

# MJE5850, MJE5851, MJE5852

MJE5851 and MJE5852 are Preferred Devices

## SWITCHMODE™ Series PNP Silicon Power Transistors

The MJE5850, MJE5851 and the MJE5852 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.

### Features

- Switching Regulators
- Inverters
- Solenoid and Relay Drivers
- Motor Controls
- Deflection Circuits
- Fast Turn-Off Times
  - ♦ 100 ns Inductive Fall Time @ 25°C (Typ)
  - ♦ 125 ns Inductive Crossover Time @ 25°C (Typ)
- Operating Temperature Range – 65 to +150°C
- 100°C Performance Specified for:
  - ♦ Reversed Biased SOA with Inductive Loads
  - ♦ Switching Times with Inductive Loads
  - ♦ Saturation Voltages
  - ♦ Leakage Currents
- Pb-Free Packages are Available\*

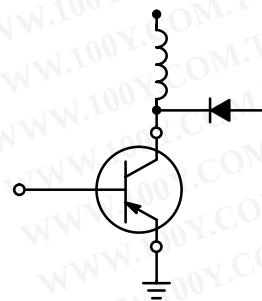
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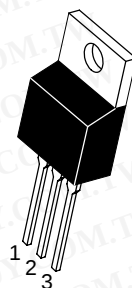
ON Semiconductor®

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**8 AMPERE  
PCP SILICON  
POWER TRANSISTORS  
300–350–400 VOLTS  
80 WATTS**



### MARKING DIAGRAM



TO-220AB  
CASE 221A-09  
STYLE 1



MJE585x = Device Code  
          x = 0, 1, or 2  
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 2 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.

# MJE5850, MJE5851, MJE5852

## MAXIMUM RATINGS

| Rating                                                                                | Symbol            | MJE5850 | MJE5851     | MJE5852 | Unit                     |
|---------------------------------------------------------------------------------------|-------------------|---------|-------------|---------|--------------------------|
| Collector-Emitter Voltage                                                             | $V_{CEO(sus)}$    | 300     | 350         | 400     | Vdc                      |
| Collector-Emitter Voltage                                                             | $V_{CEV}$         | 350     | 400         | 450     | Vdc                      |
| Emitter Base Voltage                                                                  | $V_{EB}$          |         | 6.0         |         | Vdc                      |
| Collector Current<br>– Continuous<br>– Peak (Note 1)                                  | $I_C$<br>$I_{CM}$ |         | 8.0<br>1.6  |         | Adc                      |
| Base Current<br>– Continuous<br>– Peak (Note 1)                                       | $I_B$<br>$I_{BM}$ |         | 4.0<br>8.0  |         | Adc                      |
| Total Power Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$             |         | 80<br>0.640 |         | W<br>W/ $^\circ\text{C}$ |
| Operating and Storage Junction Temperature Range                                      | $T_J, T_{stg}$    |         | –65 to 150  |         | $^\circ\text{C}$         |

## THERMAL CHARACTERISTICS

| Rating                                                                        | Symbol          | Max  | Unit               |
|-------------------------------------------------------------------------------|-----------------|------|--------------------|
| Thermal Resistance, Junction-to-Case                                          | $R_{\theta JC}$ | 1.25 | $^\circ\text{C/W}$ |
| Maximum Lead Temperature for Soldering Purposes: 1/8" from Case for 5 Seconds | $T_L$           | 275  | $^\circ\text{C}$   |

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  $\leq 10\%$ .

## ORDERING INFORMATION

| Device   | Package             | Shipping        |
|----------|---------------------|-----------------|
| MJE5850  | TO-220              | 50 Units / Rail |
| MJE5850G | TO-220<br>(Pb-Free) |                 |
| MJE5851  | TO-220              |                 |
| MJE5851G | TO-220<br>(Pb-Free) |                 |
| MJE5852  | TO-220              |                 |
| MJE5852G | TO-220<br>(Pb-Free) |                 |

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# MJE5850, MJE5851, MJE5852

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

### OFF CHARACTERISTICS

|                                                                                                                                                                                                    |                               |                |                   |             |                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------|-------------------|-------------|--------------------|
| Collector-Emitter Sustaining Voltage<br>( $I_C = 10\text{ mA}$ , $I_B = 0$ )                                                                                                                       | MJE5850<br>MJE5851<br>MJE5852 | $V_{CEO(sus)}$ | 300<br>350<br>400 | –<br>–<br>– | Vdc                |
| Collector Cutoff Current<br>( $V_{CEV} = \text{Rated Value}$ , $V_{BE(off)} = 1.5\text{ Vdc}$ )<br>( $V_{CEV} = \text{Rated Value}$ , $V_{BE(off)} = 1.5\text{ Vdc}$ , $T_C = 100^\circ\text{C}$ ) |                               | $I_{CEV}$      | –<br>–            | –<br>–      | 0.5<br>2.5<br>mAdc |
| Collector Cutoff Current<br>( $V_{CE} = \text{Rated } V_{CEV}$ , $R_{BE} = 50\ \Omega$ , $T_C = 100^\circ\text{C}$ )                                                                               |                               | $I_{CER}$      | –                 | –           | 3.0<br>mAdc        |
| Emitter Cutoff Current<br>( $V_{EB} = 6.0\text{ Vdc}$ , $I_C = 0$ )                                                                                                                                |                               | $I_{EBO}$      | –                 | –           | 1.0<br>mAdc        |

### SECOND BREAKDOWN

|                                                             |           |               |
|-------------------------------------------------------------|-----------|---------------|
| Second Breakdown Collector Current with base forward biased | $I_{S/b}$ | See Figure 12 |
| Clamped Inductive SOA with base reverse biased              | RBSOA     | See Figure 13 |

### ON CHARACTERISTICS (Note 2)

|                                                                                                                                                                                                                                       |               |             |             |                   |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------|-------------|-------------------|-----|
| DC Current Gain<br>( $I_C = 2.0\text{ Adc}$ , $V_{CE} = 5\text{ Vdc}$ )<br>( $I_C = 5.0\text{ Adc}$ , $V_{CE} = 5\text{ Vdc}$ )                                                                                                       | $h_{FE}$      | 15<br>5     | –<br>–      | –<br>–            | –   |
| Collector-Emitter Saturation Voltage<br>( $I_C = 4.0\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ )<br>( $I_C = 8.0\text{ Adc}$ , $I_B = 3.0\text{ Adc}$ )<br>( $I_C = 4.0\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ , $T_C = 100^\circ\text{C}$ ) | $V_{CE(sat)}$ | –<br>–<br>– | –<br>–<br>– | 2.0<br>5.0<br>2.5 | Vdc |
| Base-Emitter Saturation Voltage<br>( $I_C = 4.0\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ )<br>( $I_C = 4.0\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ , $T_C = 100^\circ\text{C}$ )                                                             | $V_{BE(sat)}$ | –<br>–      | –<br>–      | 1.5<br>1.5        | Vdc |

### DYNAMIC CHARACTERISTICS

|                                                                                              |          |   |     |   |    |
|----------------------------------------------------------------------------------------------|----------|---|-----|---|----|
| Output Capacitance<br>( $V_{CB} = 10\text{ Vdc}$ , $I_E = 0$ , $f_{test} = 1.0\text{ kHz}$ ) | $C_{ob}$ | – | 270 | – | pF |
|----------------------------------------------------------------------------------------------|----------|---|-----|---|----|

### SWITCHING CHARACTERISTICS

#### Resistive Load (Table 1)

|              |                                                                                                                                                                   |       |   |       |     |               |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---|-------|-----|---------------|
| Delay Time   | $(V_{CC} = 250\text{ Vdc}$ , $I_C = 4.0\text{ A}$ , $I_{B1} = 1.0\text{ A}$ ,<br>$t_p = 50\ \mu\text{s}$ , Duty Cycle $\leq 2\%$ )                                | $t_d$ | – | 0.025 | 0.1 | $\mu\text{s}$ |
| Rise Time    |                                                                                                                                                                   | $t_r$ | – | 0.100 | 0.5 | $\mu\text{s}$ |
| Storage Time | $(V_{CC} = 250\text{ Vdc}$ , $I_C = 4.0\text{ A}$ , $I_{B1} = 1.0\text{ A}$ ,<br>$V_{BE(off)} = 5\text{ Vdc}$ , $t_p = 50\ \mu\text{s}$ , Duty Cycle $\leq 2\%$ ) | $t_s$ | – | 0.60  | 2.0 | $\mu\text{s}$ |
| Fall Time    |                                                                                                                                                                   | $t_f$ | – | 0.11  | 0.5 | $\mu\text{s}$ |

#### Inductive Load, Clamped (Table 1)

|                |                                                                                                                                             |          |   |       |     |               |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------|----------|---|-------|-----|---------------|
| Storage Time   | $(I_{CM} = 4\text{ A}$ , $V_{CEM} = 250\text{ V}$ , $I_{B1} = 1.0\text{ A}$ ,<br>$V_{BE(off)} = 5\text{ Vdc}$ , $T_C = 100^\circ\text{C}$ ) | $t_{sv}$ | – | 0.8   | 3.0 | $\mu\text{s}$ |
| Crossover Time |                                                                                                                                             | $t_c$    | – | 0.4   | 1.5 | $\mu\text{s}$ |
| Fall Time      |                                                                                                                                             | $t_{fi}$ | – | 0.1   | –   | $\mu\text{s}$ |
| Storage Time   | $(I_{CM} = 4\text{ A}$ , $V_{CEM} = 250\text{ V}$ , $I_{B1} = 1.0\text{ A}$ ,<br>$V_{BE(off)} = 5\text{ Vdc}$ , $T_C = 25^\circ\text{C}$ )  | $t_{sv}$ | – | 0.5   | –   | $\mu\text{s}$ |
| Crossover Time |                                                                                                                                             | $t_c$    | – | 0.125 | –   | $\mu\text{s}$ |
| Fall Time      |                                                                                                                                             | $t_{fi}$ | – | 0.1   | –   | $\mu\text{s}$ |

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

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TYPICAL ELECTRICAL CHARACTERISTICS

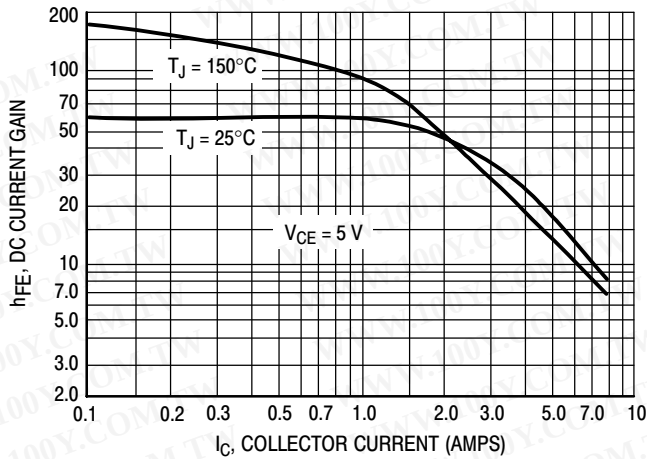


Figure 1. DC Current Gain

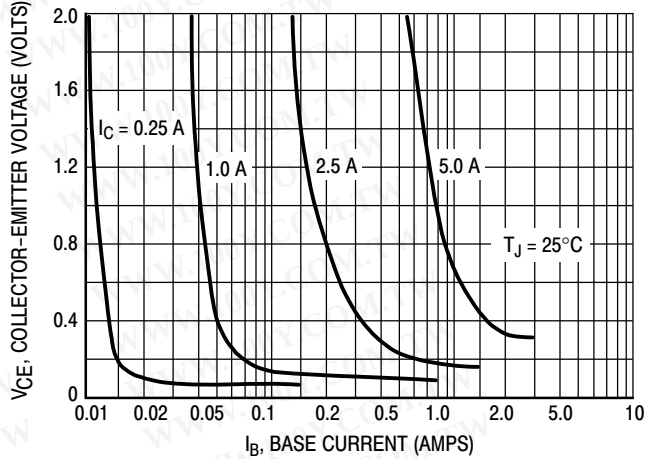


Figure 2. Collector Saturation Region

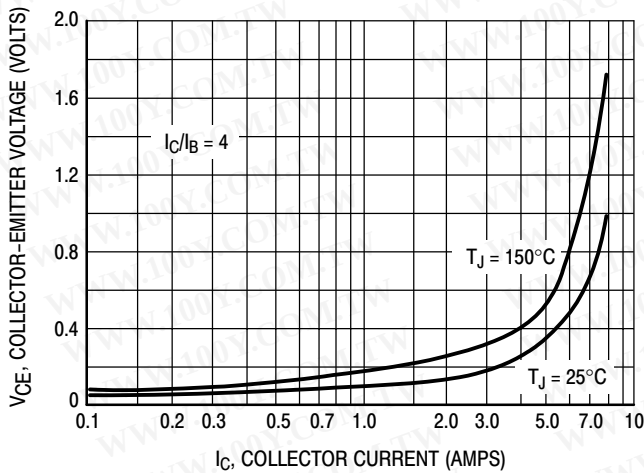


Figure 3. Collector-Emitter Saturation Voltage

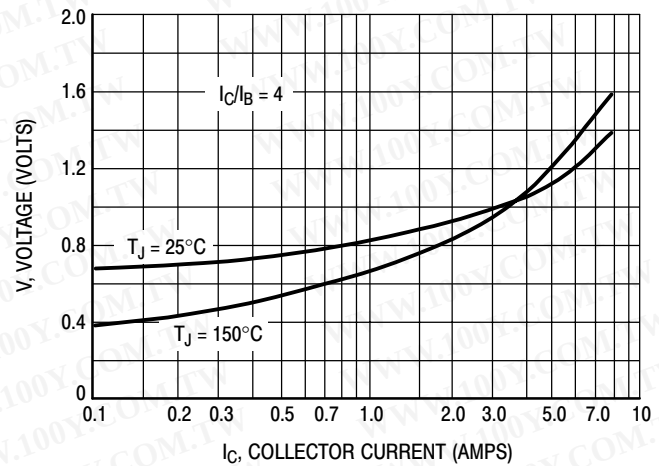


Figure 4. Base-Emitter Voltage

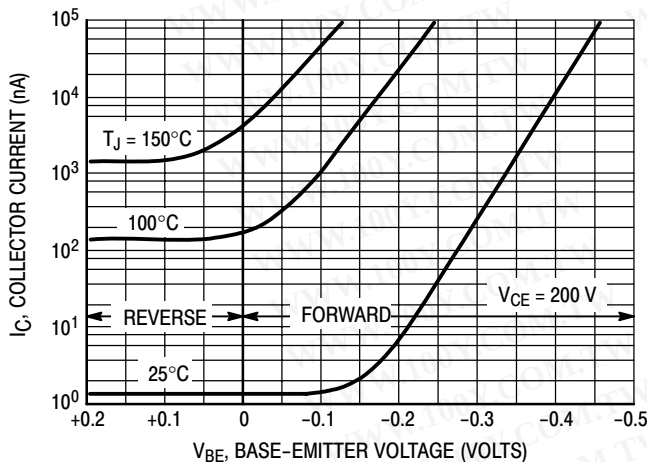


Figure 5. Collector Cutoff Region

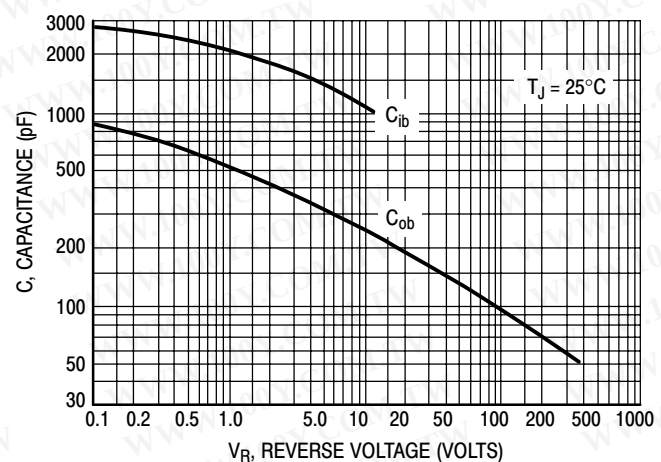
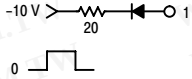
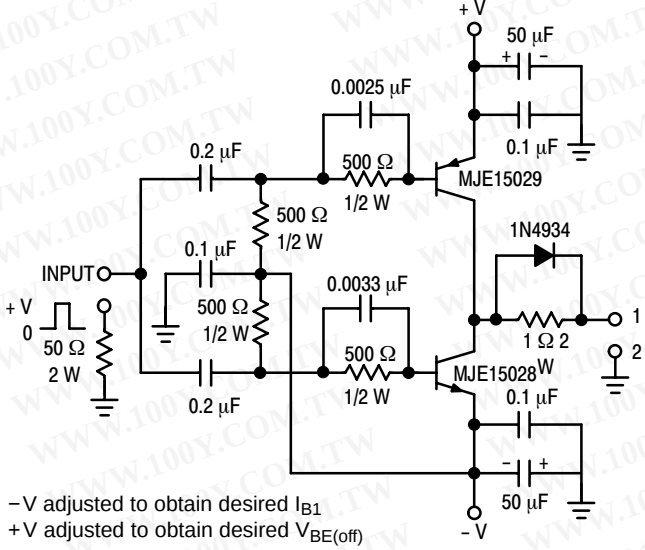
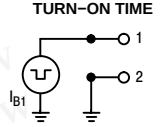
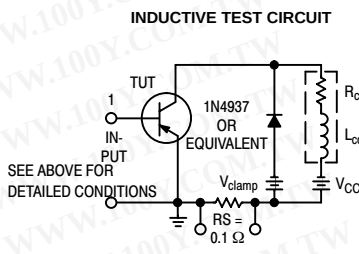
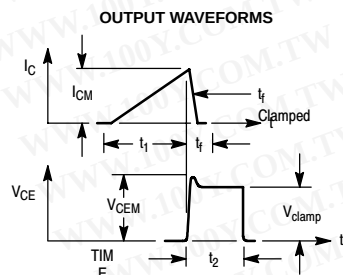
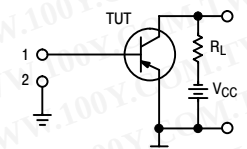
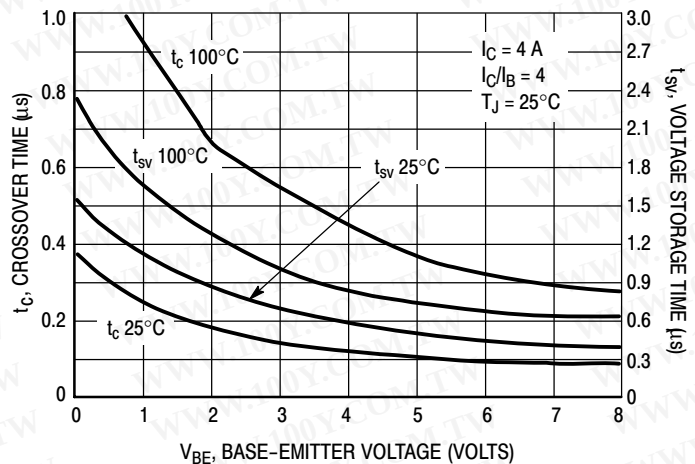
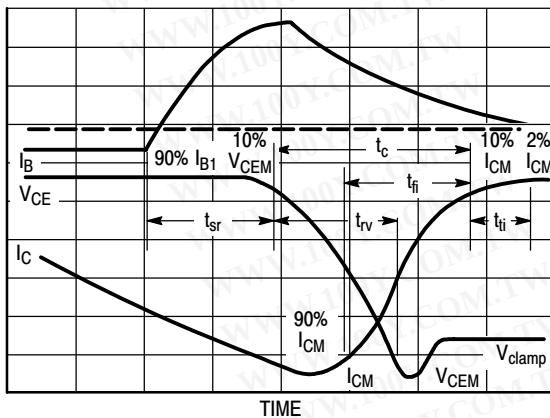


Figure 6. Capacitance

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Table 1. Test Conditions for Dynamic Performance

|                  | $V_{CEO(sus)}$                                                                                                                                            | RBSOA AND INDUCTIVE SWITCHING                                                                                                                                                                                                                                                                                                                                             | RESISTIVE SWITCHING                                                                                                                                                                                                                                                                           |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| INPUT CONDITIONS |  <p>PW Varied to Attain <math>I_C = 100 \text{ mA}</math></p>            |  <p>-V adjusted to obtain desired <math>I_{B1}</math><br/>+V adjusted to obtain desired <math>V_{BE(off)}</math></p>                                                                                                                                                                    |  <p>TURN-ON TIME<br/><math>I_{B1}</math> adjusted to obtain the forced <math>h_{FE}</math> desired</p> <p>TURN-OFF TIME<br/>Use inductive switching driver as the input to the resistive test circuit.</p> |
| CIRCUIT VALUES   | $L_{coil} = 80 \text{ mH}$ , $V_{CC} = 10 \text{ V}$<br>$R_{coil} = 0.7 \Omega$                                                                           | $L_{coil} = 180 \mu\text{H}$<br>$R_{coil} = 0.05 \Omega$<br>$V_{CC} = 20 \text{ V}$<br>$V_{clamp} = 250 \text{ V}$<br>$R_B$ adjusted to attain desired $I_{B1}$                                                                                                                                                                                                           | $V_{CC} = 250 \text{ V}$<br>$R_L = 62 \Omega$<br>Pulse Width = 10 $\mu\text{s}$                                                                                                                                                                                                               |
| TEST CIRCUITS    |  <p>INDUCTIVE TEST CIRCUIT</p> <p>SEE ABOVE FOR DETAILED CONDITIONS</p> |  <p>OUTPUT WAVEFORMS</p> <p><math>t_1</math> Adjusted to Obtain <math>I_C</math></p> <p><math>t_1 \approx \frac{L_{coil} (I_{CM})}{V_{CC}}</math></p> <p><math>t_2 \approx \frac{L_{coil} (I_{CM})}{V_{Clamp}}</math></p> <p>Test Equipment<br/>Scope — Tektronix 475 or Equivalent</p> |  <p>RESISTIVE TEST CIRCUIT</p>                                                                                                                                                                           |



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# SWITCHING TIMES NOTE

In resistive switching circuits, rise, fall, and storage times have been defined and apply to both current and voltage waveforms since they are in phase. However, for inductive loads which are common to SWITCHMODE power supplies and hammer drivers, current and voltage waveforms are not in phase. Therefore, separate measurements must be made on each waveform to determine the total switching time. For this reason, the following new terms have been defined.

$t_{SV}$  = Voltage Storage Time, 90%  $I_{B1}$  to 10%  $V_{CEM}$

$t_{RV}$  = Voltage Rise Time, 10–90%  $V_{CEM}$

$t_{fi}$  = Current Fall Time, 90–10%  $I_{CM}$

$t_{ti}$  = Current Tail, 10–2%  $I_{CM}$

$t_c$  = Crossover Time, 10%  $V_{CEM}$  to 10%  $I_{CM}$

An enlarged portion of the inductive switching waveform is shown in Figure 7 to aid on the visual identity of these terms.

For the designer, there is minimal switching loss during storage time and the predominant switching power losses occur during the crossover interval and can be obtained using the standard equation from AN-222A:

$$P_{SWT} = 1/2 V_{CC} I_C (t_c) f$$

In general,  $t_{RV} + t_{fi} \approx t_c$ . However, at lower test currents this relationship may not be valid.

As is common with most switching transistors, resistive switching is specified at 25°C and has become a benchmark for designers. However, for designers of high frequency converter circuits, the user oriented specifications which make this a “SWITCHMODE” transistor are the inductive switching speeds ( $t_c$  and  $t_{SV}$ ) which are guaranteed at 100°C.

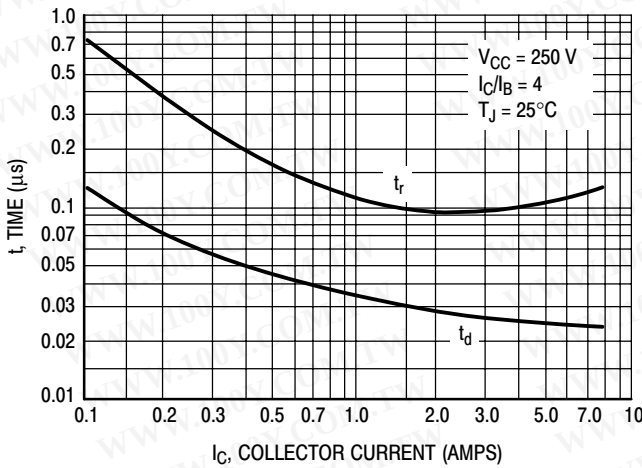


Figure 9. Turn-On Switching Times

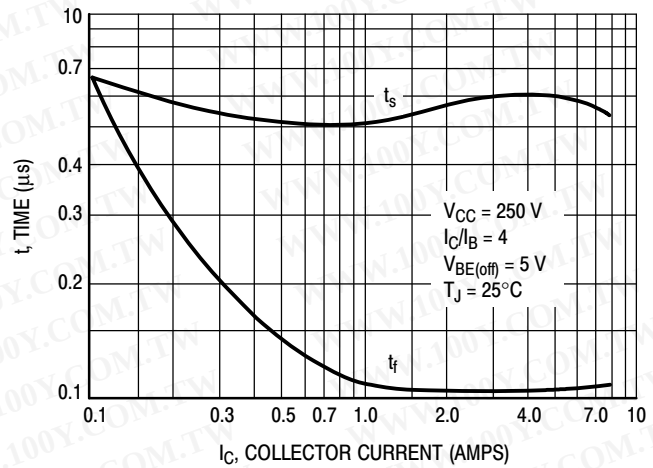


Figure 10. Turn-Off Switching Time

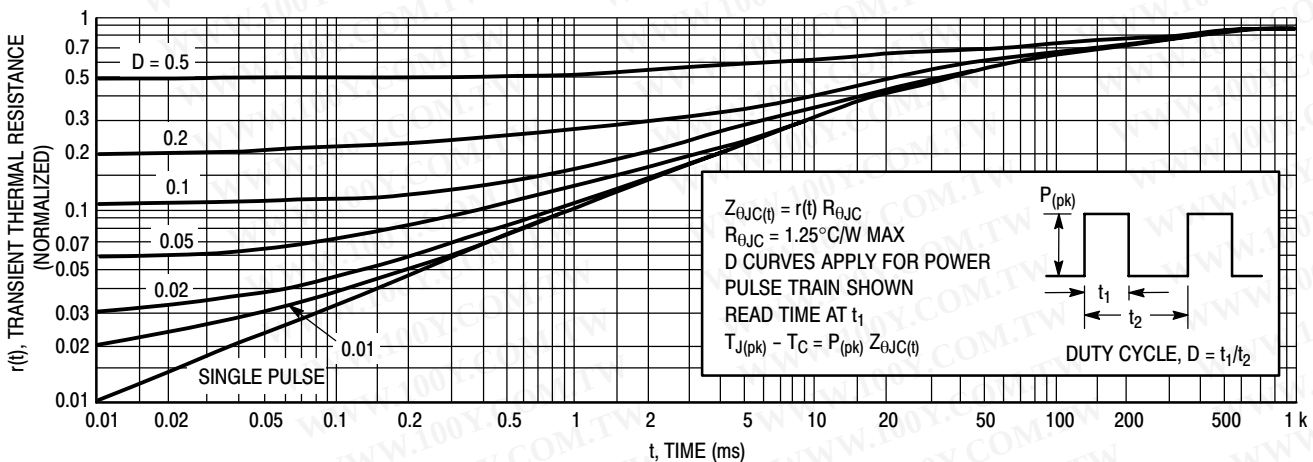


Figure 11. Typical Thermal Response [ $Z_{\theta JC}(t)$ ]

## MJE5850, MJE5851, MJE5852

The Safe Operating Area figures shown in Figures 12 and 13 are specified for these devices under the test conditions shown.

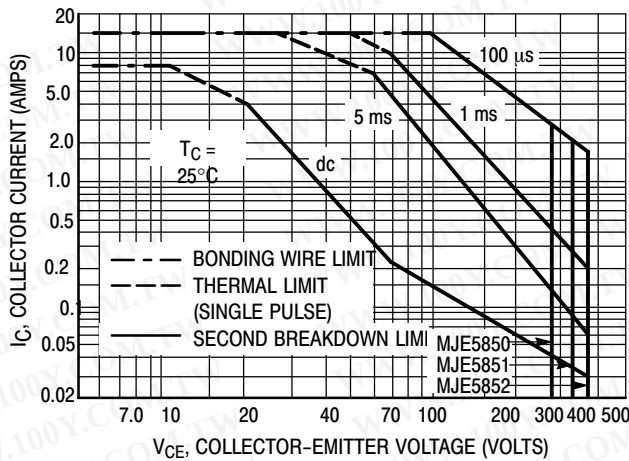


Figure 12. Maximum Forward Bias Safe Operating Area

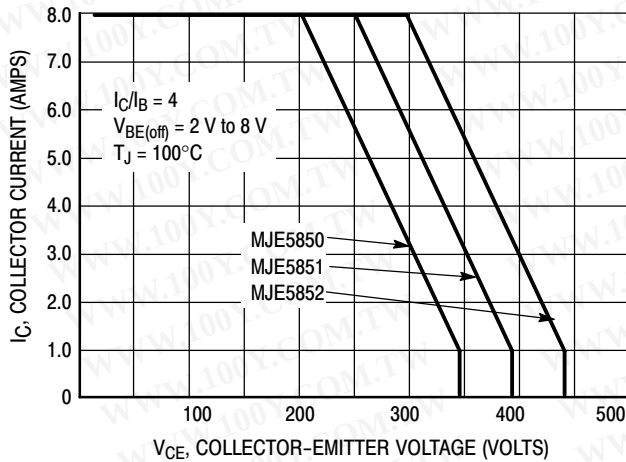


Figure 13. RBSOA, Maximum Reverse Bias Safe Operating Area

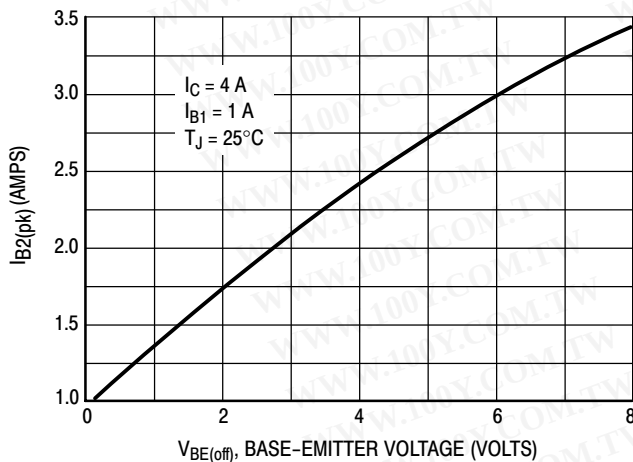


Figure 14. Peak Reverse Base Current

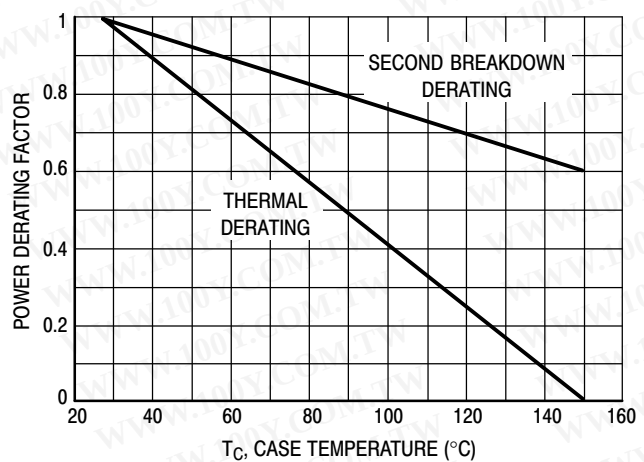


Figure 15. Forward Bias Power Derating

## 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 12 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 Figure 12 may be found at any case temperature by using the appropriate curve on Figure 15.

$T_{J(pk)}$  may be calculated from the data in Figure 11. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

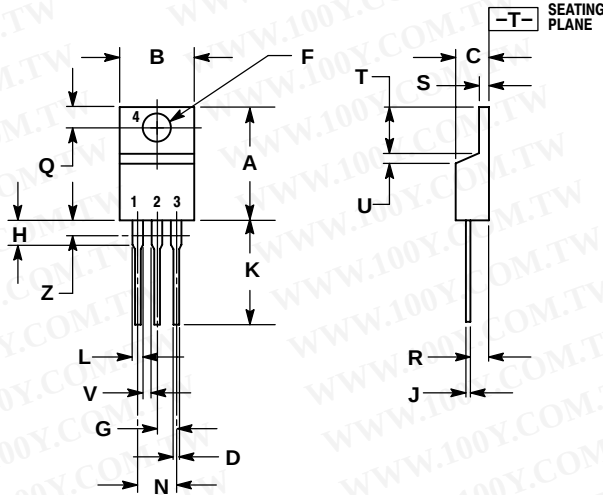
### REVERSE BIAS

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 Operating Area and represents the voltage-current condition allowable during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 13 gives the RBSOA characteristics.

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## 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:

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

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