

## 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


 Available  
**RoHS**  
 COMPLIANT


### 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>                    | 2.0           | A     |
| Continuous Drain Current                                  |                         | T <sub>C</sub> = 100 °C |                                   | 1.28          |       |
| Pulsed Drain Current <sup>a</sup>                         |                         |                         | I <sub>DM</sub>                   | 8             |       |
| Linear Derating Factor                                    |                         |                         |                                   | 0.48          | W/°C  |
| Single Pulse Avalanche Energy <sup>b</sup>                |                         |                         | E <sub>AS</sub>                   | 165           | mJ    |
| Repetitive Avalanche Current <sup>a</sup>                 |                         |                         | I <sub>AR</sub>                   | 2             | A     |
| Repetitive Avalanche Energy <sup>a</sup>                  |                         |                         | E <sub>AR</sub>                   | 6             | mJ    |
| Maximum Power Dissipation                                 | T <sub>C</sub> = 25 °C  |                         | P <sub>D</sub>                    | 45            | W     |
| Peak Diode Recovery dV/dt <sup>c</sup>                    |                         |                         | dV/dt                             | 2.8           | 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           | 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                 |
|-------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------|------|-----------|----------------------|
| 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 $25\text{ }^\circ\text{C}$ , $I_D = 1\text{ mA}^d$                                                                                         |                                                                                 | -    | 670  | -         | mV/ $^\circ\text{C}$ |
| 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          | $R_{DS(on)}$          | $V_{GS} = 10\text{ V}$                                                                                                                                  | $I_D = 1\text{ A}$ <sup>b</sup>                                                 | -    | 4.0  | 5.0       | $\Omega$             |
| Forward Transconductance                  | $g_{fs}$              | $V_{DS} = 50\text{ V}$ , $I_D = 1\text{ A}$                                                                                                             |                                                                                 | 3.9  | -    | -         | S                    |
| Dynamic                                   |                       |                                                                                                                                                         |                                                                                 |      |      |           |                      |
| Input Capacitance                         | $C_{iss}$             | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 25\text{ V}$ ,<br>$f = 1.0\text{ MHz}$ , 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  | -         |                      |
|                                           |                       |                                                                                                                                                         | $V_{DS} = 520\text{ V}$ , $f = 1.0\text{ MHz}$                                  | -    | 26   |           |                      |
| Effective Output Capacitance              | $C_{oss\text{ eff.}}$ | $V_{DS} = 0\text{ V to } 520\text{ V}^c$                                                                                                                |                                                                                 | -    | 42   | -         |                      |
| Total Gate Charge                         | $Q_g$                 | $V_{GS} = 10\text{ V}$                                                                                                                                  | $I_D = 12\text{ A}$ , $V_{DS} = 400\text{ V}$<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   | -         |                      |
| Drain-Source Body Diode Characteristics   |                       |                                                                                                                                                         |                                                                                 |      |      |           |                      |
| 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

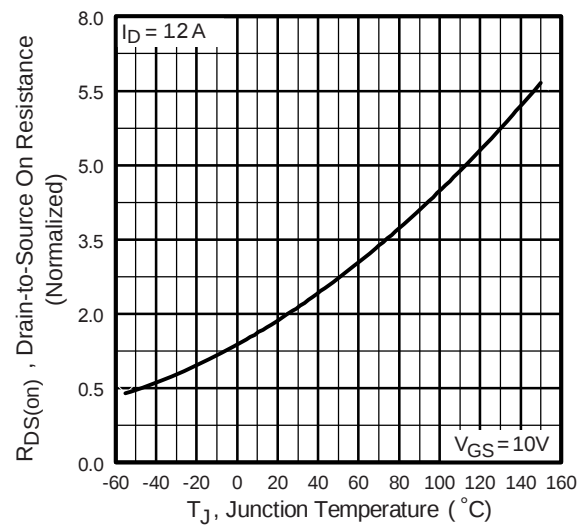
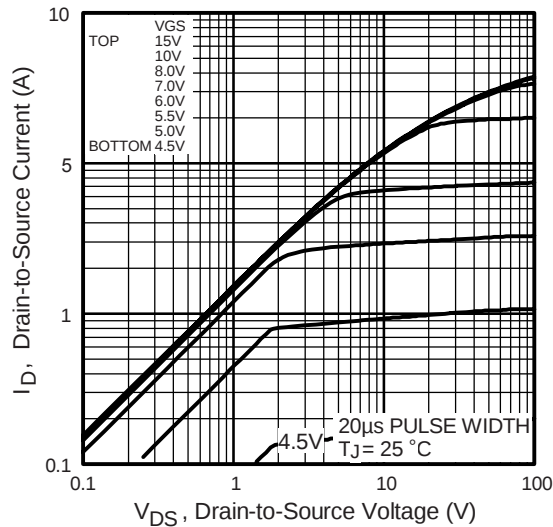




Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage



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

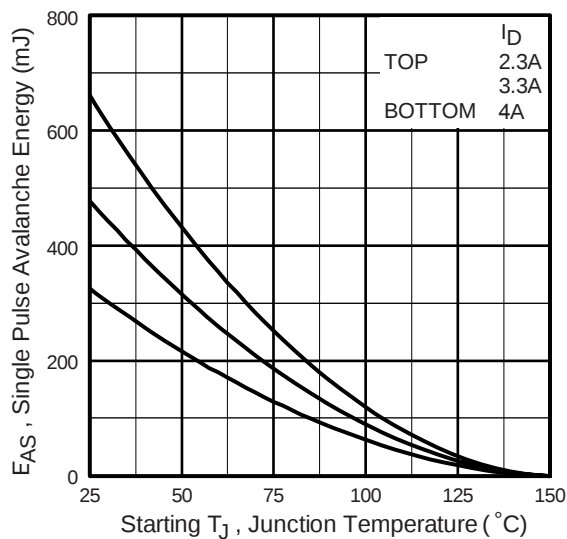


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

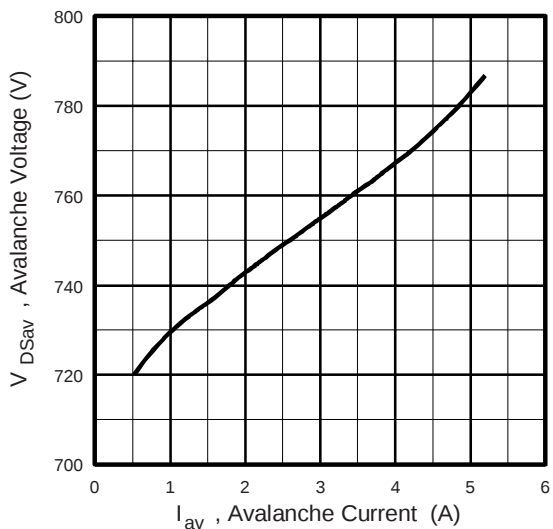


Fig. 12d - Typical Drain-to Source Voltage vs. Avalanche Current

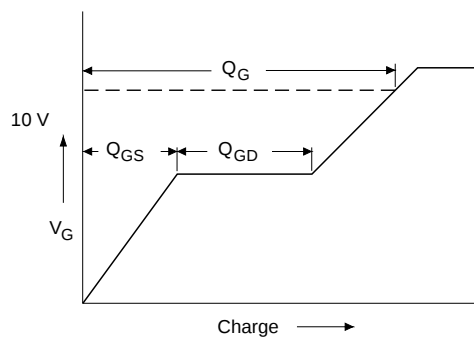


Fig. 13a - Basic Gate Charge Waveform

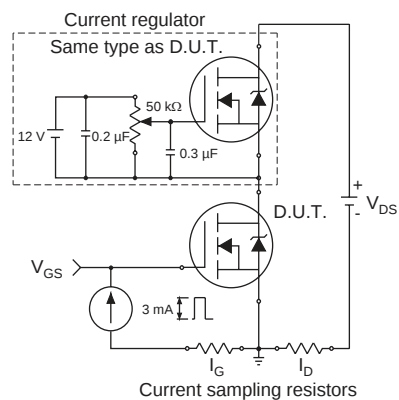


Fig. 13b - Gate Charge Test Circuit

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



\*  $V_{GS} = 5\text{ V}$  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   |
| 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   | 3.89        | 9.53 | 0.153     | 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 |

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