

## TSM6N60CPROG-VB Datasheet

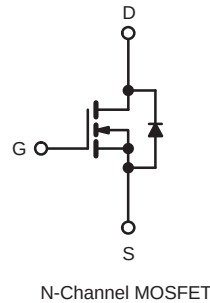
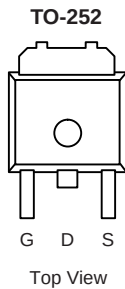
## N-Channel 650V (D-S) Super Junction Power MOSFET

## 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
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            | 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**

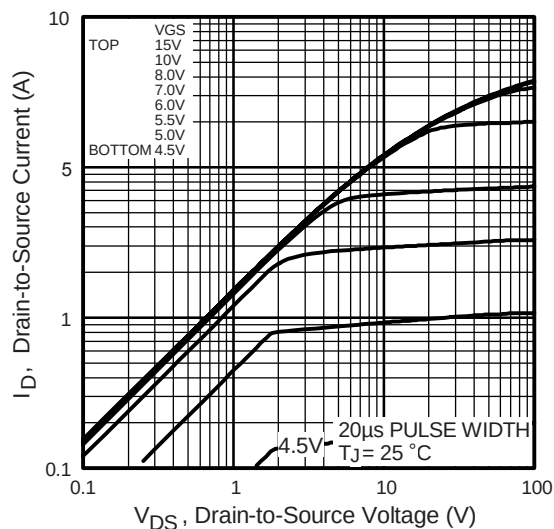
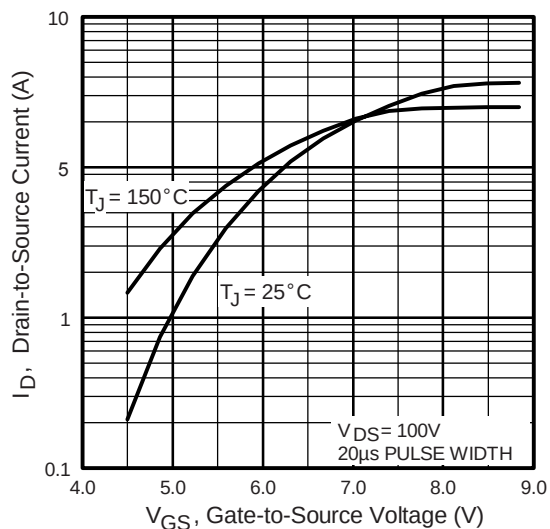
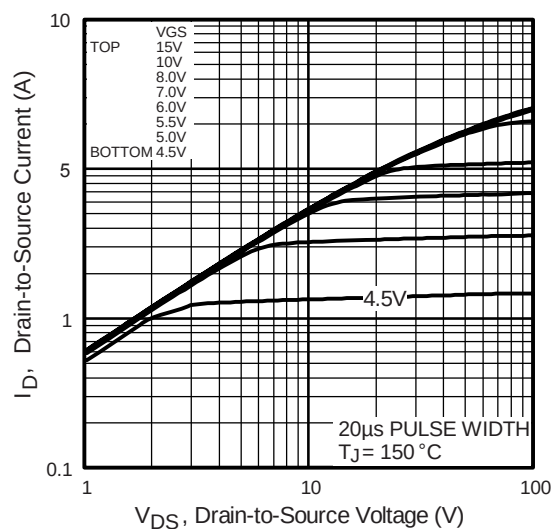
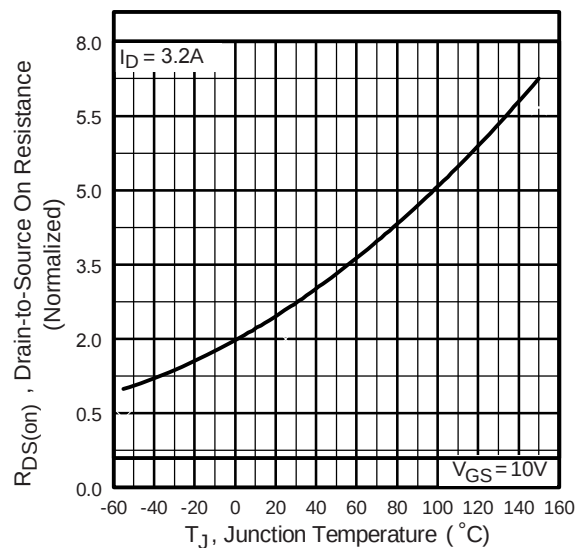
| PARAMETER                        | SYMBOL     | TYP. | MAX.        | UNIT |
|----------------------------------|------------|------|-------------|------|
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 62          | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 3.6/1.2/0.6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

**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  | -     |       |
| Effective Output Capacitance              | C <sub>oss eff.</sub>            |                                                                                                                                                         | V <sub>DS</sub> = 520 V, f = 1.0 MHz                                              | -    | 83   | -     |       |
|                                           |                                  | 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**

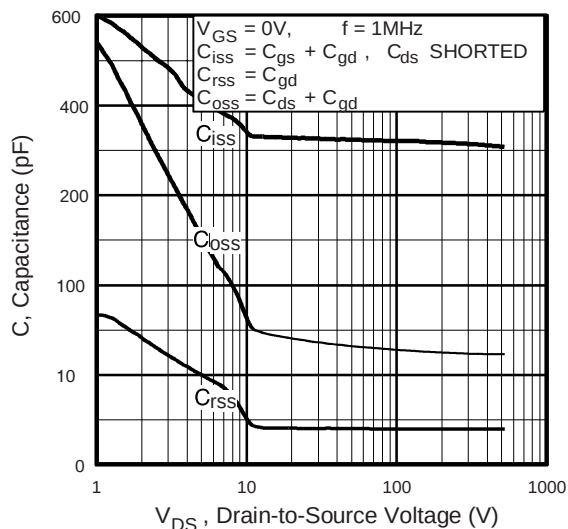


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

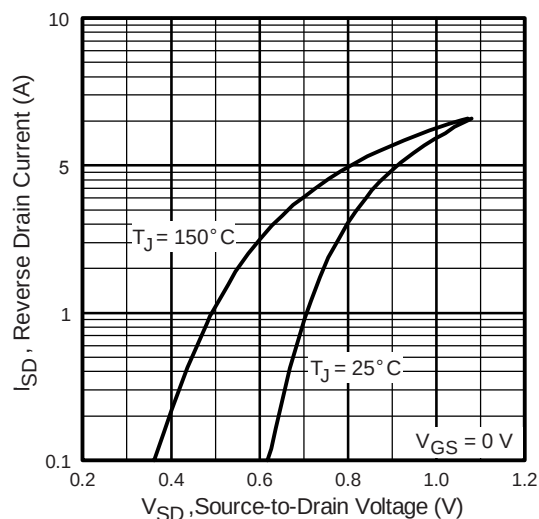


Fig. 7 - Typical Source-Drain Diode Forward Voltage

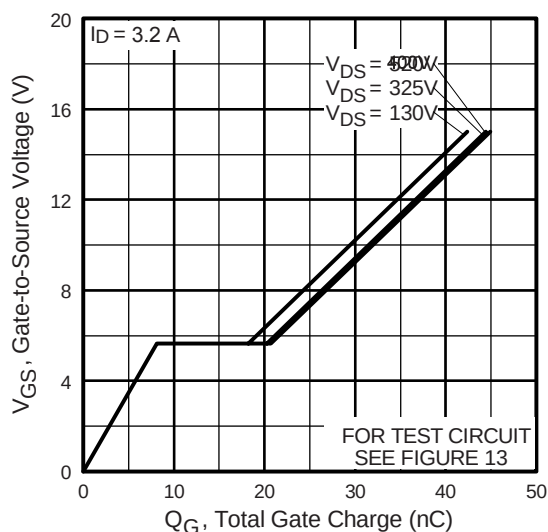


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

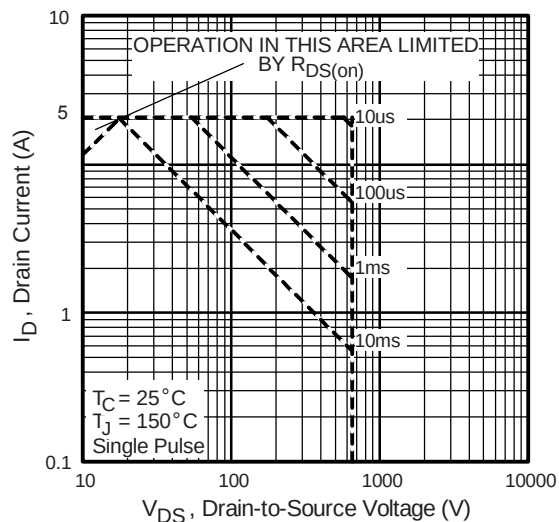


Fig. 8 - Maximum Safe Operating Area

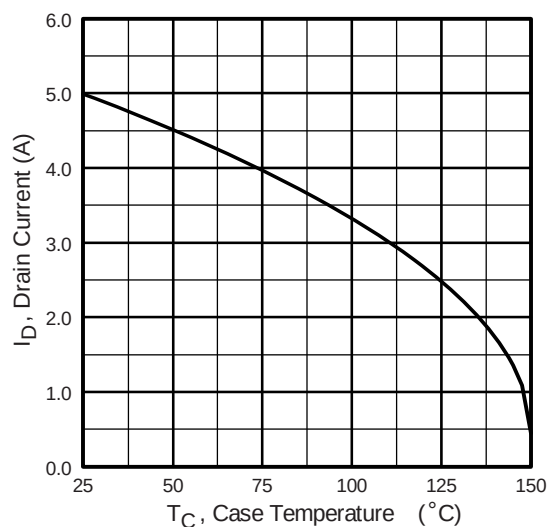


Fig. 9 - Maximum Drain Current vs. Case Temperature

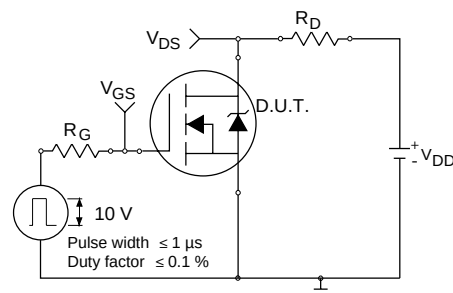


Fig. 10a - Switching Time Test Circuit

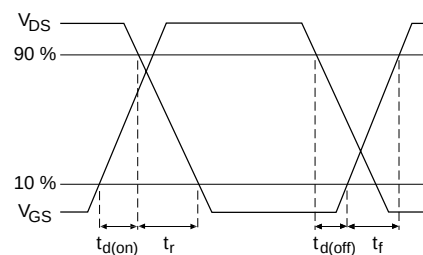


Fig. 10b - Switching Time Waveforms

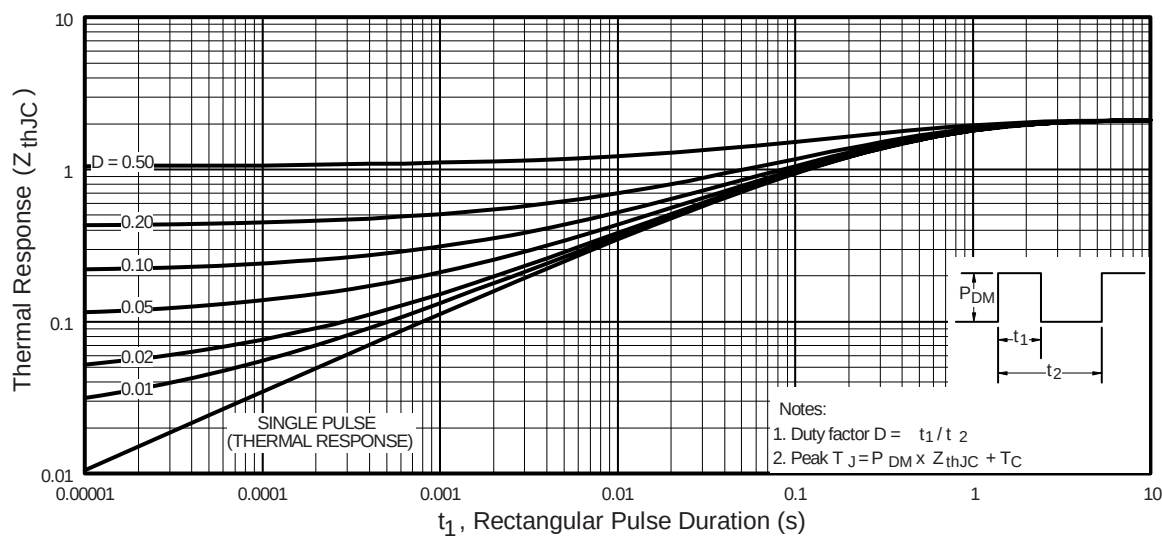


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

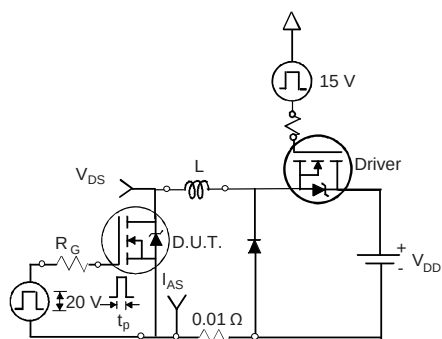


Fig. 12a - Unclamped Inductive Test Circuit

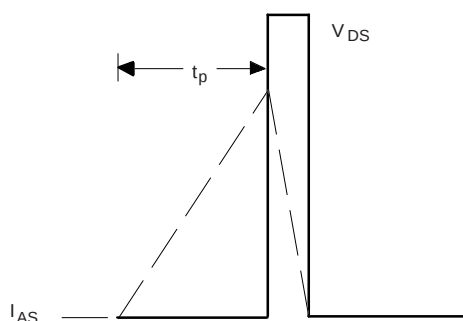


Fig. 12b - Unclamped Inductive Waveforms

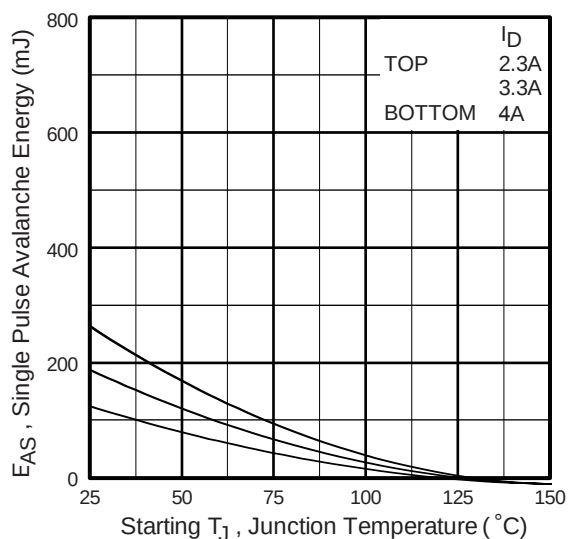


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

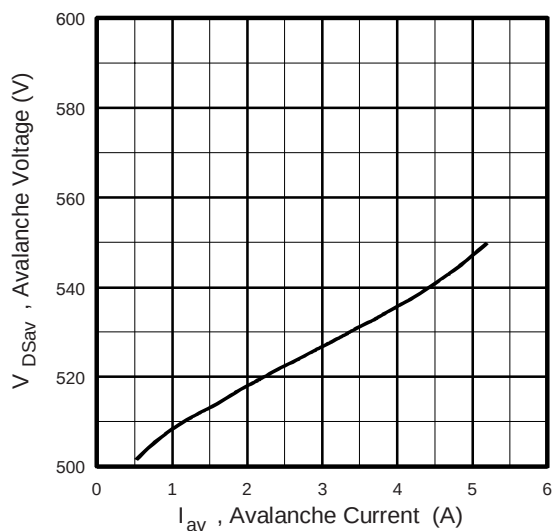


Fig. 12d - Typical Drain-to Source Voltage vs. Avalanche Current

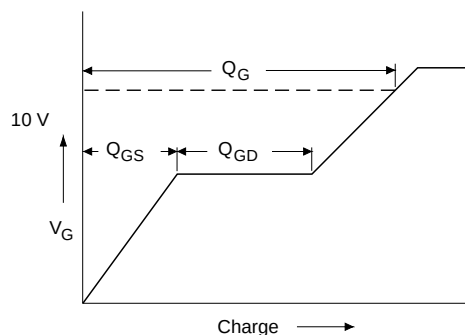


Fig. 13a - Basic Gate Charge Waveform

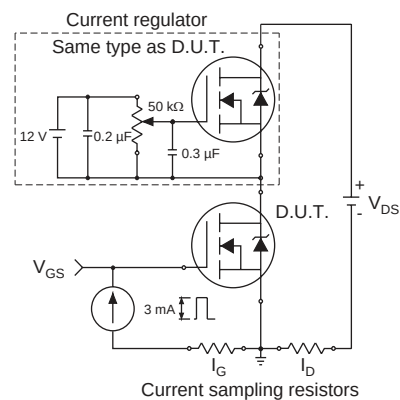


Fig. 13b - Gate Charge Test Circuit

**Circuit layout considerations**

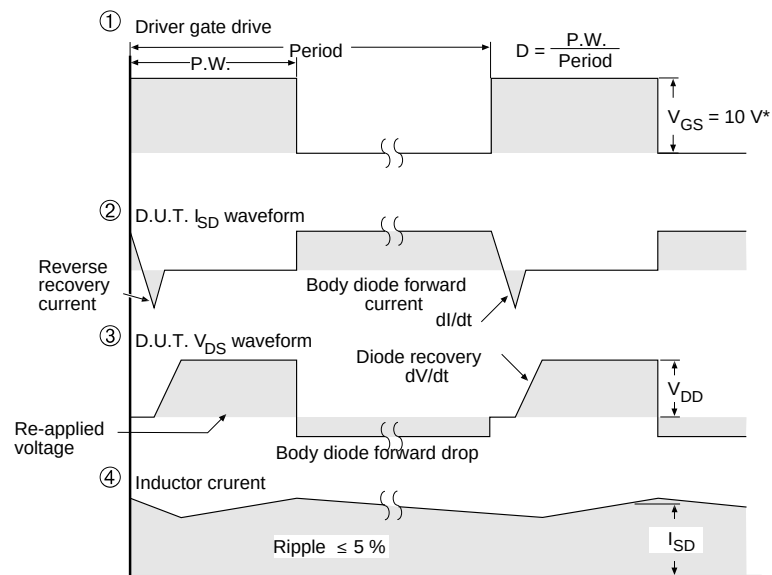
- Low stray inductance
- Ground plane
- Low leakage inductance current transformer

**Circuit components and connections:**

- 1:** Pulse voltage source connected to the gate of the driver MOSFET through resistor  $R_G$ .
- 2:** Current transformer (CT) in series with the drain of the driver MOSFET.
- 3:** Drain of the driver MOSFET connected to the gate of the D.U.T. MOSFET.
- 4:** Load resistor connected between the drain of the D.U.T. MOSFET and the  $V_{DD}$  supply.

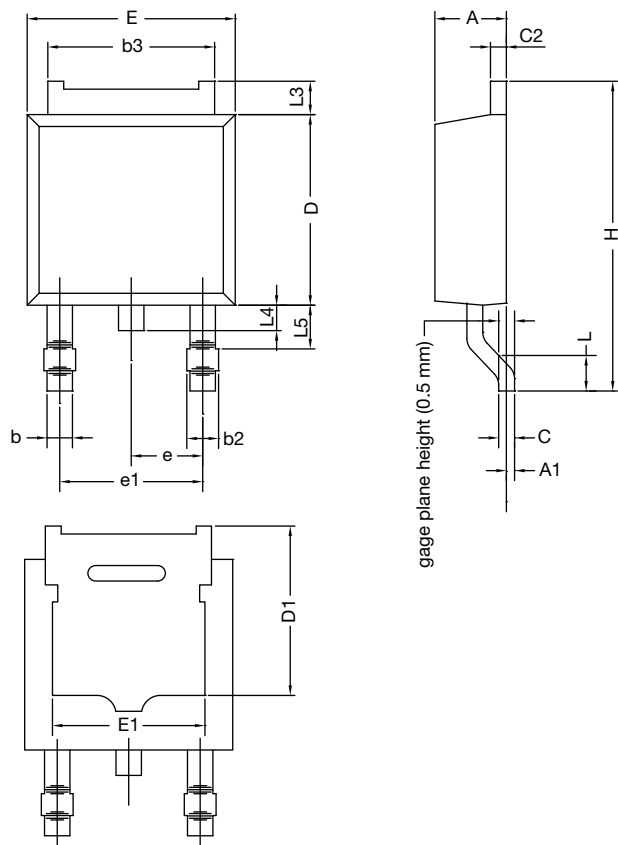
**Device Parameters and Control:**

- $dV/dt$  controlled by  $R_G$
- Driver same type as D.U.T.
- $I_{SD}$  controlled by duty factor "D"
- D.U.T. - device under test



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

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.



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