# MJE13009*

*Motorola Preferred Device

*Designer's™ Data Sheet*

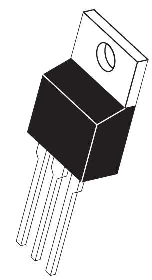
# SWITCHMODE Series
# NPN Silicon Power Transistors

The MJE13009 is designed for high–voltage, high–speed power switching inductive circuits where fall time is critical. They are particularly suited for 115 and 220 V switchmode applications such as Switching Regulators, Inverters, Motor Controls, Solenoid/Relay drivers and Deflection circuits.

SPECIFICATION FEATURES:

- $V_{CEO(sus)}$ 400 V and 300 V
- Reverse Bias SOA with Inductive Loads @ $T_C$ = 100°C
- Inductive Switching Matrix 3 to 12 Amp, 25 and 100°C
  . . . $t_c$ @ 8 A, 100°C is 120 ns (Typ).
- 700 V Blocking Capability
- SOA and Switching Applications Information.

**12 AMPERE**
**NPN SILICON**
**POWER TRANSISTOR**
**400 VOLTS**
**100 WATTS**



**CASE 221A–06**
**TO–220AB**

**MAXIMUM RATINGS**



| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector–Emitter Voltage | $V_{CEO(sus)}$ | 400 | Vdc |
| Collector–Emitter Voltage | $V_{CEV}$ | 700 | Vdc |
| Emitter Base Voltage | $V_{EBO}$ | 9 | Vdc |
| Collector Current — Continuous<br>— Peak (1) | $I_C$<br>$I_{CM}$ | 12<br>24 | Adc |
| Base Current — Continuous<br>— Peak (1) | $I_B$<br>$I_{BM}$ | 6<br>12 | Adc |
| Emitter Current — Continuous<br>— Peak (1) | $I_E$<br>$I_{EM}$ | 18<br>36 | Adc |
| Total Power Dissipation @ $T_A$ = 25°C<br>Derate above 25°C | $P_D$ | 2<br>16 | Watts<br>mW/°C |
| Total Power Dissipation @ $T_C$ = 25°C<br>Derate above 25°C | $P_D$ | 100<br>800 | Watts<br>mW/°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 Ambient | $R_{\theta JA}$ | 62.5 | °C/W |
| Thermal Resistance, Junction to Case | $R_{\theta JC}$ | 1.25 | °C/W |
| Maximum Lead Temperature for Soldering Purposes:<br>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.

**REV 2**

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

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| ***OFF CHARACTERISTICS** | | | | | |
| Collector–Emitter Sustaining Voltage ($I_C$ = 10 mA, $I_B$ = 0) | $V_{CEO(sus)}$ | 400 | — | — | Vdc |
| Collector Cutoff Current | $I_{CEV}$ | | | | mAdc |
| ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc) | | — | — | 1 | |
| ($V_{CEV}$ = Rated Value, $V_{BE(off)}$ = 1.5 Vdc, $T_C$ = 100°C) | | — | — | 5 | |
| Emitter Cutoff Current ($V_{EB}$ = 9 Vdc, $I_C$ = 0) | $I_{EBO}$ | — | — | 1 | mAdc |
| **SECOND BREAKDOWN** | | | | | |
| Second Breakdown Collector Current with base forward biased | $I_{S/b}$ | See Figure 1 | | | |
| Clamped Inductive SOA with Base Reverse Biased | — | See Figure 2 | | | |
| ***ON CHARACTERISTICS** | | | | | |
| DC Current Gain | $h_{FE}$ | | | | |
| ($I_C$ = 5 Adc, $V_{CE}$ = 5 Vdc) | | 8 | — | 40 | |
| ($I_C$ = 8 Adc, $V_{CE}$ = 5 Vdc) | | 6 | — | 30 | |
| Collector–Emitter Saturation Voltage | $V_{CE(sat)}$ | | | | Vdc |
| ($I_C$ = 5 Adc, $I_B$ = 1 Adc) | | — | — | 1 | |
| ($I_C$ = 8 Adc, $I_B$ = 1.6 Adc) | | — | — | 1.5 | |
| ($I_C$ = 12 Adc, $I_B$ = 3 Adc) | | — | — | 3 | |
| ($I_C$ = 8 Adc, $I_B$ = 1.6 Adc, $T_C$ = 100°C) | | — | — | 2 | |
| Base–Emitter Saturation Voltage | $V_{BE(sat)}$ | | | | Vdc |
| ($I_C$ = 5 Adc, $I_B$ = 1 Adc) | | — | — | 1.2 | |
| ($I_C$ = 8 Adc, $I_B$ = 1.6 Adc) | | — | — | 1.6 | |
| ($I_C$ = 8 Adc, $I_B$ = 1.6 Adc, $T_C$ = 100°C) | | — | — | 1.5 | |
| **DYNAMIC CHARACTERISTICS** | | | | | |
| Current–Gain — Bandwidth Product ($I_C$ = 500 mAdc, $V_{CE}$ = 10 Vdc, f = 1 MHz) | $f_T$ | 4 | — | — | MHz |
| Output Capacitance ($V_{CB}$ = 10 Vdc, $I_E$ = 0, f = 0.1 MHz) | $C_{ob}$ | — | 180 | — | pF |

**SWITCHING CHARACTERISTICS**

| Characteristic | Conditions | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Resistive Load (Table 1)** | | | | | | |
| Delay Time | ($V_{CC}$ = 125 Vdc, $I_C$ = 8 A, $I_{B1}$ = $I_{B2}$ = 1.6 A, $t_p$ = 25 µs, Duty Cycle ≤ 1%) | $t_d$ | — | 0.06 | 0.1 | µs |
| Rise Time | | $t_r$ | — | 0.45 | 1 | µs |
| Storage Time | | $t_s$ | — | 1.3 | 3 | µs |
| Fall Time | | $t_f$ | — | 0.2 | 0.7 | µs |
| **Inductive Load, Clamped (Table 1, Figure 13)** | | | | | | |
| Voltage Storage Time | ($I_C$ = 8 A, $V_{clamp}$ = 300 Vdc, $I_{B1}$ = 1.6 A, $V_{BE(off)}$ = 5 Vdc, $T_C$ = 100°C) | $t_{sv}$ | — | 0.92 | 2.3 | µs |
| Crossover Time | | $t_c$ | — | 0.12 | 0.7 | µs |

*Pulse Test: Pulse Width = 300 µs, Duty Cycle = 2%.

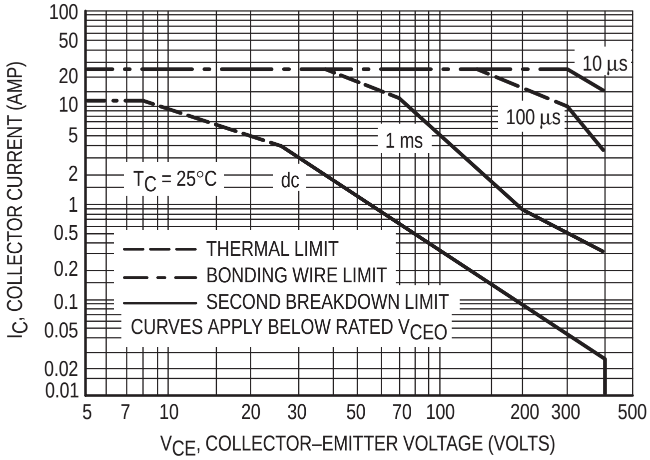



**Figure 1. Forward Bias Safe Operating Area**

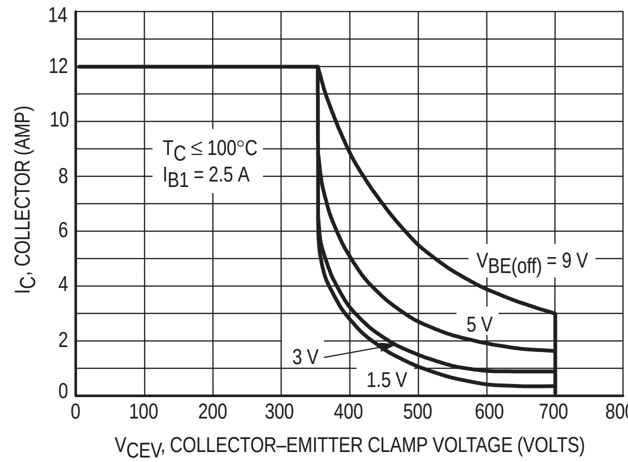



**Figure 2. Reverse Bias Switching Safe Operating Area**

**The Safe Operating Area figures shown in Figures 1 and 2 are specified ratings for these devices under the test conditions shown.**

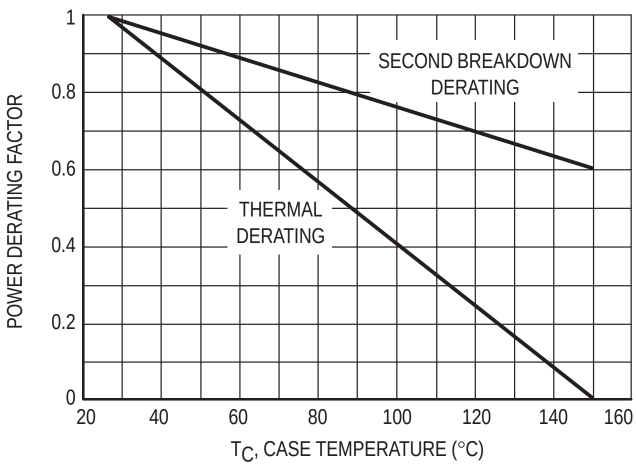



**Figure 3. Forward Bias Power Derating**

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 1 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 Figure 1 may be found at any case temperature by using the appropriate curve on Figure 3.

$T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. Use of reverse biased safe operating area data (Figure 2) is discussed in the applications information section.

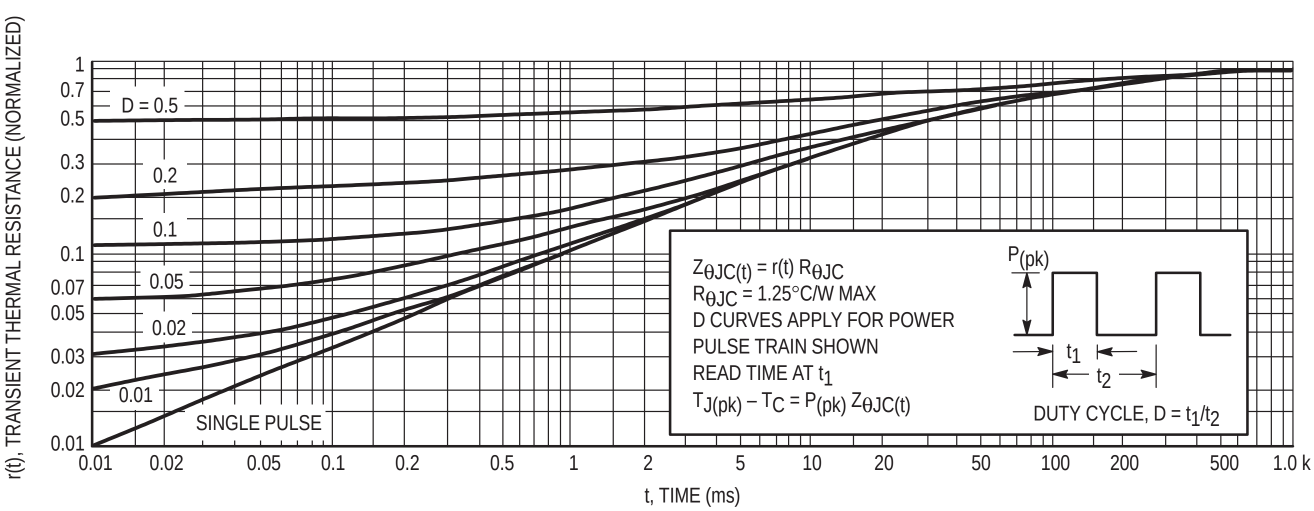



**Figure 4. Typical Thermal Response [$Z_{\theta JC}(t)$]**

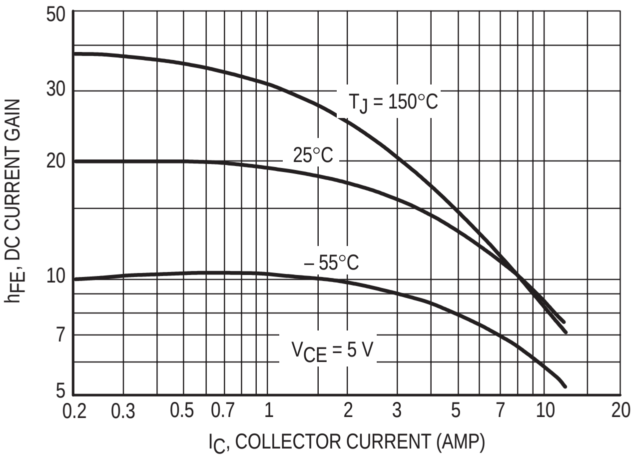



**Figure 5. DC Current Gain**

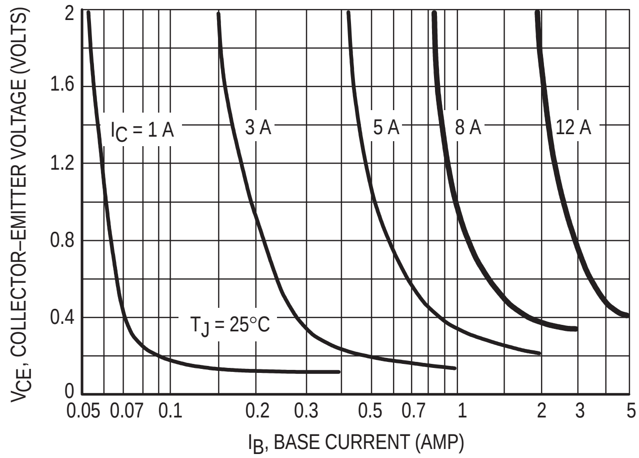



**Figure 6. Collector Saturation Region**

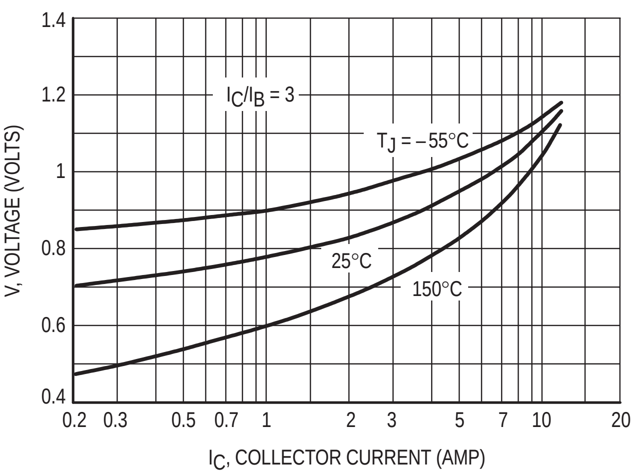



**Figure 7. Base–Emitter Saturation Voltage**

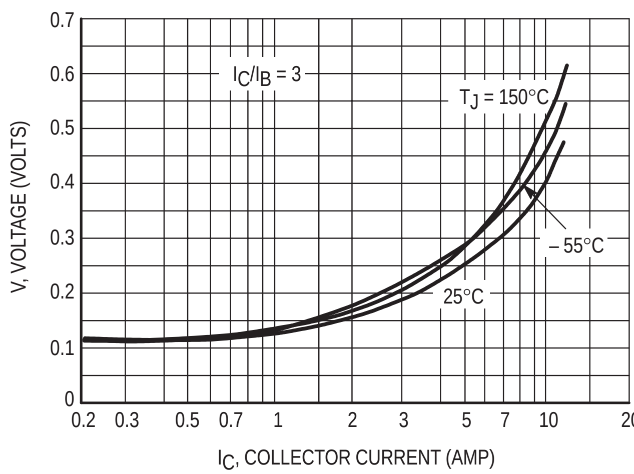



**Figure 8. Collector–Emitter Saturation Voltage**

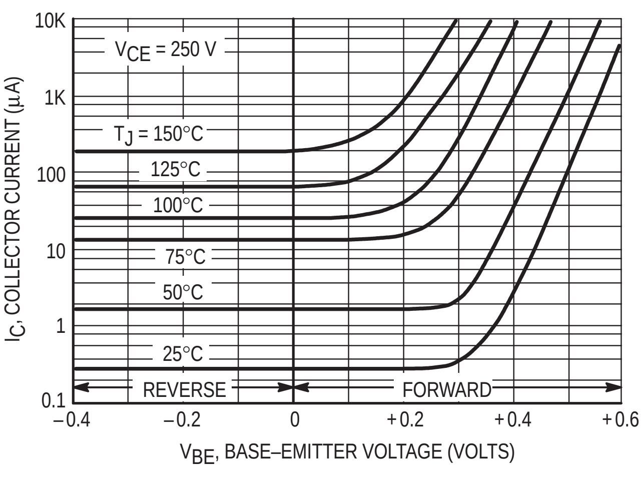



**Figure 9. Collector Cutoff Region**

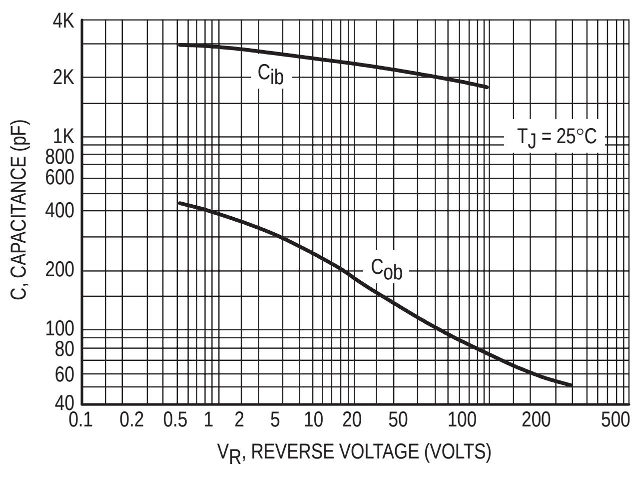
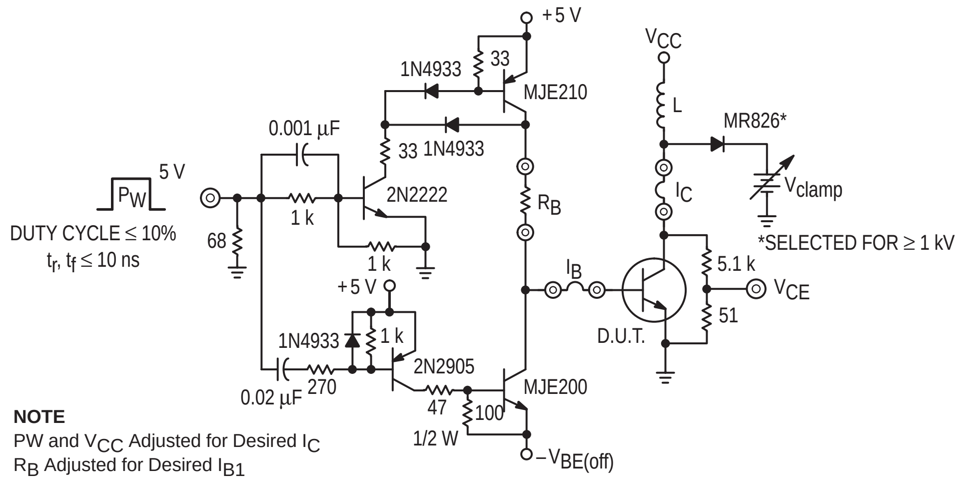
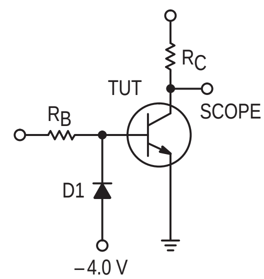
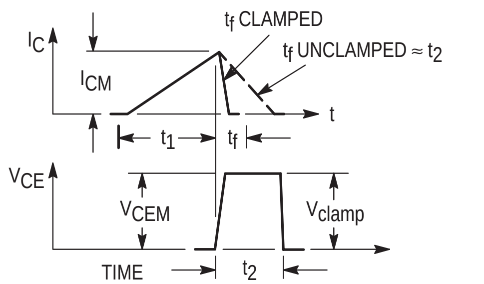
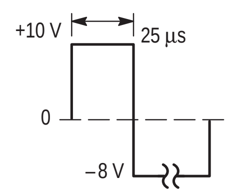



**Figure 10. Capacitance**

**Table 1. Test Conditions for Dynamic Performance**

| | REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING | RESISTIVE SWITCHING |
|---|---|---|
| TEST CIRCUITS |   **NOTE**<br>PW and $V_{CC}$ Adjusted for Desired $I_C$<br>$R_B$ Adjusted for Desired $I_{B1}$ |   |
| CIRCUIT VALUES | Coil Data:<br>Ferroxcube Core #6656<br>Full Bobbin (~16 Turns) #16<br><br>GAP for 200 μH/20 A<br>$L_{coil}$ = 200 μH<br><br>$V_{CC}$ = 20 V<br>$V_{clamp}$ = 300 Vdc | $V_{CC}$ = 125 V<br>$R_C$ = 15 Ω<br>D1 = 1N5820 or Equiv.<br>$R_B$ = Ω |
| TEST WAVEFORMS | **OUTPUT WAVEFORMS**<br>  $t_1$ ADJUSTED TO OBTAIN $I_C$<br>$t_1 \approx \frac{L_{coil}(I_{CM})}{V_{CC}}$<br>$t_2 \approx \frac{L_{coil}(I_{CM})}{V_{clamp}}$<br><br>Test Equipment<br>Scope–Tektronics<br>475 or Equivalent |   $t_r$, $t_f$ < 10 ns<br>Duty Cycle = 1.0%<br>$R_B$ and $R_C$ adjusted for desired $I_B$ and $I_C$ |

## APPLICATIONS INFORMATION FOR SWITCHMODE SPECIFICATIONS

### INTRODUCTION

The primary considerations when selecting a power transistor for SWITCHMODE applications are voltage and current ratings, switching speed, and energy handling capability. In this section, these specifications will be discussed and related to the circuit examples illustrated in Table 2.(1)

### VOLTAGE REQUIREMENTS

Both blocking voltage and sustaining voltage are important in SWITCHMODE applications.

Circuits B and C in Table 2 illustrate applications that require high blocking voltage capability. In both circuits the switching transistor is subjected to voltages substantially higher than $V_{CC}$ after the device is completely off (see load line diagrams at $I_C = I_{leakage} \approx 0$ in Table 2). The blocking capability at this point depends on the base to emitter conditions and the device junction temperature. Since the highest device capability occurs when the base to emitter junction is reverse biased ($V_{CEV}$), this is the recommended and specified use condition. Maximum $I_{CEV}$ at rated $V_{CEV}$ is specified at a relatively low reverse bias (1.5 Volts) both at 25°C and 100°C. Increasing the reverse bias will give some improvement in device blocking capability.

The sustaining or active region voltage requirements in switching applications occur during turn–on and turn–off. If the load contains a significant capacitive component, high current and voltage can exist simultaneously during turn–on and the pulsed forward bias SOA curves (Figure 1) are the proper design limits.

For inductive loads, high voltage and 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 a Reverse Bias Safe Operating Area (Figure 2) which represents voltage–current conditions that can be sustained during reverse biased turn–off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode.

(1) For detailed information on specific switching applications, see Motorola Application Notes AN–719, AN–767.

**VOLTAGE REQUIREMENTS (continued)**

In the four application examples (Table 2) load lines are shown in relation to the pulsed forward and reverse biased SOA curves.

In circuits A and D, inductive reactance is clamped by the diodes shown. In circuits B and C the voltage is clamped by the output rectifiers, however, the voltage induced in the primary leakage inductance is not clamped by these diodes and could be large enough to destroy the device. A snubber network or an additional clamp may be required to keep the turn–off load line within the Reverse Bias SOA curve.

Load lines that fall within the pulsed forward biased SOA curve during turn–on and within the reverse bias SOA curve during turn–off are considered safe, with the following assumptions:

(1) The device thermal limitations are not exceeded.
(2) The turn–on time does not exceed 10 μs (see standard pulsed forward SOA curves in Figure 1).
(3) The base drive conditions are within the specified limits shown on the Reverse Bias SOA curve (Figure 2).

**CURRENT REQUIREMENTS**

An efficient switching transistor must operate at the required current level with good fall time, high energy handling capability and low saturation voltage. On this data sheet, these parameters have been specified at 8 amperes which represents typical design conditions for these devices. The current drive requirements are usually dictated by the $V_{CE(sat)}$ specification because the maximum saturation voltage is specified at a forced gain condition which must be duplicated or exceeded in the application to control the saturation voltage.

**SWITCHING REQUIREMENTS**

In many switching applications, a major portion of the transistor power dissipation occurs during the fall time ($t_{fi}$). For this reason considerable effort is usually devoted to reducing the fall time. The recommended way to accomplish this is to reverse bias the base–emitter junction during turn–off. The reverse biased switching characteristics for inductive loads are discussed in Figure 11 and Table 3 and resistive loads in Figures 13 and 14. Usually the inductive load component will be the dominant factor in SWITCHMODE applications and the inductive switching data will more closely represent the device performance in actual application. The inductive switching characteristics are derived from the same circuit used to specify the reverse biased SOA curves, (See Table 1) providing correlation between test procedures and actual use conditions.

**RESISTIVE SWITCHING PERFORMANCE**

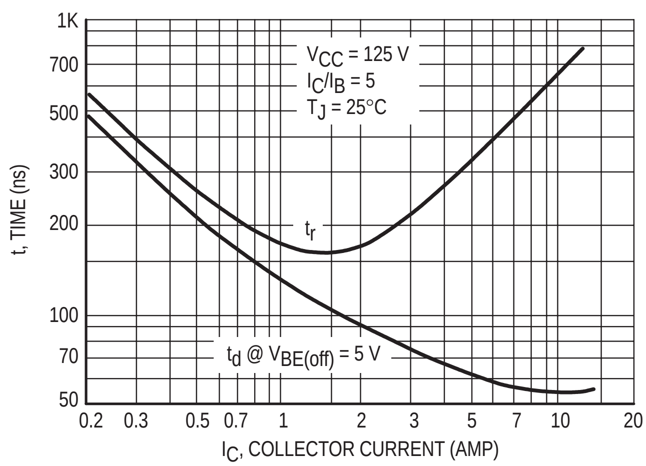



**Figure 11. Turn–On Time**

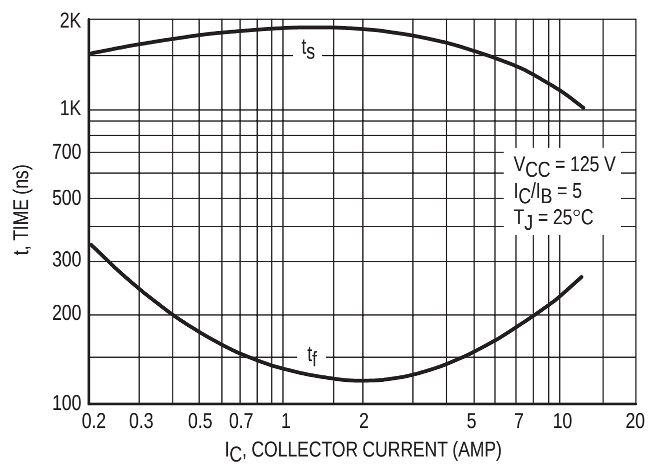



**Figure 12. Turn–Off Time**

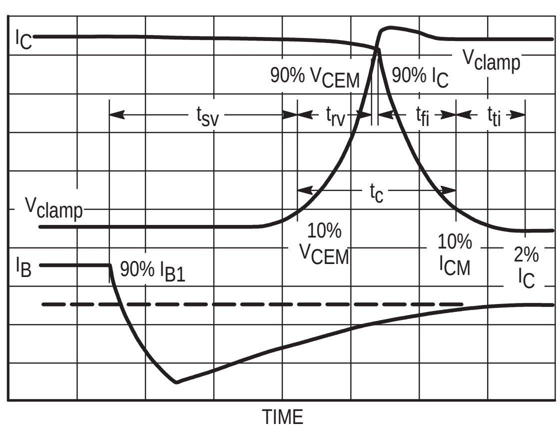



**Figure 13. Inductive Switching Measurements**

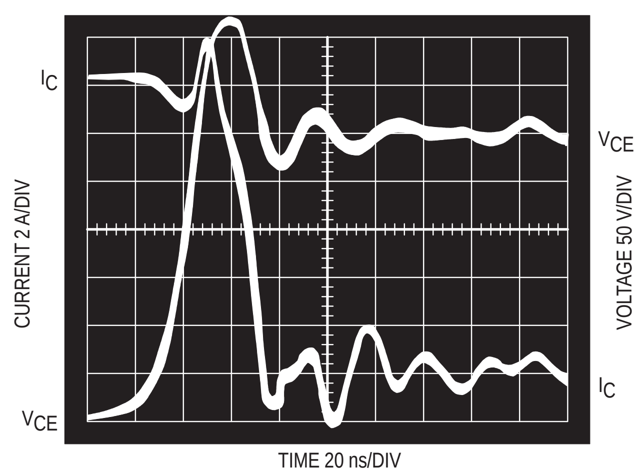
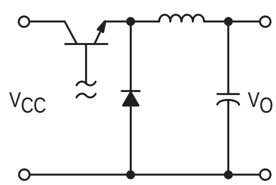


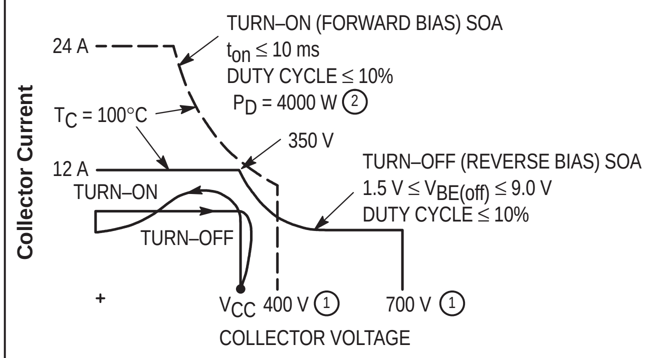

**Figure 14. Typical Inductive Switching Waveforms (at 300 V and 12 A with $I_{B1}$ = 2.4 A and $V_{BE(off)}$ = 5 V)**

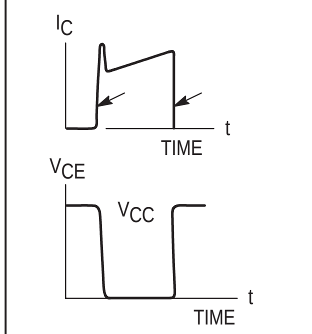
**Table 2. Applications Examples of Switching Circuits**

| | CIRCUIT | LOAD LINE DIAGRAMS | TIME DIAGRAMS |
|---|---|---|---|

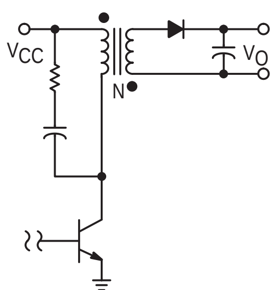
**A** — SERIES SWITCHING REGULATOR

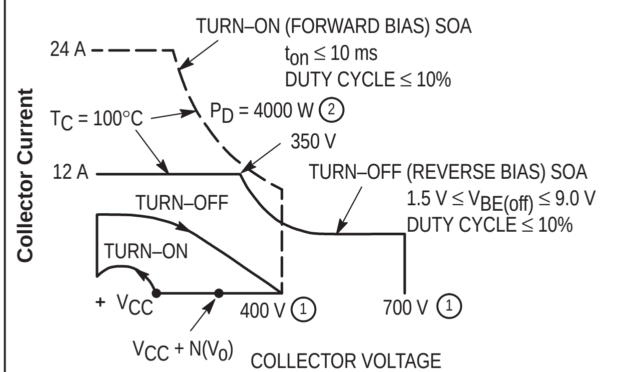


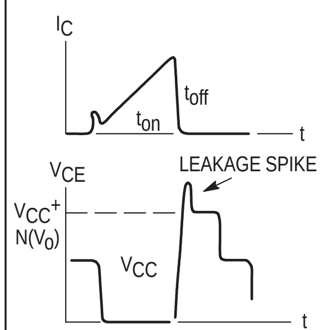



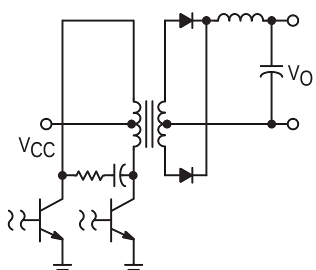

**B** — RINGING CHOKE INVERTER

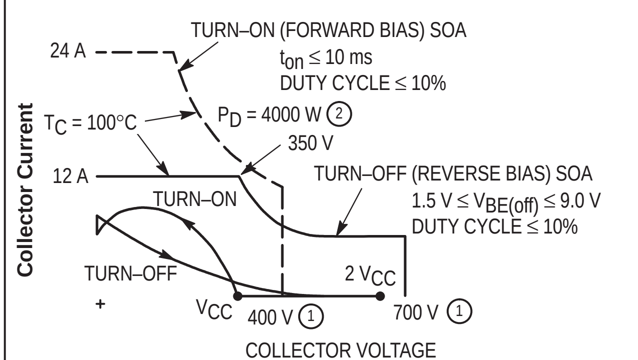


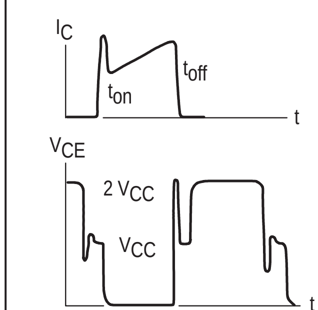



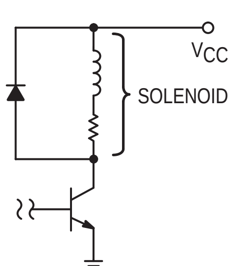

**C** — PUSH–PULL INVERTER/CONVERTER

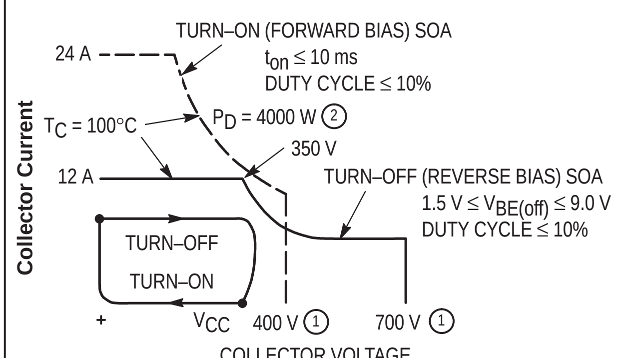



**D** — SOLENOID DRIVER



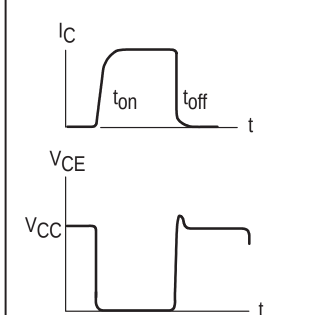



**Table 3. Typical Inductive Switching Performance**

| $I_C$ AMP | $T_C$ °C | $t_{sv}$ ns | $t_{rv}$ ns | $t_{fi}$ ns | $t_{ti}$ ns | $t_c$ ns |
|---|---|---|---|---|---|---|
| 3 | 25<br>100 | 770<br>1000 | 100<br>230 | 150<br>160 | 200<br>200 | 240<br>320 |
| 5 | 25<br>100 | 630<br>820 | 72<br>100 | 26<br>55 | 10<br>30 | 100<br>180 |
| 8 | 25<br>100 | 720<br>920 | 55<br>70 | 27<br>50 | 2<br>8 | 77<br>120 |
| 12 | 25<br>100 | 640<br>800 | 20<br>32 | 17<br>24 | 2<br>4 | 41<br>54 |

NOTE: All Data recorded In the Inductive Switching Circuit In Table 1.

## SWITCHING TIME NOTES

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 turn–off waveforms is shown in Figure 13 to aid in the visual identity of these terms.

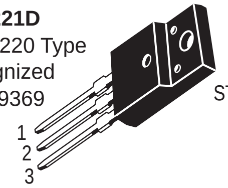
For the designer, there is minimal switching loss during storage time and the predominant switching power losses occur during the crossover interval and can be obtained using the standard equation from AN–222:

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

Typical inductive switching waveforms are shown in Figure 14. In general, $t_{rv} + t_{fi} \simeq t_c$. 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.

**CASE 221D**
Isolated TO–220 Type
UL Recognized
File #E69369




STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER

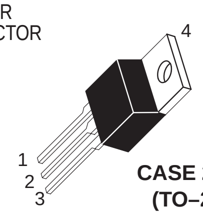
**Table 1. Plastic (Isolated TO–220 Type)**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | $V_{CES}$ Volts Min | Device Type NPN | PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 250 | | ***MJF47*** | | 30/150 | 0.3 | 2 typ | 0.17 typ | 0.3 | 10 | 28 |
| 2 | 400 | 700 | ***BUL44F*** | | 14/34 | 0.2 | 2.75(3) | 0.2(3) | 1 | 13 typ | 25 |
| | | 1000 | ***MJF18002*** | | 14/34 | 0.2 | 2.75(3) | 0.175(3) | 1 | 13 typ | 25 |
| 3 | 100 | | ***MJF31C*** | ***MJF32C*** | 10 min | 1 | 0.6 | 0.3 | 1 | 3 | 28 |
| 5 | 100 | | ***MJF122***(2) | ***MJF127***(2) | 2000 min | 3 | 1.5 typ | 1.5 typ | 3 | 4(1) | 28 |
| | 400 | 700 | ***BUL45F*** | | 14/34 | 0.3 | 1.7(3) | 0.15(3) | 1 | 12 typ | 35 |
| | 450 | 1000 | ***BUT11AF*** | | 10 min | .005 | 4 | 0.8 | 2.5 | | 40 |
| | | 1000 | ***MJF18004*** | | 14/34 | 0.3 | 1.7(3) | 0.15(3) | 1 | 13 typ | 35 |
| | 550 | 1200 | ***MJF18204*** | | 18/35 | 0.5 | 2.75(3) | 0.2(3) | 2 | 12 | 35 |
| 6 | 400 | 700 | ***BUL146F*** | | 14/34 | 0.5 | 2.5(3) | 0.15(3) | 3 | 14 typ | 40 |
| | 450 | 1000 | ***MJF18006*** | | 14/34 | 0.5 | 3.2(3) | 0.15(3) | 3 | 14 typ | 40 |
| 8 | 80 | | | ***MJF6107*** | 30/90 | 2 | 0.5 typ | 0.13 typ | 2 | 4 | 35 |
| | 150 | | ***MJF15030*** | ***MJF15031*** | 40 min | 3 | 1 typ | 0.15 typ | 3 | 30 | 35 |
| | 400 | 700 | ***MJF13007*** | | 5/30 | 5 | 3 | 0.7 | 5 | 4 | 40 |
| | | | ***BUL147F*** | | 14/34 | 1 | 2.5(3) | 0.18(3) | 2 | 14 typ | 45 |
| | 450 | 1000 | ***MJF18008*** | | 16/34 | 1 | 2.75(3) | 0.18(3) | 2 | 13 typ | 45 |
| 10 | 60 | | ***MJF3055*** | ***MJF2955*** | 20/100 | 4 | — | — | — | 2 | 40 |
| | 80 | | ***MJF44H11*** | ***MJF45H11*** | 40/100 | 4 | 0.5 typ | 0.14 typ | 5 | 40 | 35 |
| | 100 | | ***MJF6388***(2) | ***MJF6668***(2) | 3k/20k | 3 | 1.5 typ | 1.5 typ | | 20(1) | 40 |
| | 450 | 1000 | ***MJF18009*** | | 14/34 | 1.5 | 2.75(3) | 0.2(3) | 3 | 12 | 50 |
| 12 | 400 | 700 | ***MJF13009*** | | 6/30 | 8 | 3 | 0.7 | 8 | 8 | 40 |

(1) $|h_{FE}|$ @ 1 MHz
(2) Darlington
(3) Switching tests performed w/special application simulator circuit. See data sheet for details.

Devices listed in bold, italic are Motorola preferred devices.

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR




**CASE 221A–06**
**(TO–220AB)**

**Table 2. Plastic TO–220AB**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min[8] | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 0.5 | 350 | MJE2360T | | 15 min | 0.1 | | | | 10 typ | 30 |
| | | ***MJE2361T*** | | 40 min | 0.1 | | | | 10 typ | 30 |
| 1 | 100 | TIP29C | TIP30C | 15/75 | 1 | 0.6 typ | 0.3 typ | 1 | 3 | 30 |
| | 250 | TIP47 | | 30/150 | 0.3 | 2 typ | 0.18 typ | 0.3 | 10 | 40 |
| | 300 | TIP48 | MJE5730 | 30/150 | 0.3 | 2 typ | 0.18 typ | 0.3 | 10 | 40 |
| | 350 | ***TIP49*** | ***MJE5731*** | 30/150 | 0.3 | 2 typ | 0.18 typ | 0.3 | 10 | 40 |
| | 400 | ***TIP50*** | ***MJE5731A***[7] | 30/150 | 0.3 | 2 typ | 0.18 typ | 0.3 | 10 | 40 |
| 2 | 100 | ***TIP112***[2] | ***TIP117***[2] | 500 min | 2 | 1.7 typ | 1.3 typ | 2 | 25[1] | 50 |
| | 400/700 | ***BUL44*** | | 14/36 | 0.4 | 2.75[3] | 0.175[3] | 1 | 13 typ | 50 |
| | 450/1000 | ***BUX85*** | | 30 | 0.1 | 3.5 | 1.4 | 1 | 4 | 50 |
| | 450/1000 | ***MJE18002*** | | 14/34 | 0.2 | 3[3] | 0.17[3] | 1 | 12 typ | 40 |
| | 900/1800 | ***MJE1320*** | | 3 min | 1 | 4 typ | 0.8 typ | 1 | | 80 |
| 3 | 80 | BD241B | BD242B | 25 min | 1 | | | | 3 | 40 |
| | 100 | BD241C | BD242C | 25 min | 1 | | | | 3 | 40 |
| | | ***TIP31C*** | ***TIP32C*** | 25 min | 1 | 0.6 typ | 0.3 typ | 1 | 3 | 40 |
| | 150 | | ***MJE9780*** | 50/200 | 0.5 | | | | 5 typ | 40 |

(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(3)Switching tests performed w/special application simulator circuit. See data sheet for details.
(7)$V_{CEO}$ = 375 V
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.

Devices listed in bold, italic are Motorola preferred devices.

**Table 2. Plastic TO–220AB (continued)**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min[8] | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 4 | 40 | | ***MJE1123*** | 45/100 | 4 | | | | 5 | 75 |
| | 60 | ***MJE800***[2] | ***MJE700***[2] | 750 min | 1.5 | | | | 1[1] | 40 |
| | 80 | ***D44C12*** | ***D45C12*** | 40/120 | 0.2 | | | 1 | 40 typ | 30 |
| | 400/700 | ***MJE13005*** | | 6/30 | 3 | 3 | 0.7 | 3 | 4 | 60 |
| 5 | 100 | ***TIP122***[2] | ***TIP127***[2] | 1k min | 3 | 1.5 typ | 1.5 typ | 4 | 4[1] | 75 |
| | 250 | 2N6497 | | 10/75 | 2.5 | 1.8 | 0.8 | 2.5 | 5 | 80 |
| | 300 | ***2N6498*** | | 10/75 | 2.5 | 1.8 | 0.8 | 2.5 | 5 | 80 |
| | 400/700 | ***BUL45*** | | 14/34 | 0.3 | 1.7[3] | 0.15[3] | 1 | 12 typ | 75 |
| | 450/1000 | MJE16002 | | 5 min | 5 | 3 | 0.3 | 3 | | 80 |
| | 450/850 | ***MJE16004*** | | 7 min | 5 | 2.7 | 0.35 | 3 | | 80 |
| | 450/1000 | ***MJE18004*** | | 14/34 | 0.3 | 1.7 | 0.15 | 1.0 | 13 | 75 |
| | 550/1200 | ***MJE18204*** | | 18/35 | 0.5 | 2.75[3] | 0.2[3] | 2 | 12 | 75 |
| 6 | 80 | ***BD243B*** | ***BD244B*** | 15 min | 3 | 0.4 typ | 0.15 typ | 3 | 3 | 65 |
| | 100 | ***BD243C*** | ***BD244C*** | 15 min | 3 | 0.4 typ | 0.15 typ | 3 | 3 | 65 |
| | | ***TIP41C*** | ***TIP42C*** | 15/75 | 3 | 0.4 typ | 0.15 typ | 3 | 3 | 65 |
| | 250/550 | ***MJE16204*** | | 5 min | 6 | 1.5[2] | 0.15[2] | 1 | 10 | 80 |
| | 400/700 | ***BUL146*** | | 14/34 | 0.5 | 1.75[3] | 0.15[3] | 3 | 14 typ | 100 |
| | 450/1000 | ***MJE18006*** | | 14/34 | 0.5 | 3.2[3] | 0.13[3] | 3 | 14 typ | 100 |
| 7 | 30 | 2N6288 | 2N6111 | 30/150 | 3 | 0.4 typ | 0.15 typ | 3 | 4 | 40 |
| | 50 | | 2N6109 | 30/150 | 2.5 | 0.4 typ | 0.15 typ | 3 | 4 | 40 |
| | 70 | ***2N6292*** | ***2N6107*** | 30/150 | 2 | 0.4 typ | 0.15 typ | 3 | 4 | 40 |
| | 100 | ***BD801*** | ***BD802*** | 15 min | 3 | | | | 3 | 65 |
| | 150 | BU407 | | 30 min | 1.5 | | 0.75 | 5 | 10 | 60 |
| | 200 | ***BU406*** | | 30 min | 1.5 | | 0.75 | 5 | 10 | 60 |
| | 450 | ***BU522B***[2] | | 250 min | 2.5 | | | | 7.5 | 75 |

(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(3)Switching tests performed w/special application simulator circuit. See data sheet for details.
(7)$V_{CEO}$ = 375 V
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.

Devices listed in bold, italic are Motorola preferred devices.

**Table 2. Plastic TO–220AB (continued)**

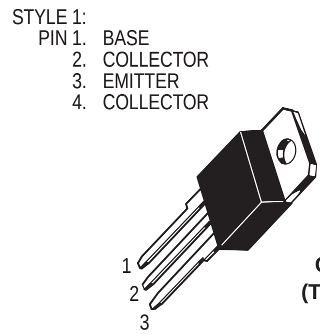
| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 8 | 60 | 2N6043(2) | 2N6040(2) | 1k/10k | 4 | 1.5 typ | 1.5 typ | 3 | 4(1) | 75 |
| | 80 | ***2N6044***(2) | ***2N6041***(2) | 1k/10k | 4 | 1.5 typ | 1.5 typ | 3 | 4(1) | 75 |
| | | ***BDX53B***(2) | ***BDX54B***(2) | 750 min | 3 | | | | 4(1) | 60 |
| | 100 | ***2N6045***(2) | ***2N6042***(2) | 1k/10k | 3 | 1.5 typ | 1.5 typ | 3 | 4(1) | 75 |
| | | ***BDX53C***(2) | ***BDX54C***(2) | 750 min | 3 | | | | | |
| | | ***TIP102***(2) | ***TIP107***(2) | 1k/20k | 3 | 1.5 typ | 1.5 typ | 3 | 4(1) | 80 |
| | 120 | MJE15028 | MJE15029 | 20 min | 4 | | | | 30 | 50 |
| | 150 | ***MJE15030*** | ***MJE15031*** | 20 min | 4 | | | | 30 | 50 |
| | 200 | ***BU806***(2) | | 100 min | 5 | 0.55 typ | 0.2 typ | 5 | | 60 |
| | 300/600 | MJE5740(2) | | 200 min | 4 | 8 typ | 2 typ | 6 | 4 | 80 |
| | | | MJE5850 | 15 min | 2 | 2 | 0.5 | 4 | | 80 |
| | 350 | ***MJE5741***(2) | | 200 min | 4 | 8 typ | 2 typ | 6 | | 80 |
| | | | ***MJE5851*** | 15 min | 2 | 2 | 0.5 | 4 | | 80 |
| | | ***MJE5742***(2) | | 200 min | 4 | 8 typ | 2 typ | 6 | | 80 |
| | | ***MJE13007*** | | 5/30 | 5 | 3 | 0.7 | 5 | | 80 |
| | | | ***MJE5852*** | 15 min | 2 | 2 | 0.5 | 4 | | 80 |
| | 400/650 | ***MJE16106*** | | 6/22 | 8 | 2 typ | 0.1 typ | 5 | | 100 |
| | 400/700 | ***BUL147*** | | 14/34 | 1 | 2.5(3) | 0.18(3) | 2 | 14 typ | 125 |
| | 450/1000 | ***MJE18008*** | | 16/34 | 1 | 2.75(3) | 0.18(3) | 2 | 13 typ | 125 |
| 10 | 20 | | ***BD808*** | 15 min | 4 | | | | 1.5 | 90 |
| | 60 | D44H8 | D45H8 | 40 min | 4 | | | | | 50 |
| | | ***MJE3055T*** | ***MJE2955T*** | 20/70 | 4 | | | | | 75 |
| | | ***2N6387***(2) | ***2N6667***(2) | 1k/20k | 5 | | | | 20(1) | 65 |
| | 80 | ***BDX33B***(2) | ***BDX34B***(2) | 750 min | 3 | | | | 3 | 70 |
| | | ***BD809*** | ***BD810*** | 15 min | 4 | | | | 1.5 | 90 |
| | | ***2N6388***(2) | ***2N6668***(2) | 1k/20k | 5 | | | | 20(1) | 65 |
| | | D44H10 | D45H10 | 20 min | 4 | 0.5 typ | 0.14 typ | 5 | 50 typ | 50 |
| | | ***D44H11*** | ***D45H11*** | 40 min | 4 | 0.5 typ | 0.14 typ | 5 | 50 typ | 50 |

(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(3)Switching tests performed w/special application simulator circuit. See data sheet for details.
(7)$V_{CEO}$ = 375 V
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.
(9)Self protected Darlington

Devices listed in bold, italic are Motorola preferred devices.

**Table 2. Plastic TO–220AB (continued)**

| $I_C$Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 10 | 100 | ***BDX33C***(2) | ***BDX34C***(2) | 750 min | 3 | | | | 3 | 70 |
| | 450/1000 | ***MJE18009*** | | 14/34 | 1.5 | 2.75(3) | 0.2(3) | 3 | 12 | 150 |
| 12 | 400/700 | ***MJE13009*** | | 6/30 | 8 | 3 | 0.7 | 8 | 4 | 100 |
| 15 | 80 | ***2N6488*** | ***2N6491*** | 20/150 | 5 | 0.6 typ | 0.3 typ | 5 | 5 | 75 |
| | | ***D44VH10*** | ***D45VH10*** | 20 min | 4 | 0.5 | 0.09 | 8 | 50 typ | 83 |
| | 100 | ***BDW42***(2) | ***BDW47***(2) | 1k min | 5 | 1 typ | 1.5 typ | 5 | 4 | 85 |




**CASE 340D**
**(TO–218 Type,**
**SOT–93)**

**Table 3. Plastic TO–218 Type**

| $I_C$Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 8 | 500/1000 | ***MJH16006A*** | | 5 min | 8 | 2.5 | 0.25 | 5 | | 125 |
| 10 | 60 | TIP140(2) | TIP145(2) | 500 min | 10 | 2.5 typ | 2.5 typ | 5 | 4(1) | 125 |
| | | TIP141(2) | TIP146(2) | 500 min | 10 | 2.5 typ | 2.5 typ | 5 | 4(1) | 125 |
| | 100 | ***BDV65B***(2) | ***BDV64B***(2) | 1k min | 5 | | | | | 125 |
| | | TIP33C | TIP34C | 20/100 | 3 | | | | 3 | 80 |
| | | ***TIP142***(2) | ***TIP147***(2) | 500 min | 10 | 2.5 typ | 2.5 typ | 5 | 4(1) | 125 |
| | 400 | ***BU323AP***(2) | | 150/100 | 6 | 15 | 15 | 6 | | 125 |
| | | ***MJH10012***(2) | | 100/2k | 6 | 15 | 15 | 6 | | 118 |

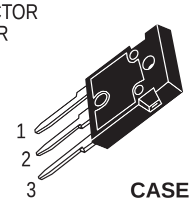
(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.

Devices listed in bold, italic are Motorola preferred devices.

**Table 3. Plastic TO–218 Type (continued)**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type NPN | PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 60 | ***TIP3055*** | ***TIP2955*** | 5 min | 10 | | | | 2.5 | 80 |
| | 150 | MJH11018(2) | MJH11017(2) | 400/15k | 10 | | | | 3 | 150 |
| | 200 | MJH11020(2) | MJH11019(2) | 400/15k | 10 | | | | 3 | 150 |
| | 250 | ***MJH11022***(2) | ***MJH11021***(2) | 400/15k | 10 | | | | 3 | 150 |
| | 400 | BUV48 | | 8 min | 10 | 2 | 0.4 | 10 | | 150 |
| | 450 | ***BUV48A*** | | 8 min | 8 | 2 | 0.4 | 10 | | 150 |
| 16 | 140 | MJE4342 | MJE4352 | 15 min | 8 | 1.2 typ | 1.2 typ | 8 | 1 | 125 |
| | 160 | ***MJE4343*** | ***MJE4353*** | 15 min | 8 | 1.2 typ | 1.2 typ | 8 | 1 | 125 |
| 20 | 60 | MJH6282(2) | MJH6285(2) | 750/18k | 10 | | | | 4 | 125 |
| | 100 | ***MJH6284***(2) | ***MJH6287***(2) | 750/18k | 10 | | | | 4 | 125 |
| 25 | 80 | TIP35A | TIP36A | 15/75 | 15 | 0.6 typ | 0.3 typ | 10 | 3 | 125 |
| | 100 | ***BD249C*** | ***BD250C*** | 10 min | 15 | | | | 3 | 125 |
| | | ***TIP35C*** | ***TIP36C*** | 15/75 | 15 | 0.6 typ | 0.3 typ | 10 | 3 | 125 |

(2)Darlington
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.



**CASE 340F**
**(TO–247 Type)**

**Table 4. Isolated Mounting Hole — Plastic TO–247 Type**

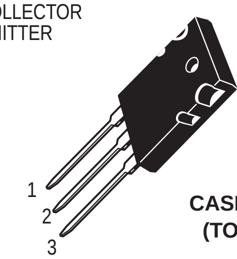
| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | $V_{CES}$ Volts Min | Device Type NPN | PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 650 | 1500 | ***MJW16212*** | | 4/10 | 10 | 4(3) | 0.5(3) | 5.5 | | 150 |
| | 800 | 1500 | ***MJW16018*** | | 4 min | 5 | 4.5 typ | 0.2 typ | 5 | 3 typ | 150 |
| 12 | 500 | 1200 | ***MJW16206*** | | 5/13 | 10 | 2.25 | 0.25 | 6.5 | 3 typ | 150 |
| 15 | 450 | 850 | ***MJW16010*** | | 5 min | 15 | 1.2 typ | 0.2 typ | 10 | | 150 |
| | | 850 | ***MJW16012*** | | 7 min | 15 | 0.9 typ | 0.15 typ | 10 | | 150 |
| | 500 | 1000 | ***MJW16010A*** | | 5 min | 15 | 3 | 0.4 | 10 | | 150 |

(3)Switching tests performed w/special application simulator circuit. See data sheet for details.
(10)Tested in Applications simulator: see Data Sheet.

Devices listed in bold, italic are Motorola preferred devices.

## New Product New Product New Product New Product

STYLE 2:
PIN 1. BASE
2. COLLECTOR
3. EMITTER




CASE 340G
(TO–264)

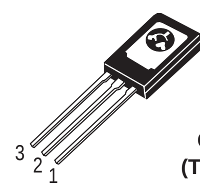
**Table 5. Large Plastic TO–264**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type | | hFE Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ μs Max | $t_f$ μs Max | @ $I_C$ Amp | | |
| 15 | 200 | ***MJL3281A*** | ***MJL1302A*** | 60/175 | 0.1 | | | | 30 typ | 200 |
| | 650/1500 | ***MJL16218*** | | 4/11 | 12 | | | | 2.5 typ | 170 |
| 16 | 250 | ***MJL21194*** | ***MJL21193*** | 25/75 | 8 | | | | 4 | 200 |

## New Product New Product New Product New Product

STYLE 1:
PIN 1. EMITTER
2. COLLECTOR
3. BASE

STYLE 3:
PIN 1. BASE
2. COLLECTOR
3. EMITTER




CASE 77
(TO–225AA)

**Table 6. Plastic TO–225AA Type (Formerly TO–126 Type)**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ μs Max | $t_f$ μs Max | @ $I_C$ Amp | | |
| 0.3 | 350 | ***MJE3439*** | | 40/160 | 0.02 | | | | 15 | 15 |
| 0.5 | 150 | MJE341 | | 25/200 | 0.05 | | | | 15 | 20.8 |
| | 200 | ***MJE344*** | | 30/300 | 0.05 | | | | 15 | 20.8 |
| | 250 | 2N5655 | | 30/250 | 0.1 | 3.5 typ | 0.24 typ | 0.1 | 10 | 20 |
| | | BD157 | | 30/240 | 0.05 | | | | | 20 |
| | 300 | ***BD158*** | | 30/240 | 0.05 | | | | | 20 |
| | | ***MJE340*** | ***MJE350*** | 30/240 | 0.05 | | | | | 20.8 |
| | | 2N5656 | | 30/250 | 0.1 | 3.5 typ | 0.24 typ | 0.1 | 10 | 20 |

Devices listed in bold, italic are Motorola preferred devices.

**Table 6. Plastic TO–225AA Type (Formerly TO–126 Type) (continued)**

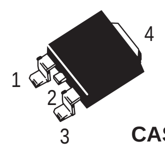
| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 0.5 | 350 | ***2N5657*** | | 30/250 | 0.1 | 3.5 typ | 0.24 typ | 0.1 | 10 | 20 |
| | | ***BD159*** | | 30/240 | 0.05 | | | | | 20 |
| 1 | 40 | 2N4921 | 2N4918 | 20/100 | 0.5 | 0.6 typ | 0.3 typ | 0.5 | 3 | 30 |
| | 60 | 2N4922 | 2N4919 | 20/100 | 0.5 | 0.6 typ | 0.3 typ | 0.5 | 3 | 30 |
| | 80 | ***2N4923*** | ***2N4920*** | 20/100 | 0.5 | 0.6 typ | 0.3 typ | 0.5 | 3 | 30 |
| 1.5 | 45 | ***BD165*** | ***BD166*** | 15 min | 0.5 | | | | 6 | 20 |
| | | BD135 | BD136 | 40/250 | 0.15 | | | | | 12.5 |
| | 60 | BD137 | BD138 | 40/250 | 0.15 | | | | | 12.5 |
| | 80 | ***BD169*** | | 15 min | 0.5 | | | | 6 | 20 |
| | | ***BD139*** | ***BD140*** | 40/250 | 0.15 | | | | | 12.5 |
| | | | ***BD140–10*** | 63/160 | 0.15 | | | | | 12.5 |
| | 300 | MJE13002[11] | | 5/25 | 1 | 4 | 0.7 | 1 | 5 | 40 |
| | 400 | ***MJE13003***[11] | | 5/25 | 1 | 4 | 0.7 | 1 | 5 | 40 |
| 2 | 80 | ***BD237*** | ***BD238*** | 25 min | 1 | | | | 3 | 25 |
| | 100 | ***MJE270***[2][11] | ***MJE271***[2][11] | 1.5k min | 0.12 | | | | 6 | 15 |
| 3 | 60 | MJE181 | MJE171 | 50/250 | 0.1 | 0.6 typ | 0.12 typ | 0.1 | 50 | 12.5 |
| | 80 | ***BD179*** | ***BD180*** | 40/250 | 0.15 | | | | 3 | 30 |
| | | ***MJE182*** | ***MJE172*** | 50/250 | 0.1 | 0.6 typ | 0.12 typ | 0.1 | 50 | 12.5 |
| | 200 | ***BUY49P*** | | 30 min | 0.5 | | | | 25 | 20 |
| 4 | 40 | ***MJE521*** | ***MJE371*** | 40 min | 1 | | | | | 40 |
| | 45 | ***BD437*** | ***BD438*** | 40 min | 2 | | | | 3 | 36 |
| | | | ***BD776***[2] | 750 min | 2 | | | | 20 | 15 |
| | 60 | | ***BD440*** | 25 min | 2 | | | | 3 | 36 |
| | | ***BD677***[2] | ***BD678***[2] | 750 min | 1.5 | | | | | 40 |
| | | ***BD677A***[2] | ***BD678A***[2] | 750 min | 2 | | | | | 40 |
| | | ***BD787*** | ***BD788*** | 20 min | 2 | | | | 50 | 15 |
| | | ***BD777***[2] | ***BD778***[2] | 750 min | 2 | | | | 20 | 15 |
| | | ***2N5191*** | ***2N5194*** | 25/100 | 1.5 | 0.4 typ | 0.4 typ | 1.5 | 2 | 40 |
| | | ***MJE800***[2] | ***MJE700***[2] | 750 min | 1.5 | | | | 1[1] | 40 |
| | | ***2N6038***[2] | ***2N6035***[2] | 750/18k | 2 | 1.7 typ | 1.2 typ | 2 | 25 | 40 |
| | 80 | ***2N5192*** | ***2N5195*** | 25/100 | 1.5 | 0.4 typ | 0.4 typ | 1.5 | 2 | 40 |
| | | ***BD441*** | ***BD442*** | 15 min | 2 | | | | 3 | 36 |
| | | ***BD679***[2] | ***BD680***[2] | 750 min | 1.5 | | | | | 40 |
| | | ***BD679A***[2] | ***BD680A***[2] | 750 min | 2 | | | | | 40 |
| | | ***BD789*** | ***BD790*** | 10 min | 2 | | | | 40 | 15 |

(1) $|h_{FE}|$ @ 1 MHz
(2) Darlington
(11) Case 77, Style 3

Devices listed in bold, italic are Motorola preferred devices.

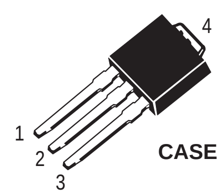
**Table 6. Plastic TO–225AA Type (Formerly TO–126 Type) (continued)**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 4 | 80 | ***BD779***[2] | ***BD780***[2] | 750 min | 2 | | | | 20 | 15 |
| | | MJE802[2] | MJE702[2] | 750 min | 1.5 | | | | 1[1] | 40 |
| | | ***MJE803***[2] | ***MJE703***[2] | 750 min | 2 | | | | 1[1] | 40 |
| | | ***2N6039***[2] | ***2N6036***[2] | 750/18k | 2 | 1.7 typ | 1.2 typ | 2 | 25 | 40 |
| | 100 | ***BD681***[2] | ***BD682***[2] | 750 min | 1.5 | | | | | 40 |
| | | ***BD791*** | ***BD792*** | 10 min | 2 | | | | 40 | 15 |
| | | ***MJE243*** | ***MJE253*** | 40/120 | 0.2 | 0.15 typ | 0.07 typ | 2 | 40 | 15 |
| 5 | 25 | ***MJE200*** | ***MJE210*** | 45/180 | 2 | 0.13 typ | 0.035 typ | 2 | 65 | 15 |




**CASE 369A[13]**

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR




**CASE 369[12]**

**Table 7. DPAK – Surface Mount Power Packages**

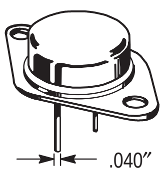
| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 0.5 | 300 | ***MJD340*** | ***MJD350*** | 30/240 | 0.05 | | | | | 15 |
| 1 | 250 | MJD47 | | 30/150 | 0.3 | 2 | 0.2 | 0.3 | 10 | 15 |
| | 375 | | ***MJD5731*** | TBD | TBD | TBD | TBD | TBD | TBD | TBD |
| | 400 | ***MJD50*** | | 30/150 | 0.3 | 2 | 0.2 | 0.3 | 10 | 15 |
| 1.5 | 400 | ***MJD13003*** | | 5/25 | 1 | 4 | 0.7 | 1 | 4 | 15 |

[1] $|h_{FE}|$ @ 1 MHz
[2] Darlington
[12] Case 369–07 may be ordered by adding –1 suffix to part number.
[13] Case 369A–13 may be ordered as tape and reel by adding a “T4” suffix; 2500 units/reel.

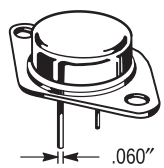
Devices listed in bold, italic are Motorola preferred devices.

**Table 7. DPAK – Surface Mount Power Packages (continued)**

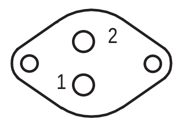
| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min | Device Type NPN | Device Type PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ μs Max | Resistive Switching $t_f$ μs Max | Resistive Switching @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 100 | ***MJD112***[2] | ***MJD117***[2] | 1000 min | 2 | 1.7 | 1.3 | 2 | 25[1] | 20 |
| 3 | 40 | MJD31 | MJD32 | 10 min | 1 | 0.6 | 0.3 | 1 | 3 | 15 |
| | 100 | ***MJD31C*** | ***MJD32C*** | 10 min | 1 | 0.6 | 0.3 | 1 | 3 | 15 |
| 4 | 80 | ***MJD6039***[2] | ***MJD6036***[2] | 1k/12k | 2 | 1.7 | 1.2 | 2 | 25 | 20 |
| | 100 | ***MJD243*** | ***MJD253*** | 40/180 | 0.2 | 0.16 | 0.04 | 1 | 40 | 12.5 |
| 5 | 25 | ***MJD200*** | ***MJD210*** | 45/180 | 2 | 0.15 | 0.04 | 2 | 65 | 12.5 |
| 6 | 100 | ***MJD41C*** | ***MJD42C*** | 15/75 | 3 | 0.4 | 0.15 | 3 | 3 | 20 |
| 8 | 80 | ***MJD44H11*** | ***MJD45H11*** | 40 min | 4 | 0.5 | 0.14 | 5 | 50 typ | 20 |
| | 100 | ***MJD122***[2] | ***MJD127***[2] | 1k/12k | 4 | 1.5 | 2 | 4 | 4[1] | 20 |
| 10 | 60 | ***MJD3055*** | ***MJD2955*** | 20/100 | 4 | 1.5 | 1.5 | 3 | 2 | 20 |
| | 80 | ***MJD44E3***[2] | | 1k min | 5 | 2 | 0.5 | 10 | | 20 |




**CASE 1–07**
**TO–204AA**




**CASE 197A TO–204AE**
(Used for high current types at end of table. See types w/footnote(16).)




STYLE 1:
PIN 1. BASE
2. EMITTER
3. COLLECTOR

**Table 8. Metal TO–204AA (Formerly TO–3), TO–204AE**

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min[8] | Device Type NPN | Device Type PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ μs Max | Resistive Switching $t_f$ μs Max | Resistive Switching @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 200 | MJ15018 | | 30 min | 1 | | | | 20 | 150 |
| | 250 | ***MJ15020*** | ***MJ15021*** | 30 min | 1 | | | | 20 | 150 |
| 5 | 700/1500 | ***BU208A*** | | 2.5 min | 4.5 | 8 typ | 0.4 typ | 4.5 | 4 typ | 90 |
| 8 | 60 | MJ1000[2] | | 1k min | 3 | | | | | 90 |
| | | 2N6055[2] | | 750/18k | 4 | 1.5 typ | 1.5 typ | 4 | 4[1] | 100 |
| | 80 | ***MJ1001***[2] | | 1k min | 3 | | | | | 90 |
| | | ***2N6056***[2] | | 750/18k | 4 | 1.5 typ | 1.5 typ | 4 | 4[1] | 100 |

(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.
(12)Case 369 may be ordered by adding –1 suffix to part number.
(13)Case 369A may be ordered as tape and reel by adding a "T4" suffix; 2500 units/reel.

Devices listed in bold, italic are Motorola preferred devices.

### Table 8. Metal TO–204AA (Formerly TO–3), TO–204AE (continued)

| $I_C$ Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ μs Max | $t_f$ μs Max | @ $I_C$ Amp | | |
| 10 | 60 | 2N3715 | 2N3791 | 30 min | 3 | 0.3 typ | 0.4 typ | 5 | 4 | 150 |
| | | MJ3000(2) | MJ2500(2) | 1k min | 5 | | | | | 150 |
| | 80 | 2N3716 | 2N3792 | 30 min | 3 | 0.3 typ | 0.4 typ | 5 | 4 | 150 |
| | | 2N5878 | | 20/100 | 4 | 1 | 0.8 | 4 | 4 | 150 |
| | | MJ3001(2) | ***MJ2501***(2) | 1k min | 5 | | | | | 150 |
| | 140 | 2N3442 | | 20/70 | 4 | | | | | 117 |
| | 250 | ***MJ15011*** | ***MJ15012*** | 20/100 | 2 | | | | | 200 |
| | 325 | ***MJ413*** | | 20/80 | 0.5 | | | | 2.5 | 125 |
| | | MJ423 | | 30/90 | 1 | | | | 2.5 | 125 |
| | 400 | ***BU323A***(2) | | 150 min | 6 | 7.5 typ | 5.2 typ | 6 | | 175 |
| | | ***MJ10007***(2) | | 30/300 | 5 | 1.5 | 0.5 | 5 | 10(1) | 150 |
| | | ***MJ10012***(2) | | 100/2k | 6 | 15 | 15 | 6 | | 175 |
| 12 | 60 | 2N6057(2) | 2N6050(2) | 750/18k | 6 | 1.6 typ | 1.5 typ | 6 | 4(1) | 150 |
| | 80 | 2N6058(2) | 2N6051(2) | 750/18k | 6 | 1.6 typ | 1.5 typ | 6 | 4(1) | 150 |
| | 100 | ***2N6059***(2) | ***2N6052***(2) | 750/18k | 6 | 1.6 typ | 1.5 typ | 6 | 4(1) | 150 |
| 15 | 60 | ***2N3055*** | ***MJ2955*** | 20/70 | 4 | 0.7 typ | 0.3 typ | 4 | 2.5 | 115 |
| | | ***2N3055A*** | ***MJ2955A*** | 20/70 | 4 | | | | 0.8 | 115 |
| | | 2N6576(2) | | 2k/20k | 4 | 2 | 7 | 10 | 10–200(1) | 120 |
| | | 2N5881 | 2N5879 | 20/100 | 6 | 1 | 0.8 | 6 | 4 | 160 |
| | 80 | ***2N5882*** | ***2N5880*** | 20/100 | 6 | 1 | 0.8 | 6 | 4 | 160 |
| | 90 | 2N6577(2) | | 2k/20k | 4 | 2 | 7 | 10 | 10–200(1) | 120 |
| | 120 | ***MJ15015*** | ***MJ15016*** | 20/70 | 4 | 0.7 typ | 0.3 typ | 4 | 1 | 180 |
| | | ***2N6578***(2) | | 2k/20k | 4 | 2 | 7 | 10 | 10–200(1) | 120 |
| | 140 | MJ15001 | MJ15002 | 25/150 | 4 | | | | 2 | 200 |
| | 150 | MJ11018(2) | MJ11017(2) | 100 min | 15 | | | | 3(1) | 175 |
| | 200 | MJ11020(2) | | 100 min | 15 | | | | 3(1) | 175 |
| | | ***MJ3281A*** | ***MJ1302A*** | 60/175 | 0.1 | | | | 30 typ | 250 |
| | 250 | ***MJ11022***(2) | MJ11019(2) | 100 min | 15 | | | | 3(1) | 175 |
| | | | ***MJ11021(2)*** | 6/30 | 10 | 4 | 0.7 | 10 | 6 to 24 | 175 |
| | 400/850 | ***BUX48*** | | 8 min | 10 | 2 | 0.4 | 10 | | 175 |
| | | 2N6547 | | 6/30 | 10 | 4 | 0.7 | 10 | 6 to 24 | 175 |
| | 400/650 | ***MJ16110*** | | 6/20 | 15 | 0.8 typ | 0.1 typ | 10 | | 175 |
| | 450/1000 | ***BUX48A*** | | 8 min | 8 | 2 | 0.4 | 10 | | 175 |

(1) $|h_{FE}|$ @ 1 MHz
(2) Darlington
(8) When 2 voltages are given, the format is $V_{CEO(sus)} / V_{CES}$.

Devices listed in bold, italic are Motorola preferred devices.

**Table 8. Metal TO–204AA (Formerly TO–3), TO–204AE (continued)**

| $I_C$Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type | | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching | | | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NPN | PNP | | | $t_s$ µs Max | $t_f$ µs Max | @ $I_C$ Amp | | |
| 15 | 450/850 | MJ16010 | | 5 min | 15 | 1.2 typ | 0.2 typ | 10 | | 175 |
| | | ***MJ16012*** | | 7 min | 15 | 0.9 typ | 0.15 typ | 10 | | 175 |
| 16 | 140 | ***2N3773*** | 2N6609 | 15/60 | 8 | 1.1 typ | 1.5 typ | 8 | 4 | 150 |
| | | 2N5631 | 2N6031 | 15/60 | 8 | 1.2 typ | 1.2 typ | 8 | 1 | 200 |
| | 200 | MJ15022 | MJ15023 | 15/60 | 8 | | | | 5 | 250 |
| | 250 | ***MJ15024*** | ***MJ15025*** | 15/60 | 8 | | | | 5 | 250 |
| | | ***MJ21194*** | ***MJ21193*** | 25/75 | 8 | | | | 4 | 250 |
| 20 | 60 | ***2N3772*** | | 15/60 | 10 | | | | 2 | 150 |
| | | 2N6282(2) | 2N6285(2) | 750/18k | 10 | 2.5 typ | 2.5 typ | 10 | 4(1) | 160 |
| | 75 | 2N5039 | | 20/100 | 10 | 1.5 | 0.5 | 10 | 60 | 140 |
| | 80 | ***2N6283***(2) | 2N6286(2) | 750/18k | 10 | 2.5 typ | 2.5 typ | 10 | 4(1) | 160 |
| | 90 | 2N5038 | | 20/100 | 12 | 1.5 | 0.5 | 12 | 60 | 140 |
| | 100 | ***2N6284***(2) | ***2N6287***(2) | 750/18k | 10 | 2.5 typ | 2.5 typ | 10 | 4(1) | 160 |
| | 140 | ***MJ15003*** | ***MJ15004*** | 25/150 | 5 | | | | 2 | 250 |
| | 200 | ***BUV11*** | | 10 min | 12 | 1.8 | 0.4 | 12 | 8 | 150 |
| | 350 | ***MJ10000***(2) | | 40/400 | 10 | 3 | 1.8 | 10 | 10(1) | 175 |
| | 400 | ***MJ10005***(2) | | 40/400 | 10 | 1.5 | 0.5 | 10 | 10(1) | 175 |
| | | ***MJ13333*** | | 10/60 | 5 | 4 | 0.7 | 10 | | 175 |
| | 500 | ***MJ10009***(2) | | 30/300 | 10 | 2 | 0.6 | 10 | 8(1) | 175 |
| 25 | 60 | 2N5885 | 2N5883 | 20/100 | 10 | 1 | 0.8 | 10 | 4 | 200 |
| | 80 | ***2N5886*** | ***2N5884*** | 20/100 | 10 | 1 | 0.8 | 10 | 4 | 200 |
| | | | 2N6436 | 30/120 | 10 | 1 | 0.25 | 10 | 40 | 200 |
| | 100 | 2N6338 | 2N6437 | 30/120 | 10 | 1 | 0.25 | 10 | 40 | 200 |
| | 120 | 2N6339 | ***2N6438*** | 30/120 | 10 | 1 | 0.25 | 10 | 40 | 200 |
| | 140 | 2N6340 | | 30/120 | 10 | 1 | 0.25 | 10 | 40 | 200 |
| | 150 | ***2N6341*** | | 30/120 | 10 | 1 | 0.25 | 10 | 40 | 200 |
| 30 | 40 | ***2N3771*** | | 15/60 | 15 | | | | 2 | 150 |
| | | 2N5301 | 2N4398 | 15/60 | 15 | 2 | 1 | 10 | 2 | 200 |
| | 60 | 2N5302 | 2N4399 | 15/60 | 15 | 2 | 1 | 10 | 2 | 200 |
| | | MJ11012(2) | MJ11011(2) | 1k min | 20 | | | | 4(1) | 200 |
| | 90 | ***MJ11014***(2) | ***MJ11013***(2) | 1k min | 20 | | | | 4(1) | 200 |
| | 100 | 2N6328 | | 6/30 | 30 | | | | 3 | 200 |
| | | ***MJ802*** | ***MJ4502*** | 25/100 | 7.5 | | | | 2 | 200 |
| | 120 | ***MJ11016***(2) | ***MJ11015***(2) | 1k min | 20 | | | | 4(1) | 200 |

(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(8)When 2 voltages are given, the format is $V_{CEO(sus)}$ / $V_{CES}$.

Devices listed in bold, italic are Motorola preferred devices.

**Table 8. Metal TO–204AA (Formerly TO–3), TO–204AE (continued)**

| $I_C$Cont Amps Max | $V_{CEO(sus)}$ Volts Min(8) | Device Type NPN | Device Type PNP | $h_{FE}$ Min/Max | @ $I_C$ Amp | Resistive Switching $t_s$ μs Max | Resistive Switching $t_f$ μs Max | Resistive Switching @ $I_C$ Amp | $f_T$ MHz Min | $P_D$ (Case) Watts @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 325 | ***BUV23*** | | 8 min | 16 | 1.8 | 0.4 | 16 | 8 | 250 |
| | 400/1000 | ***BUS98*** | | 8 min | 20 | 2.3 | 0.4 | 20 | | 250 |
| | | ***BUX98*** | | 8 min | 20 | 3 | 0.8 | 20 | | 250 |
| | 450/850 | MJ16020(16) | | 5 min | 30 | 1.8 | 0.2 | 20 | | 250 |
| | | ***MJ16022***(16) | | 7 min | 30 | 1.5 | 0.15 | 20 | | 250 |
| | 450/1000 | ***BUS98A*** | | 8 min | 16 | 2.3 | 0.4 | 16 | | 250 |
| | | ***BUX98A*** | | 8 min | 16 | 3 | 0.8 | 16 | | 250 |
| 40 | 200 | BUV21(16) | | 10 min | 25 | 1.8 | 0.4 | 25 | 8 | 150 |
| | 250 | ***BUV22***(16) | | 10 min | 20 | 1.1 | 0.35 | 20 | 8 | 250 |
| | 350 | MJ10022(2)(16) | | 50/600 | 10 | 2.5 | 0.9 | 20 | | 250 |
| | 400 | ***MJ10023***(2)(16) | | 50/600 | 10 | 2.5 | 0.9 | 20 | | 250 |
| 50 | 60 | 2N5685(16) | | 15/60 | 25 | 0.5 typ | 0.3 typ | 25 | 2 | 300 |
| | 80 | ***2N5686***(16) | ***2N5684***(16) | 15/60 | 25 | 0.5 typ | 0.3 typ | 25 | 2 | 300 |
| | 90 | ***MJ11030***(2)(16) | ***MJ11031***(2)(16) | 400 min | 50 | | | | | 300 |
| | 100 | 2N6274(16) | | 30/120 | 20 | 0.8 | 0.25 | 20 | 30 | 250 |
| | 120 | 2N6275(16) | ***2N6379***(16) | 30/120 | 20 | 0.8 | 0.25 | 20 | 30 | 250 |
| | | ***MJ11032***(2)(16) | ***MJ11033***(2)(16) | 400 min | 50 | | | | | 300 |
| | 125 | ***BUV20***(16) | | 10 min | 50 | 1.2 | 0.25 | 50 | 8 | 250 |
| | | ***BUV60***(16) | | 10 min | 80 | 1.1 | 0.25 | 80 | | 250 |
| | 150 | ***2N6277***(16) | | 30/120 | 20 | 0.8 | 0.25 | 20 | 30 | 250 |
| | 400 | ***MJ10015***(2)(16) | | 10 min | 40 | 2.5 | 1 | 20 | | 250 |
| | 500 | ***BUT34***(2)(16) | | 15 min | 32 | 3 | 1.5 | 32 | | 250 |
| | | ***MJ10016***(2)(16) | | 10 min | 40 | 2.5 | 1 | 20 | | 250 |
| 56 | 400 | ***BUT33***(2)(16) | | 20 min | 36 | 3.3 | 1.6 | 36 | | 250 |
| 60 | 60 | | MJ14001(16) | 15/100 | 50 | | | | | 300 |
| | 80 | ***MJ14002***(16) | ***MJ14003***(16) | 15/100 | 50 | | | | | 300 |
| | 200 | MJ10020(2)(16) | | 75 min | 15 | 3.5 | 0.5 | 30 | | 250 |
| | 250 | ***MJ10021***(2)(16) | | 75 min | 15 | 3.5 | 0.5 | 30 | | 250 |
| 70 | 125 | ***BUS50***(16) | | 15 min | 50 | 1.5 | 0.3 | 70 | | 350 |
| 80 | 100 | ***BUV18A***(16) | | 10 min | 80 | 1.1 | 0.25 | 80 | | 250 |

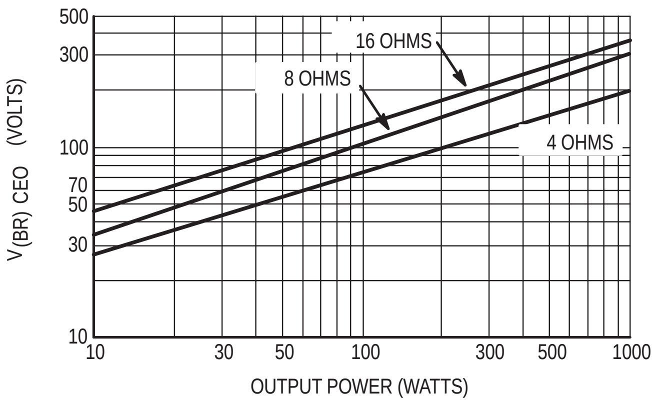
(1)$|h_{FE}|$ @ 1 MHz
(2)Darlington
(8)When 2 voltages are given, the format is $V_{CEO(sus)}/V_{CES}$.
(16)Case 197A–03 (TO–204AE)

Devices listed in bold, italic are Motorola preferred devices.

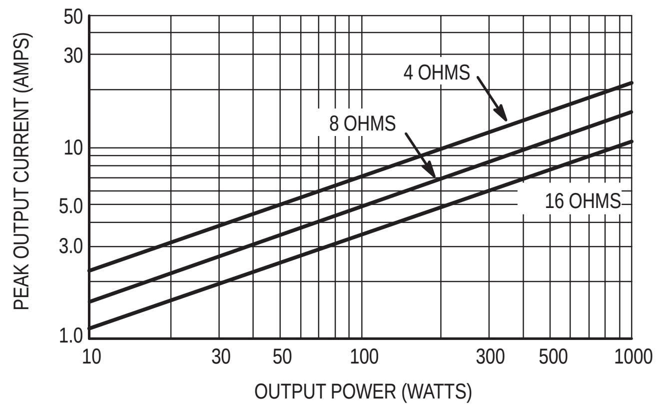
# Audio

## GENERAL DESIGN CURVES FOR POWER AUDIO OUTPUT STAGES

**$V_{(BR)CEO}$ Required on Output and Driver Transistor versus Output Power for 4, 8 and 18 Ohm Loads**




**Output Transistor Peak Collector Current versus Output Power for 4, 8 and 16 Ohm Loads**




Another important parameter that must be considered before selecting the output transistors is the safe–operating area these devices must withstand. For a complete discussion see Application Note AN485.

**Table 9. Recommended Power Transistors for Audio/Servo Loads**

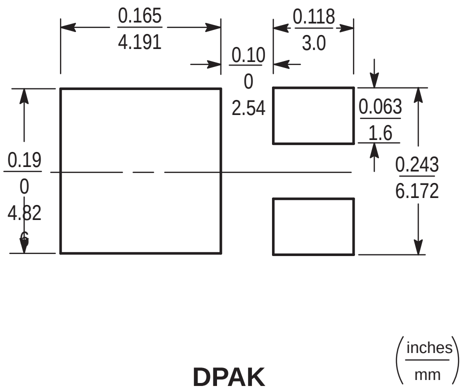
| RMS Power Output | NPN | PNP | Case | $P_D$ Watts @ 25°C | $V_{CEO}$ | $h_{FE}$ @ Min/Max | $I_C$ Amps | $f_T$ MHz Typ | ISB Volts/Amps |
|---|---|---|---|---|---|---|---|---|---|
| To 25W | MJE15030 | MJE15031 | TO–220 | 50 | 150 | 20 min | 4 | 30 | 14/3.6 |
| | MJE15032 | MJE15033 | TO–220 | 50 | 250 | 50 min | 1 | 40 | 50/1 |
| 25 to 50W | 2N3055A | MJ2955A | TO–204 | 120 | 120 | 20/70 | 4 | 3 | 60/2 |
| | MJ15001 | MJ15002 | TO–204 | 200 | 140 | 25/150 | 4 | 3 | 40/5 |
| 50 to 100W | MJ15015 | MJ15016 | TO–204 | 180 | 120 | 20/70 | 4 | 3 | 60/3 |
| | MJ15003 | MJ15004 | TO–204 | 250 | 140 | 25/150 | 5 | 3 | 100/1 |
| | MJ15020 | MJ15021 | TO–204 | 150 | 250 | 30 min | 1 | 20 | 50/3 |
| Over 100W | MJ15024 | MJ15025 | TO–204 | 250 | 250 | 15/60 | 8 | 8 | 80/2.2 |
| | MJ3281A | MJ1302A | TO–204 | 250 | 200 | 60/175 | 7 | 30 | 50/4 |
| | MJL3281A | MJL1302A | 340G–01 | 150 | 200 | 60/175 | 7 | 30 | 40/4 |
| | MJ21194 | MJ21193 | TO–204 | 250 | 250 | 25/75 | 8 | 7 | 100/2 |
| | MJL21194 | MJL21193 | 340G–01 | 200 | 200 | 25/75 | 8 | 7 | 100/2 |

The Power Transistors shown are provided for reference only and show device capability. The final choice of the Power Transistors used is left to the circuit designer and depends upon the particular safe–operating area required and the mounting and heat sinking configuration used.

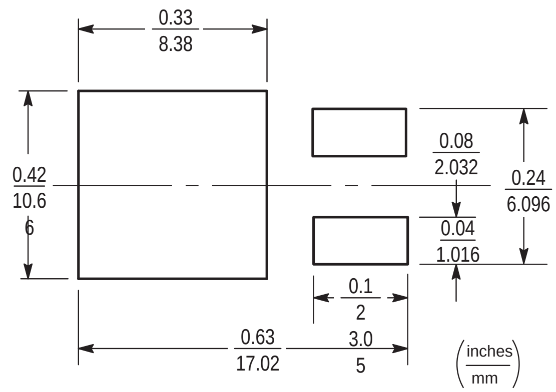
# INFORMATION FOR USING SURFACE MOUNT PACKAGES

## RECOMMENDED FOOTPRINTS FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the semiconductor packages must be the correct size to ensure proper solder connection interface between the board and the package. With the correct pad geometry, the packages will self align when subjected to a solder reflow process.




**DPAK**




**D2PAK**

## POWER DISSIPATION FOR A SURFACE MOUNT DEVICE

The values for the equation are found in the maximum ratings table on the data sheet. Substituting these values into the equation for an ambient temperature $T_A$ of 25°C, one can calculate the power dissipation of the device. For example, for a D2PAK, $P_D$ is calculated as follows.

$$P_D = \frac{150°C - 25°C}{50°C/W} = 2.5 \text{ watts}$$

The 50 °C/W for the D2PAK package assumes the use of the recommended footprint on a glass epoxy printed circuit board to achieve a power dissipation of 2.5 watts. There are other alternatives to achieving higher power dissipation from the surface mount packages. One is to increase the area of the drain/collector pad. By increasing the area of the drain/collector pad, the power dissipation can be increased. Although the power dissipation can almost be doubled with this method, area is taken up on the printed circuit board which can defeat the purpose of using surface mount technology. For example, a graph of $R_{\theta JA}$ versus drain pad area is shown in Figures 1 and 2.

Another alternative would be to use a ceramic substrate or an aluminum core board such as Thermal Clad™. Using a board material such as Thermal Clad, an aluminum core board, the power dissipation can be doubled using the same footprint.

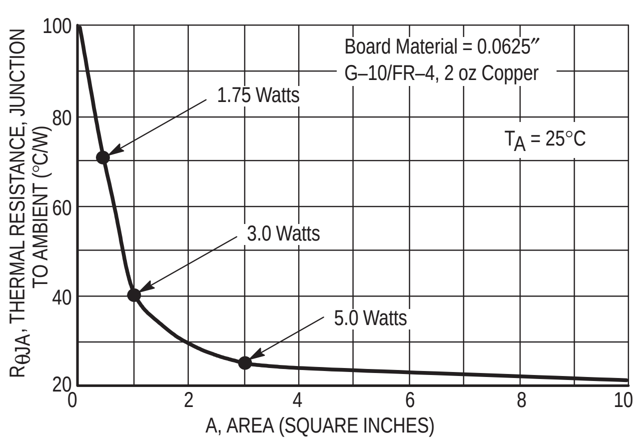



**Figure 1. Thermal Resistance versus Drain Pad Area for the DPAK Package (Typical)**

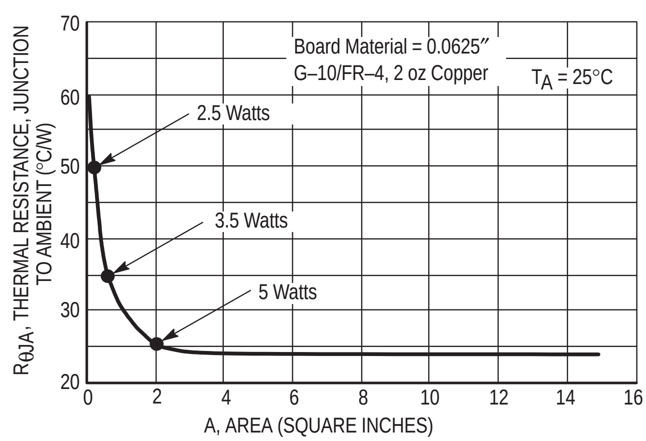



**Figure 2. Thermal Resistance versus Drain Pad Area for the D2PAK Package (Typical)**

Prior to placing surface mount components onto a printed circuit board, solder paste must be applied to the pads. Solder stencils are used to screen the optimum amount. These stencils are typically 0.008 inches thick and may be made of brass or stainless steel. This is not the case with the DPAK and $D^2PAK$ packages. If a 1:1 opening is used to screen solder onto the drain pad, misalignment and/or “tombstoning” may occur due to an excess of solder. For these two packages, the opening in the stencil for the paste should be approximately 50% of the tab area. The opening for the leads is still a 1:1 registration. Figure 3 shows a typical stencil for the DPAK and $D^2PAK$ packages. The pattern of the opening in the stencil for the drain pad is not critical as long as it allows approximately 50% of the pad to be covered with paste.

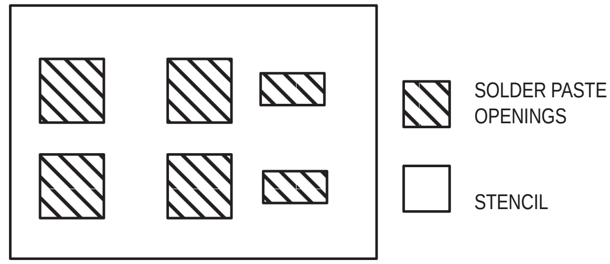



**Figure 3. Typical Stencil for DPAK and $D^2PAK$ Packages**

## SOLDERING PRECAUTIONS

The melting temperature of solder is higher than the rated temperature of the device. When the entire device is heated to a high temperature, failure to complete soldering within a short time could result in device failure. Therefore, the following items should always be observed in order to minimize the thermal stress to which the devices are subjected.

- Always preheat the device.
- The delta temperature between the preheat and soldering should be 100°C or less.*
- When preheating and soldering, the temperature of the leads and the case must not exceed the maximum temperature ratings as shown on the data sheet. When using infrared heating with the reflow soldering method, the difference should be a maximum of 10°C.
- The soldering temperature and time should not exceed 260°C for more than 10 seconds.
- When shifting from preheating to soldering, the maximum temperature gradient shall be 5°C or less.
- After soldering has been completed, the device should be allowed to cool naturally for at least three minutes. Gradual cooling should be used since the use of forced cooling will increase the temperature gradient and will result in latent failure due to mechanical stress.
- Mechanical stress or shock should not be applied during cooling.

* Soldering a device without preheating can cause excessive thermal shock and stress which can result in damage to the device.

* Due to shadowing and the inability to set the wave height to incorporate other surface mount components, the $D^2PAK$ is not recommended for wave soldering.

## TYPICAL SOLDER HEATING PROFILE

For any given circuit board, there will be a group of control settings that will give the desired heat pattern. The operator must set temperatures for several heating zones and a figure for belt speed. Taken together, these control settings make up a heating “profile” for that particular circuit board. On machines controlled by a computer, the computer remembers these profiles from one operating session to the next. Figure 5 shows a typical heating profile for use when soldering a surface mount device to a printed circuit board. This profile will vary among soldering systems, but it is a good starting point. Factors that can affect the profile include the type of soldering system in use, density and types of components on the board, type of solder used, and the type of board or substrate material being used. This profile shows temperature versus time. The line on the graph shows the actual temperature that might be experienced on the surface of a test board at or near a central solder joint. The two profiles are based on a high density and a low density board. The Vitronics SMD310 convection/infrared reflow soldering system was used to generate this profile. The type of solder used was 62/36/2 Tin Lead Silver with a melting point between 177–189°C. When this type of furnace is used for solder reflow work, the circuit boards and solder joints tend to heat first. The components on the board are then heated by conduction. The circuit board, because it has a large surface area, absorbs the thermal energy more efficiently, then distributes this energy to the components. Because of this effect, the main body of a component may be up to 30 degrees cooler than the adjacent solder joints.

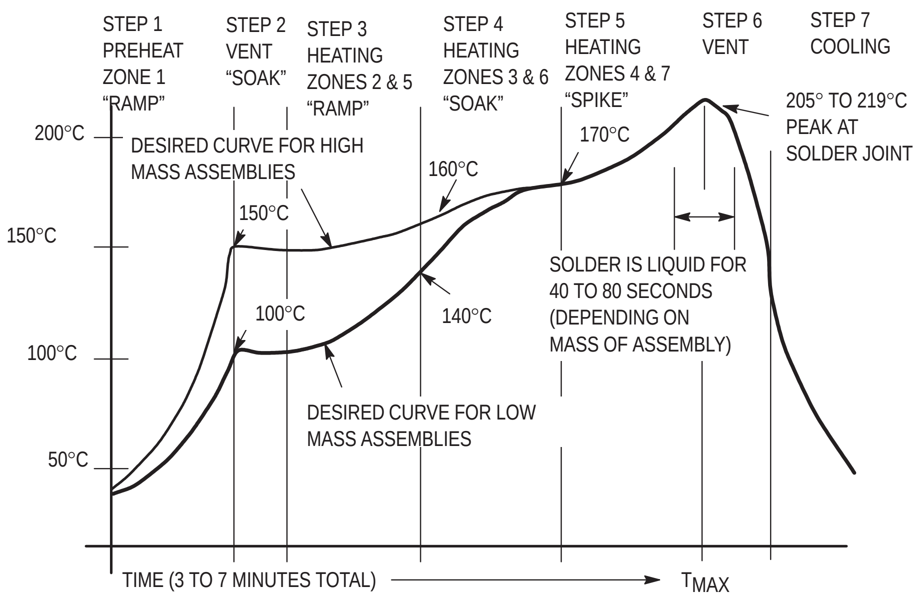



**Figure 4. Typical Solder Heating Profile**

# Mounting Hardware and Techniques

There are many methods available and options possible for installing power semiconductors. A complete discussion of mounting is contained in Motorola Application Note AN1040,"Mounting Considerations for Power Semiconductors," reprinted in Section 6 of this data book. Various suppliers of mounting hardware, listed below, may be contacted for their catalogs which contain considerable technical information.

## Sources for Mounting Hardware

| Manufacturer | Joint Compound | Adhesives | Insulators | | | | | | Heatsinks | Clips |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BeO | $AlO_2$ | Anodize | Mica | Plastic Film | Silicone Rubber | | |
| Aavid Eng. | — | — | — | — | — | — | X | X | X | X |
| AHAM-TOR | — | — | — | — | — | — | — | — | X | — |
| Asheville-Schoonmaker | — | — | — | — | — | X | — | — | — | — |
| Astrodynamics | X | — | — | — | — | — | — | — | X | — |
| Delbert Blinn | — | — | X | — | X | X | X | X | X | — |
| IERC | X | — | — | — | — | — | — | — | X | — |
| Staver | — | — | — | — | — | — | — | — | X | — |
| Thermalloy | X | X | X | X | X | X | X | X | X | X |
| Tran-tec | X | — | X | X | X | X | — | X | X | — |
| Wakefield Eng. | X | X | X | — | X | — | — | X | X | X |

Other sources for silicone rubber pads: Chomerics, Berquist

**Suppliers Addresses**

Aavid Engineering, Inc., P.O. Box 400, Laconia, New Hampshire 03247 (603) 528-1478

AHAM-TOR Heatsinks, 27901 Front Street, Rancho, California 92390 (714) 676-4151

Asheville-Schoonmaker, 900 Jefferson Ave., Newport News, VA 23607 (804) 244-7311

Astro Dynamics, Inc., 2 Gill St., Woburn, Massachusetts 01801 (617) 935-4944

Berquist, 5300 Edina Industrial Blvd., Minneapolis, Minnesota 55435 (612) 835-2322

Chomerics, Inc., 16 Flagstone Drive, Hudson, New Hampshire 03051 1-800-633-8800

Delbert Blinn Company, P.O. Box 2007, Pomona, California 91769 (714) 623-1257

International Electronic Research Corporation, 135 West Magnolia Boulevard, Burbank, California 91502 (213) 849-2481

The Staver Company, Inc., 41-51 Saxon Avenue, Bay Shore, Long Island, New York 11706 (516) 666-8000

Thermalloy, Inc., P.O. Box 34829, 2021 West Valley View Lane, Dallas, Texas 75234 (214) 243-4321

Tran-tec Corporation, P.O. Box 1044, Columbus, Nebraska 68601 (402) 564-2748

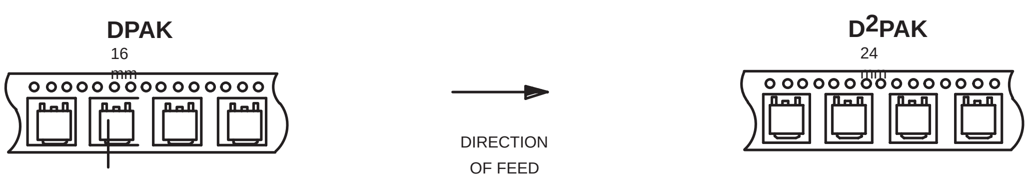
Wakefield Engineering, Inc., Wakefield, Massachusetts 01880 (617) 245-5900

# Tape and Reel Specifications
# and Packaging Specifications

Embossed Tape and Reel is used to facilitate automatic pick and place equipment feed requirements. The tape is used as the shipping container for various products and requires a minimum of handling. The antistatic/conductive tape provides a secure cavity for the product when sealed with the “peel–back” cover tape.

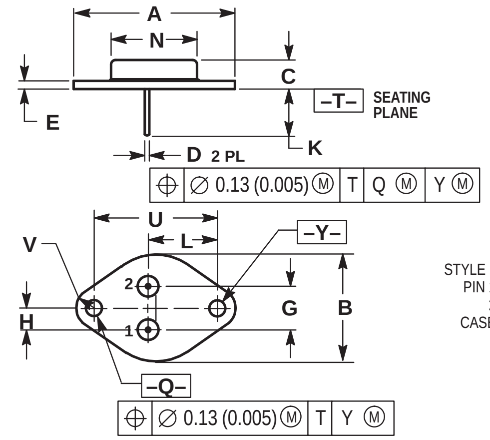
- Two Reel Sizes Available (7″ and 13″)
- Used for Automatic Pick and Place Feed Systems
- Minimizes Product Handling
- EIA 481, –1, –2
- DPAK SO–14, in 16 mm Tape
- $D^2$PAK in 24 mm Tape

Use the standard device title and add the required suffix as listed in the option table on the following page. Note that the individual reels have a finite number of devices depending on the type of product contained in the tape. Also note the minimum lot size is one full reel for each line item, and orders are required to be in increments of the single reel quantity.




| Package | Tape Width (mm) | Reel Size (inch) | | | | |
|---|---|---|---|---|---|---|
| DPAK | 16 | 8.0 ± 0.1 (.315 ± .004) | | 330 (13) | 2,500 | T4 |
| $D^2$PAK | 24 | 16.0 ± 0.1 (.630 ± .004) | | 330 (13) | 800 | T4 |

# Outline Dimensions

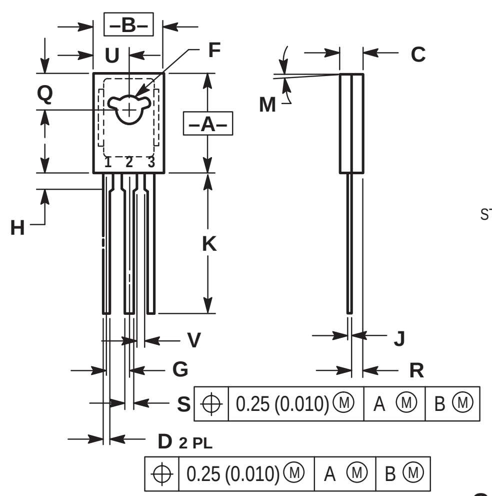



STYLE 1:
PIN 1. BASE
2. EMITTER
CASE: COLLECTOR

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. ALL RULES AND NOTES ASSOCIATED WITH REFERENCED TO–204AA OUTLINE SHALL APPLY.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 1.550 REF | | 39.37 REF | |
| B | — | 1.050 | — | 26.67 |
| C | 0.250 | 0.335 | 6.35 | 8.51 |
| D | 0.038 | 0.043 | 0.97 | 1.09 |
| E | 0.055 | 0.070 | 1.40 | 1.77 |
| G | 0.430 BSC | | 10.92 BSC | |
| H | 0.215 BSC | | 5.46 BSC | |
| K | 0.440 | 0.480 | 11.18 | 12.19 |
| L | 0.665 BSC | | 16.89 BSC | |
| N | — | 0.830 | — | 21.08 |
| Q | 0.151 | 0.165 | 3.84 | 4.19 |
| U | 1.187 BSC | | 30.15 BSC | |
| V | 0.131 | 0.188 | 3.33 | 4.77 |

**CASE 1–07**
**(TO–204AA)**

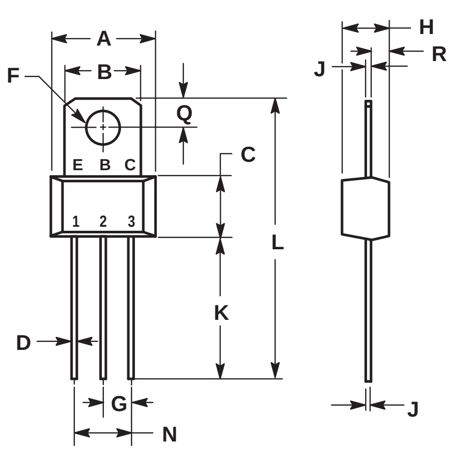



STYLE 1:
PIN 1. EMITTER
2. COLLECTOR
3. BASE

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

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.425 | 0.435 | 10.80 | 11.04 |
| B | 0.295 | 0.305 | 7.50 | 7.74 |
| C | 0.095 | 0.105 | 2.42 | 2.66 |
| D | 0.020 | 0.026 | 0.51 | 0.66 |
| F | 0.115 | 0.130 | 2.93 | 3.30 |
| G | 0.094 BSC | | 2.39 BSC | |
| H | 0.050 | 0.095 | 1.27 | 2.41 |
| J | 0.015 | 0.025 | 0.39 | 0.63 |
| K | 0.575 | 0.655 | 14.61 | 16.63 |
| M | 5° TYP | | 5° TYP | |
| Q | 0.148 | 0.158 | 3.76 | 4.01 |
| R | 0.045 | 0.055 | 1.15 | 1.39 |
| S | 0.025 | 0.035 | 0.64 | 0.88 |
| U | 0.145 | 0.155 | 3.69 | 3.93 |
| V | 0.040 | — | 1.02 | — |

**CASE 77–08**
**(TO–225AA)**



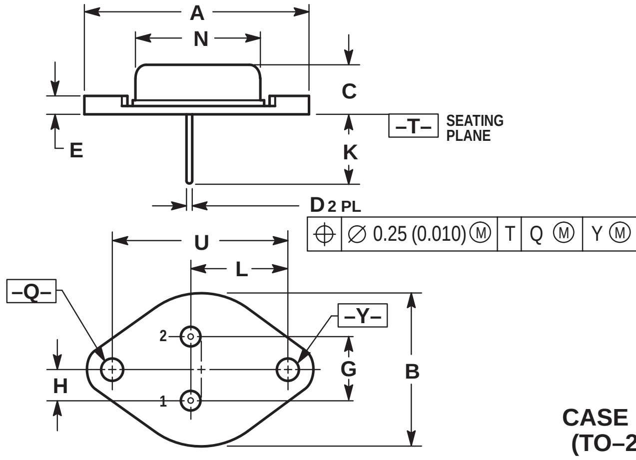

STYLE 1:
PIN 1. EMITTER
2. BASE
3. COLLECTOR
(COLLECTOR CONNECTED TO TAB)

NOTES:
1. LEADS WITHIN 0.15 (0.006) TOTAL OF TRUE POSITION AT CASE, AT MAXIMUM MATERIAL CONDITION.

| | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 9.14 | 9.53 | 0.360 | 0.375 |
| B | 6.60 | 7.24 | 0.260 | 0.285 |
| C | 5.41 | 5.66 | 0.213 | 0.223 |
| D | 0.38 | 0.53 | 0.015 | 0.021 |
| F | 3.18 | 3.33 | 0.125 | 0.131 |
| G | 2.54 BSC | | 0.100 BSC | |
| H | 3.94 | 4.19 | 0.155 | 0.165 |
| J | 0.36 | 0.41 | 0.014 | 0.016 |
| K | 11.63 | 12.70 | 0.458 | 0.500 |
| L | 24.58 | 25.53 | 0.968 | 1.005 |
| N | 5.08 BSC | | 0.200 BSC | |
| Q | 2.39 | 2.69 | 0.094 | 0.106 |
| R | 1.14 | 1.40 | 0.045 | 0.055 |

**CASE 152-02**

# Outline Dimensions (continued)

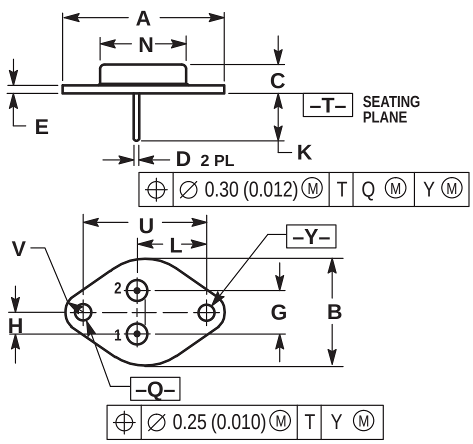



STYLE 1:
PIN 1. BASE
2. EMITTER
CASE: COLLECTOR

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

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | 1.510 | 1.550 | 38.35 | 39.37 |
| B | 0.980 | 1.050 | 24.89 | 26.67 |
| C | 0.250 | 0.335 | 6.35 | 8.51 |
| D | 0.057 | 0.063 | 1.45 | 1.60 |
| E | 0.060 | 0.135 | 1.52 | 3.43 |
| G | 0.420 | 0.440 | 10.67 | 11.18 |
| H | 0.205 | 0.225 | 5.21 | 5.72 |
| K | 0.440 | 0.480 | 11.18 | 12.19 |
| L | 0.655 | 0.675 | 16.64 | 17.15 |
| N | 0.760 | 0.830 | 19.30 | 21.08 |
| Q | 0.151 | 0.175 | 3.84 | 4.19 |
| U | 1.177 | 1.197 | 29.90 | 30.40 |

**CASE 197–05**
**(TO–204AE)**

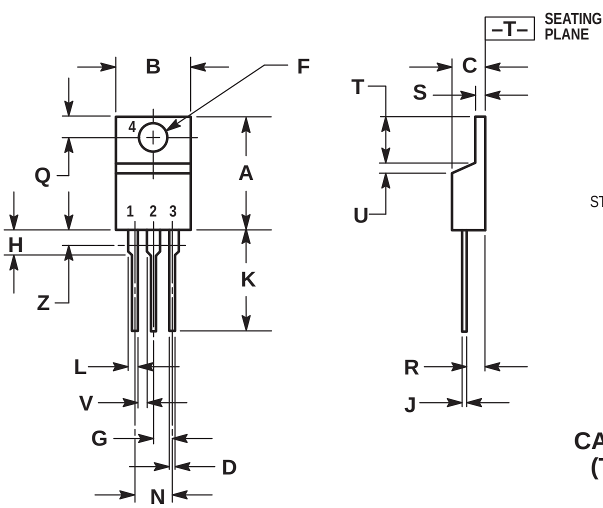



STYLE 1:
PIN 1. BASE
2. EMITTER
CASE: COLLECTOR

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

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | 1.530 REF | | 38.86 REF | |
| B | 0.990 | 1.050 | 25.15 | 26.67 |
| C | 0.250 | 0.335 | 6.35 | 8.51 |
| D | 0.057 | 0.063 | 1.45 | 1.60 |
| E | 0.060 | 0.070 | 1.53 | 1.77 |
| G | 0.430 BSC | | 10.92 BSC | |
| H | 0.215 BSC | | 5.46 BSC | |
| K | 0.440 | 0.480 | 11.18 | 12.19 |
| L | 0.665 BSC | | 16.89 BSC | |
| N | 0.760 | 0.830 | 19.31 | 21.08 |
| Q | 0.151 | 0.165 | 3.84 | 4.19 |
| U | 1.187 BSC | | 30.15 BSC | |
| V | 0.131 | 0.188 | 3.33 | 4.77 |

**CASE 197A–05**
**(TO–204AA)**



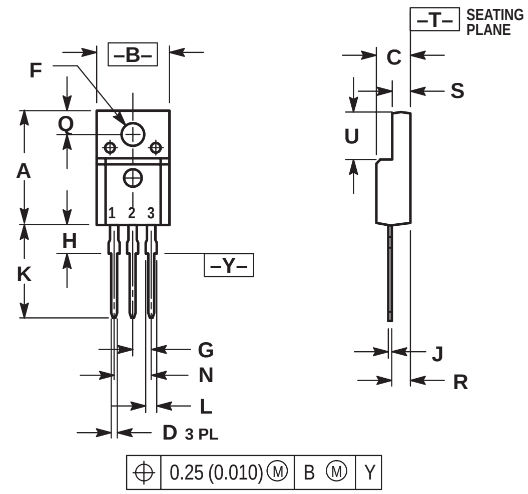

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

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 MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS 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 |

**CASE 221A–06**
**(TO220–AB)**

# Outline Dimensions (continued)

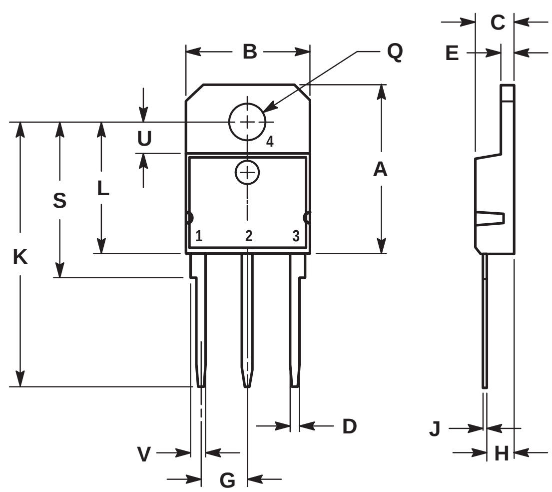



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

STYLE 2:
PIN 1. BASE
2. COLLECTOR
3. EMITTER

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | 0.621 | 0.629 | 15.78 | 15.97 |
| B | 0.394 | 0.402 | 10.01 | 10.21 |
| C | 0.181 | 0.189 | 4.60 | 4.80 |
| D | 0.026 | 0.034 | 0.67 | 0.86 |
| F | 0.121 | 0.129 | 3.08 | 3.27 |
| G | 0.100 BSC | | 2.54 BSC | |
| H | 0.123 | 0.129 | 3.13 | 3.27 |
| J | 0.018 | 0.025 | 0.46 | 0.64 |
| K | 0.500 | 0.562 | 12.70 | 14.27 |
| L | 0.045 | 0.060 | 1.14 | 1.52 |
| N | 0.200 BSC | | 5.08 BSC | |
| Q | 0.126 | 0.134 | 3.21 | 3.40 |
| R | 0.107 | 0.111 | 2.72 | 2.81 |
| S | 0.096 | 0.104 | 2.44 | 2.64 |
| U | 0.259 | 0.267 | 6.58 | 6.78 |

**CASE 221D–02 (TO–220)**

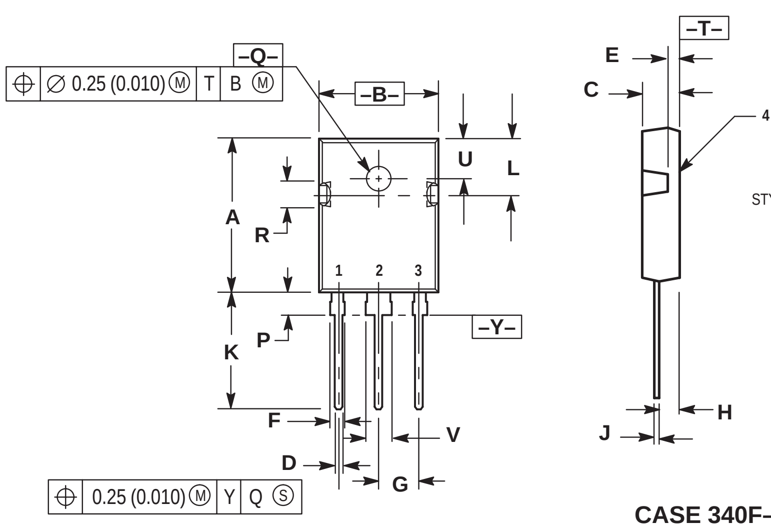



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 19.00 | 19.60 | 0.749 | 0.771 |
| B | 14.00 | 14.50 | 0.551 | 0.570 |
| C | 4.20 | 4.70 | 0.165 | 0.185 |
| D | 1.00 | 1.30 | 0.040 | 0.051 |
| E | 1.45 | 1.65 | 0.058 | 0.064 |
| G | 5.21 | 5.72 | 0.206 | 0.225 |
| H | 2.60 | 3.00 | 0.103 | 0.118 |
| J | 0.40 | 0.60 | 0.016 | 0.023 |
| K | 28.50 | 32.00 | 1.123 | 1.259 |
| L | 14.70 | 15.30 | 0.579 | 0.602 |
| Q | 4.00 | 4.25 | 0.158 | 0.167 |
| S | 17.50 | 18.10 | 0.689 | 0.712 |
| U | 3.40 | 3.80 | 0.134 | 0.149 |
| V | 1.50 | 2.00 | 0.060 | 0.078 |

**CASE 340D–01 (TO–218)**



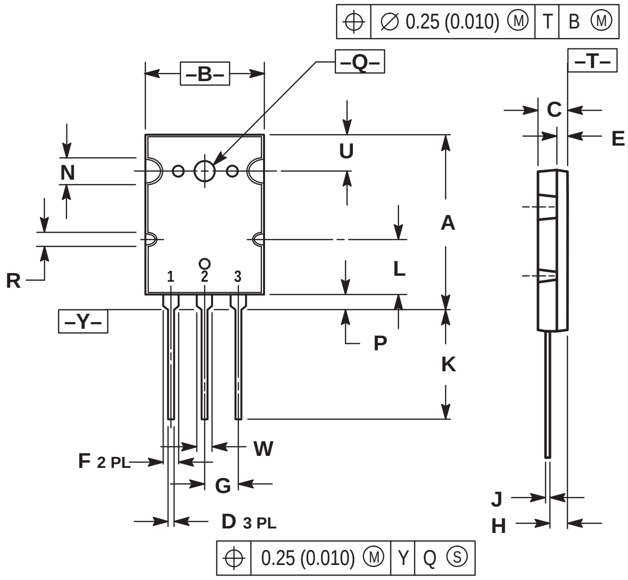

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.

STYLE 3:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 20.40 | 20.90 | 0.803 | 0.823 |
| B | 15.44 | 15.95 | 0.608 | 0.628 |
| C | 4.70 | 5.21 | 0.185 | 0.205 |
| D | 1.09 | 1.30 | 0.043 | 0.051 |
| E | 1.50 | 1.63 | 0.059 | 0.064 |
| F | 1.80 | 2.18 | 0.071 | 0.086 |
| G | 5.45 BSC | | 0.215 BSC | |
| H | 2.56 | 2.87 | 0.101 | 0.113 |
| J | 0.48 | 0.68 | 0.019 | 0.027 |
| K | 15.57 | 16.08 | 0.613 | 0.633 |
| L | 7.26 | 7.50 | 0.286 | 0.295 |
| P | 3.10 | 3.38 | 0.122 | 0.133 |
| Q | 3.50 | 3.70 | 0.138 | 0.145 |
| R | 3.30 | 3.80 | 0.130 | 0.150 |
| U | 5.30 BSC | | 0.209 BSC | |
| V | 3.05 | 3.40 | 0.120 | 0.134 |

**CASE 340F–03 (TO–247AE)**

# Outline Dimensions (continued)

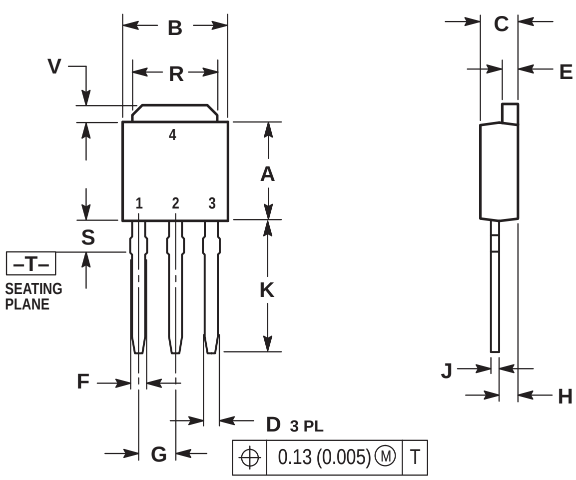



STYLE 2:
PIN 1. BASE
2. COLLECTOR
3. EMITTER

CASE 340G–02
(TO–3PBL)

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

| DIM | MILLIMETERS MIN | MILLIMETERS MAX | INCHES MIN | INCHES MAX |
|---|---|---|---|---|
| A | 2.8 | 2.9 | 1.102 | 1.142 |
| B | 19.3 | 20.3 | 0.760 | 0.800 |
| C | 4.7 | 5.3 | 0.185 | 0.209 |
| D | 0.93 | 1.48 | 0.037 | 0.058 |
| E | 1.9 | 2.1 | 0.075 | 0.083 |
| F | 2.2 | 2.4 | 0.087 | 0.102 |
| G | 5.45 BSC | | 0.215 BSC | |
| H | 2.6 | 3.0 | 0.102 | 0.118 |
| J | 0.43 | 0.78 | 0.017 | 0.031 |
| K | 17.6 | 18.8 | 0.693 | 0.740 |
| L | 11.0 | 11.4 | 0.433 | 0.449 |
| N | 3.95 | 4.75 | 0.156 | 0.187 |
| P | 2.2 | 2.6 | 0.087 | 0.102 |
| Q | 3.1 | 3.5 | 0.122 | 0.137 |
| R | 2.15 | 2.35 | 0.085 | 0.093 |
| U | 6.1 | 6.5 | 0.240 | 0.256 |
| W | 2.8 | 3.2 | 0.110 | 0.125 |

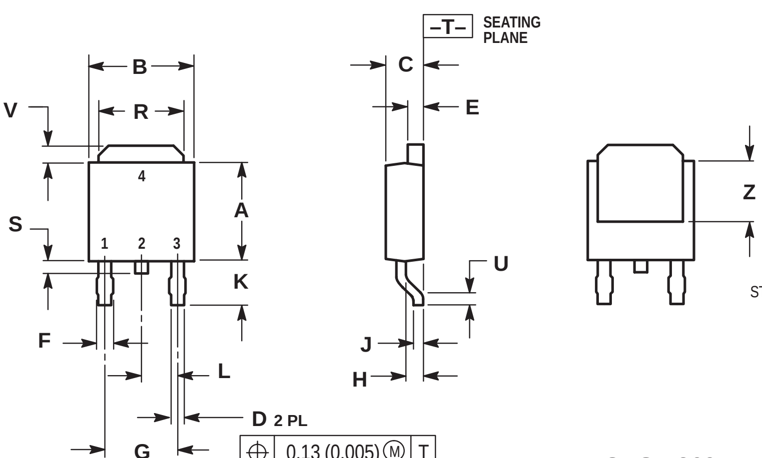



STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

CASE 369–07

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

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | 0.235 | 0.250 | 5.97 | 6.35 |
| B | 0.250 | 0.265 | 6.35 | 6.73 |
| C | 0.086 | 0.094 | 2.19 | 2.38 |
| D | 0.027 | 0.035 | 0.69 | 0.88 |
| E | 0.033 | 0.040 | 0.84 | 1.01 |
| F | 0.037 | 0.047 | 0.94 | 1.19 |
| G | 0.090 BSC | | 2.29 BSC | |
| H | 0.034 | 0.040 | 0.87 | 1.01 |
| J | 0.018 | 0.023 | 0.46 | 0.58 |
| K | 0.350 | 0.380 | 8.89 | 9.65 |
| R | 0.175 | 0.215 | 4.45 | 5.46 |
| S | 0.050 | 0.090 | 1.27 | 2.28 |
| V | 0.030 | 0.050 | 0.77 | 1.27 |




STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

CASE 369A–13

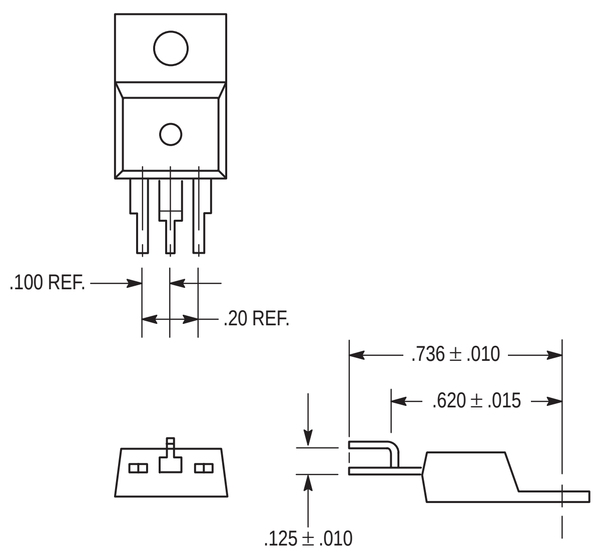
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | 0.235 | 0.250 | 5.97 | 6.35 |
| B | 0.250 | 0.265 | 6.35 | 6.73 |
| C | 0.086 | 0.094 | 2.19 | 2.38 |
| D | 0.027 | 0.035 | 0.69 | 0.88 |
| E | 0.033 | 0.040 | 0.84 | 1.01 |
| F | 0.037 | 0.047 | 0.94 | 1.19 |
| G | 0.180 BSC | | 4.58 BSC | |
| H | 0.034 | 0.040 | 0.87 | 1.01 |
| J | 0.018 | 0.023 | 0.46 | 0.58 |
| K | 0.102 | 0.114 | 2.60 | 2.89 |
| L | 0.090 BSC | | 2.29 BSC | |
| R | 0.175 | 0.215 | 4.45 | 5.46 |
| S | 0.020 | 0.050 | 0.51 | 1.27 |
| U | 0.020 | — | 0.51 | — |
| V | 0.030 | 0.050 | 0.77 | 1.27 |
| Z | 0.138 | — | 3.51 | — |

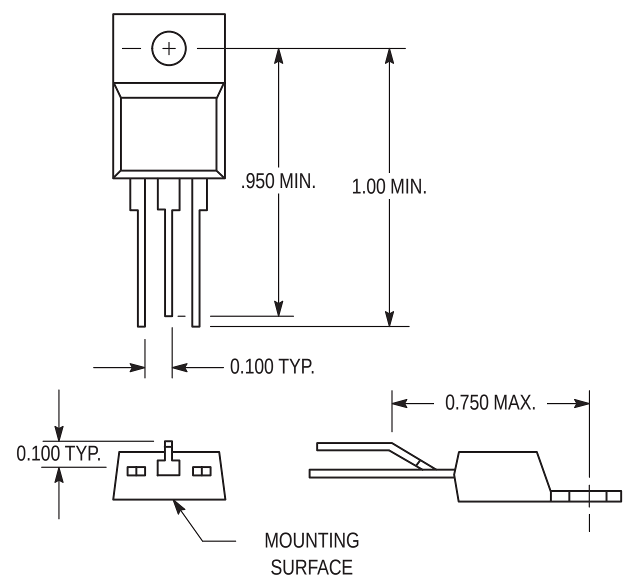
# Leadform Options — TO–220 (Case 221A)

- Leadform options require assignment of a special part number before ordering.
- Contact your local Motorola representative for special part number and pricing.
- 10,000 piece minimum quantity orders are required.
- Leadform orders are non–cancellable after processing.
- Leadforms apply to both Motorola Case 221A–04 and 221A–06 except as noted.

**LEADFORM AS**

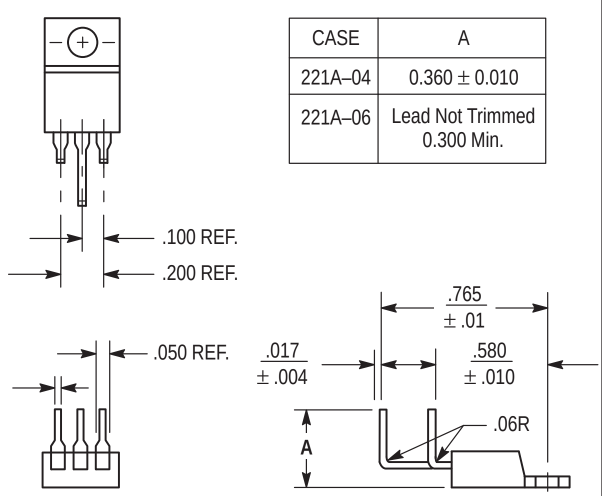



**LEADFORM BC**



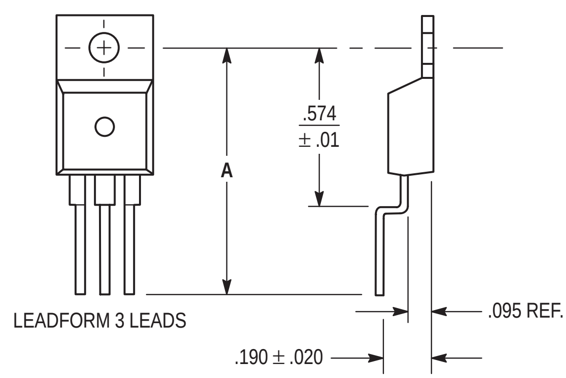

**LEADFORM AJ**

| CASE | A |
|---|---|
| 221A–04 | 0.360 ± 0.010 |
| 221A–06 | Lead Not Trimmed 0.300 Min. |



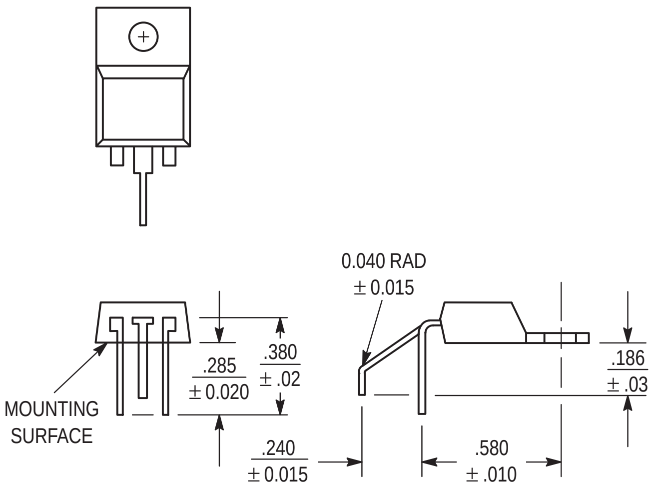

**LEADFORM AU**

| CASE | A |
|---|---|
| 221A–04 | 0.920 Min. |
| 221A–06 | 0.885 Min. |

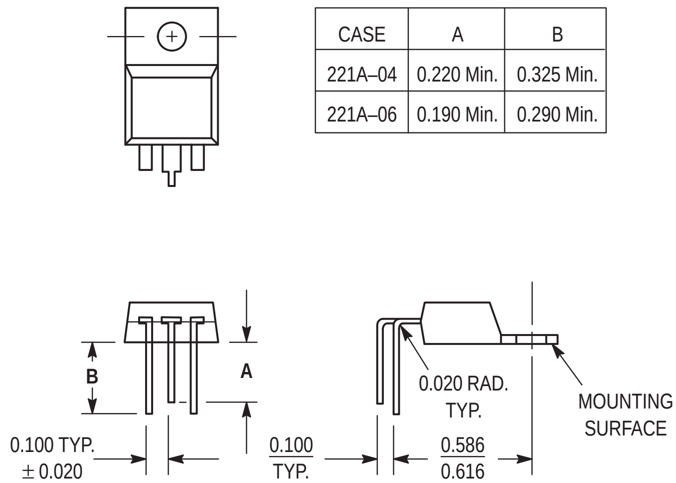


# TO–220 Leadform Options (continued)

**LEADFORM AN**

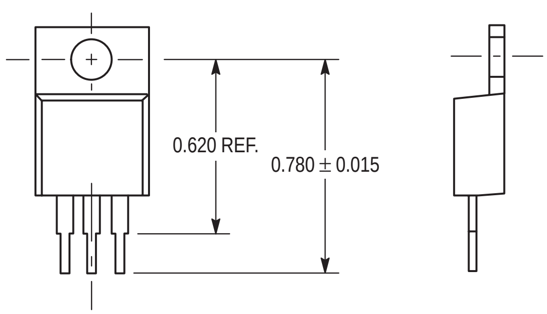



**LEADFORM BA**

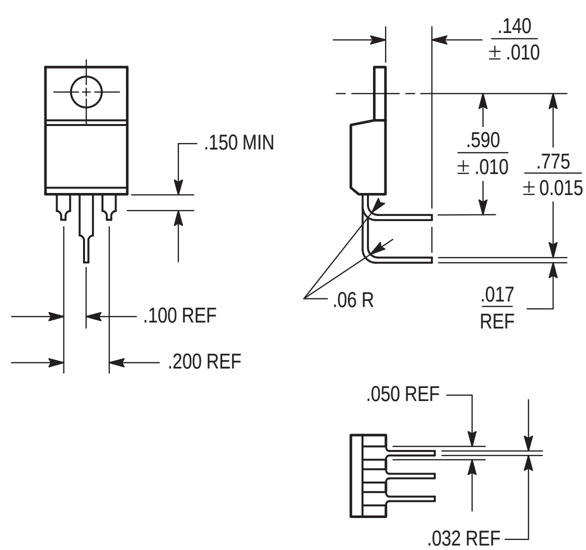



| CASE | A | B |
|---|---|---|
| 221A–04 | 0.220 Min. | 0.325 Min. |
| 221A–06 | 0.190 Min. | 0.290 Min. |

**LEADFORM BG**

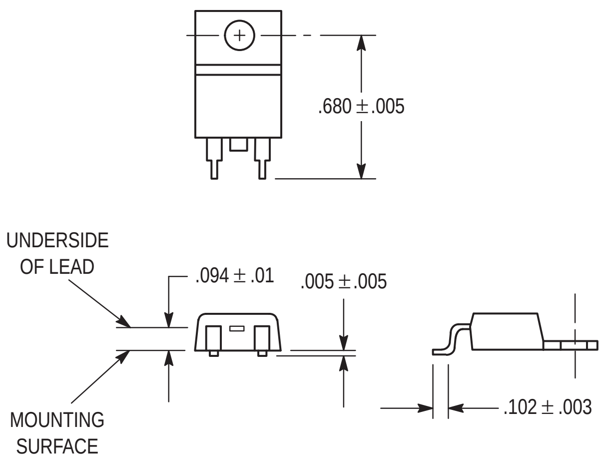



**LEADFORM AK**

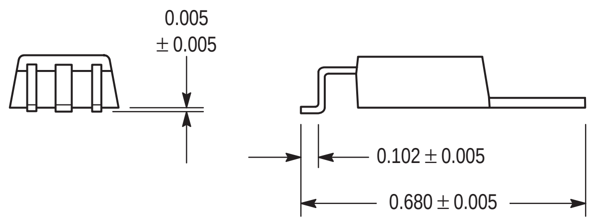


# TO–220 Leadform Options (continued)

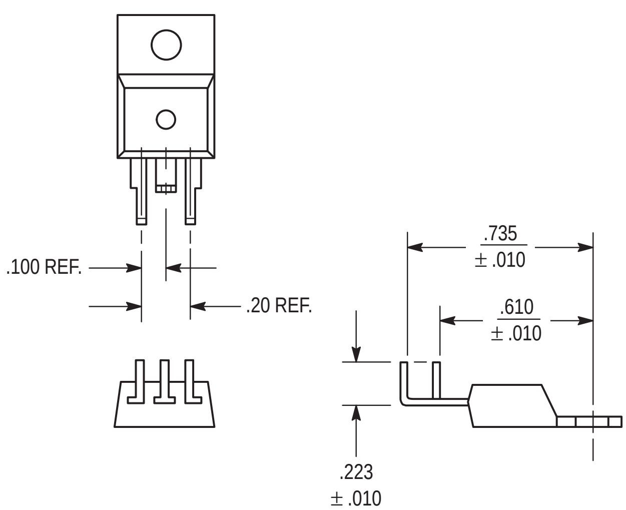
LEADFORM BU



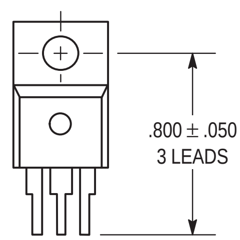

LEADFORM BV




LEADFORM BD

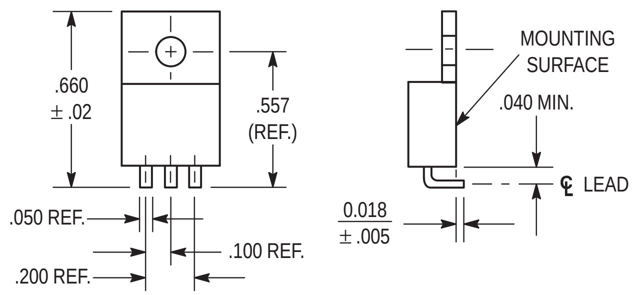



LEADFORM DW

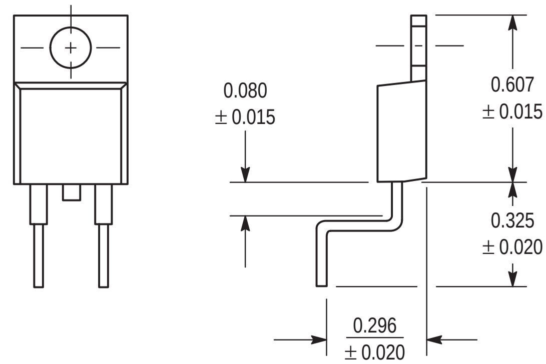


# TO–220 Leadform Options (continued)

LEADFORM AF




LEADFORM BS



# INDEX AND CROSS REFERENCE

The following table represents an index and cross–reference guide for all low–frequency power transistors which are either manufactured directly by Motorola or for which Motorola manufactures a suitable equivalent. Where the Motorola part number differs from the industry part number, the Motorola device is a “form, fit and function” replacement for the industry type number — however, subtle differences in characteristics and/or specifications may exist. Where multiple replacement parts appear for a given industry part number, the page number represents the first replacement device listed.

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