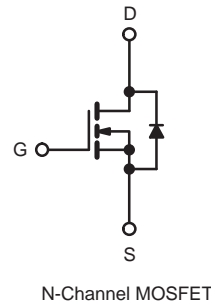
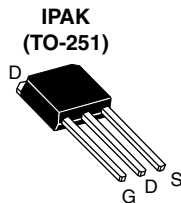


## N-Channel 650V (D-S) Power MOSFET

| PRODUCT SUMMARY           |                            |
|---------------------------|----------------------------|
| $V_{DS}$ (V)              | 650                        |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10\text{ V}$   5 |
| $Q_g$ (Max.) (nC)         | 11                         |
| $Q_{gs}$ (nC)             | 2.3                        |
| $Q_{gd}$ (nC)             | 5.2                        |
| 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




| 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 <sup>e</sup>  | $V_{GS}$ at 10 V | $T_C = 25\text{ }^\circ\text{C}$  | A                   |                  |
| Continuous Drain Current   |                  | $T_C = 100\text{ }^\circ\text{C}$ |                     |                  |
| Pulsed Drain Current <sup>a</sup>  | $I_{DM}$         | 8                                 |                     |                  |
| Linear Derating Factor   |                  | 0.48                              | W/ $^\circ\text{C}$ |                  |
| Single Pulse Avalanche Energy <sup>b</sup>   | $E_{AS}$         | 165                               | mJ                  |                  |
| Repetitive Avalanche Current <sup>a</sup>  | $I_{AR}$         | 2                                 | A                   |                  |
| Repetitive Avalanche Energy <sup>a</sup>   | $E_{AR}$         | 6                                 | mJ                  |                  |
| Maximum Power Dissipation  |                  | $T_C = 25\text{ }^\circ\text{C}$  | 45                  | W                |
| Peak Diode Recovery $dV/dt$ <sup>c</sup>   | $dV/dt$          |                                   | 2.8                 | 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                  | lbf · in         |
|  |                  |                                   | 1.1                 | N · m            |

### 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.

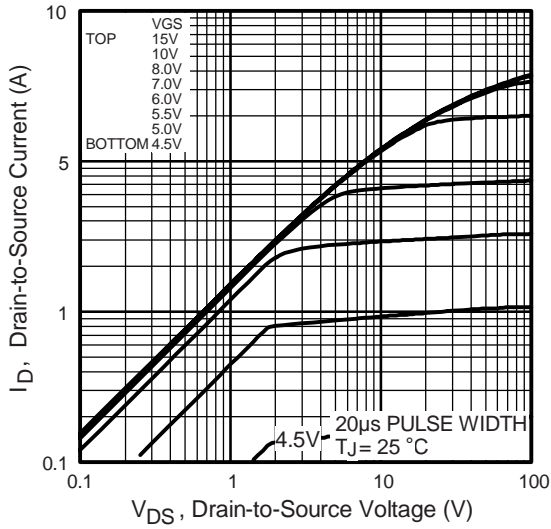
| THERMAL RESISTANCE RATINGS       |            |      |      |      |
|----------------------------------|------------|------|------|------|
| PARAMETER                        | SYMBOL     | TYP. | MAX. | UNIT |
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 65   | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 2.1  |      |

| 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 $25\text{ }^\circ\text{C}$ , $I_D = 1\text{ mA}^d$   |   | -    | 670  | -         | 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  | $I_{DSS}$             | $V_{DS} = 650\text{ V}, V_{GS} = 0\text{ V}$  |   | -    | -    | 25        | $\mu\text{A}$ |
|  |                       | $V_{DS} = 520\text{ V}, V_{GS} = 0\text{ V}, T_J = 125\text{ }^\circ\text{C}$   |   | -    | -    | 250       |               |
| Drain-Source On-State Resistance   | $R_{DS(on)}$          | $V_{GS} = 10\text{ V}$  | $I_D = 1\text{ A}^b$  | -    | 4.0  | 5.0       | $\Omega$      |
| Forward Transconductance   | $g_{fs}$              | $V_{DS} = 50\text{ V}, I_D = 1\text{ A}$  |   | 3.9  | -    | -         | 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  |   | -    | 417  | -         | pF            |
| Output Capacitance   | $C_{oss}$             |   |   | -    | 45   | -         |               |
| Reverse Transfer Capacitance   | $C_{rss}$             |   |   | -    | 5    | -         |               |
| Output Capacitance   | $C_{oss}$             | $V_{GS} = 0\text{ V}$   | $V_{DS} = 1.0\text{ V}, f = 1.0\text{ MHz}$                                   | -    | 912  | -         | pF            |
|  |                       |   | $V_{DS} = 520\text{ V}, f = 1.0\text{ MHz}$                                   | -    | 26   | -         |               |
| Effective Output Capacitance   | $C_{oss\text{ eff.}}$ | $V_{DS} = 0\text{ V to } 520\text{ V}^c$  |   | -    | 42   | -         |               |
| Total Gate Charge  | $Q_g$                 | $V_{GS} = 10\text{ V}$  | $I_D = 1.2\text{ A}, V_{DS} = 400\text{ V}$<br>see fig. 6 and 13 <sup>b</sup> | -    | -    | 11        | nC            |
| Gate-Source Charge   | $Q_{gs}$              |   |   | -    | -    | 2.3       |               |
| Gate-Drain Charge  | $Q_{gd}$              |   |   | -    | -    | 5.2       |               |
| Turn-On Delay Time   | $t_{d(on)}$           | $V_{DD} = 325\text{ V}, I_D = 1.2\text{ A}$<br>$R_G = 9.1\text{ }\Omega, R_D = 62\text{ }\Omega$ ,<br>see fig. 10 <sup>b</sup>                          |   | -    | 14   | -         | ns            |
| Rise Time  | $t_r$                 |   |   | -    | 20   | -         |               |
| Turn-Off Delay Time  | $t_{d(off)}$          |   |   | -    | 34   | -         |               |
| Fall Time  | $t_f$                 |   |   | -    | 18   | -         |               |
| <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> | -   | -    | 2    | A         |               |
| Pulsed Diode Forward Current <sup>a</sup>                                | $I_{SM}$              |   | -   | -    | 8    |           |               |
| 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  | 230       | 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 $L_D$ )   |   |      |      |           |               |

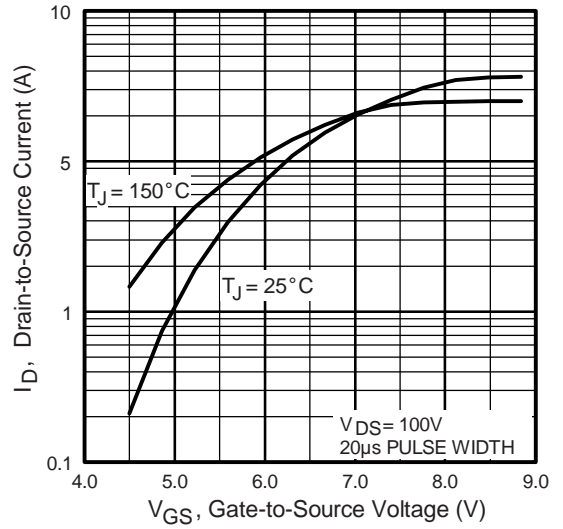
**Notes**

- 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.  $t = 60\text{ s}, f = 60\text{ Hz}$ .

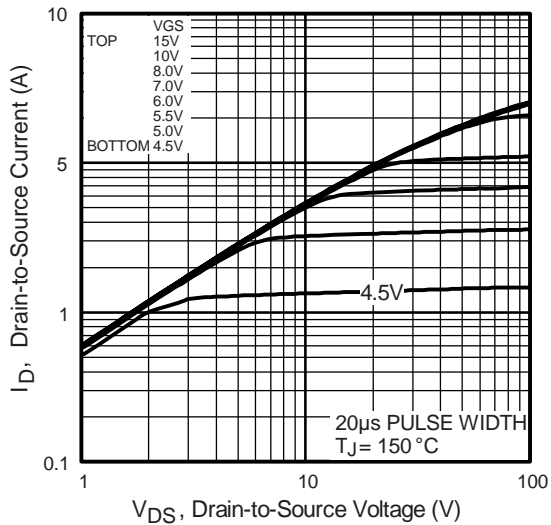
**TYPICAL CHARACTERISTICS** 25 °C, unless otherwise noted



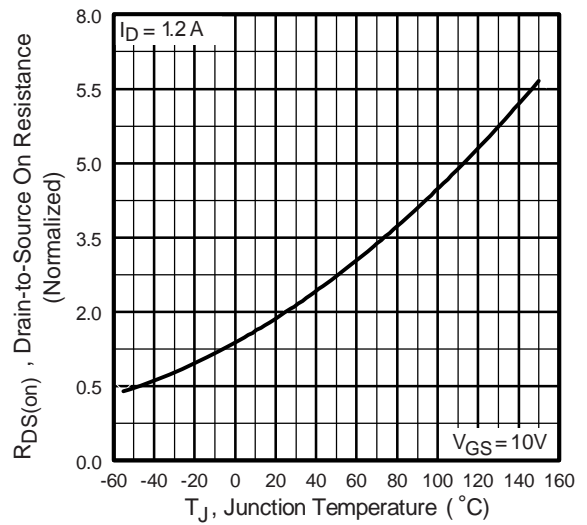
**Fig. 1 - Typical Output Characteristics**



**Fig. 3 - Typical Transfer Characteristics**



**Fig. 2 - Typical Output Characteristics**



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

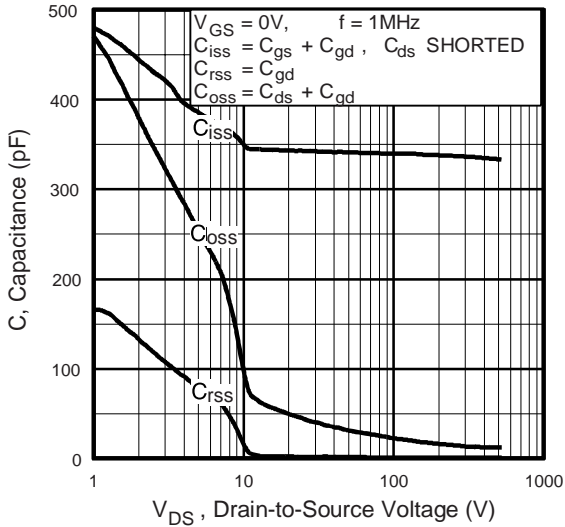


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage



Fig. 7 - Typical Source-Drain Diode Forward Voltage

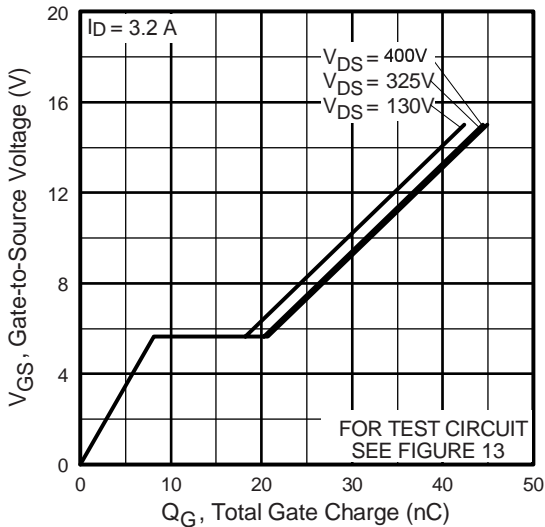


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

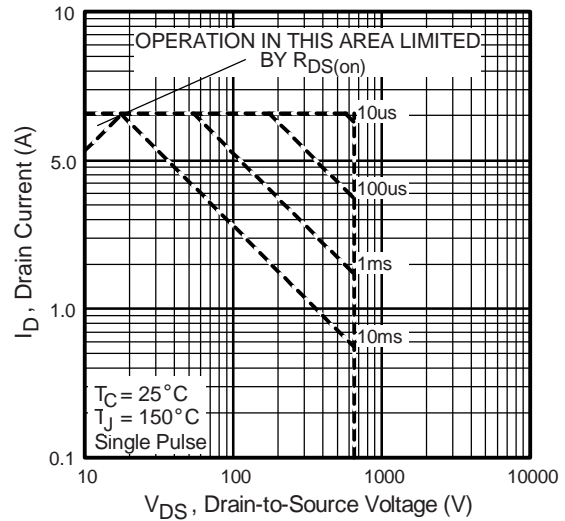


Fig. 8 - Maximum Safe Operating Area



Fig. 9 - Maximum Drain Current vs. Case Temperature



Fig. 10a - Switching Time Test Circuit



Fig. 10b - Switching Time Waveforms

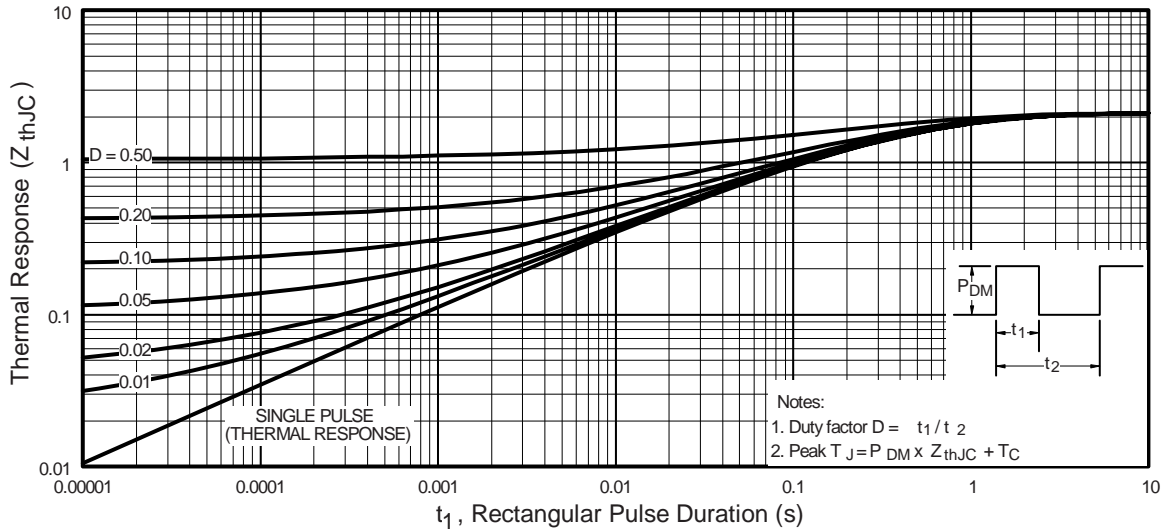


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

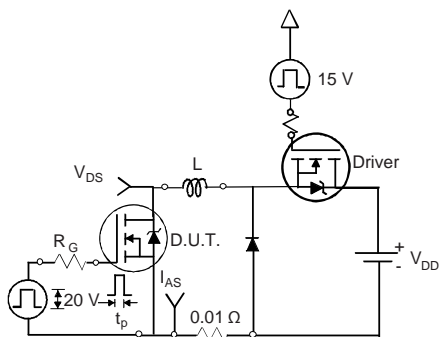


Fig. 12a - Unclamped Inductive Test Circuit



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

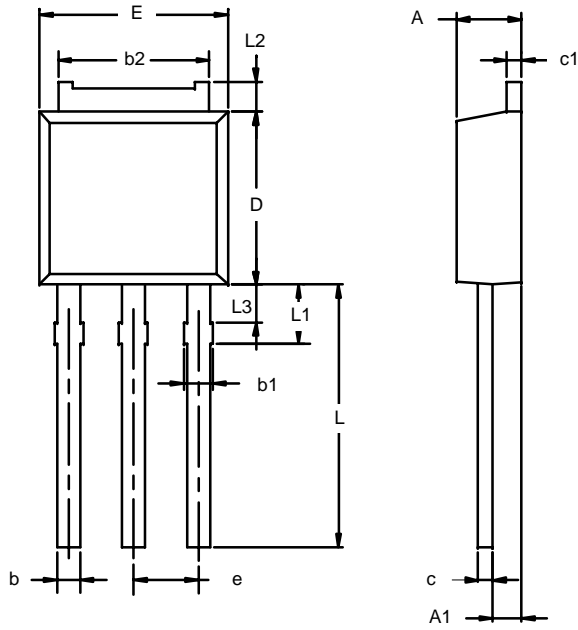
Peak Diode Recovery dV/dt Test Circuit



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

Fig. 14 - For N-Channel

**TO-251AA**



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>  | 3.89        | 9.53 | 0.153     | 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 |



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