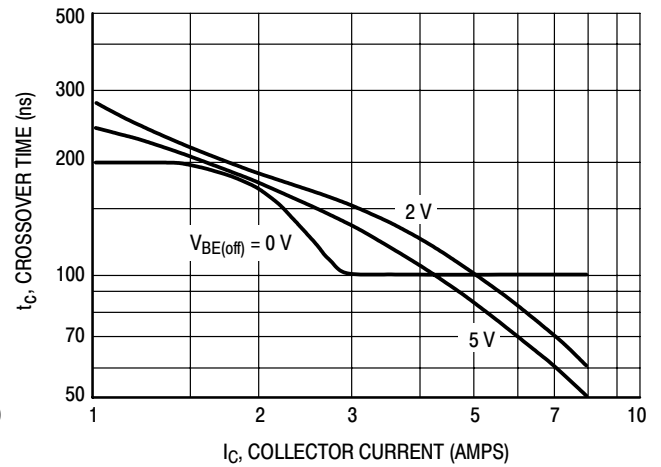
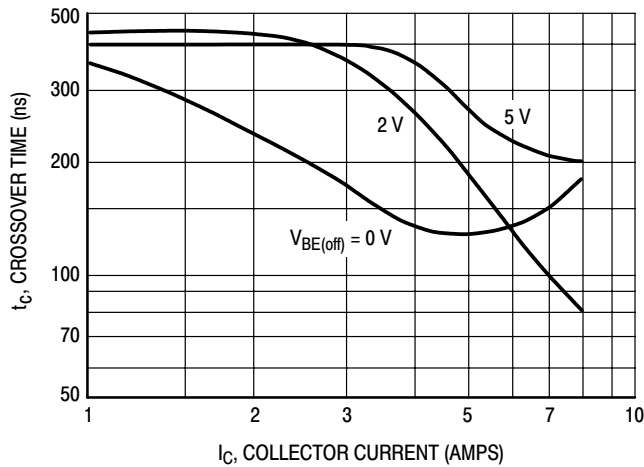
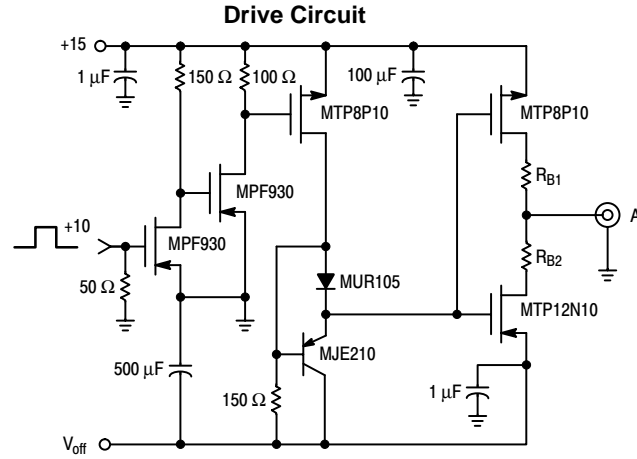


Table 1. Inductive Load Switching



\*Tektronix AM503  
P6302 or Equivalent

Scope — Tektronix  
7403 or Equivalent

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

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

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

$V_{CE0(\text{sus})}$   
 $L = 10 \text{ mH}$   
 $R_{B2} = \infty$   
 $V_{CC} = 20 \text{ Volts}$

**Inductive Switching**

$L = 750 \mu\text{H}$   
 $R_{B2} = 0$   
 $V_{CC} = 20 \text{ Volts}$   
 $R_{B1}$  selected for desired  $I_{B1}$

**RBSOA**

$L = 750 \mu\text{H}$   
 $R_{B2} = 0$   
 $V_{CC} = 20 \text{ Volts}$   
 $R_{B1}$  selected for desired  $I_{B1}$

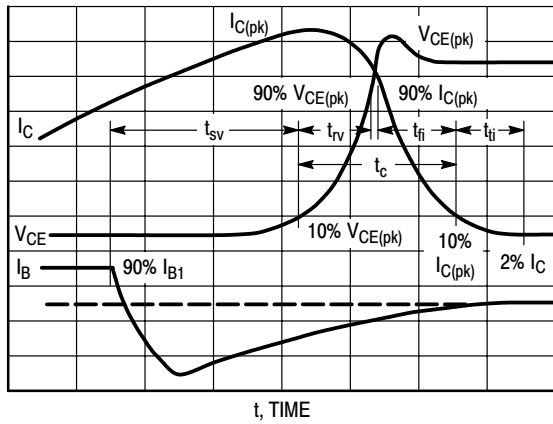
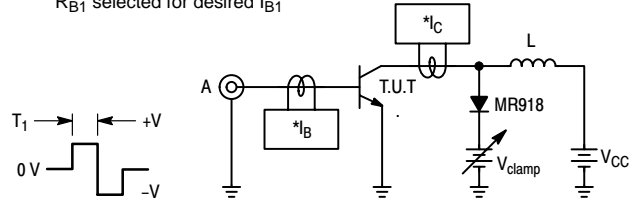
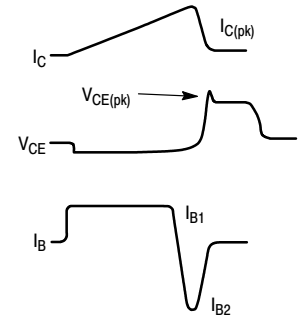


Figure 17. Inductive Switching Measurements

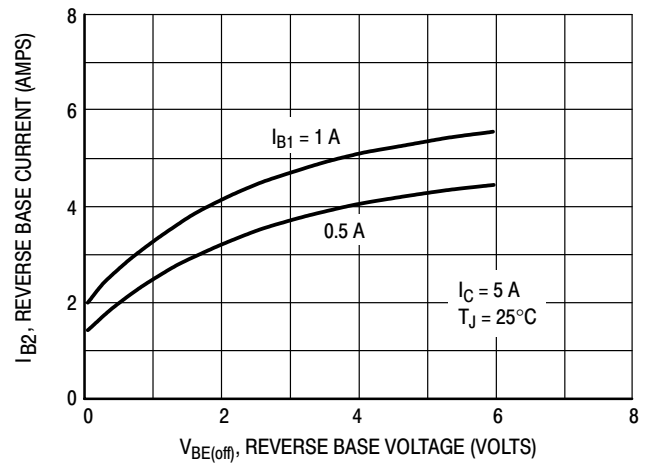
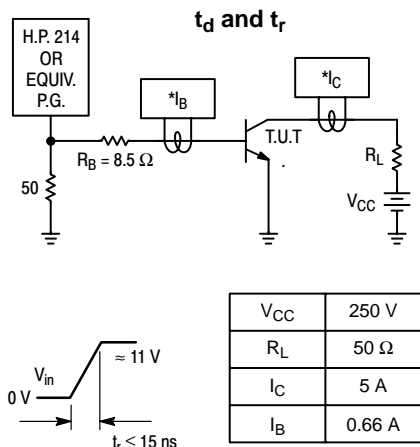


Figure 18. Peak Reverse Base Current

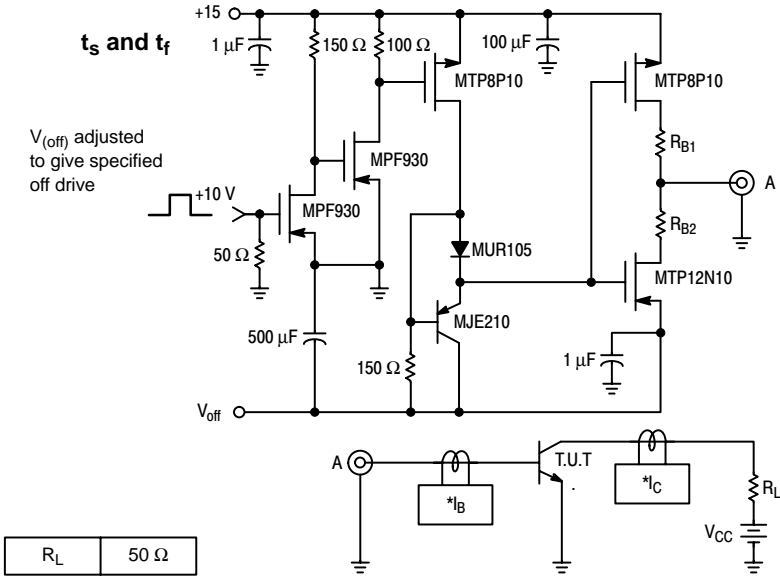
MJH16006A

Table 2. Resistive Load Switching



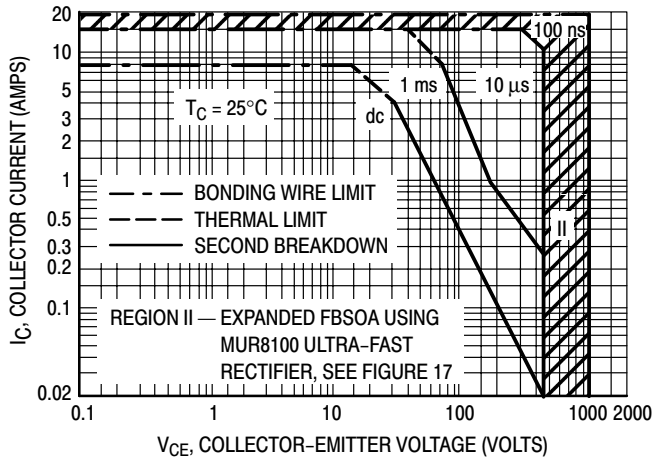
$V_{CC}$	250 V
$R_L$	50 $\Omega$
$I_C$	5 A
$I_B$	0.66 A

\*Tektronix AM503  
P6302 or Equivalent

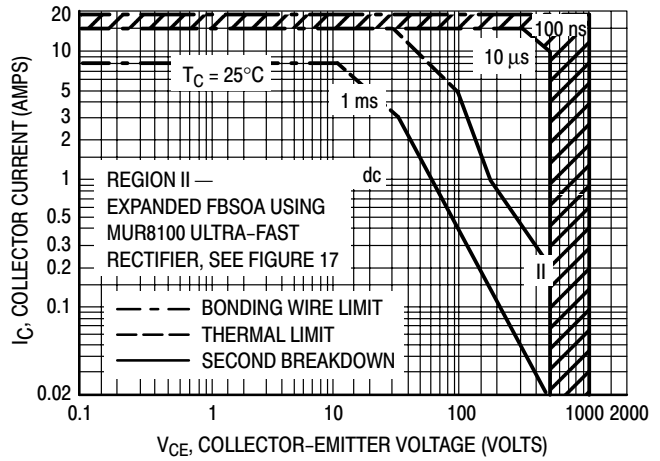


$R_L$	50 $\Omega$
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GUARANTEED SAFE OPERATING AREA LIMITS



a. MJ16006A



a. MJH16006A

Figure 19. Maximum Rated Forward Biased Safe Operating Area

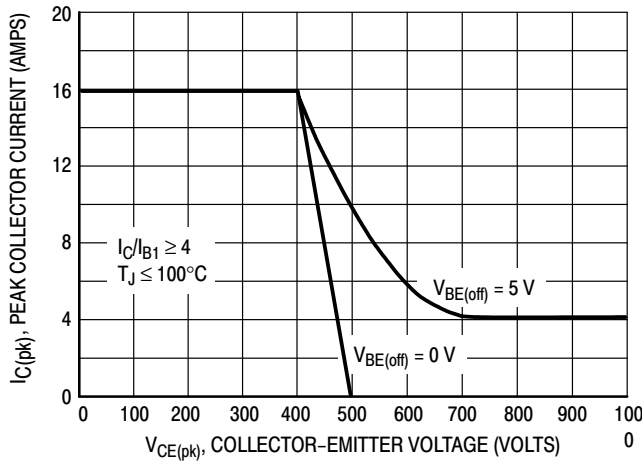


Figure 20. Maximum Reverse Biased Safe Operating Area

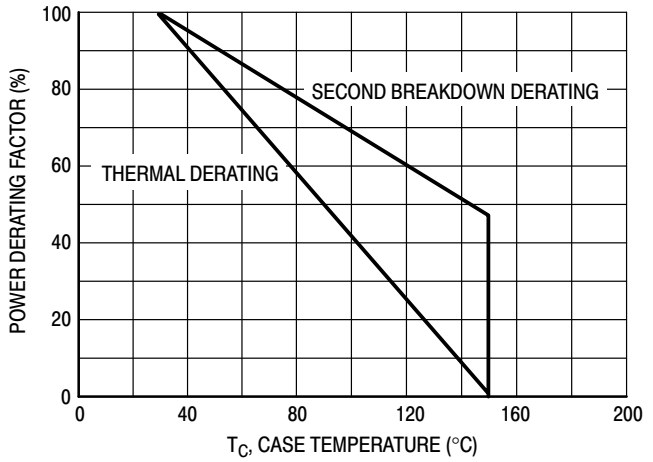


Figure 21. Power Derating



# MJH16006A

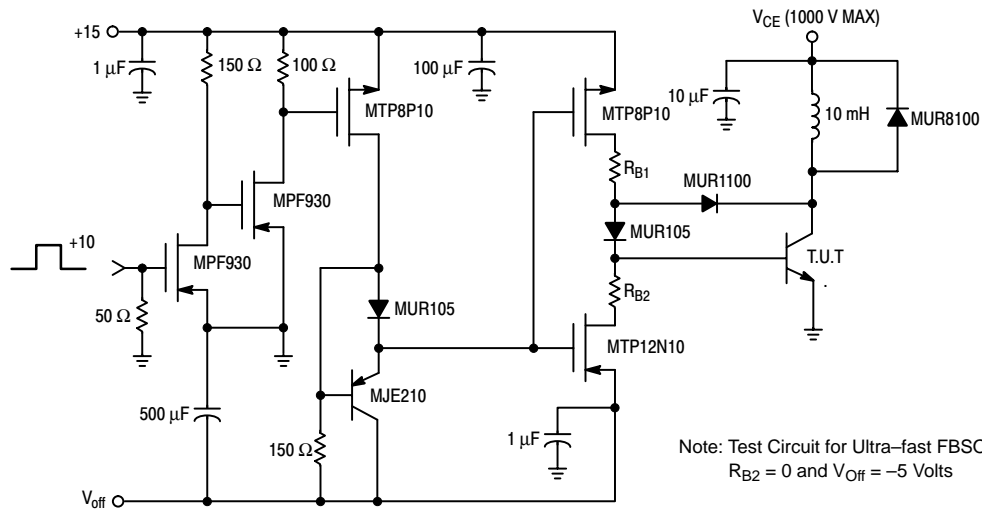


Figure 22. Switching Safe Operating Area

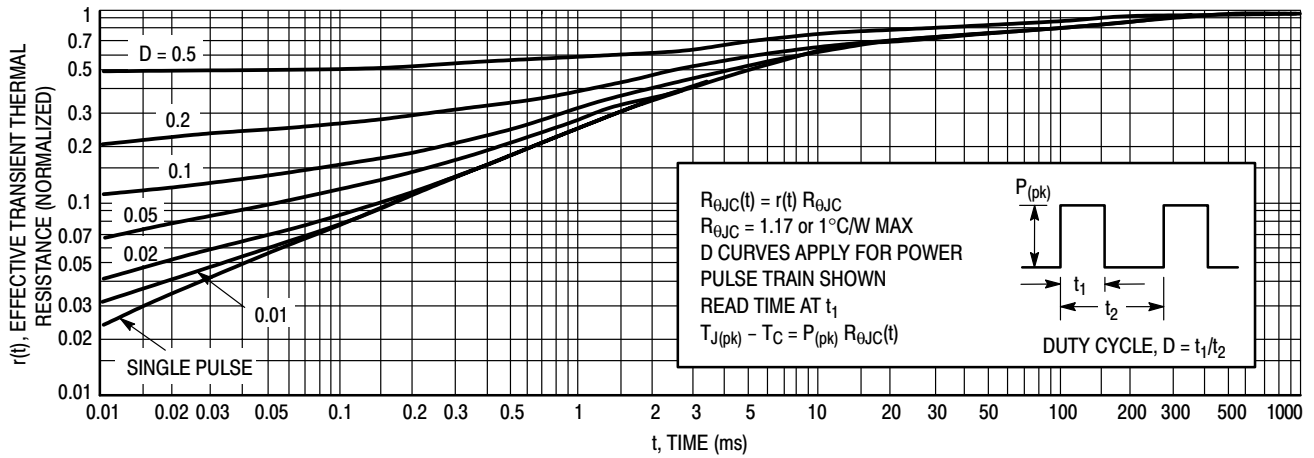


Figure 23. Thermal Response

## 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 Figures 14a and 14b 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  $T_C \geq 25^\circ\text{C}$ . Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figures 14a and 14b may be found at any case temperature by using the appropriate curve on Figure 16.

$T_{J(pk)}$  may be calculated from the data in Figure 18. 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 Biased Safe Operating Area and represents the voltage current condition allowable during reverse biased turnoff. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 15 gives the RBSOA characteristics.

## SWITCHMODE III DESIGN CONSIDERATIONS

### 1. FBSOA —

Allowable dc power dissipation in bipolar power transistors decreases dramatically with increasing collector

emitter voltage. A transistor which safely dissipates 100 watts at 10 volts will typically dissipate less than 10 watts at its rated  $V_{CE(sus)}$ . From a power handling point of view, current and voltage are not interchangeable (see Application Note AN875).

### 2. TURN-ON —

Safe turn-on load line excursions are bounded by pulsed FBSOA curves. The 10  $\mu\text{s}$  curve applies for resistive loads, most capacitive loads, and inductive loads that are clamped by standard or fast recovery rectifiers. Similarly, the 100 ns curve applies to inductive loads which are clamped by ultra-fast recovery rectifiers, and are valid for turn-on crossover times less than 100 ns (see Application Note AN952).

At voltages above 75% of  $V_{CE(sus)}$ , it is essential to provide the transistor with an adequate amount of base drive VERY RAPIDLY at turn-on. More specifically, safe operation according to the curves is dependent upon base current rise time being less than collector current rise time. As a general rule, a base drive compliance voltage in excess of 10 volts is required to meet this condition (see Application Note AN875).

### 3. TURN-OFF —

A bipolar transistor's ability to withstand turn-off stress is dependent upon its forward base drive. Gross overdrive violates the RBSOA curve and risks transistor failure. For this reason, circuits which use fixed base drive are often more likely to fail at light loads due to heavy overdrive (see Application Note AN875).

### 4. OPERATION ABOVE $V_{CE(sus)}$ —

When bipolars are operated above collector-emitter breakdown, base drive is crucial. A rapid application of adequate forward base current is needed for safe turn-on, as is a stiff negative bias needed for safe turn-off. Any hiccup in the base-drive circuitry that even momentarily violates either of these conditions will likely cause the transistor to fail. Therefore, it is important to design the driver so that its output is negative in the absence of anything but a clean crisp input signal (see Application Note AN952).

## SWITCHMODE DESIGN CONSIDERATIONS (Cont.)

### 5. RBSOA —

Reverse Biased Safe Operating Area has a first order dependency on circuit configuration and drive parameters. The RBSOA curves in this data sheet are valid only for the conditions specified. For a comparison of RBSOA results in several types of circuits (see Application Note AN951).

### 6. DESIGN SAMPLES —

Transistor parameters tend to vary much more from wafer lot to wafer lot, over long periods of time, than from one

device to the next in the same wafer lot. For design evaluation it is advisable to use transistors from several different date codes.

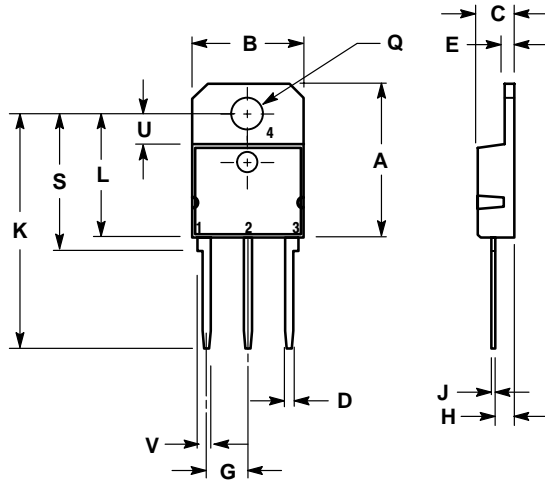
### 7. BAKER CLAMPS —

Many unanticipated pitfalls can be avoided by using Baker Clamps. MUR105 and MUR1100 diodes are recommended for base drives less than 1 amp. Similarly, MUR405 and MUR4100 types are well-suited for higher drive requirements (see Article Reprint AR131).

# MJH16006A

## PACKAGE DIMENSIONS

### CASE 340D-02 ISSUE B



#### NOTES:


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

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	---	20.35	---	0.801
B	14.70	15.20	0.579	0.598
C	4.70	4.90	0.185	0.193
D	1.10	1.30	0.043	0.051
E	1.17	1.37	0.046	0.054
G	5.40	5.55	0.213	0.219
H	2.00	3.00	0.079	0.118
J	0.50	0.78	0.020	0.031
K	31.00 REF		1.220 REF	
L	---	16.20	---	0.638
Q	4.00	4.10	0.158	0.161
S	17.80	18.20	0.701	0.717
U	4.00 REF		0.157 REF	
V	1.75 REF		0.069	

#### STYLE 1:

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

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