

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

### PRODUCT SUMMARY

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

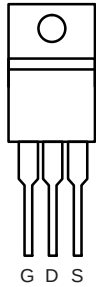
### FEATURES

- 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



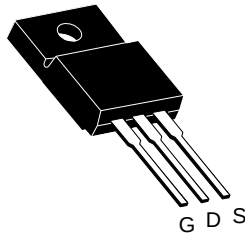
**RoHS\***  
COMPLIANT

TO-220AB



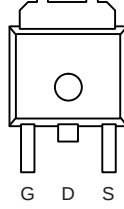
Top View

TO-220 FULLPAK



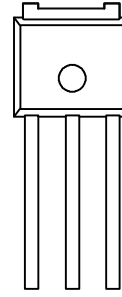
Top View

TO-252

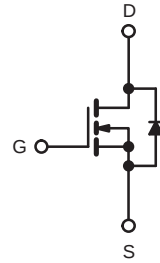


Top View

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 <sub>DS</sub>                   | 650           | V    |
| Gate-Source Voltage                                       |                         |                         | V <sub>GS</sub>                   | ± 30          |      |
| Continuous Drain Current <sup>e</sup>                     | V <sub>GS</sub> at 10 V | T <sub>C</sub> = 25 °C  | I <sub>D</sub>                    | 5             | A    |
| Continuous Drain Current                                  |                         | T <sub>C</sub> = 100 °C |                                   | 4             |      |
| Pulsed Drain Current <sup>a</sup>                         |                         |                         | I <sub>DM</sub>                   | 16            |      |
| Linear Derating Factor                                    |                         |                         |                                   | 1.67/0.8/0.3  | W/°C |
| Single Pulse Avalanche Energy <sup>b</sup>                |                         |                         | E <sub>AS</sub>                   | 120           | mJ   |
| Repetitive Avalanche Current <sup>a</sup>                 |                         |                         | I <sub>AR</sub>                   | 34            | A    |
| Repetitive Avalanche Energy <sup>a</sup>                  |                         |                         | E <sub>AR</sub>                   | 17            | mJ   |
| Maximum Power Dissipation                                 | T <sub>C</sub> = 25 °C  |                         | P <sub>D</sub>                    | 205/35/30     | W    |
| Peak Diode Recovery dV/dt <sup>c</sup>                    |                         |                         | dV/dt                             | 4.5           | V/ns |
| Operating Junction and Storage Temperature Range          |                         |                         | T <sub>J</sub> , T <sub>stg</sub> | - 55 to + 150 | °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  $T_J = 25\text{ }^\circ\text{C}$ ,  $L = 24\text{ mH}$ ,  $R_G = 25\text{ }\Omega$ ,  $I_{AS} = 3.2\text{ A}$  (see fig. 12).
- $I_{SD} \leq 3.2\text{ A}$ ,  $dI/dt \leq 90\text{ A}/\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150\text{ }^\circ\text{C}$ .
- 1.6 mm from case.
- Drain current limited by maximum junction temperature.

**THERMAL RESISTANCE RATINGS**

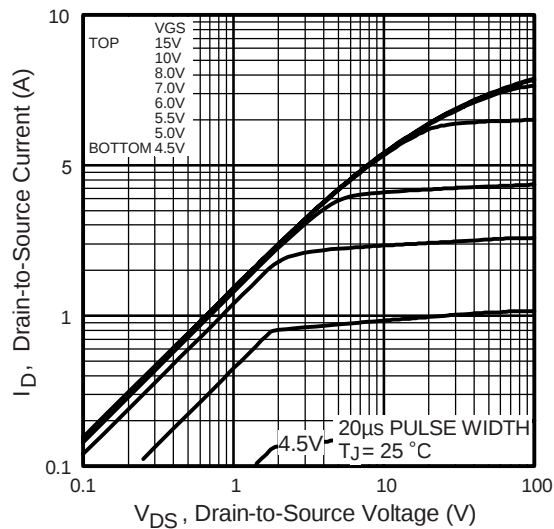
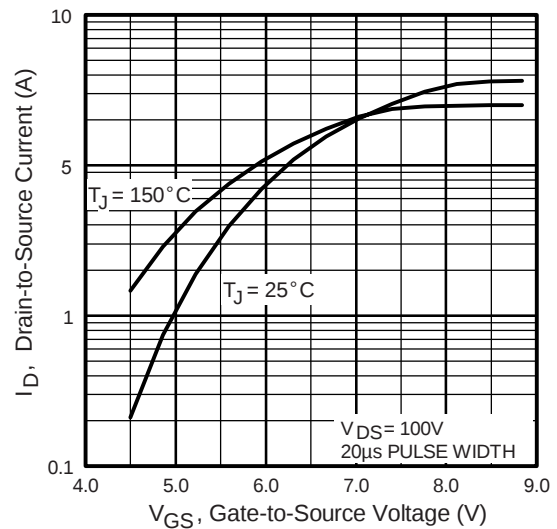
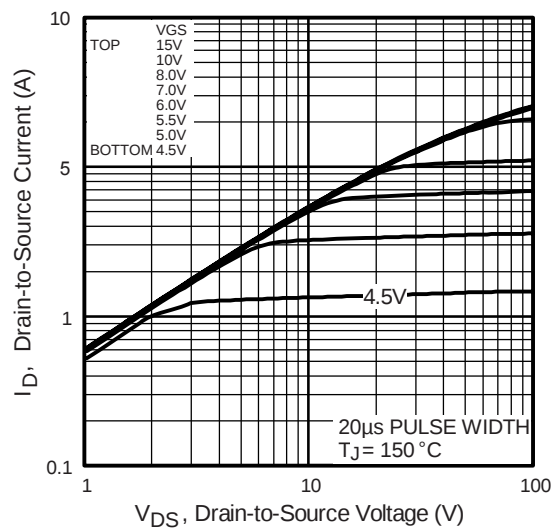
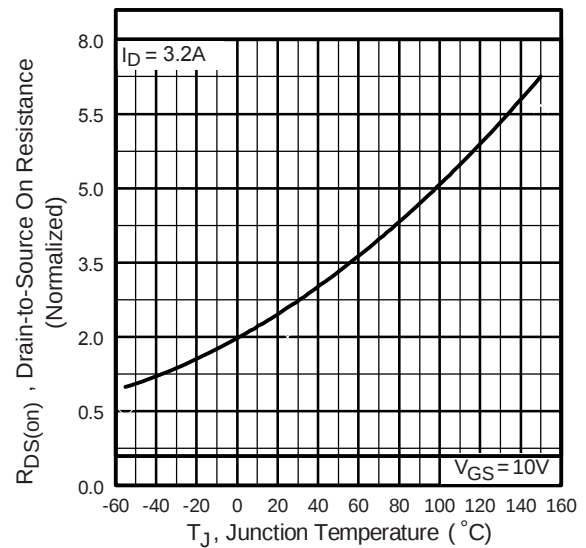
| PARAMETER                        | SYMBOL     | TYP. | MAX.        | UNIT |
|----------------------------------|------------|------|-------------|------|
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 62          | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 3.6/1.2/0.6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

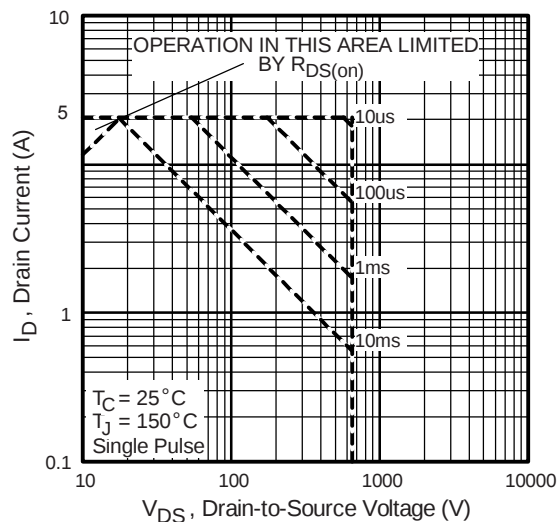
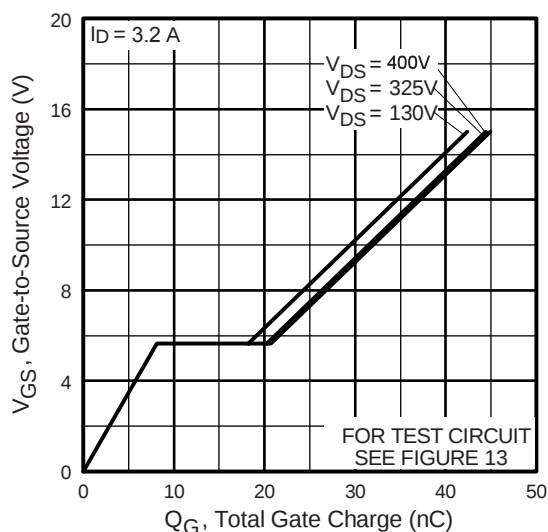
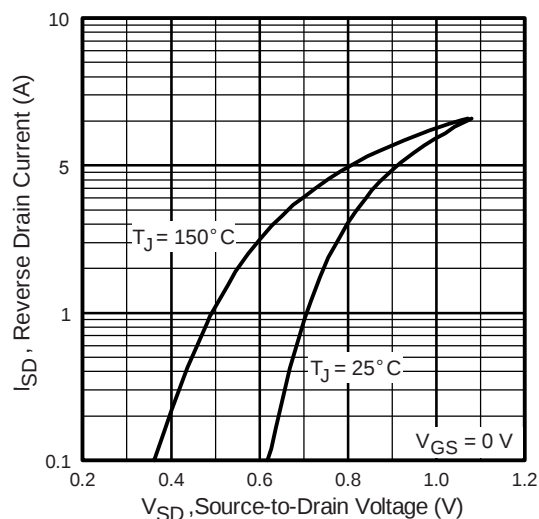
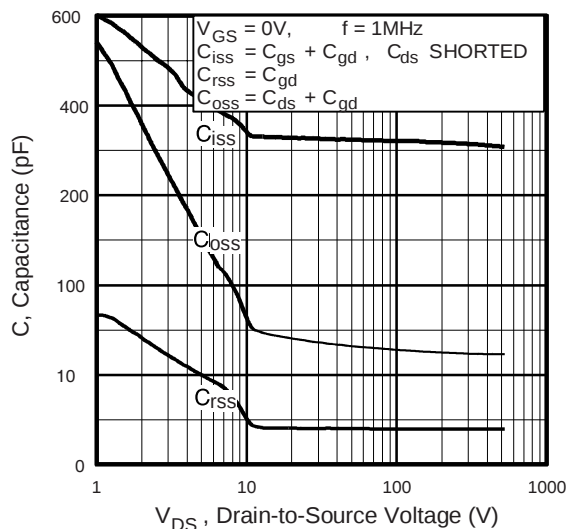
**SPECIFICATIONS**  $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted

| PARAMETER                                 | SYMBOL                           | TEST CONDITIONS                                                                                                                                         |                                                                                   | MIN. | TYP. | MAX.  | UNIT  |
|-------------------------------------------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------|------|-------|-------|
| Static                                    |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Drain-Source Breakdown Voltage            | V <sub>DS</sub>                  | V <sub>GS</sub> = 0 V, I <sub>D</sub> = 250 μA                                                                                                          |                                                                                   | 650  | -    | -     | V     |
| V <sub>DS</sub> Temperature Coefficient   | ΔV <sub>DS</sub> /T <sub>J</sub> | Reference to 25 °C, I <sub>D</sub> = 1 mA <sup>d</sup>                                                                                                  |                                                                                   | -    | 0.6  | -     | mV/°C |
| Gate-Source Threshold Voltage             | V <sub>GS(th)</sub>              | V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 250 μA                                                                                             |                                                                                   | 2.0  | -    | 4.0   | V     |
| Gate-Source Leakage                       | I <sub>GSS</sub>                 | V <sub>GS</sub> = ± 30 V                                                                                                                                |                                                                                   | -    | -    | ± 100 | nA    |
| Zero Gate Voltage Drain Current           | I <sub>DSS</sub>                 | V <sub>DS</sub> = 650 V, V <sub>GS</sub> = 0 V                                                                                                          |                                                                                   | -    | -    | 10    | μA    |
|                                           |                                  | V <sub>DS</sub> = 520 V, V <sub>GS</sub> = 0 V, T <sub>J</sub> = 125 °C                                                                                 |                                                                                   | -    | -    | 100   |       |
| Drain-Source On-State Resistance          | R <sub>DS(on)</sub>              | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 2.5 A <sup>b</sup>                                               | -    | 0.95 | -     | Ω     |
| Forward Transconductance                  | g <sub>fs</sub>                  | V <sub>DS</sub> = 50 V, I <sub>D</sub> = 2.5 A                                                                                                          |                                                                                   | 8    | -    | -     | S     |
| Dynamic                                   |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Input Capacitance                         | C <sub>iss</sub>                 | V <sub>GS</sub> = 0 V,<br>V <sub>DS</sub> = 25 V,<br>f = 1.0 MHz, see fig. 5                                                                            |                                                                                   | -    | 320  | -     | pF    |
| Output Capacitance                        | C <sub>oss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 75   | -     |       |
| Reverse Transfer Capacitance              | C <sub>rss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 4    | -     |       |
| Output Capacitance                        | C <sub>oss</sub>                 | V <sub>GS</sub> = 0 V                                                                                                                                   | V <sub>DS</sub> = 1.0 V, f = 1.0 MHz                                              | -    | 500  | -     |       |
|                                           |                                  |                                                                                                                                                         | V <sub>DS</sub> = 520 V, f = 1.0 MHz                                              | -    | 83   | -     |       |
| Effective Output Capacitance              | C <sub>oss eff.</sub>            |                                                                                                                                                         | V <sub>DS</sub> = 0 V to 520 V <sup>c</sup>                                       | -    | 14   | -     |       |
| Total Gate Charge                         | Q <sub>g</sub>                   | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 2.5 A, V <sub>DS</sub> = 400 V<br>see fig. 6 and 13 <sup>b</sup> | -    | -    | 15    | nC    |
| Gate-Source Charge                        | Q <sub>gs</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 3     |       |
| Gate-Drain Charge                         | Q <sub>gd</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 6     |       |
| Turn-On Delay Time                        | t <sub>d(on)</sub>               | V <sub>DD</sub> = 325 V, I <sub>D</sub> = 3.2 A<br>R <sub>G</sub> = 9.1 Ω, R <sub>D</sub> = 62 Ω,<br>see fig. 10 <sup>b</sup>                           |                                                                                   | -    | 18   | -     | ns    |
| Rise Time                                 | t <sub>r</sub>                   |                                                                                                                                                         |                                                                                   | -    | 40   | -     |       |
| Turn-Off Delay Time                       | t <sub>d(off)</sub>              |                                                                                                                                                         |                                                                                   | -    | 50   | -     |       |
| Fall Time                                 | t <sub>f</sub>                   |                                                                                                                                                         |                                                                                   | -    | 30   | -     |       |
| Drain-Source Body Diode Characteristics   |                                  |                                                                                                                                                         |                                                                                   |      |      |       |       |
| Continuous Source-Drain Diode Current     | I <sub>S</sub>                   | MOSFET symbol showing the integral reverse p - n junction diode<br> | -                                                                                 | -    | 5    | A     |       |
| Pulsed Diode Forward Current <sup>a</sup> | I <sub>SM</sub>                  |                                                                                                                                                         | -                                                                                 | -    | 16   |       |       |
| Body Diode Voltage                        | V <sub>SD</sub>                  | T <sub>J</sub> = 25 °C, I <sub>S</sub> = 3.2 A, V <sub>GS</sub> = 0 V <sup>b</sup>                                                                      |                                                                                   | -    | -    | 1.5   | V     |
| Body Diode Reverse Recovery Time          | t <sub>rr</sub>                  | T <sub>J</sub> = 25 °C, I <sub>F</sub> = 3.2 A, dI/dt = 100 A/μs <sup>b</sup>                                                                           |                                                                                   | -    | 180  | -     | ns    |
| Body Diode Reverse Recovery Charge        | Q <sub>rr</sub>                  |                                                                                                                                                         |                                                                                   | -    | 2.1  | 3.2   | μC    |
| Forward Turn-On Time                      | t <sub>on</sub>                  | Intrinsic turn-on time is negligible (turn-on is dominated by L <sub>S</sub> and L <sub>D</sub> )                                                       |                                                                                   |      |      |       |       |

**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**



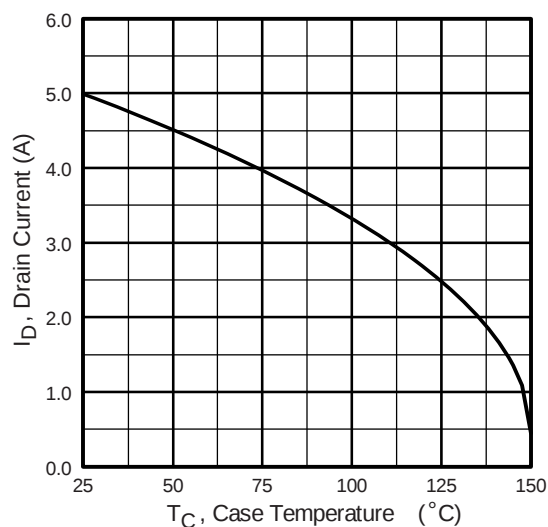


Fig. 9 - Maximum Drain Current vs. Case Temperature

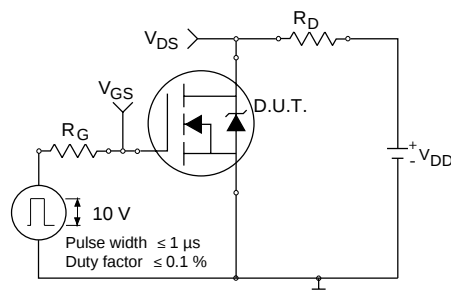


Fig. 10a - Switching Time Test Circuit

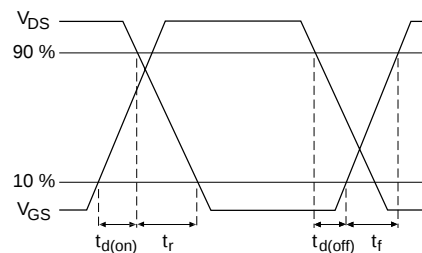


Fig. 10b - Switching Time Waveforms

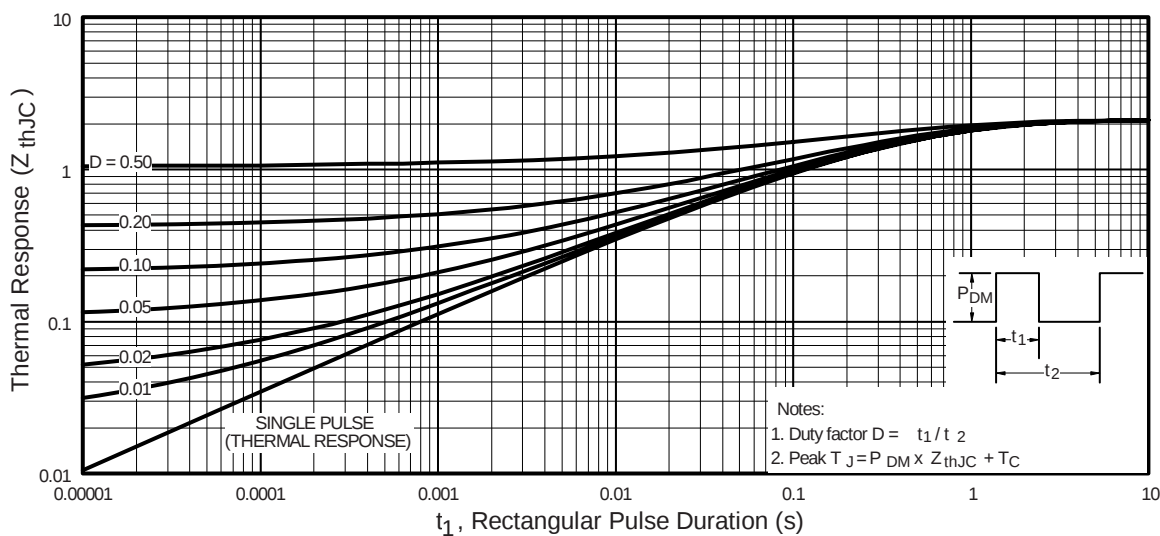


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

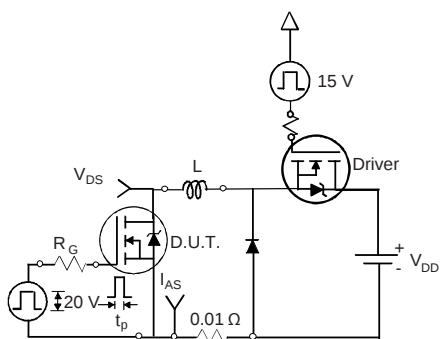


Fig. 12a - Unclamped Inductive Test Circuit

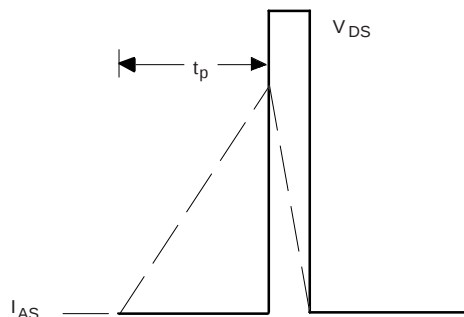


Fig. 12b - Unclamped Inductive Waveforms

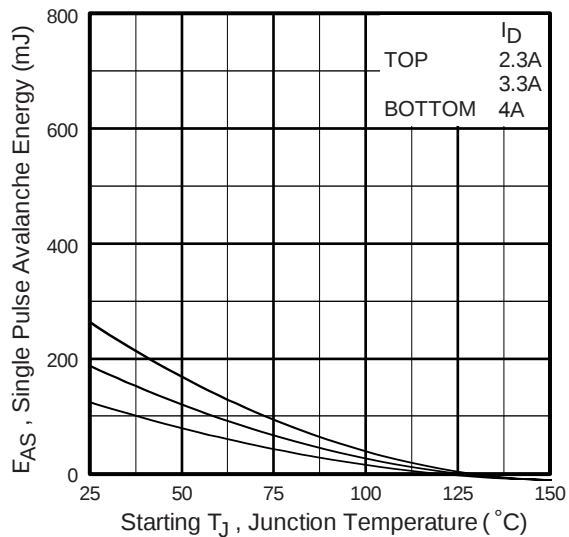


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

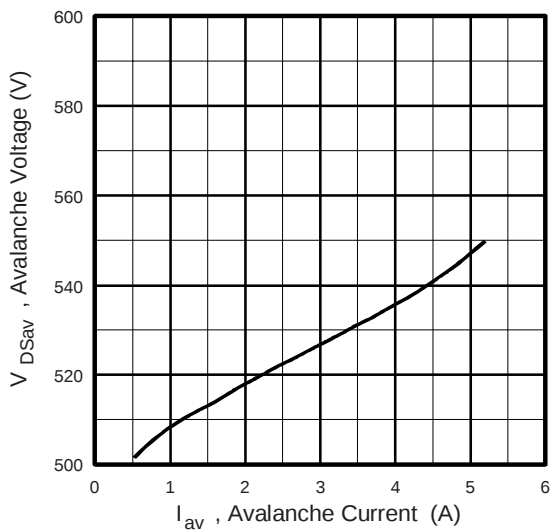


Fig. 12d - Typical Drain-to Source Voltage vs. Avalanche Current

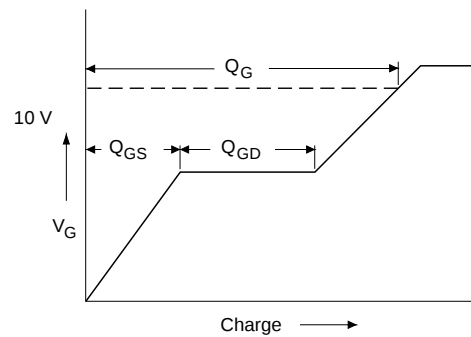


Fig. 13a - Basic Gate Charge Waveform

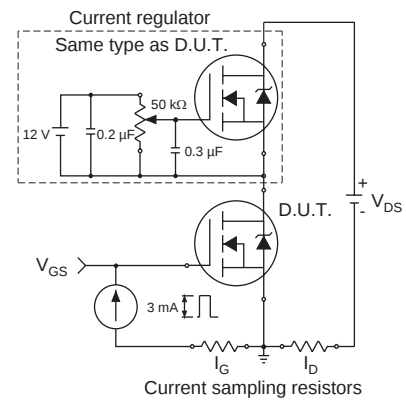
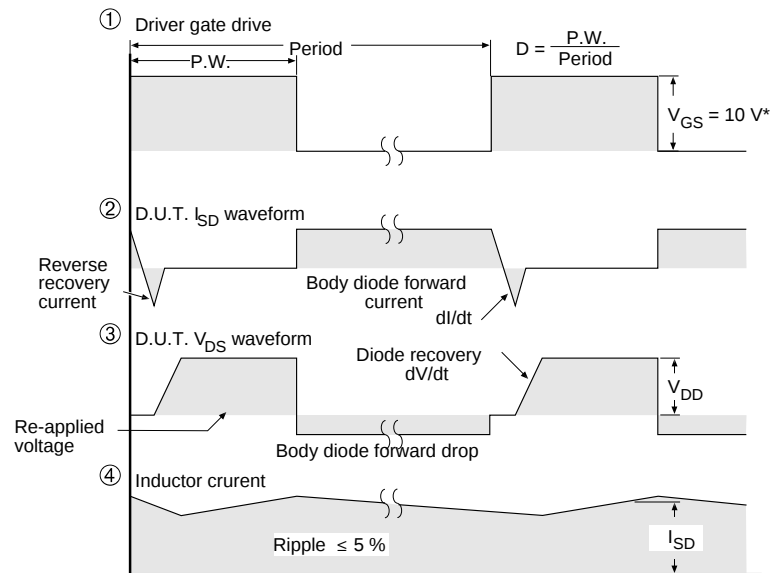
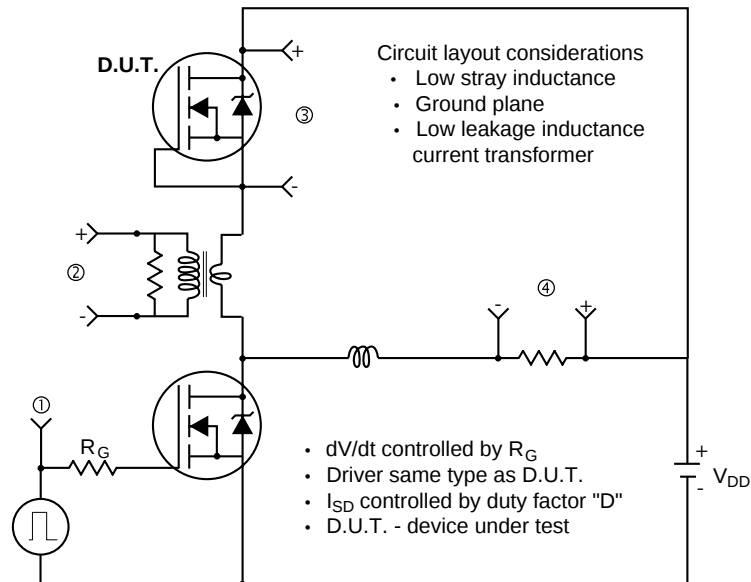


Fig. 13b - Gate Charge Test Circuit

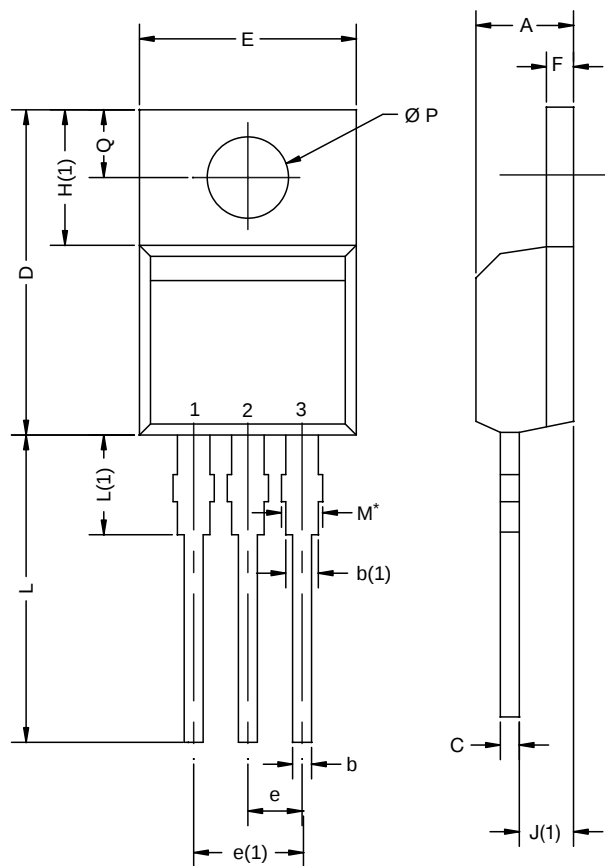
## Peak Diode Recovery dV/dt Test Circuit



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

**Fig. 14 - For N-Channel**

## TO-220AB

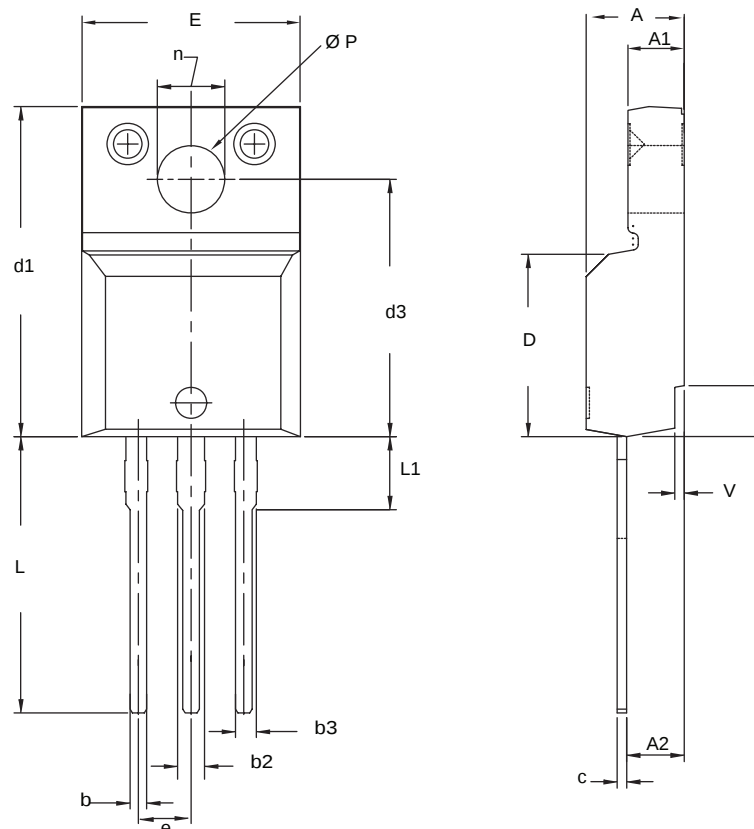


| DIM. | MILLIMETERS |       | INCHES |       |
|------|-------------|-------|--------|-------|
|      | MIN.        | MAX.  | MIN.   | MAX.  |
| A    | 4.25        | 4.65  | 0.167  | 0.183 |
| b    | 0.69        | 1.01  | 0.027  | 0.040 |
| b(1) | 1.20        | 1.73  | 0.047  | 0.068 |
| c    | 0.36        | 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)**

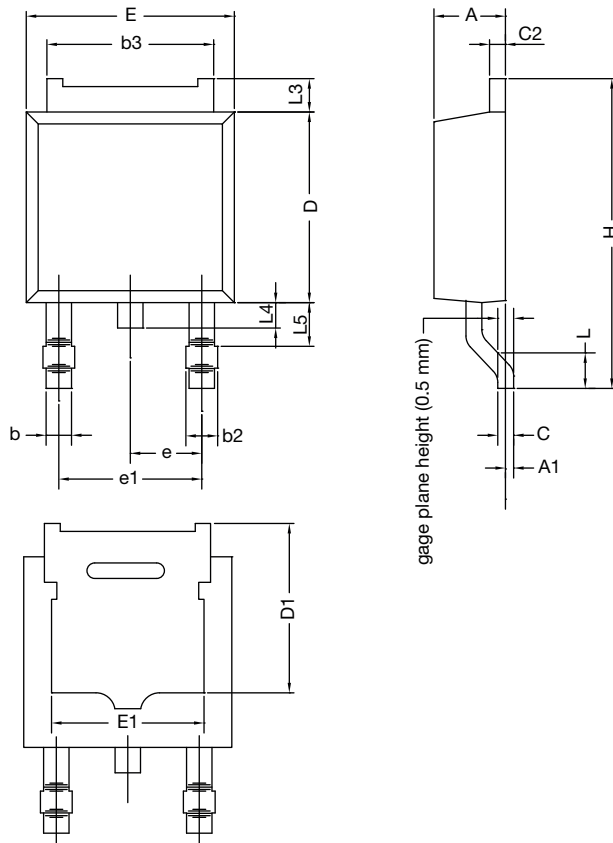
| DIM. | MILLIMETERS |        | INCHES    |       |
|------|-------------|--------|-----------|-------|
|      | MIN.        | MAX.   | MIN.      | MAX.  |
| A    | 4.570       | 4.830  | 0.180     | 0.190 |
| A1   | 2.570       | 2.830  | 0.101     | 0.111 |
| A2   | 2.510       | 2.850  | 0.099   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

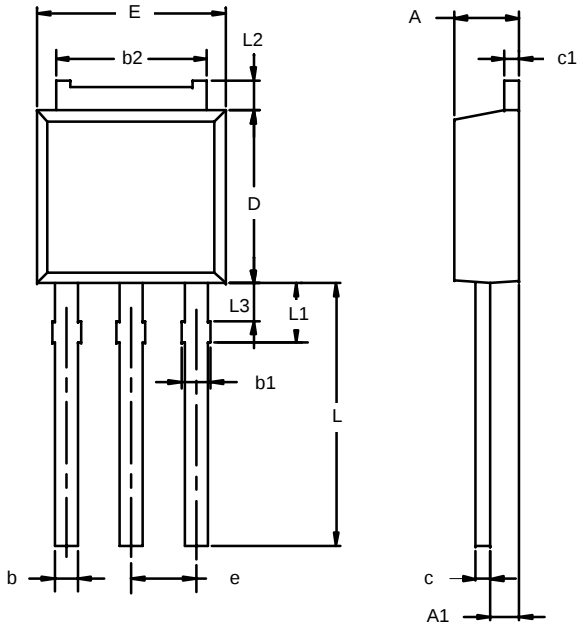


| DIM.                            | MILLIMETERS |       | INCHES    |       |
|---------------------------------|-------------|-------|-----------|-------|
|                                 | MIN.        | MAX.  | MIN.      | MAX.  |
| A                               | 2.18        | 2.38  | 0.086     | 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 |             |       |           |       |
| 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   |
| A                              | 2.21        | 2.38 | 0.087     | 0.094 |
| A1                             | 0.89        | 1.14 | 0.035     | 0.045 |
| b                              | 0.71        | 0.89 | 0.028     | 0.035 |
| b1                             | 0.76        | 1.14 | 0.030     | 0.045 |
| b2                             | 5.23        | 5.43 | 0.206     | 0.214 |
| c                              | 0.46        | 0.58 | 0.018     | 0.023 |
| c1                             | 0.46        | 0.58 | 0.018     | 0.023 |
| D                              | 5.97        | 6.22 | 0.235     | 0.245 |
| E                              | 6.48        | 6.73 | 0.255     | 0.265 |
| e                              | 2.28 BSC    |      | 0.090 BSC |       |
| L                              | 8.89        | 9.53 | 0.350     | 0.375 |
| L1                             | 1.91        | 2.28 | 0.075     | 0.090 |
| L2                             | 0.89        | 1.27 | 0.035     | 0.050 |
| L3                             | 1.15        | 1.52 | 0.045     | 0.060 |
| ECN: S-03946—Rev. E, 09-Jul-01 |             |      |           |       |
| DWG: 5346                      |             |      |           |       |

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