

## N-Channel 650V (D-S) Super Junction Power MOSFET

| PRODUCT SUMMARY                         |                              |
|---|------------------------------|
| $V_{DS}$ (V) at $T_J$ max.              | 650                          |
| $R_{DS(on)}$ max. at 25 °C ( $\Omega$ ) | $V_{GS} = 10\text{ V}$   0.7 |
| $Q_g$ max. (nC)                         | 25                           |
| $Q_{gs}$ (nC)                           | 2.0                          |
| $Q_{gd}$ (nC)                           | 2.7                          |
| Configuration                           | Single                       |

### FEATURES

- Low figure-of-merit (FOM)  $R_{on} \times Q_g$
- Low input capacitance ( $C_{iss}$ )
- Reduced switching and conduction losses
- Ultra low gate charge ( $Q_g$ )
- Avalanche energy rated (UIS)

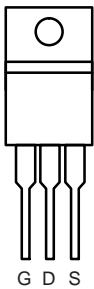


RoHS

### APPLICATIONS

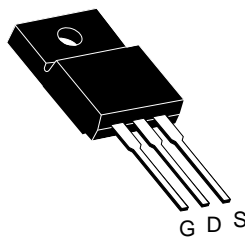
- Server and telecom power supplies
- Switch mode power supplies (SMPS)
- Power factor correction power supplies (PFC)
- Lighting
  - High-intensity discharge (HID)
  - Fluorescent ballast lighting
- Industrial

TO-220AB



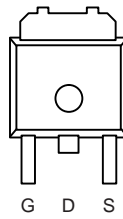
Top View

TO-220 FULLPAK



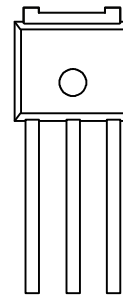
Top View

TO-252

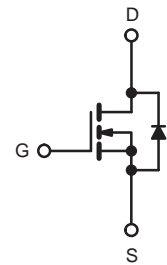


Top View

TO-251



Top View




N-Channel MOSFET

| ABSOLUTE MAXIMUM RATINGS ( $T_C = 25\text{ }^\circ\text{C}$ , unless otherwise noted) |                  |                                   |                     |      |
|---|------------------|-----------------------------------|---------------------|------|
| PARAMETER   | SYMBOL           | LIMIT                             | UNIT                |      |
| Drain-Source Voltage  | $V_{DS}$         | 650                               | V                   |      |
| Gate-Source Voltage   | $V_{GS}$         | $\pm 30$                          |                     |      |
| Continuous Drain Current ( $T_J = 150\text{ }^\circ\text{C}$ )                        | $V_{GS}$ at 10 V | $T_C = 25\text{ }^\circ\text{C}$  | 7                   | A    |
|   |                  | $T_C = 100\text{ }^\circ\text{C}$ | 6                   |      |
| Pulsed Drain Current <sup>a</sup>   | $I_{DM}$         | 10                                |                     |      |
| Linear Derating Factor  |                  | 1.67/1.5/0.3                      | W/ $^\circ\text{C}$ |      |
| Single Pulse Avalanche Energy <sup>b</sup>  | $E_{AS}$         | 86                                | mJ                  |      |
| Maximum Power Dissipation   | $P_D$            | 83/83/31                          | W                   |      |
| Operating Junction and Storage Temperature Range                                      | $T_J, T_{stg}$   | -55 to +150                       | $^\circ\text{C}$    |      |
| Drain-Source Voltage Slope  | $dV/dt$          | $T_J = 125\text{ }^\circ\text{C}$ | 50                  | V/ns |
| Reverse Diode $dV/dt$ <sup>d</sup>  |                  | 4.5                               |                     |      |
| Soldering Recommendations (Peak Temperature) <sup>c</sup>                             | for 10 s         | 300                               | $^\circ\text{C}$    |      |

### Notes

- Repetitive rating; pulse width limited by maximum junction temperature.
- $V_{DD} = 50\text{ V}$ , starting  $T_J = 25\text{ }^\circ\text{C}$ ,  $L = 28.2\text{ mH}$ ,  $R_g = 25\text{ }\Omega$ ,  $I_{AS} = 3.5\text{ A}$ .
- 1.6 mm from case.
- $I_{SD} \leq I_D$ ,  $dI/dt = 100\text{ A}/\mu\text{s}$ , starting  $T_J = 25\text{ }^\circ\text{C}$ .

| THERMAL RESISTANCE RATINGS       |            |      |      |      |
|----------------------------------|------------|------|------|------|
| PARAMETER                        | SYMBOL     | TYP. | MAX. | UNIT |
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 63   | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 0.6  |      |

| SPECIFICATIONS ( $T_J = 25\text{ }^\circ\text{C}$ , unless otherwise noted) |                     |  |   |      |      |           |               |
|---|---------------------|--|---|------|------|-----------|---------------|
| PARAMETER   | SYMBOL              | TEST CONDITIONS  |   | MIN. | TYP. | MAX.      | UNIT          |
| <b>Static</b>   |                     |  |   |      |      |           |               |
| Drain-Source Breakdown Voltage  | $V_{DS}$            | $V_{GS} = 0\text{ V}, I_D = 250\text{ }\mu\text{A}$  |   | 650  | -    | -         | V             |
| $V_{DS}$ Temperature Coefficient  | $\Delta V_{DS}/T_J$ | Reference to $25\text{ }^\circ\text{C}, I_D = 1\text{ mA}$   |   | -    | 0.65 | -         | V/°C          |
| Gate-Source Threshold Voltage (N)   | $V_{GS(th)}$        | $V_{DS} = V_{GS}, I_D = 250\text{ }\mu\text{A}$  |   | 2    | -    | 4         | V             |
| Gate-Source Leakage   | $I_{GSS}$           | $V_{GS} = \pm 20\text{ V}$   |   | -    | -    | $\pm 100$ | nA            |
|   |                     | $V_{GS} = \pm 30\text{ V}$   |   | -    | -    | $\pm 1$   | $\mu\text{A}$ |
| Zero Gate Voltage Drain Current   | $I_{DSS}$           | $V_{DS} = 650\text{ V}, V_{GS} = 0\text{ V}$   |   | -    | -    | 1         | $\mu\text{A}$ |
|   |                     | $V_{DS} = 520\text{ V}, V_{GS} = 0\text{ V}, T_J = 125\text{ }^\circ\text{C}$  |   | -    | -    | 10        |               |
| Drain-Source On-State Resistance  | $R_{DS(on)}$        | $V_{GS} = 10\text{ V}$   | $I_D = 4\text{ A}$                        | -    | 0.70 | -         | $\Omega$      |
| Forward Transconductance  | $g_{fs}$            | $V_{DS} = 30\text{ V}, I_D = 4\text{ A}$   |   | -    | 16   | -         | S             |
| <b>Dynamic</b>  |                     |  |   |      |      |           |               |
| Input Capacitance   | $C_{iss}$           | $V_{GS} = 0\text{ V}, V_{DS} = 100\text{ V}, f = 1\text{ MHz}$   |   | -    | 360  | -         | pF            |
| Output Capacitance  | $C_{oss}$           |  |   | -    | 25   | -         |               |
| Reverse Transfer Capacitance  | $C_{rss}$           |  |   | -    | 12   | -         |               |
| Effective Output Capacitance, Energy Related <sup>a</sup>                   | $C_{o(er)}$         | $V_{DS} = 0\text{ V to } 520\text{ V}, V_{GS} = 0\text{ V}$  |   | -    | 45   | -         |               |
| Effective Output Capacitance, Time Related <sup>b</sup>                     | $C_{o(tr)}$         |  |   | -    | 62   | -         |               |
| Total Gate Charge   | $Q_g$               | $V_{GS} = 10\text{ V}$   | $I_D = 4\text{ A}, V_{DS} = 520\text{ V}$ | -    | 25   | -         | nC            |
| Gate-Source Charge  | $Q_{gs}$            |  |   | -    | 2.0  | -         |               |
| Gate-Drain Charge   | $Q_{gd}$            |  |   | -    | 2.7  | -         |               |
| Turn-On Delay Time  | $t_{d(on)}$         | $V_{DD} = 520\text{ V}, I_D = 4\text{ A}, V_{GS} = 10\text{ V}, R_g = 9.1\text{ }\Omega$   |   | -    | 25   | -         | ns            |
| Rise Time   | $t_r$               |  |   | -    | 55   | -         |               |
| Turn-Off Delay Time   | $t_{d(off)}$        |  |   | -    | 70   | -         |               |
| Fall Time   | $t_f$               |  |   | -    | 40   | -         |               |
| Gate Input Resistance   | $R_g$               | $f = 1\text{ MHz}, \text{open drain}$  |   | -    | 3.5  | -         | $\Omega$      |
| <b>Drain-Source Body Diode Characteristics</b>                              |                     |  |   |      |      |           |               |
| Continuous Source-Drain Diode Current                                       | $I_S$               | MOSFET symbol showing the integral reverse p - n junction diode  |   | -    | -    | 7         | A             |
| Pulsed Diode Forward Current  | $I_{SM}$            |  |   | -    | -    | 18        |               |
| Diode Forward Voltage   | $V_{SD}$            | $T_J = 25\text{ }^\circ\text{C}, I_S = 4\text{ A}, V_{GS} = 0\text{ V}$  |   | -    | -    | 1.5       | V             |
| Reverse Recovery Time   | $t_{rr}$            | $T_J = 25\text{ }^\circ\text{C}, I_F = I_S = 4\text{ A}, dI/dt = 100\text{ A}/\mu\text{s}, V_R = 400\text{ V}$                                       |   | -    | 190  | -         | ns            |
| Reverse Recovery Charge   | $Q_{rr}$            |  |   | -    | 2.3  | -         | $\mu\text{C}$ |
| Reverse Recovery Current  | $I_{RRM}$           |  |   | -    | 10   | -         | A             |

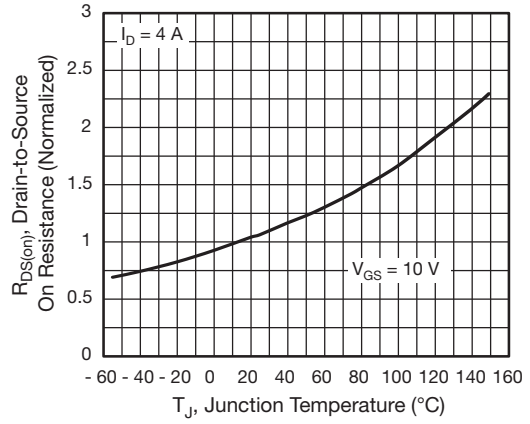
**Notes**

- a.  $C_{oss(er)}$  is a fixed capacitance that gives the same energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$ .
- b.  $C_{oss(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$ .

**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



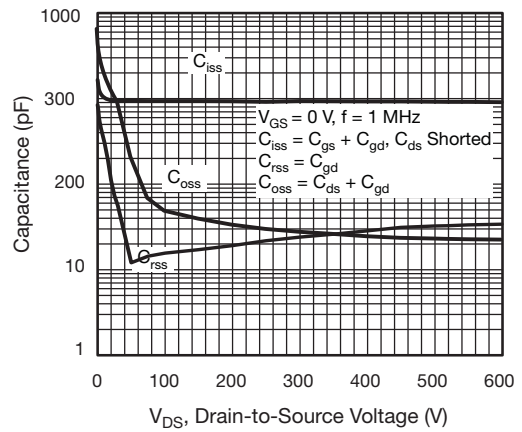
**Fig. 1 - Typical Output Characteristics**



**Fig. 4 - Normalized On-Resistance vs. Temperature**



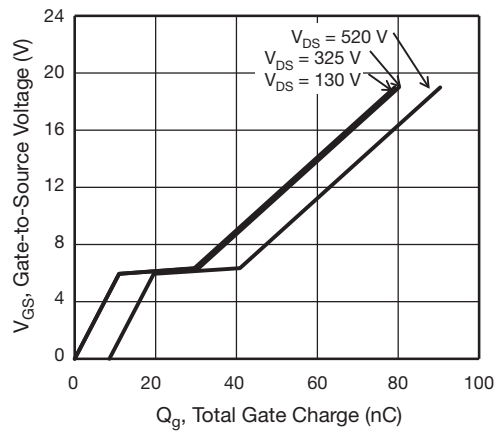
**Fig. 2 - Typical Output Characteristics**



**Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage**



**Fig. 3 - Typical Transfer Characteristics**



**Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage**

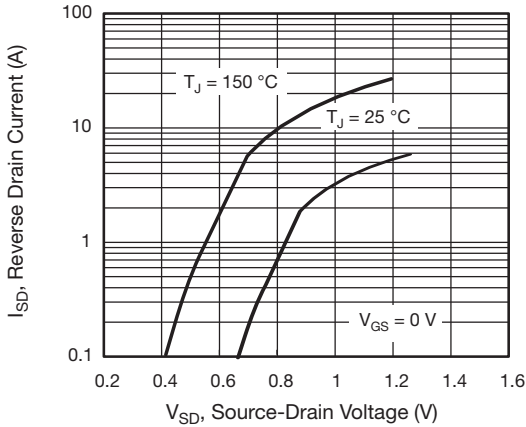


Fig. 7 - Typical Source-Drain Diode Forward Voltage

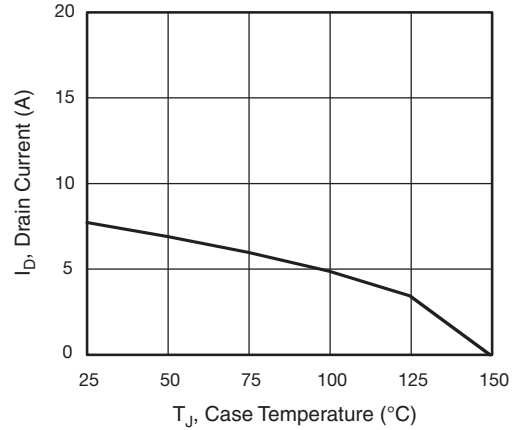


Fig. 9 - Maximum Drain Current vs. Case Temperature



Fig. 8 - Maximum Safe Operating Area

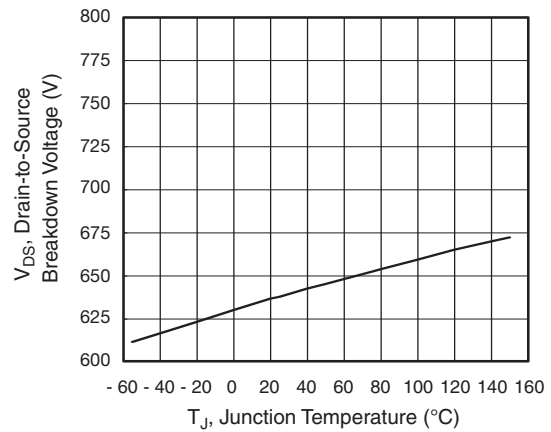


Fig. 10 - Temperature vs. Drain-to-Source Voltage



Fig. 11 - Normalized Thermal Transient Impedance, Junction-to-Case



Fig. 12 - Switching Time Test Circuit



Fig. 16 - Basic Gate Charge Waveform



Fig. 13 - Switching Time Waveforms



Fig. 17 - Gate Charge Test Circuit

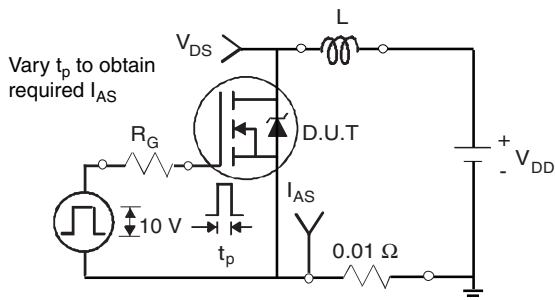


Fig. 14 - Unclamped Inductive Test Circuit



Fig. 15 - Unclamped Inductive Waveforms

**Peak Diode Recovery dV/dt Test Circuit**

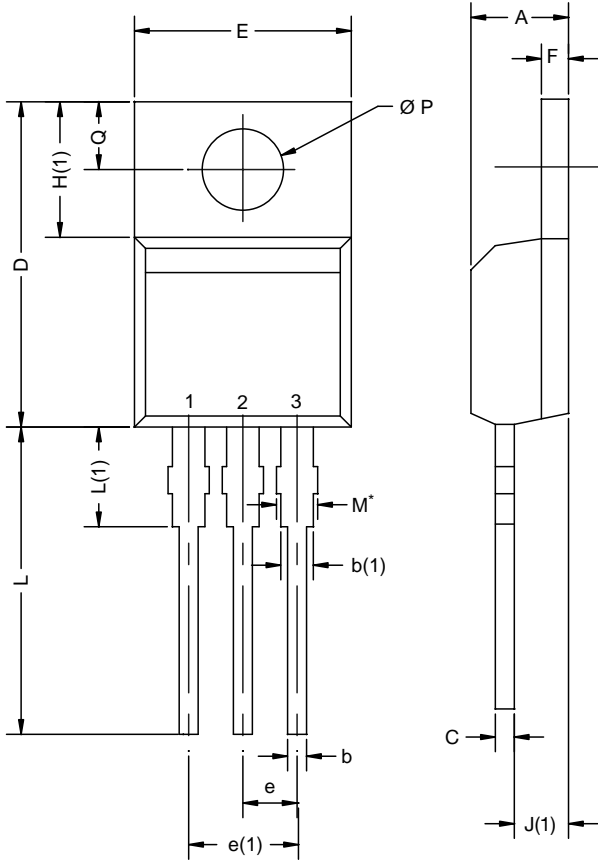


**Note**

a.  $V_{GS} = 5 V$  for logic level devices

**Fig. 18 - For N-Channel**

TO-220AB



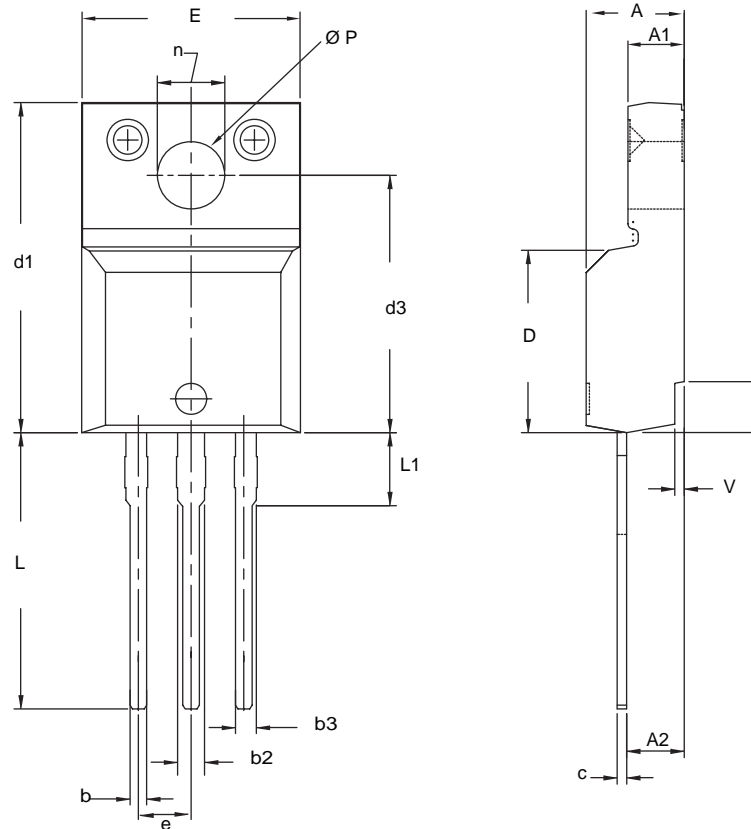
| DIM. | MILLIMETERS |       | INCHES |       |
|------|-------------|-------|--------|-------|
|      | MIN.        | MAX.  | MIN.   | MAX.  |
| A    | 4.25        | 4.65  | 0.167  | 0.183 |
| b    | 0.69        | 1.01  | 0.027  | 0.040 |
| b(1) | 1.20        | 1.73  | 0.047  | 0.068 |
| c    | 0.36        | 0.61  | 0.014  | 0.024 |
| D    | 14.85       | 15.49 | 0.585  | 0.610 |
| E    | 10.04       | 10.51 | 0.395  | 0.414 |
| e    | 2.41        | 2.67  | 0.095  | 0.105 |
| e(1) | 4.88        | 5.28  | 0.192  | 0.208 |
| F    | 1.14        | 1.40  | 0.045  | 0.055 |
| H(1) | 6.09        | 6.48  | 0.240  | 0.255 |
| J(1) | 2.41        | 2.92  | 0.095  | 0.115 |
| L    | 13.35       | 14.02 | 0.526  | 0.552 |
| L(1) | 3.32        | 3.82  | 0.131  | 0.150 |
| Ø P  | 3.54        | 3.94  | 0.139  | 0.155 |
| Q    | 2.60        | 3.00  | 0.102  | 0.118 |

ECN: X12-0208-Rev. N, 08-Oct-12  
DWG: 5471

Notes

\* M = 1.32 mm to 1.62 mm (dimension including protrusion)  
Heatsink hole for HVM

**TO-220 FULLPAK (HIGH VOLTAGE)**



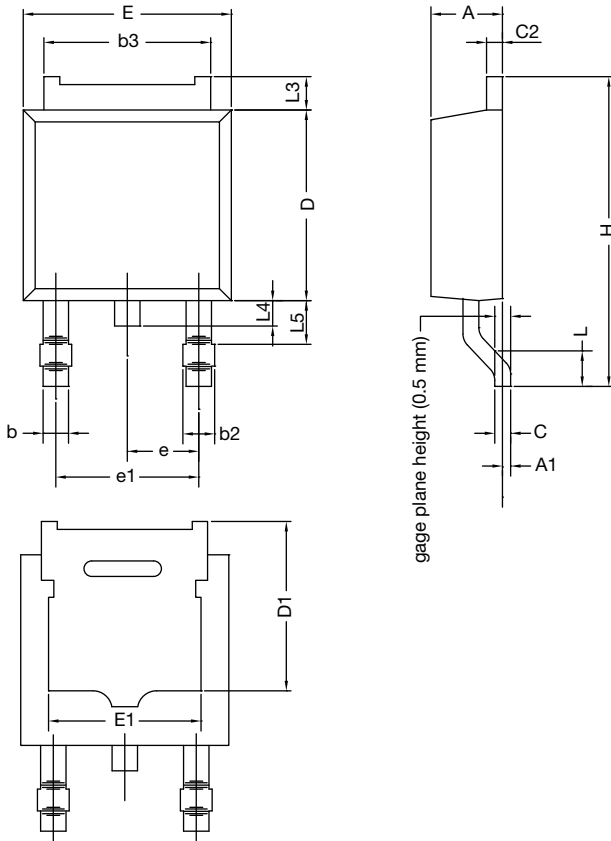
| DIM.   | MILLIMETERS |        | INCHES    |       |
|--|-------------|--------|-----------|-------|
|  | MIN.        | MAX.   | MIN.      | MAX.  |
| A  | 4.570       | 4.830  | 0.180     | 0.190 |
| A1   | 2.570       | 2.830  | 0.101     | 0.111 |
| A2   | 2.510       | 2.850  | 0.099     | 0.112 |
| b  | 0.622       | 0.890  | 0.024     | 0.035 |
| b2   | 1.229       | 1.400  | 0.048     | 0.055 |
| b3   | 1.229       | 1.400  | 0.048     | 0.055 |
| c  | 0.440       | 0.629  | 0.017     | 0.025 |
| D  | 8.650       | 9.800  | 0.341     | 0.386 |
| d1   | 15.88       | 16.120 | 0.622     | 0.635 |
| d3   | 12.300      | 12.920 | 0.484     | 0.509 |
| E  | 10.360      | 10.630 | 0.408     | 0.419 |
| e  | 2.54 BSC    |        | 0.100 BSC |       |
| L  | 13.200      | 13.730 | 0.520     | 0.541 |
| L1   | 3.100       | 3.500  | 0.122     | 0.138 |
| n  | 6.050       | 6.150  | 0.238     | 0.242 |
| Ø P  | 3.050       | 3.450  | 0.120     | 0.136 |
| u  | 2.400       | 2.500  | 0.094     | 0.098 |
| v  | 0.400       | 0.500  | 0.016     | 0.020 |
| ECN: X09-0126-Rev. B, 26-Oct-09<br>DWG: 5972 |             |        |           |       |

**Notes**

1. To be used only for process drawing.
2. These dimensions apply to all TO-220, FULLPAK leadframe versions 3 leads.
3. All critical dimensions should C meet  $C_{pk} > 1.33$ .
4. All dimensions include burrs and plating thickness.
5. No chipping or package damage.



## TO-252AA CASE OUTLINE



| DIM.   | MILLIMETERS |       | INCHES    |       |
|--|-------------|-------|-----------|-------|
|  | MIN.        | MAX.  | MIN.      | MAX.  |
| A  | 2.18        | 2.38  | 0.086     | 0.094 |
| A1   | -           | 0.127 | -         | 0.005 |
| b  | 0.64        | 0.88  | 0.025     | 0.035 |
| b2   | 0.76        | 1.14  | 0.030     | 0.045 |
| b3   | 4.95        | 5.46  | 0.195     | 0.215 |
| C  | 0.46        | 0.61  | 0.018     | 0.024 |
| C2   | 0.46        | 0.89  | 0.018     | 0.035 |
| D  | 5.97        | 6.22  | 0.235     | 0.245 |
| D1   | 5.21        | -     | 0.205     | -     |
| E  | 6.35        | 6.73  | 0.250     | 0.265 |
| E1   | 4.32        | -     | 0.170     | -     |
| H  | 9.40        | 10.41 | 0.370     | 0.410 |
| e  | 2.28 BSC    |       | 0.090 BSC |       |
| e1   | 4.56 BSC    |       | 0.180 BSC |       |
| L  | 1.40        | 1.78  | 0.055     | 0.070 |
| L3   | 0.89        | 1.27  | 0.035     | 0.050 |
| L4   | -           | 1.02  | -         | 0.040 |
| L5   | 1.14        | 1.52  | 0.045     | 0.060 |
| ECN: X12-0247-Rev. M, 24-Dec-12<br>DWG: 5347 |             |       |           |       |

**Note**

- Dimension L3 is for reference only.

**TO-251AA (DPAK)**



Note: Dimension L3 is for reference only.

| Dim   | MILLIMETERS |      | INCHES    |       |
|---|-------------|------|-----------|-------|
|   | Min         | Max  | Min       | Max   |
| <b>A</b>                                    | 2.21        | 2.38 | 0.087     | 0.094 |
| <b>A1</b>                                   | 0.89        | 1.14 | 0.035     | 0.045 |
| <b>b</b>                                    | 0.71        | 0.89 | 0.028     | 0.035 |
| <b>b1</b>                                   | 0.76        | 1.14 | 0.030     | 0.045 |
| <b>b2</b>                                   | 5.23        | 5.43 | 0.206     | 0.214 |
| <b>c</b>                                    | 0.46        | 0.58 | 0.018     | 0.023 |
| <b>c1</b>                                   | 0.46        | 0.58 | 0.018     | 0.023 |
| <b>D</b>                                    | 5.97        | 6.22 | 0.235     | 0.245 |
| <b>E</b>                                    | 6.48        | 6.73 | 0.255     | 0.265 |
| <b>e</b>                                    | 2.28 BSC    |      | 0.090 BSC |       |
| <b>L</b>                                    | 8.89        | 9.53 | 0.350     | 0.375 |
| <b>L1</b>                                   | 1.91        | 2.28 | 0.075     | 0.090 |
| <b>L2</b>                                   | 0.89        | 1.27 | 0.035     | 0.050 |
| <b>L3</b>                                   | 1.15        | 1.52 | 0.045     | 0.060 |
| ECN: S-03946—Rev. E, 09-Jul-01<br>DWG: 5346 |             |      |           |       |

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