

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

| PRODUCT SUMMARY           |                 |      |
|---------------------------|-----------------|------|
| $V_{DS}$ (V)              | 650             |      |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10$ V | 0.95 |
| $Q_g$ (Max.) (nC)         | 15              |      |
| $Q_{gs}$ (nC)             | 3               |      |
| $Q_{gd}$ (nC)             | 6               |      |
| Configuration             | Single          |      |

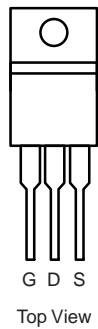
### FEATURES

- Low Gate Charge  $Q_g$  Results in Simple Drive Requirement
- Improved Gate, Avalanche and Dynamic  $dV/dt$  Ruggedness
- Fully Characterized Capacitance and Avalanche Voltage and Current
- Compliant to RoHS directive 2002/95/EC

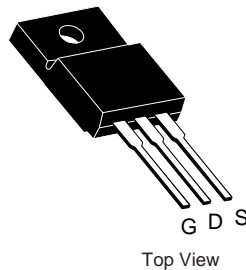


**RoHS\***  
COMPLIANT

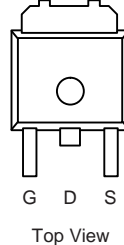
TO-220AB



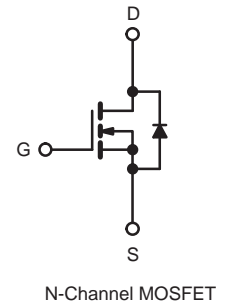
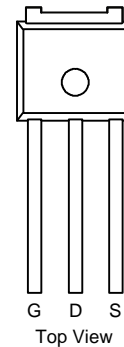
TO-220 FULLPAK



TO-252



TO-251




| ABSOLUTE MAXIMUM RATINGS $T_C = 25^\circ\text{C}$ , unless otherwise noted |                          |                           |                     |
|--|--------------------------|---------------------------|---------------------|
| PARAMETER  | SYMBOL                   | LIMIT                     | UNIT                |
| Drain-Source Voltage   | $V_{DS}$                 | 650                       | V                   |
| Gate-Source Voltage  | $V_{GS}$                 | $\pm 30$                  |                     |
| Continuous Drain Current <sup>e</sup>                                      | $V_{GS}$ at 10 V         | $T_C = 25^\circ\text{C}$  | A                   |
| Continuous Drain Current   |                          | $T_C = 100^\circ\text{C}$ |                     |
| Pulsed Drain Current <sup>a</sup>  | $I_{DM}$                 | 16                        |                     |
| Linear Derating Factor   |                          | 1.67/0.8/0.3              | W/ $^\circ\text{C}$ |
| Single Pulse Avalanche Energy <sup>b</sup>                                 | $E_{AS}$                 | 120                       | mJ                  |
| Repetitive Avalanche Current <sup>a</sup>                                  | $I_{AR}$                 | 34                        | A                   |
| Repetitive Avalanche Energy <sup>a</sup>                                   | $E_{AR}$                 | 17                        | mJ                  |
| Maximum Power Dissipation  | $T_C = 25^\circ\text{C}$ | $P_D$                     | 205/35/30           |
| Peak Diode Recovery $dV/dt^c$  | $dV/dt$                  | 4.5                       | V/ns                |
| Operating Junction and Storage Temperature Range                           | $T_J, T_{stg}$           | - 55 to + 150             | $^\circ\text{C}$    |
| Soldering Recommendations (Peak Temperature) <sup>d</sup>                  | for 10 s                 | 300                       |                     |
| Mounting Torque  | 6-32 or M3 screw         |                           | 10                  |
|  |                          |                           | 1.1                 |

### Notes

- Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
- Starting  $T_J = 25^\circ\text{C}$ ,  $L = 24$  mH,  $R_G = 25 \Omega$ ,  $I_{AS} = 3.2$  A (see fig. 12).
- $I_{SD} \leq 3.2$  A,  $dI/dt \leq 90$  A/ $\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150^\circ\text{C}$ .
- 1.6 mm from case.
- Drain current limited by maximum junction temperature.

| THERMAL RESISTANCE RATINGS       |            |      |             |      |
|----------------------------------|------------|------|-------------|------|
| PARAMETER                        | SYMBOL     | TYP. | MAX.        | UNIT |
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 62          | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 3.6/1.2/0.6 |      |

| 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 $25\text{ }^\circ\text{C}$ , $I_D = 1\text{ mA}^d$   |   | -    | 0.6  | -         | mV/°C         |
| Gate-Source Threshold Voltage  | $V_{GS(th)}$          | $V_{DS} = V_{GS}, I_D = 250\text{ }\mu\text{A}$   |   | 2.0  | -    | 4.0       | V             |
| Gate-Source Leakage  | $I_{GSS}$             | $V_{GS} = \pm 30\text{ V}$  |   | -    | -    | $\pm 100$ | nA            |
| Zero Gate Voltage Drain Current  | $I_{DSS}$             | $V_{DS} = 650\text{ V}, V_{GS} = 0\text{ V}$  |   | -    | -    | 10        | $\mu\text{A}$ |
|  |                       | $V_{DS} = 520\text{ V}, V_{GS} = 0\text{ V}, T_J = 125\text{ }^\circ\text{C}$   |   | -    | -    | 100       |               |
| Drain-Source On-State Resistance   | $R_{DS(on)}$          | $V_{GS} = 10\text{ V}$  | $I_D = 2.5\text{ A}^b$  | -    | 0.95 | -         | $\Omega$      |
| Forward Transconductance   | $g_{fs}$              | $V_{DS} = 50\text{ V}, I_D = 2.5\text{ A}$  |   | 8    | -    | -         | S             |
| <b>Dynamic</b>   |                       |   |   |      |      |           |               |
| Input Capacitance  | $C_{iss}$             | $V_{GS} = 0\text{ V}, V_{DS} = 25\text{ V}, f = 1.0\text{ MHz}$ , see fig. 5  |   | -    | 320  | -         | pF            |
| Output Capacitance   | $C_{oss}$             |   |   | -    | 75   | -         |               |
| Reverse Transfer Capacitance   | $C_{rss}$             |   |   | -    | 4    | -         |               |
| Output Capacitance   | $C_{oss}$             | $V_{GS} = 0\text{ V}$   | $V_{DS} = 1.0\text{ V}, f = 1.0\text{ MHz}$                                   | -    | 500  | -         | pF            |
|  |                       |   | $V_{DS} = 520\text{ V}, f = 1.0\text{ MHz}$                                   | -    | 83   | -         |               |
| Effective Output Capacitance   | $C_{oss\text{ eff.}}$ | $V_{DS} = 0\text{ V to } 520\text{ V}^c$  |   | -    | 14   | -         |               |
| Total Gate Charge  | $Q_g$                 | $V_{GS} = 10\text{ V}$  | $I_D = 2.5\text{ A}, V_{DS} = 400\text{ V}$<br>see fig. 6 and 13 <sup>b</sup> | -    | -    | 15        | nC            |
| Gate-Source Charge   | $Q_{gs}$              |   |   | -    | -    | 3         |               |
| Gate-Drain Charge  | $Q_{gd}$              |   |   | -    | -    | 6         |               |
| Turn-On Delay Time   | $t_{d(on)}$           | $V_{DD} = 325\text{ V}, I_D = 3.2\text{ A}$<br>$R_G = 9.1\text{ }\Omega, R_D = 62\text{ }\Omega$ ,<br>see fig. 10 <sup>b</sup>                          |   | -    | 18   | -         | ns            |
| Rise Time  | $t_r$                 |   |   | -    | 40   | -         |               |
| Turn-Off Delay Time  | $t_{d(off)}$          |   |   | -    | 50   | -         |               |
| Fall Time  | $t_f$                 |   |   | -    | 30   | -         |               |
| <b>Drain-Source Body Diode Characteristics</b>                           |                       |   |   |      |      |           |               |
| Continuous Source-Drain Diode Current                                    | $I_S$                 | MOSFET symbol showing the integral reverse p - n junction diode<br> | -   | -    | 5    | A         |               |
| Pulsed Diode Forward Current <sup>a</sup>                                | $I_{SM}$              |   | -   | -    | 16   |           |               |
| Body Diode Voltage   | $V_{SD}$              | $T_J = 25\text{ }^\circ\text{C}, I_S = 3.2\text{ A}, V_{GS} = 0\text{ V}^b$   |   | -    | -    | 1.5       | V             |
| Body Diode Reverse Recovery Time   | $t_{rr}$              | $T_J = 25\text{ }^\circ\text{C}, I_F = 3.2\text{ A}, di/dt = 100\text{ A}/\mu\text{s}^b$  |   | -    | 180  | -         | ns            |
| Body Diode Reverse Recovery Charge                                       | $Q_{rr}$              |   |   | -    | 2.1  | 3.2       | $\mu\text{C}$ |
| Forward Turn-On Time   | $t_{on}$              | Intrinsic turn-on time is negligible (turn-on is dominated by $L_S$ and $L_D$ )   |   |      |      |           |               |

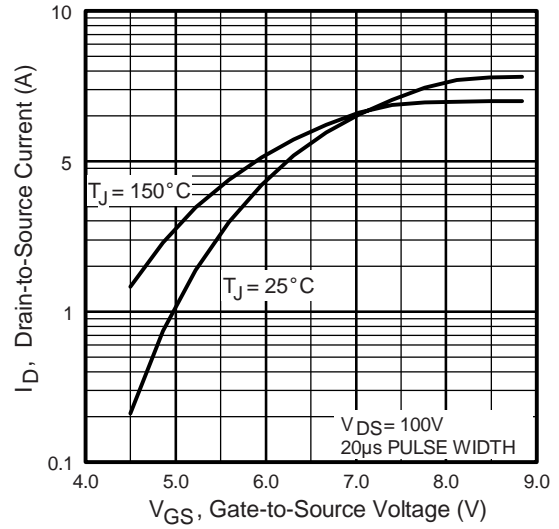
**Notes**

- a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
- b. Pulse width  $\leq 300\text{ }\mu\text{s}$ ; duty cycle  $\leq 2\%$ .
- c.  $C_{oss\text{ eff.}}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DS}$ .
- d.  $t = 60\text{ s}, f = 60\text{ Hz}$ .

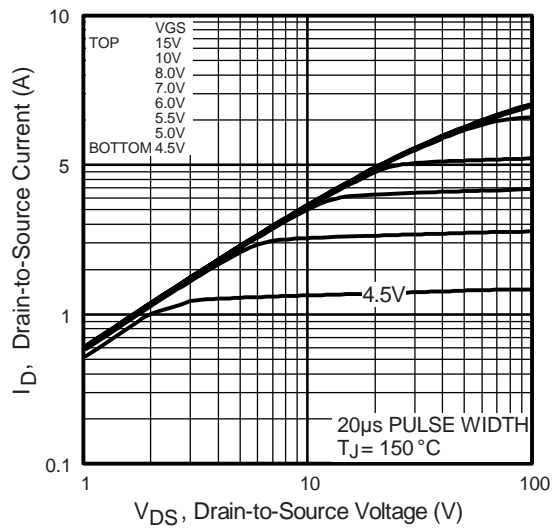
**TYPICAL CHARACTERISTICS** 25 °C, unless otherwise noted



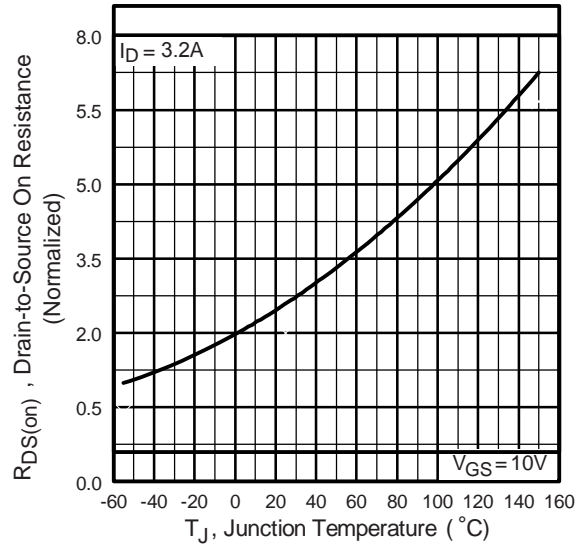
**Fig. 1 - Typical Output Characteristics**



**Fig. 3 - Typical Transfer Characteristics**



**Fig. 2 - Typical Output Characteristics**



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

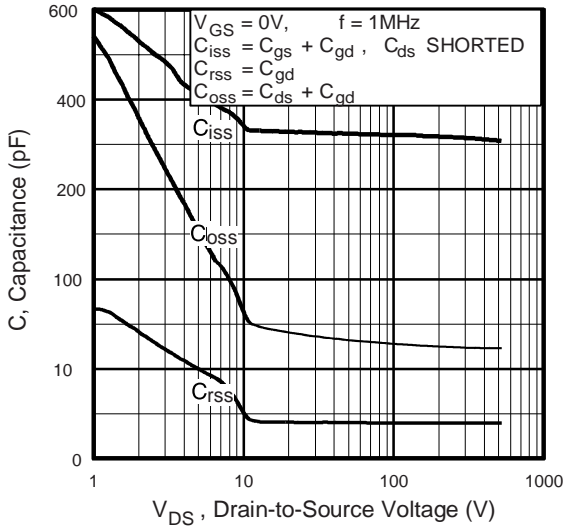


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage



Fig. 7 - Typical Source-Drain Diode Forward Voltage



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

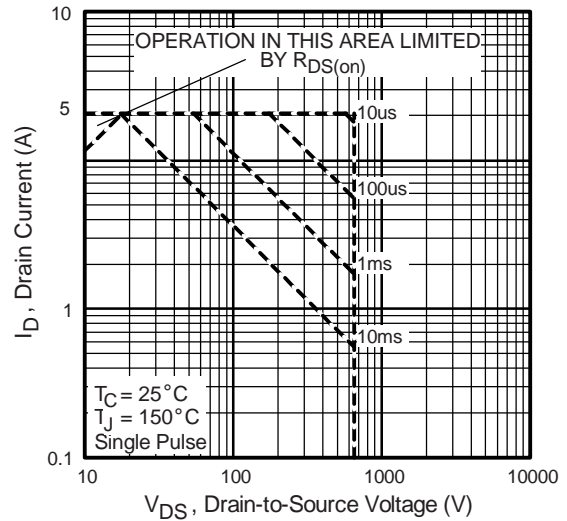


Fig. 8 - Maximum Safe Operating Area

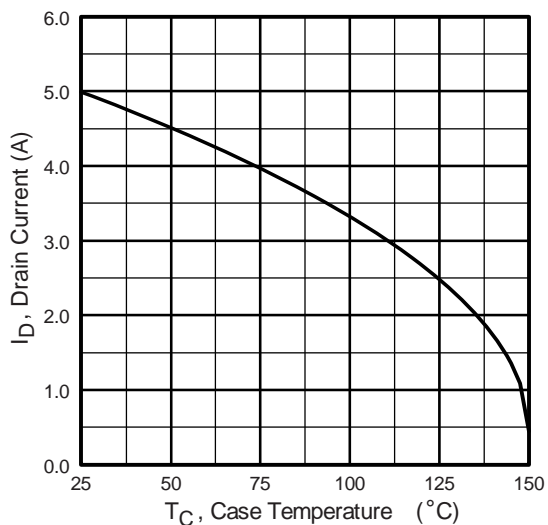


Fig. 9 - Maximum Drain Current vs. Case Temperature

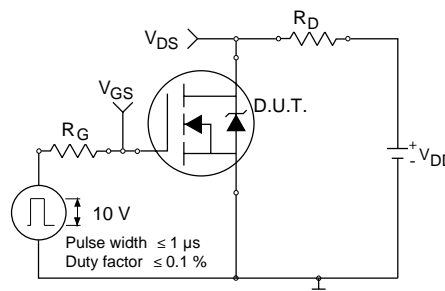


Fig. 10a - Switching Time Test Circuit

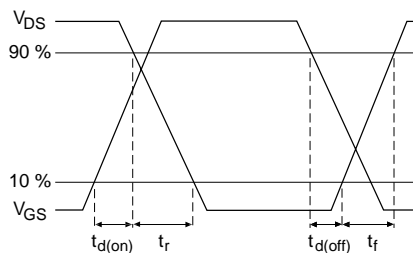


Fig. 10b - Switching Time Waveforms

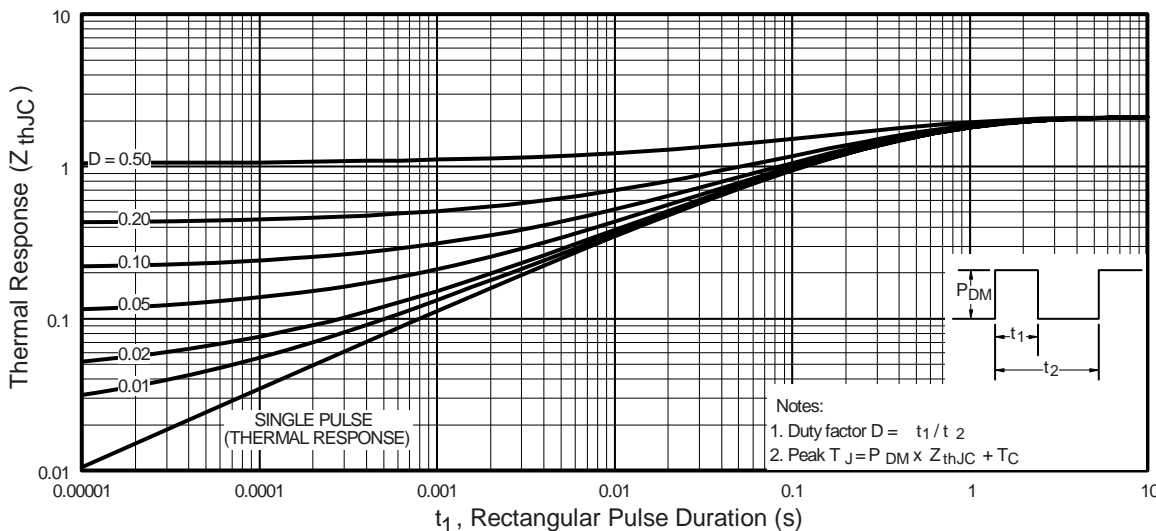


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

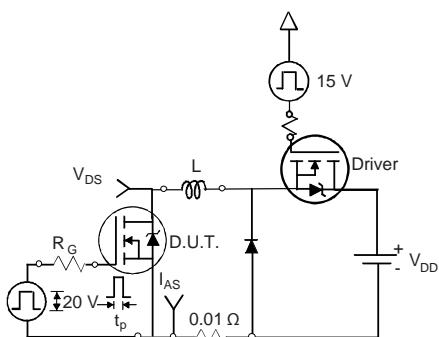


Fig. 12a - Unclamped Inductive Test Circuit

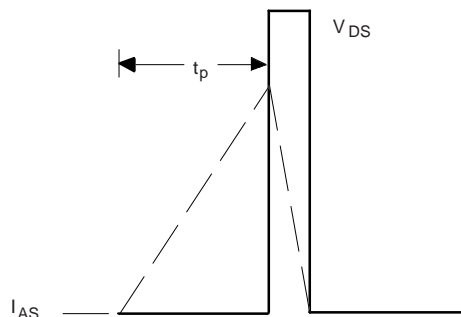


Fig. 12b - Unclamped Inductive Waveforms

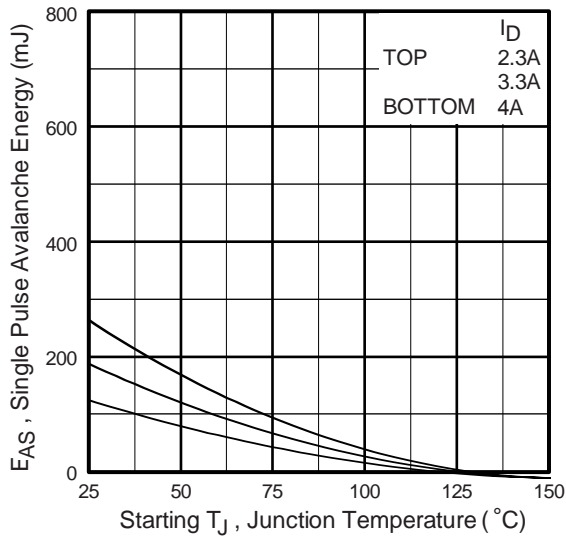


Fig. 12c - Maximum Avalanche Energy vs. Drain Current



Fig. 12d - Typical Drain-to Source Voltage vs. Avalanche Current

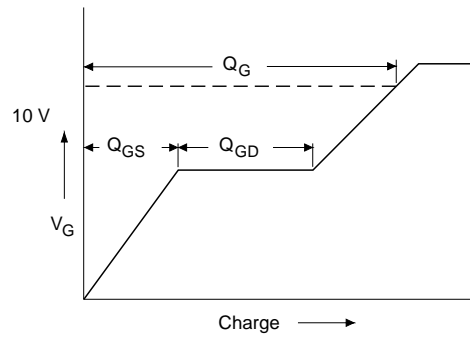


Fig. 13a - Basic Gate Charge Waveform



Fig. 13b - Gate Charge Test Circuit

### Peak Diode Recovery dV/dt Test Circuit



\*  $V_{GS} = 5 V$  for logic level devices

Fig. 14 - 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 |

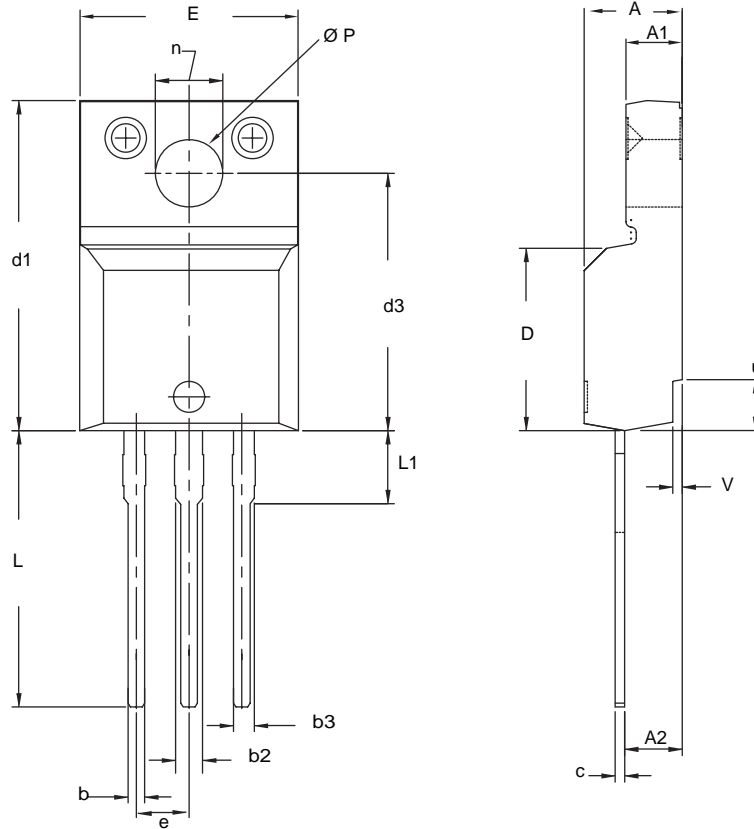
ECN: X12-0208-Rev. N, 08-Oct-12  
DWG: 5471

**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  
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

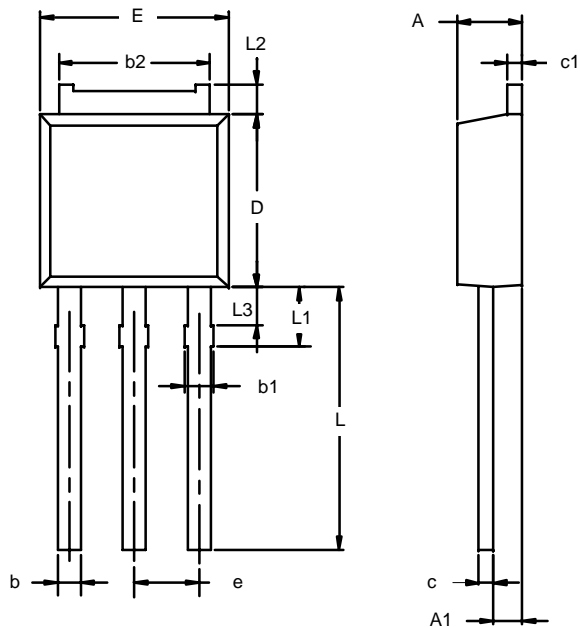


| DIM.   | MILLIMETERS |       | INCHES    |       |
|--|-------------|-------|-----------|-------|
|  | MIN.        | MAX.  | MIN.      | MAX.  |
| A  | 2.18        | 2.38  | 0.086     | 0.094 |
| A1   | -           | 0.127 | -         | 0.005 |
| b  | 0.64        | 0.88  | 0.025     | 0.035 |
| b2   | 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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