

## 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 ( $\Omega$ ) | $V_{GS} = 10$ 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)

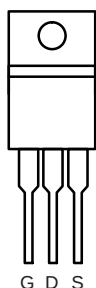


RoHS

### APPLICATIONS

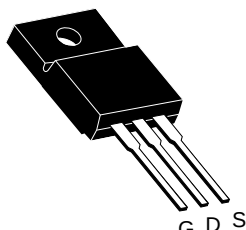
- Server and telecom power supplies
- Switch mode power supplies (SMPS)
- Power factor correction power supplies (PFC)
- Lighting
  - High-intensity discharge (HID)
  - Fluorescent ballast lighting
- Industrial

TO-220AB



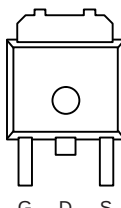
Top View

TO-220 FULLPAK



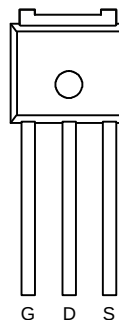
Top View

TO-252



Top View

TO-251



Top View



N-Channel MOSFET

### ABSOLUTE MAXIMUM RATINGS ( $T_C = 25$ °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                    | $T_C = 25\text{ }^{\circ}\text{C}$  | $I_D$          | 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                                       | $T_J = 125\text{ }^{\circ}\text{C}$ |                                     | dV/dt          | 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

- a. Repetitive rating; pulse width limited by maximum junction temperature.  
 b.  $V_{DD} = 50$  V, starting  $T_J = 25$  °C,  $L = 28.2$  mH,  $R_g = 25$   $\Omega$ ,  $I_{AS} = 3.5$  A.  
 c. 1.6 mm from case.  
 d.  $I_{SD} \leq I_D$ ,  $dI/dt = 100$  A/ $\mu$ s, starting  $T_J = 25$  °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                  |
|-----------------------------------------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------|------|-----------|-----------------------|
| Static                                                    |                     |                                                                                                                                                         |                                              |      |      |           |                       |
| 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/ $^{\circ}\text{C}$ |
| 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                          | $R_{DS(on)}$        | $V_{GS} = 10\text{ V}$                                                                                                                                  | $I_D = 4\text{ A}$                           | -    | 0.7  | -         | $\Omega$              |
| Forward Transconductance                                  | $g_{fs}$            | $V_{DS} = 30\text{ V}$ , $I_D = 4\text{ A}$                                                                                                             |                                              | -    | 16   | -         | S                     |
| Dynamic                                                   |                     |                                                                                                                                                         |                                              |      |      |           |                       |
| Input Capacitance                                         | $C_{iss}$           | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 100\text{ V}$ ,<br>$f = 1\text{ MHz}$                                                                              |                                              | -    | 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                                        | $t_{d(on)}$         | $V_{DD} = 520\text{ V}$ , $I_D = 4\text{ A}$ ,<br>$V_{GS} = 10\text{ V}$ , $R_g = 9.1\text{ }\Omega$                                                    |                                              | -    | 25   | -         | ns                    |
| Rise Time                                                 | $t_r$               |                                                                                                                                                         |                                              | -    | 55   | -         |                       |
| Turn-Off Delay Time                                       | $t_{d(off)}$        |                                                                                                                                                         |                                              | -    | 70   | -         |                       |
| Fall Time                                                 | $t_f$               |                                                                                                                                                         |                                              | -    | 40   | -         |                       |
| Gate Input Resistance                                     | $R_g$               | $f = 1\text{ MHz}$ , open drain                                                                                                                         |                                              | -    | 3.5  | -         | $\Omega$              |
| Drain-Source Body Diode Characteristics                   |                     |                                                                                                                                                         |                                              |      |      |           |                       |
| Continuous Source-Drain Diode Current                     | $I_S$               | MOSFET symbol showing the integral reverse p - n junction diode<br> |                                              | -    | -    | 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                                     | $t_{rr}$            | $T_J = 25\text{ }^{\circ}\text{C}$ , $I_F = I_S = 4\text{ A}$ ,<br>$di/dt = 100\text{ A}/\mu\text{s}$ , $V_R = 400\text{ V}$                            |                                              | -    | 190  | -         | ns                    |
| Reverse Recovery Charge                                   | $Q_{rr}$            |                                                                                                                                                         |                                              | -    | 2.3  | -         | $\mu\text{C}$         |
| Reverse Recovery Current                                  | $I_{RRM}$           |                                                                                                                                                         |                                              | -    | 10   | -         | A                     |

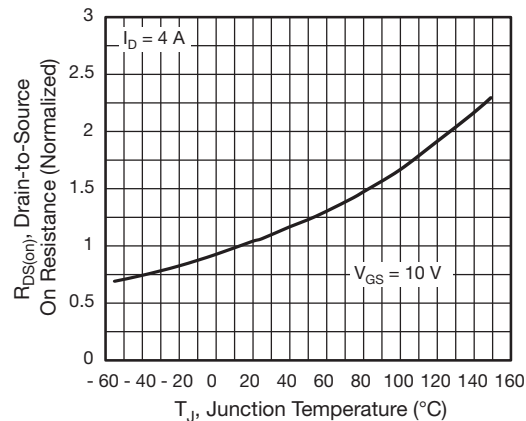
**Notes**

- 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 %  $V_{DSS}$ .

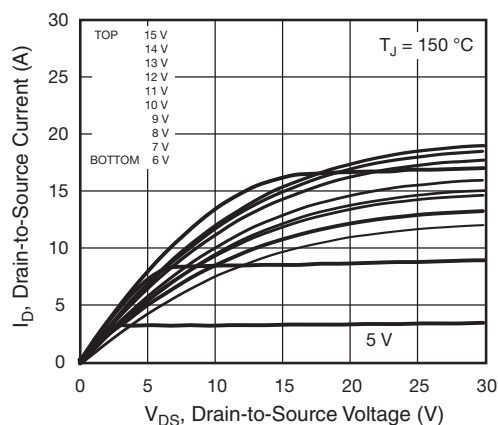
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



**Fig. 1 - Typical Output Characteristics**



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



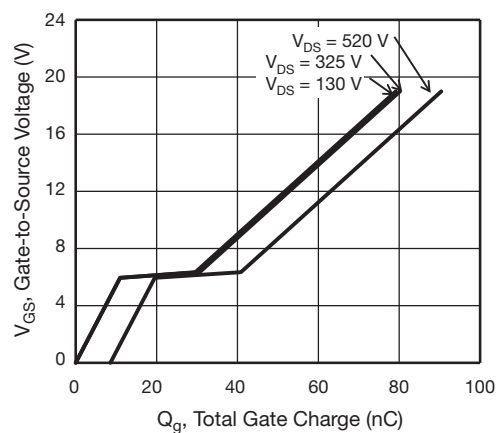
**Fig. 2 - Typical Output Characteristics**



**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

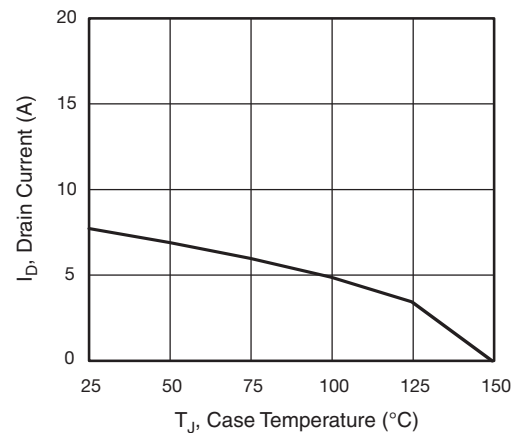


Fig. 9 - Maximum Drain Current vs. Case Temperature

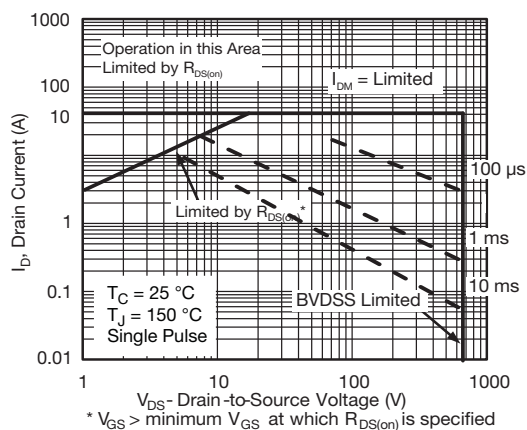


Fig. 8 - Maximum Safe Operating Area

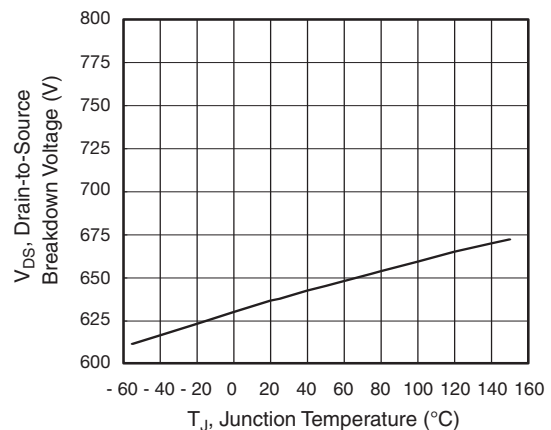


Fig. 10 - Temperature vs. Drain-to-Source Voltage



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

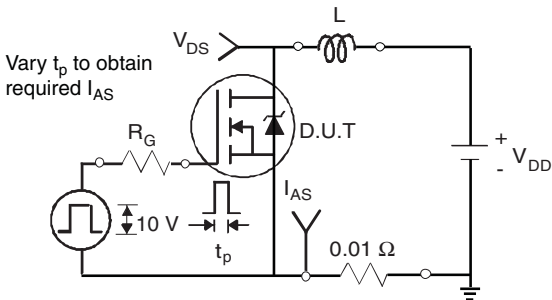


Fig. 14 - Unclamped Inductive Test Circuit

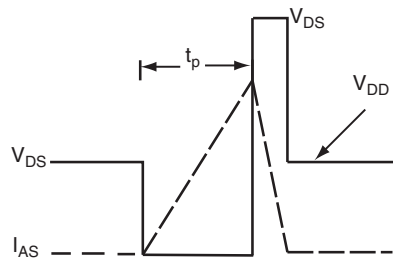


Fig. 15 - Unclamped Inductive Waveforms

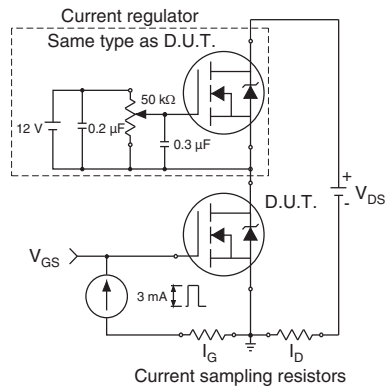


Fig. 17 - Gate Charge Test Circuit

### Peak Diode Recovery $dV/dt$ Test Circuit

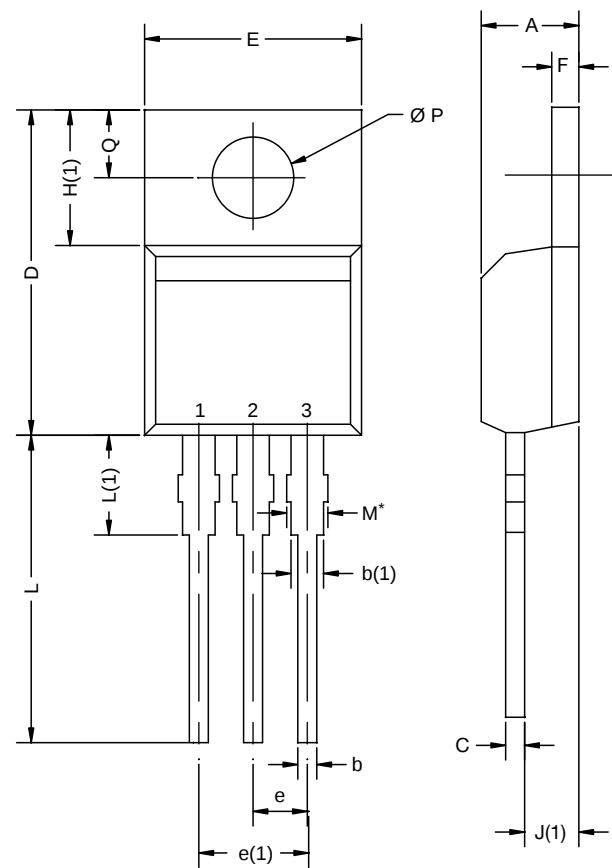


#### Note

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

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

TO-220AB

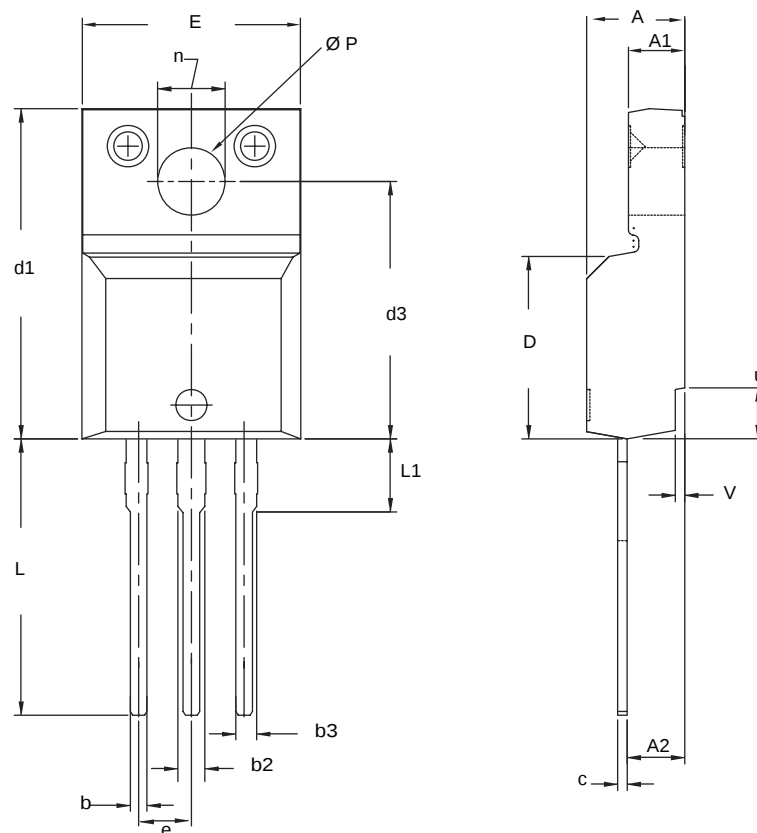


| DIM.            | MILLIMETERS |       | INCHES |       |
|-----------------|-------------|-------|--------|-------|
|                 | MIN.        | MAX.  | MIN.   | MAX.  |
| A               | 4.25        | 4.65  | 0.167  | 0.183 |
| b               | 0.69        | 1.01  | 0.027  | 0.040 |
| b(1)            | 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 |
| $\varnothing P$ | 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)**

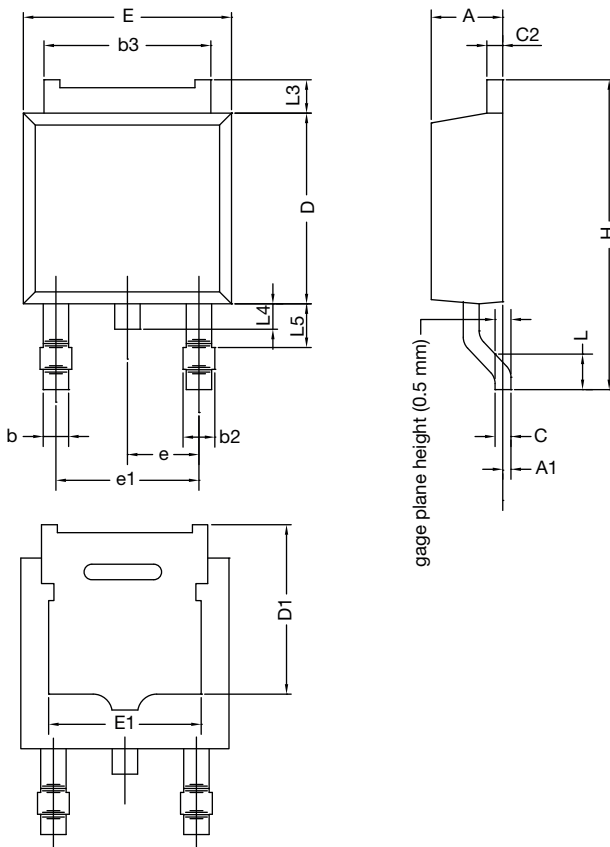
| DIM. | MILLIMETERS |        | INCHES    |       |
|------|-------------|--------|-----------|-------|
|      | MIN.        | MAX.   | MIN.      | MAX.  |
| A    | 4.570       | 4.830  | 0.180     | 0.190 |
| A1   | 2.570       | 2.830  | 0.101     | 0.111 |
| A2   | 2.510       | 2.850  | 0.099     | 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  
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.

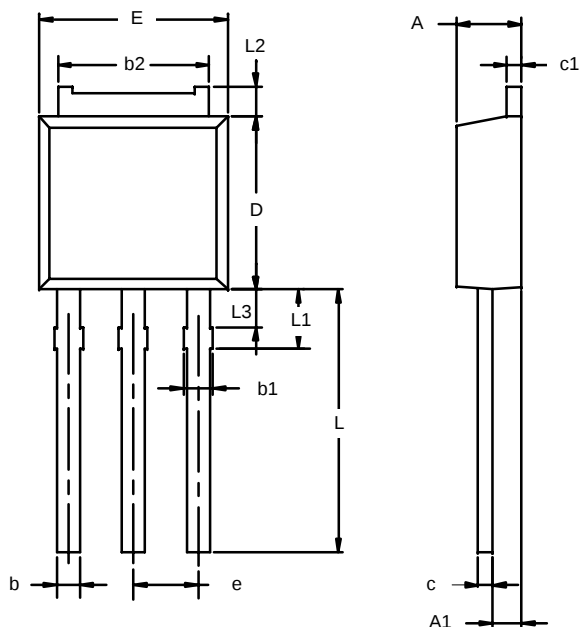
## TO-252AA CASE OUTLINE



| 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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