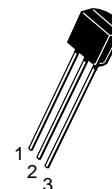
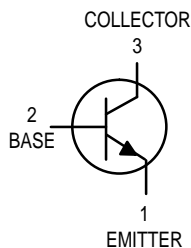


# Switching Transistor

## NPN Silicon

**MPS3646**

Motorola Preferred Device



CASE 29-04, STYLE 1  
TO-92 (TO-226AA)

### MAXIMUM RATINGS

| Rating   | Symbol         | Value       | Unit                          |
|--|----------------|-------------|-------------------------------|
| Collector–Emitter Voltage  | $V_{CEO}$      | 15          | Vdc                           |
| Collector–Emitter Voltage  | $V_{CES}$      | 40          | Vdc                           |
| Collector–Base Voltage   | $V_{CBO}$      | 40          | Vdc                           |
| Emitter–Base Voltage   | $V_{EBO}$      | 5.0         | Vdc                           |
| Collector Current — Continuous<br>— 10 $\mu$ s Pulse                                   | $I_C$          | 300<br>500  | mAdc                          |
| Total Device Dissipation @ $T_A = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$          | 625<br>5.0  | mW<br>mW/ $^\circ\text{C}$    |
| Total Device Dissipation @ $T_C = 25^\circ\text{C}$<br>Derate above $25^\circ\text{C}$ | $P_D$          | 1.5<br>12   | Watts<br>mW/ $^\circ\text{C}$ |
| Operating and Storage Junction<br>Temperature Range                                    | $T_J, T_{stg}$ | -55 to +150 | $^\circ\text{C}$              |

### THERMAL CHARACTERISTICS

| Characteristic                          | Symbol          | Max  | Unit                      |
|---|-----------------|------|---------------------------|
| Thermal Resistance, Junction to Ambient | $R_{\theta JA}$ | 200  | $^\circ\text{C}/\text{W}$ |
| Thermal Resistance, Junction to Case    | $R_{\theta JC}$ | 83.3 | $^\circ\text{C}/\text{W}$ |

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

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

### OFF CHARACTERISTICS

|  |                |        |            |                 |
|--|----------------|--------|------------|-----------------|
| Collector–Emitter Breakdown Voltage<br>( $I_C = 100 \mu\text{Adc}, V_{BE} = 0$ )   | $V_{(BR)CES}$  | 40     | —          | Vdc             |
| Collector–Emitter Sustaining Voltage <sup>(1)</sup><br>( $I_C = 10 \text{mAdc}, I_B = 0$ )   | $V_{CEO(sus)}$ | 15     | —          | Vdc             |
| Collector–Base Breakdown Voltage<br>( $I_C = 100 \mu\text{Adc}, I_E = 0$ )   | $V_{(BR)CBO}$  | 40     | —          | Vdc             |
| Emitter–Base Breakdown Voltage<br>( $I_E = 100 \mu\text{Adc}, I_C = 0$ )   | $V_{(BR)EBO}$  | 5.0    | —          | Vdc             |
| Collector Cutoff Current<br>( $V_{CE} = 20 \text{Vdc}, V_{BE} = 0$ )<br>( $V_{CE} = 20 \text{Vdc}, V_{BE} = 0, T_A = 65^\circ\text{C}$ ) | $I_{CES}$      | —<br>— | 0.5<br>3.0 | $\mu\text{Adc}$ |

1. Pulse Test: Pulse Width  $\leq 300 \mu\text{s}$ ; Duty Cycle  $\leq 2.0\%$ .

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

# MPS3646

## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise noted) (Continued)

| Characteristic  | Symbol               | Min              | Max                       | Unit |
|---|----------------------|------------------|---------------------------|------|
| <b>ON CHARACTERISTICS(1)</b>  |                      |                  |                           |      |
| DC Current Gain<br>(I <sub>C</sub> = 30 mA, V <sub>CE</sub> = 0.4 Vdc)<br>(I <sub>C</sub> = 100 mA, V <sub>CE</sub> = 0.5 Vdc)<br>(I <sub>C</sub> = 300 mA, V <sub>CE</sub> = 1.0 Vdc)  | h <sub>FE</sub>      | 30<br>25<br>15   | 120<br>—<br>—             | —    |
| Collector–Emitter Saturation Voltage<br>(I <sub>C</sub> = 30 mA, I <sub>B</sub> = 3.0 mA)<br>(I <sub>C</sub> = 100 mA, I <sub>B</sub> = 10 mA)<br>(I <sub>C</sub> = 300 mA, I <sub>B</sub> = 30 mA)<br>(I <sub>C</sub> = 30 mA, I <sub>B</sub> = 3.0 mA, T <sub>A</sub> = 65°C) | V <sub>CE(sat)</sub> | —<br>—<br>—<br>— | 0.2<br>0.28<br>0.5<br>0.3 | Vdc  |
| Base–Emitter Saturation Voltage<br>(I <sub>C</sub> = 30 mA, I <sub>B</sub> = 3.0 mA)<br>(I <sub>C</sub> = 100 mA, I <sub>B</sub> = 10 mA)<br>(I <sub>C</sub> = 300 mA, I <sub>B</sub> = 30 mA)  | V <sub>BE(sat)</sub> | 0.73<br>—<br>—   | 0.95<br>1.2<br>1.7        | Vdc  |

## SMALL–SIGNAL CHARACTERISTICS

|   |                  |     |     |     |
|---|------------------|-----|-----|-----|
| Current–Gain — Bandwidth Product<br>(I <sub>C</sub> = 30 mA, V <sub>CE</sub> = 10 Vdc, f = 100 MHz) | f <sub>T</sub>   | 350 | —   | MHz |
| Output Capacitance<br>(V <sub>CB</sub> = 5.0 Vdc, I <sub>E</sub> = 0, f = 1.0 MHz)                  | C <sub>obo</sub> | —   | 5.0 | pF  |
| Input Capacitance<br>(V <sub>EB</sub> = 0.5 Vdc, I <sub>C</sub> = 0, f = 1.0 MHz)                   | C <sub>ibo</sub> | —   | 9.0 | pF  |

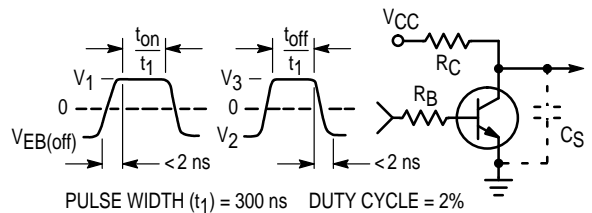
## SWITCHING CHARACTERISTICS

|  |  |                  |   |    |    |
|--|--|------------------|---|----|----|
| Turn–On Time   | (V <sub>CC</sub> = 10 Vdc, I <sub>C</sub> = 300 mA, I <sub>B1</sub> = 30 mA)<br>(Figure 1)                   | t <sub>on</sub>  | — | 18 | ns |
| Delay Time   |  | t <sub>d</sub>   | — | 10 | ns |
| Rise Time  |  | t <sub>r</sub>   | — | 15 | ns |
| Turn–Off Time  | (V <sub>CC</sub> = 10 Vdc, I <sub>C</sub> = 300 mA, I <sub>B1</sub> = I <sub>B2</sub> = 30 mA)<br>(Figure 1) | t <sub>off</sub> | — | 28 | ns |
| Fall Time  |  | t <sub>f</sub>   | — | 15 | ns |
| Storage Time<br>(V <sub>CC</sub> = 10 Vdc, I <sub>C</sub> = 10 mA, I <sub>B1</sub> = I <sub>B2</sub> = 10 mA) (Figure 2) |  | t <sub>s</sub>   | — | 18 | ns |

1. Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2.0%.

Figure 1. Switching Time Equivalent Test Circuit

| Test Condition | I <sub>C</sub> | V <sub>CC</sub> | R <sub>S</sub> | R <sub>C</sub> | C <sub>S(max)</sub> | V <sub>BE(off)</sub> | V <sub>1</sub> | V <sub>2</sub> | V <sub>3</sub> |
|----------------|----------------|-----------------|----------------|----------------|---------------------|----------------------|----------------|----------------|----------------|
|                | mA             | V               | Ω              | Ω              | pF                  | V                    | V              | V              | V              |
| <b>A</b>       | 10             | 3               | 330            | 270            | 4                   | -1.5                 | 10.55          | -4.15          | 10.70          |
| <b>B</b>       | 10             | 10              | 580            | 960            | 4                   | —                    | —              | -4.65          | 6.55           |
| <b>C</b>       | 100            | 10              | 560            | 96             | 12                  | -2.0                 | 6.35           | -4.65          | 6.55           |



CURRENT GAIN CHARACTERISTICS

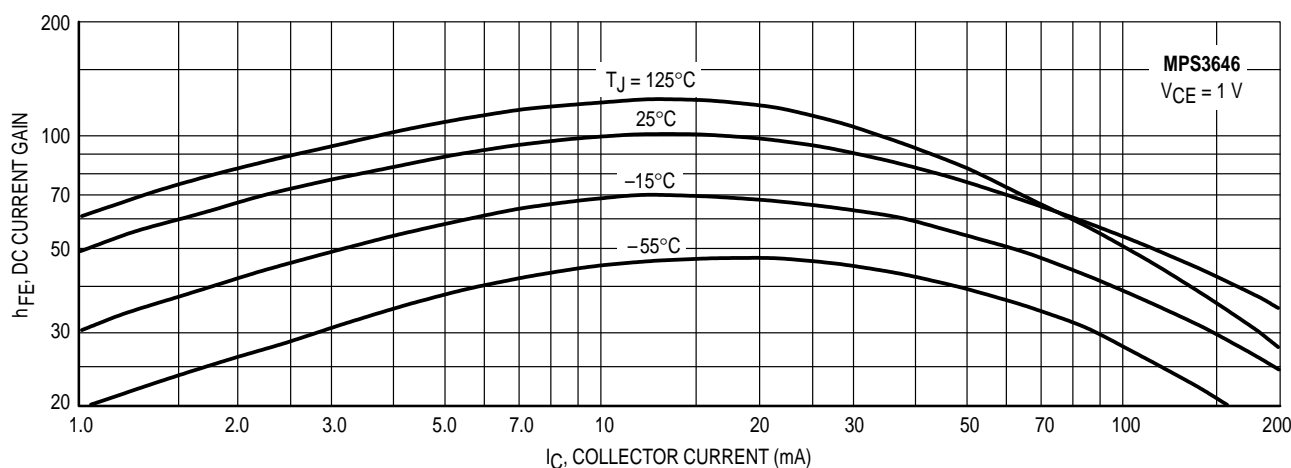
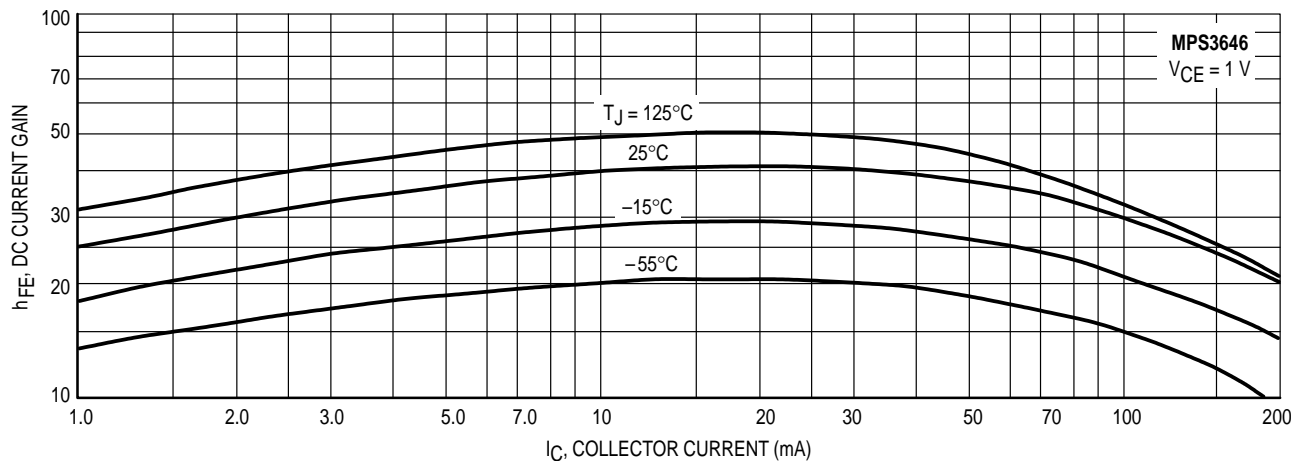


Figure 2. Minimum Current Gain

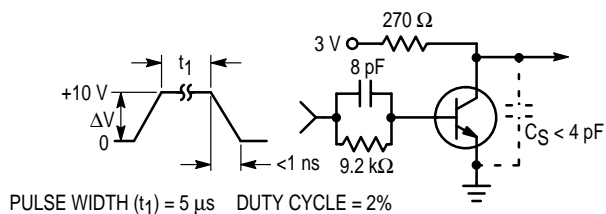


Figure 3.  $Q_T$  Test Circuit

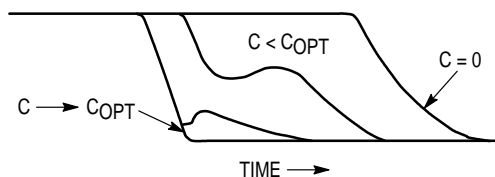


Figure 4. Turn-Off Waveform

NOTE 1

When a transistor is held in a conductive state by a base current,  $I_B$ , a charge,  $Q_S$ , is developed or "stored" in the transistor.  $Q_S$  may be written:  $Q_S = Q_1 + Q_V + Q_X$ .

$Q_1$  is the charge required to develop the required collector current. This charge is primarily a function of alpha cutoff frequency.  $Q_V$  is the charge required to charge the collector-base feedback capacity.  $Q_X$  is excess charge resulting from overdrive, i.e., operation in saturation.

The charge required to turn a transistor "on" to the edge of saturation is the sum of  $Q_1$  and  $Q_V$  which is defined as the active region charge,  $Q_A$ .  $Q_A = I_{B1}t_r$  when the transistor is driven by a constant current step

$$(I_{B1}) \text{ and } I_{B1} \ll \frac{I_C}{h_{FE}}$$

If  $I_B$  were suddenly removed, the transistor would continue to conduct until  $Q_S$  is removed from the active regions through an external path or through internal recombination. Since the internal recombination time is long compared to the ultimate capability of a transistor, a charge,  $Q_T$ , of opposite polarity, equal in magnitude, can be stored on an external capacitor,  $C$ , to neutralize the internal charge and considerably reduce the turn-off time of the transistor. Figure 3 shows the test circuit and Figure 4 the turn-off waveform. Given  $Q_T$  from Figure 13, the external  $C$  for worst-case turn-off in any circuit is:  $C = Q_T/\Delta V$ , where  $\Delta V$  is defined in Figure 3.

“ON” CONDITION CHARACTERISTICS

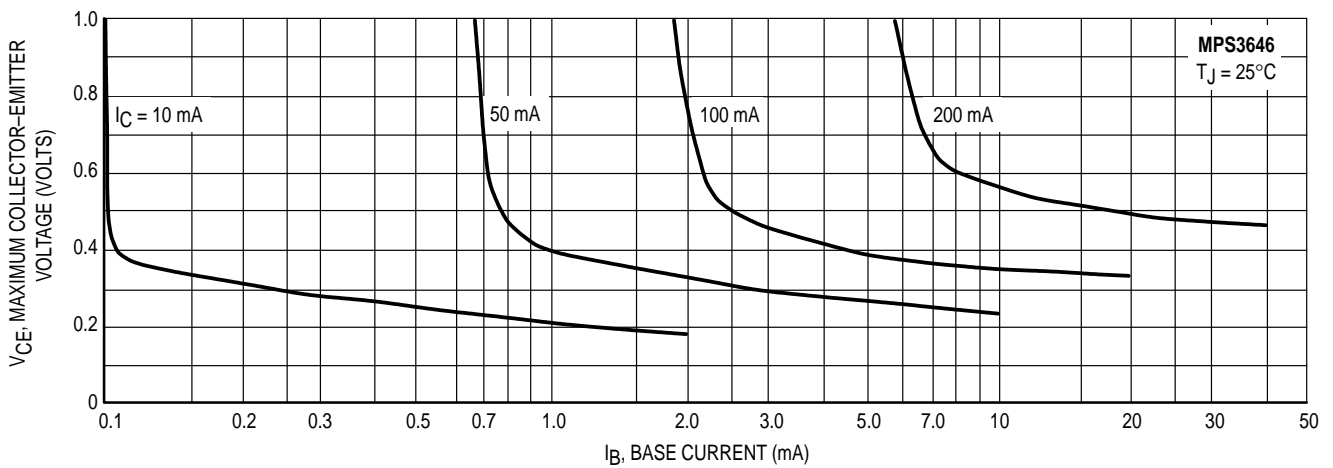
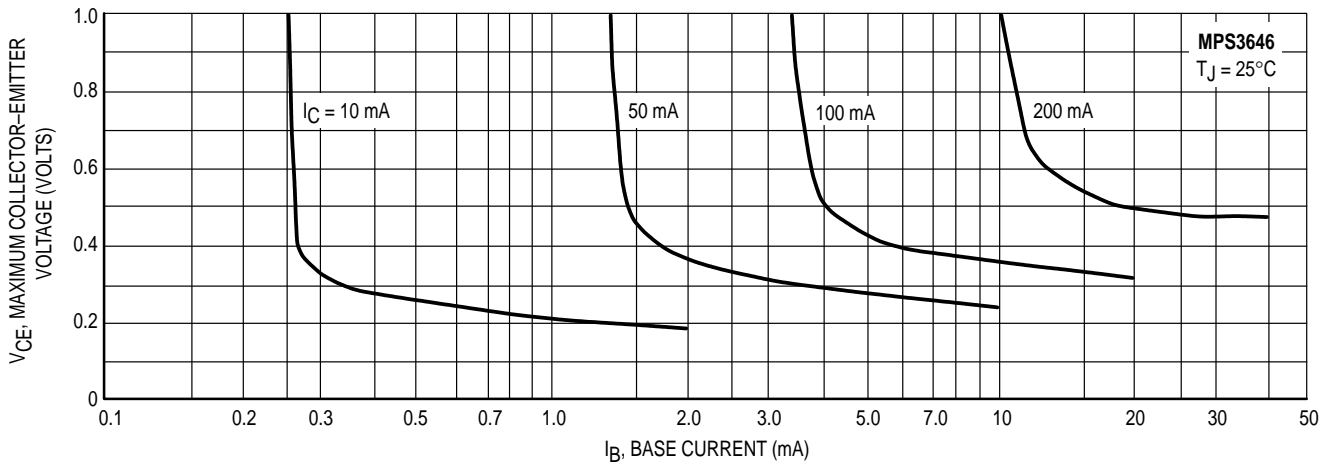


Figure 5. Collector Saturation Region

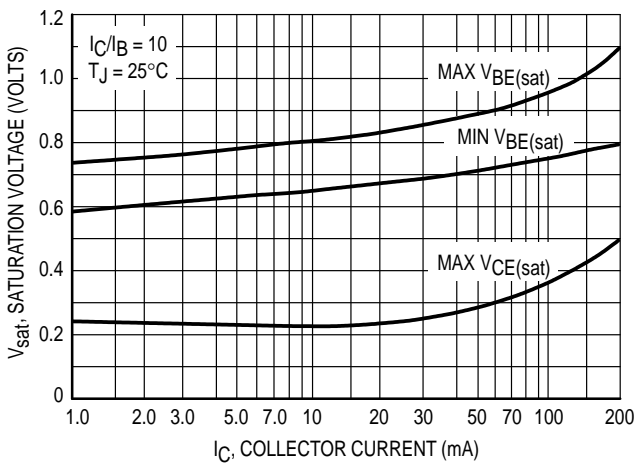


Figure 6. Saturation Voltage Limits

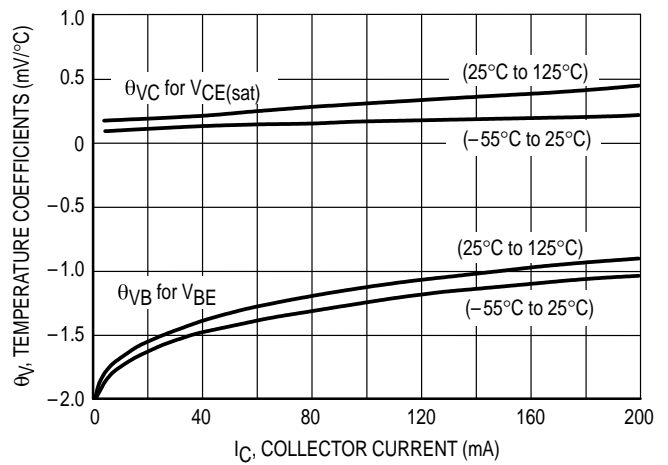


Figure 7. Temperature Coefficients

DYNAMIC CHARACTERISTICS

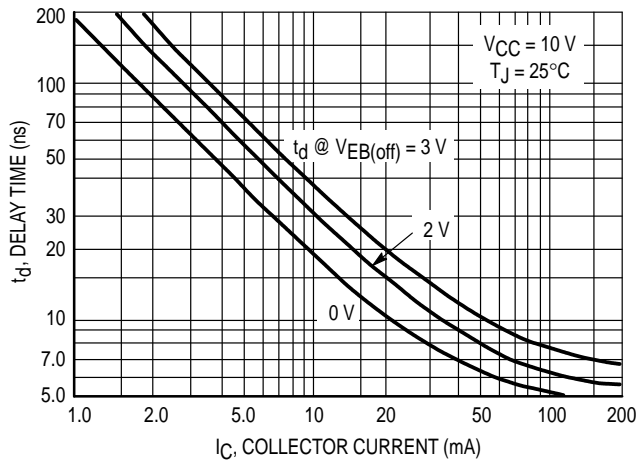


Figure 8. Delay Time

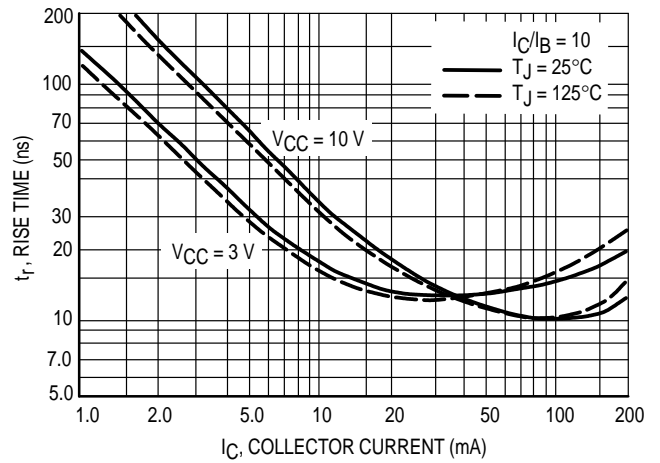


Figure 9. Rise Time

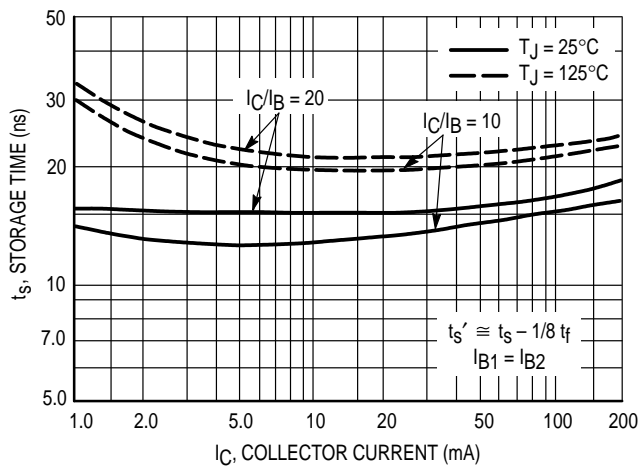


Figure 10. Storage Time

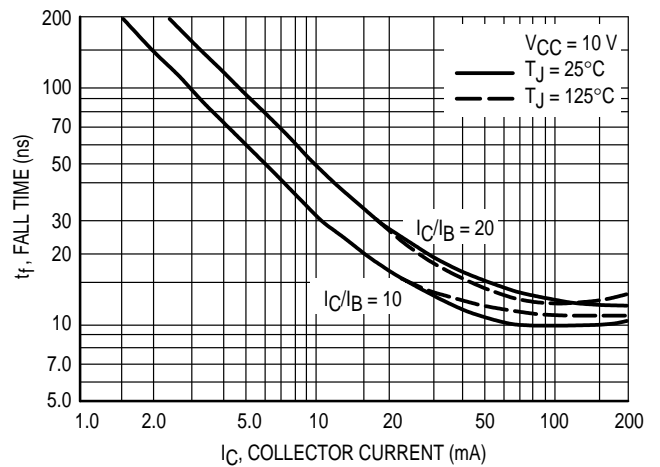


Figure 11. Fall Time

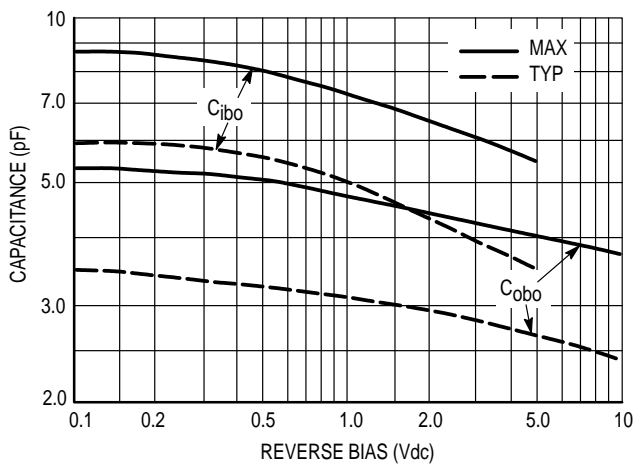


Figure 12. Junction Capacitance

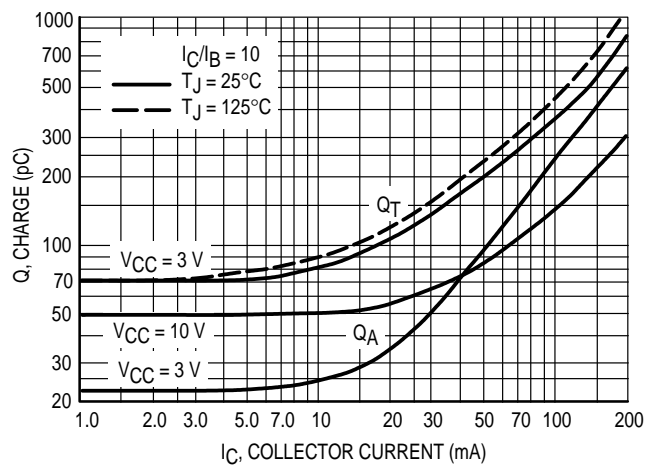
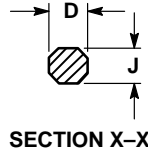
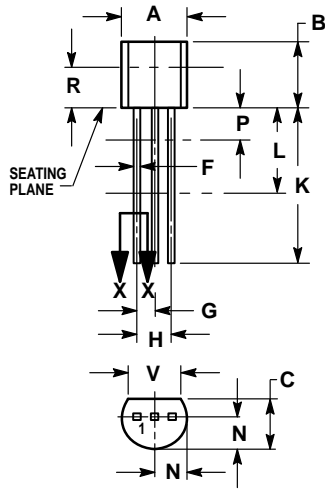


Figure 13. Maximum Charge Data

PACKAGE DIMENSIONS



CASE 029-04  
(TO-226AA)  
ISSUE AD

NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K. MINIMUM LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

| DIM | INCHES |       | MILLIMETERS |      |
|-----|--------|-------|-------------|------|
|     | MIN    | MAX   | MIN         | MAX  |
| A   | 0.175  | 0.205 | 4.45        | 5.20 |
| B   | 0.170  | 0.210 | 4.32        | 5.33 |
| C   | 0.125  | 0.165 | 3.18        | 4.19 |
| D   | 0.016  | 0.022 | 0.41        | 0.55 |
| F   | 0.016  | 0.019 | 0.41        | 0.48 |
| G   | 0.045  | 0.055 | 1.15        | 1.39 |
| H   | 0.095  | 0.105 | 2.42        | 2.66 |
| J   | 0.015  | 0.020 | 0.39        | 0.50 |
| K   | 0.500  | —     | 12.70       | —    |
| L   | 0.250  | —     | 6.35        | —    |
| N   | 0.080  | 0.105 | 2.04        | 2.66 |
| P   | —      | 0.100 | —           | 2.54 |
| R   | 0.115  | —     | 2.93        | —    |
| V   | 0.135  | —     | 3.43        | —    |

STYLE 1:

1. EMITTER
2. BASE
3. COLLECTOR

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