

6367254 MOTOROLA SC (XSTRS/R F)

96D 81082

D T-33-15

T-33-13

# **MOTOROLA** **SEMICONDUCTOR** **TECHNICAL DATA**

**MJ13090 MJH13090**  
**MJ13091 MJH13091**

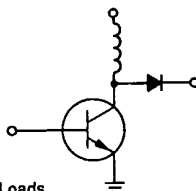
## **Designer's Data Sheet**

### **SWITCHMODE SERIES** **NPN SILICON POWER TRANSISTORS**

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 switch-mode applications such as:

- Switching Regulators
- Inverters
- Solenoid and Relay Drivers
- Motor Controls
- Deflection Circuits

100°C Performance Specified for:  
 Reverse-Biased SOA with Inductive Loads  
 Switching Times with Inductive Loads —  
 150 ns Inductive Fall Time (Typ)  
 Saturation Voltages  
 Leakage Currents



#### MAXIMUM RATINGS

| Rating                                           | Symbol         | MJ13090    | MJ13091 | MJH13090   | MJH13091 | Unit  |
|--------------------------------------------------|----------------|------------|---------|------------|----------|-------|
| Collector-Emitter Voltage                        | $V_{CE(sus)}$  | 400        | 450     | 400        | 450      | Vdc   |
| Collector-Emitter Voltage                        | $V_{CEV}$      | 650        | 750     | 650        | 750      | Vdc   |
| Emitter-Base Voltage                             | $V_{EB}$       | 6.0        |         |            |          | Vdc   |
| Collector Current                                | $I_C$          | 15         |         |            |          | Adc   |
| — Continuous                                     | $I_{CM}$       | 20         |         |            |          | Adc   |
| Base Current                                     | $I_B$          | 5.0        |         |            |          | Adc   |
| — Continuous                                     | $I_{BM}$       | 10         |         |            |          | Adc   |
| Total Device Dissipation                         | $P_D$          | 175        | 100     | 125        | 50       | Watts |
| — @ $T_C = 25^\circ\text{C}$                     |                | 100        |         | 50         |          |       |
| — @ $T_C = 100^\circ\text{C}$                    |                | 1.0        |         | 1.0        |          |       |
| Derate above $25^\circ\text{C}$                  |                |            |         |            |          | W/°C  |
| Operating and Storage Junction Temperature Range | $T_J, T_{stg}$ | -65 to 200 |         | -55 to 150 |          | °C    |

#### THERMAL CHARACTERISTICS

| Characteristic                                                        | Symbol          | Max | Unit |
|-----------------------------------------------------------------------|-----------------|-----|------|
| Thermal Resistance, Junction to Case                                  | $R_{\theta JC}$ | 1.0 | °C/W |
| Lead Temperature for Soldering Purposes, 1/8" from Case for 5 Seconds | $T_L$           | 275 | °C   |

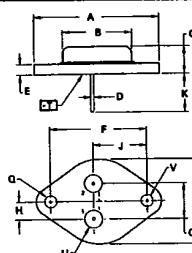
(1) Pulse Test: Pulse Width  $\leq 5.0 \mu\text{s}$ , Duty Cycle  $\geq 10\%$ .

#### Designer's Data for "Worst Case" Conditions

The Designer's Data Sheet permits the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

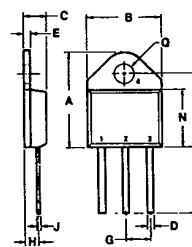
15 AMPERE

### **NPN SILICON** **POWER** **TRANSISTORS**

**400 AND 450 VOLTS**  
**125 AND 175 WATTS**

**MJ13090**  
**MJ13091**
**STYLE 1**  
**PIN 1 BASE**  
**2. EMITTER**  
**CASE COLLECTOR**

NOTES:  
 1. DIMENSIONS D AND V ARE DATUMS.  
 2.  $\square$  IS SEATING PLANE AND DATUM.  
 3. POSITIONAL TOLERANCE FOR MOUNTING HOLE D.  
 4. DIMENSIONS AND TOLERANCES PER ANSI Y14.5, 1973.

| DIM | MIN   | MAX   | MIN   | MAX   |
|-----|-------|-------|-------|-------|
| A   | 19.37 | —     | 0.763 | —     |
| B   | —     | 21.08 | —     | 0.830 |
| C   | 6.35  | 7.62  | 0.250 | 0.300 |
| D   | 0.31  | 1.01  | 0.012 | 0.040 |
| E   | 1.43  | 1.78  | 0.055 | 0.070 |
| F   | 30.15 | 35.00 | 1.187 | 1.378 |
| G   | 10.42 | 10.42 | 0.410 | 0.410 |
| H   | 5.48  | 5.48  | 0.215 | 0.215 |
| I   | 16.83 | 16.83 | 0.663 | 0.663 |
| J   | 11.18 | 12.13 | 0.440 | 0.480 |
| K   | 3.81  | 4.19  | 0.150 | 0.165 |
| L   | —     | 26.47 | —     | 1.040 |
| M   | 4.83  | 5.33  | 0.190 | 0.210 |
| N   | 3.81  | 4.19  | 0.150 | 0.165 |

**CASE 1-05**  
**TO-204AA**

**MJH13090**  
**MJH13091**
**1 BASE**  
**2 COLLECTOR**  
**3 EMITTER**  
**4. COLLECTOR**

| DIM | MIN   | MAX   | MIN   | MAX   |
|-----|-------|-------|-------|-------|
| A   | 20.32 | 21.08 | 0.800 | 0.830 |
| B   | 15.48 | 16.90 | 0.610 | 0.670 |
| C   | 4.19  | 5.08  | 0.165 | 0.200 |
| D   | 1.02  | 1.45  | 0.040 | 0.065 |
| E   | 1.35  | 1.85  | 0.053 | 0.075 |
| F   | 5.21  | 5.72  | 0.205 | 0.225 |
| G   | 2.41  | 3.30  | 0.095 | 0.130 |
| H   | 0.28  | 0.64  | 0.015 | 0.025 |
| I   | 12.70 | 15.48 | 0.500 | 0.610 |
| J   | 15.88 | 16.51 | 0.625 | 0.650 |
| K   | 12.15 | 12.70 | 0.480 | 0.500 |
| L   | 4.04  | 4.27  | 0.158 | 0.168 |

**CASE 340-01**  
**TO-218AC**

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 MJ13090, MJ13091, MJH13090, MJH13091

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

| Characteristic                                                                                                                                                                                     | Symbol         | Min        | Typ    | Max        | Unit |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------------|--------|------------|------|
| <b>OFF CHARACTERISTICS (1)</b>                                                                                                                                                                     |                |            |        |            |      |
| Collector-Emitter Sustaining Voltage (Table 1)<br>( $I_C = 100\text{ mA}$ , $I_B = 0$ )<br>MJ13090, MJH13090<br>MJ13091, MJH13091                                                                  | $V_{CEO(sus)}$ | 400<br>450 | —<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 | mA   |
| Collector Cutoff Current<br>( $V_{CE} = \text{Rated } V_{CEV}$ , $R_{BE} = 50\ \Omega$ , $T_C = 100^\circ\text{C}$ )                                                                               | $I_{CER}$      | —          | —      | 3.0        | mA   |
| Emitter Cutoff Current<br>( $V_{EB} = 6.0\text{ Vdc}$ , $I_C = 0$ )                                                                                                                                | $I_{EBO}$      | —          | —      | 1.0        | mA   |

**SECOND BREAKDOWN**

|                                                             |           |                       |  |  |  |
|-------------------------------------------------------------|-----------|-----------------------|--|--|--|
| Second Breakdown Collector Current with Base Forward Biased | $I_{S/b}$ | See Figures 12 and 13 |  |  |  |
| Clamped Inductive SOA with Base Reverse Biased              | RBSOA     | See Figure 14         |  |  |  |

**ON CHARACTERISTICS (1)**

|                                                                                                                                                                                                                                    |               |             |             |                   |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------|-------------|-------------------|-----|
| DC Current Gain<br>( $I_C = 10\text{ Adc}$ , $V_{CE} = 3.0\text{ Vdc}$ )                                                                                                                                                           | $h_{FE}$      | 8.0         | —           | —                 | —   |
| Collector-Emitter Saturation Voltage<br>( $I_C = 10\text{ Adc}$ , $I_B = 2.0\text{ Adc}$ )<br>( $I_C = 15\text{ Adc}$ , $I_B = 3.0\text{ Adc}$ )<br>( $I_C = 10\text{ Adc}$ , $I_B = 2.0\text{ Adc}$ , $T_C = 100^\circ\text{C}$ ) | $V_{CE(sat)}$ | —<br>—<br>— | —<br>—<br>— | 1.0<br>3.0<br>2.0 | Vdc |
| Base-Emitter Saturation Voltage<br>( $I_C = 10\text{ Adc}$ , $I_B = 2.0\text{ Adc}$ )<br>( $I_C = 10\text{ Adc}$ , $I_B = 2.0\text{ Adc}$ , $T_C = 100^\circ\text{C}$ )                                                            | $V_{BE(sat)}$ | —<br>—      | —<br>—      | 1.5<br>1.5        | Vdc |

**DYNAMIC CHARACTERISTICS**

|                                                                                              |          |   |   |     |    |
|----------------------------------------------------------------------------------------------|----------|---|---|-----|----|
| Output Capacitance<br>( $V_{CB} = 10\text{ Vdc}$ , $I_E = 0$ , $f_{test} = 1.0\text{ kHz}$ ) | $C_{ob}$ | — | — | 350 | pF |
|----------------------------------------------------------------------------------------------|----------|---|---|-----|----|

**SWITCHING CHARACTERISTICS****Resistive Load (Table 1)**

|              |                                                                                                                                                                             |                |   |      |      |         |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|---|------|------|---------|
| Delay Time   | (V <sub>CC</sub> = 250 Vdc, I <sub>C</sub> = 10 Adc,<br>I <sub>B1</sub> = 1.25 Adc, t <sub>p</sub> = 30 $\mu$ s,<br>Duty Cycle $\leq 2\%$ , V <sub>BE(off)</sub> = 5.0 Vdc) | t <sub>d</sub> | — | 0.03 | 0.05 | $\mu$ s |
| Rise Time    |                                                                                                                                                                             | t <sub>r</sub> | — | 0.13 | 0.50 |         |
| Storage Time |                                                                                                                                                                             | t <sub>s</sub> | — | 0.55 | 2.50 |         |
| Fall Time    |                                                                                                                                                                             | t <sub>f</sub> | — | 0.10 | 0.50 |         |

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

|                |                                                                                                                               |                          |                 |   |       |      |         |
|----------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------|---|-------|------|---------|
| Storage Time   | (I <sub>C(pk)</sub> = 10 A,<br>I <sub>B1</sub> = 1.25 Adc,<br>V <sub>BE(off)</sub> = 5.0 Vdc,<br>V <sub>CE(pk)</sub> = 250 V) | (T <sub>J</sub> = 100°C) | t <sub>sv</sub> | — | 0.80  | 3.00 | $\mu$ s |
| Crossover Time |                                                                                                                               |                          | t <sub>c</sub>  | — | 0.175 | 0.40 |         |
| Fall Time      |                                                                                                                               |                          | t <sub>fi</sub> | — | 0.15  | 0.30 |         |
| Storage Time   |                                                                                                                               | (T <sub>J</sub> = 25°C)  | t <sub>sv</sub> | — | 0.50  | —    |         |
| Crossover Time |                                                                                                                               |                          | t <sub>c</sub>  | — | 0.15  | —    |         |
| Fall Time      |                                                                                                                               |                          | t <sub>fi</sub> | — | 0.10  | —    |         |

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

$$*\beta_{ef} = \frac{I_C}{I_B}$$

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## DC CHARACTERISTICS

FIGURE 1 — DC CURRENT GAIN

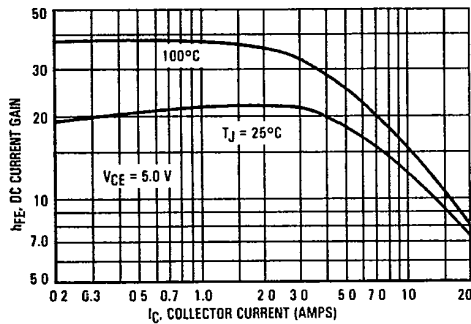


FIGURE 2 — COLLECTOR SATURATION REGION

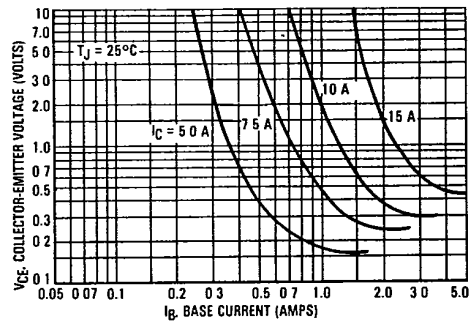


FIGURE 3 — COLLECTOR-EMITTER SATURATION VOLTAGE

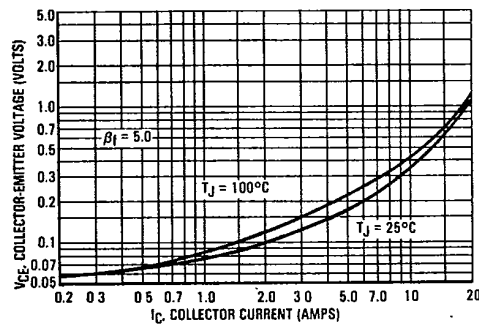


FIGURE 4 — BASE-EMITTER SATURATION VOLTAGE

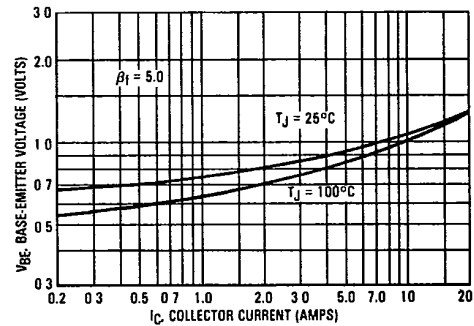


FIGURE 5 — COLLECTOR CUTOFF REGION

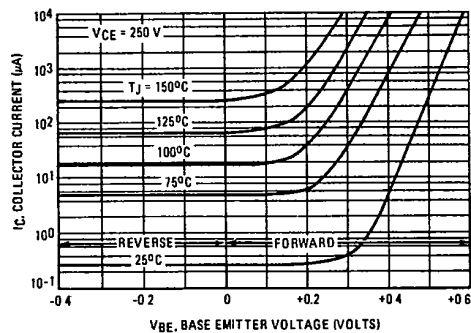
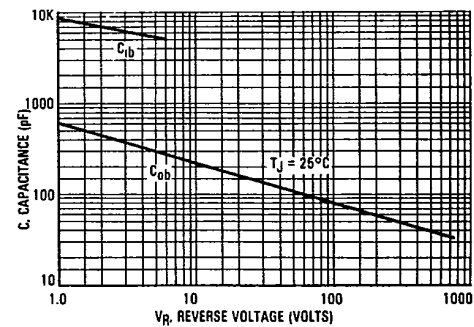


FIGURE 6 — CAPACITANCE



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 MJ13090, MJ13091, MJH13090, MJH13091

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TABLE 1 - TEST CONDITIONS FOR DYNAMIC PERFORMANCE

|                  | V <sub>CEO</sub> (sus)                                                                                                                                                                                                                                                                                                                                                                                    | RBSOA AND INDUCTIVE SWITCHING                                                                                                                                                                                       | RESISTIVE SWITCHING                                                                                                                                                                         |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| INPUT CONDITIONS | <p>PW Varied to Attain<br/>I<sub>C</sub> = 100 mA</p>                                                                                                                                                                                                                                                                                                                                                     | <p>Connect Point A to base of TUT<br/>Adjust -V to obtain desired V<sub>BE</sub>(off) at Point A<br/>Adjust R1 to obtain I<sub>B1</sub><br/>For switching and RBSOA, R2 = 0<br/>For V<sub>CEO</sub>(sus) R2 = ∞</p> | <p>TURN ON TIME<br/>I<sub>B1</sub> adjusted to obtain the forced h<sub>FE</sub> desired<br/>TURN OFF TIME<br/>Use inductive switching driver as the input to the resistive test circuit</p> |
| CIRCUIT VALUES   | <p>L<sub>coil</sub> = 80 mH V<sub>CC</sub> = 10 V<br/>R<sub>coil</sub> = 0.7 Ω</p>                                                                                                                                                                                                                                                                                                                        | <p>L<sub>coil</sub> = 180 μH<br/>R<sub>coil</sub> = 0.05 Ω<br/>V<sub>CC</sub> = 20 V<br/>V<sub>clamp</sub> = 250 V<br/>R<sub>B</sub> adjusted to attain desired I<sub>B1</sub></p>                                  | <p>V<sub>CC</sub> = 250 V<br/>R<sub>L</sub> = 25 Ω<br/>Pulse Width = 30 μs</p>                                                                                                              |
| TEST CIRCUITS    | <p>INDUCTIVE TEST CIRCUIT</p> <p>See Above for Detailed Conditions<br/>R<sub>S</sub> = 0.1 Ω</p> <p>OUTPUT WAVEFORMS</p> <p>t<sub>1</sub> Adjusted to Obtain I<sub>C</sub><br/> <math>t_1 \approx \frac{L_{coil}(I_{Cpk})}{V_{CC}}</math><br/> <math>t_2 \approx \frac{L_{coil}(I_{Cpk})}{V_{clamp}}</math><br/>           Test Equipment<br/>           Scope - Tektronix 475 or Equivalent         </p> | <p>RESISTIVE TEST CIRCUIT</p>                                                                                                                                                                                       |                                                                                                                                                                                             |

FIGURE 7 - INDUCTIVE SWITCHING MEASUREMENTS

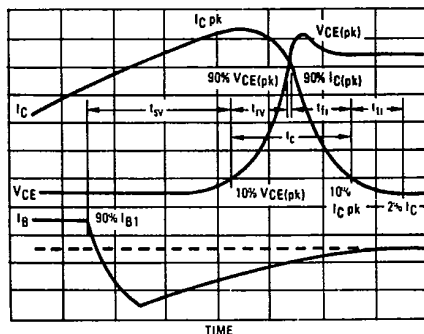
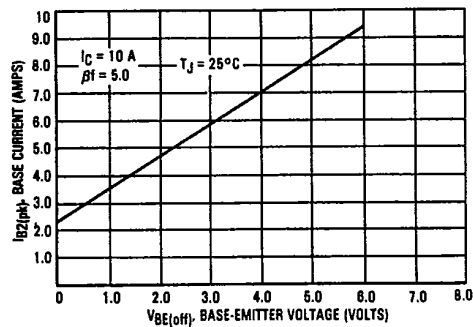


FIGURE 8 - PEAK REVERSE CURRENT



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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%  $I_B$  to 10%  $V_{clamp}$

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

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

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

$t_C$  = Crossover Time, 10%  $V_{clamp}$  to 10%  $I_C$

An enlarged portion of the inductive switching waveforms is shown in Figure 7 to aid in 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-222:

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

In general,  $t_{RV} + t_{fi} = t_C$ . 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.

## INDUCTIVE SWITCHING

FIGURE 9 — STORAGE TIME

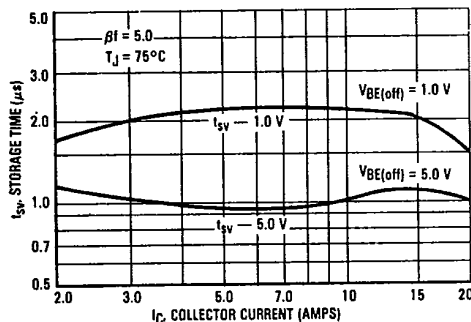


FIGURE 10 — CROSSOVER AND FALL TIMES

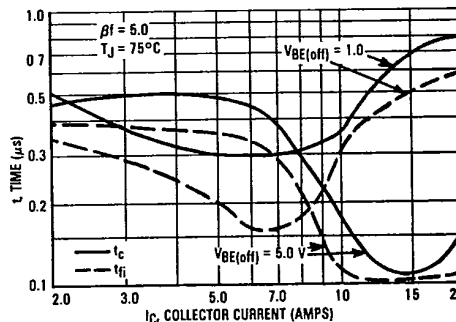
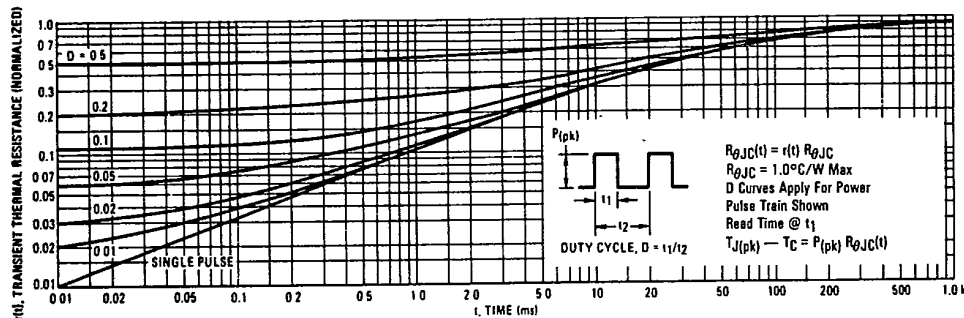


FIGURE 11 — THERMAL RESPONSE



6367254 MOTOROLA SC {XSTRS/R F}

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MJ13090, MJ13091, MJH13090, MJH13091

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

FIGURE 12 — FORWARD BIAS SAFE OPERATING AREA  
MJ13090 and MJ13091

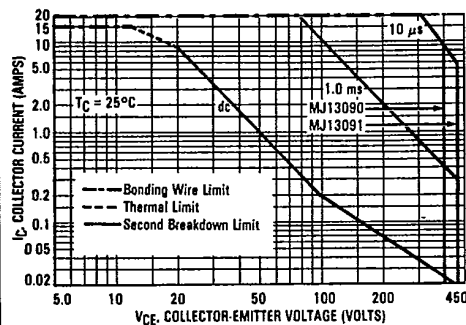


FIGURE 13 — FORWARD BIAS SAFE OPERATING AREA  
MJH13090 and MJH13091

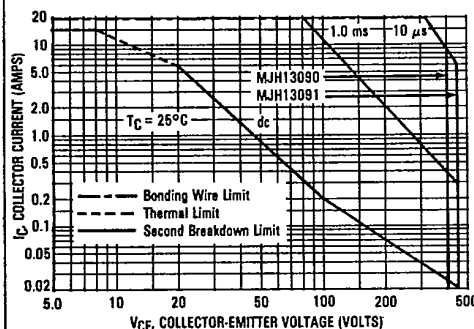
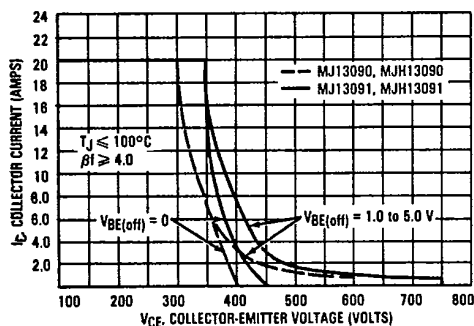


FIGURE 14 — REVERSE BIAS SAFE OPERATING AREA



## 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 12 and 13 are based on  $T_C = 25^\circ\text{C}$ ;  $T_J(\text{pk})$  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 12 and 13 may be found at any case temperature by using the appropriate curve on Figure 15.

$T_J(\text{pk})$  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 conditions during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 14 gives RBSOA characteristics.

FIGURE 15 — POWER DERATING

