

## P6N60HA-VB Datasheet

### N-Channel 600V (D-S) Power MOSFET

| PRODUCT SUMMARY           |                        |       |
|---------------------------|------------------------|-------|
| $V_{DS}$ (V)              | 600                    |       |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10\text{ V}$ | 0.780 |
| $Q_g$ max. (nC)           | 49                     |       |
| $Q_{gs}$ (nC)             | 13                     |       |
| $Q_{gd}$ (nC)             | 20                     |       |
| 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

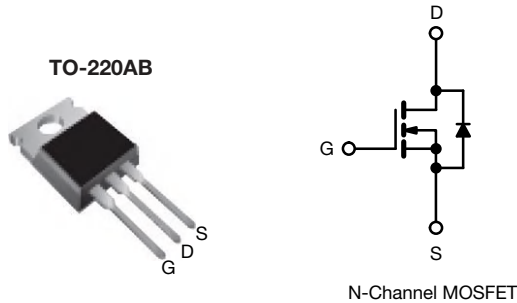

**RoHS**

#### APPLICATIONS

- Switch mode power supply (SMPS)
- Uninterruptible power supply
- High speed power switching

#### APPLICABLE OFF LINE SMPS TOPOLOGIES

- Active clamped forward
- Main switch



| ABSOLUTE MAXIMUM RATINGS (T <sub>C</sub> = 25 °C, unless otherwise noted) |                         |                         |                                   |             |          |
|---------------------------------------------------------------------------|-------------------------|-------------------------|-----------------------------------|-------------|----------|
| PARAMETER                                                                 |                         |                         | SYMBOL                            | LIMIT       | UNIT     |
| Drain-Source Voltage                                                      |                         |                         | V <sub>DS</sub>                   | 600         | V        |
| Gate-Source Voltage                                                       |                         |                         | V <sub>GS</sub>                   | ± 30        |          |
| Continuous Drain Current                                                  | V <sub>GS</sub> at 10 V | T <sub>C</sub> = 25 °C  | I <sub>D</sub>                    | 8.0         | A        |
|                                                                           |                         | T <sub>C</sub> = 100 °C |                                   | 5.8         |          |
| Pulsed Drain Current <sup>a</sup>                                         |                         |                         | I <sub>DM</sub>                   | 37          |          |
| Linear Derating Factor                                                    |                         |                         |                                   | 1.3         | W/°C     |
| Single Pulse Avalanche Energy <sup>b</sup>                                |                         |                         | E <sub>AS</sub>                   | 290         | mJ       |
| Repetitive Avalanche Current <sup>a</sup>                                 |                         |                         | I <sub>AR</sub>                   | 8.0         | 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>                    | 170         | W        |
| Peak Diode Recovery dV/dt <sup>c</sup>                                    |                         |                         | dV/dt                             | 5.0         | 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  $T_J = 25\text{ }^\circ\text{C}$ ,  $L = 6.8\text{ mH}$ ,  $R_g = 25\text{ }\Omega$ ,  $I_{AS} = 9.2\text{ A}$  (see fig. 12).
- $I_{SD} \leq 9.2\text{ A}$ ,  $dI/dt \leq 50\text{ A}/\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150\text{ }^\circ\text{C}$ .
- 1.6 mm from case.

**THERMAL RESISTANCE RATINGS**

| PARAMETER                           | SYMBOL     | TYP. | MAX. | UNIT |
|-------------------------------------|------------|------|------|------|
| Maximum Junction-to-Ambient         | $R_{thJA}$ | -    | 62   | °C/W |
| Case-to-Sink, Flat, Greased Surface | $R_{thCS}$ | 0.50 | -    |      |
| Maximum Junction-to-Case (Drain)    | $R_{thJC}$ | -    | 0.75 |      |

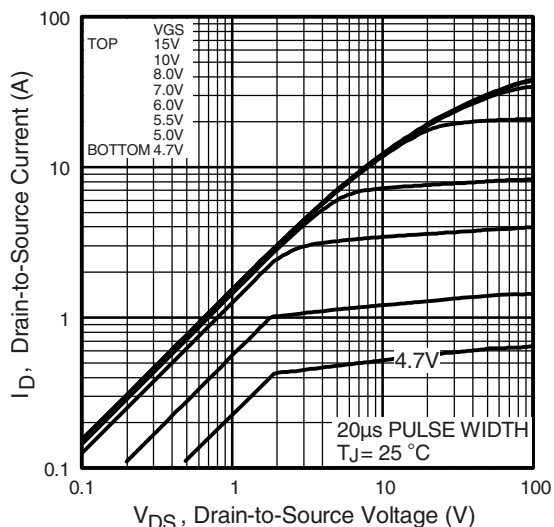
**SPECIFICATIONS** ( $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted)

| PARAMETER                                      | SYMBOL                | TEST CONDITIONS                                                                                                                                          | MIN. | TYP.  | MAX.      | UNIT                   |
|------------------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|-----------|------------------------|
| <b>Static</b>                                  |                       |                                                                                                                                                          |      |       |           |                        |
| Drain-Source Breakdown Voltage                 | $V_{DS}$              | $V_{GS} = 0\text{ V}$ , $I_D = 250\text{ }\mu\text{A}$                                                                                                   | 600  | -     | -         | V                      |
| $V_{DS}$ Temperature Coefficient               | $\Delta V_{DS}/T_J$   | Reference to $25\text{ }^{\circ}\text{C}$ , $I_D = 1\text{ mA}$                                                                                          | -    | 660   | -         | 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                | $I_{DSS}$             | $V_{DS} = 600\text{ V}$ , $V_{GS} = 0\text{ V}$                                                                                                          | -    | -     | 25        | $\mu\text{A}$          |
|                                                |                       | $V_{DS} = 480\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_J = 125\text{ }^{\circ}\text{C}$                                                                    | -    | -     | 250       |                        |
| Drain-Source On-State Resistance               | $R_{DS(on)}$          | $V_{GS} = 10\text{ V}$ , $I_D = 5.5\text{ A}^b$                                                                                                          | -    | 0.780 | -         | $\Omega$               |
| Forward Transconductance                       | $g_{fs}$              | $V_{DS} = 50\text{ V}$ , $I_D = 5.5\text{ A}$                                                                                                            | 5.5  | -     | -         | S                      |
| <b>Dynamic</b>                                 |                       |                                                                                                                                                          |      |       |           |                        |
| Input Capacitance                              | $C_{iss}$             | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 25\text{ V}$ ,<br>$f = 1.0\text{ MHz}$ , see fig. 5                                                                 | -    | 1400  | -         | pF                     |
| Output Capacitance                             | $C_{oss}$             |                                                                                                                                                          | -    | 180   | -         |                        |
| Reverse Transfer Capacitance                   | $C_{rss}$             |                                                                                                                                                          | -    | 7.1   | -         |                        |
| Output Capacitance                             | $C_{oss}$             | $V_{GS} = 0\text{ V}$<br>$V_{DS} = 1.0\text{ V}$ , $f = 1.0\text{ MHz}$<br>$V_{DS} = 480\text{ V}$ , $f = 1.0\text{ MHz}$                                | -    | 1957  | -         |                        |
| Effective Output Capacitance                   | $C_{oss\text{ eff.}}$ |                                                                                                                                                          | -    | 49    | -         |                        |
|                                                |                       | $V_{DS} = 0\text{ V to } 480\text{ V}$                                                                                                                   | -    | 96    | -         |                        |
| Total Gate Charge                              | $Q_g$                 | $V_{GS} = 10\text{ V}$<br>$I_D = 8.0\text{ A}$ , $V_{DS} = 400\text{ V}$<br>see fig. 6 and 13 <sup>b</sup>                                               | -    | -     | 49        | nC                     |
| Gate-Source Charge                             | $Q_{gs}$              |                                                                                                                                                          | -    | -     | 13        |                        |
| Gate-Drain Charge                              | $Q_{gd}$              |                                                                                                                                                          | -    | -     | 20        |                        |
| Turn-On Delay Time                             | $t_{d(on)}$           | $V_{DD} = 300\text{ V}$ , $I_D = 8.0\text{ A}$<br>$R_g = 9.1\text{ }\Omega$ , $R_D = 35.5\text{ }\Omega$ , see fig. 10 <sup>b</sup>                      | -    | 13    | -         | ns                     |
| Rise Time                                      | $t_r$                 |                                                                                                                                                          | -    | 25    | -         |                        |
| Turn-Off Delay Time                            | $t_{d(off)}$          |                                                                                                                                                          | -    | 30    | -         |                        |
| Fall Time                                      | $t_f$                 |                                                                                                                                                          | -    | 22    | -         |                        |
| Gate Input Resistance                          | $R_g$                 | $f = 1\text{ MHz}$ , open drain                                                                                                                          | 0.5  | -     | 3.2       | $\Omega$               |
| <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> | -    | -     | 9.2       | A                      |
| Pulsed Diode Forward Current <sup>a</sup>      | $I_{SM}$              |                                                                                                                                                          | -    | -     | 37        |                        |
| Body Diode Voltage                             | $V_{SD}$              | $T_J = 25\text{ }^{\circ}\text{C}$ , $I_S = 8.0\text{ A}$ , $V_{GS} = 0\text{ V}^b$                                                                      | -    | -     | 1.5       | V                      |
| Body Diode Reverse Recovery Time               | $t_{rr}$              | $T_J = 25\text{ }^{\circ}\text{C}$ , $I_F = 8.0\text{ A}$ , $dI/dt = 100\text{ A}/\mu\text{s}^b$                                                         | -    | 530   | 800       | ns                     |
| Body Diode Reverse Recovery Charge             | $Q_{rr}$              |                                                                                                                                                          | -    | 3.0   | 4.4       | $\mu\text{C}$          |
| Forward Turn-On Time                           | $t_{on}$              | Intrinsic turn-on time is negligible (turn-on is dominated by $L_S$ and $L_D$ )                                                                          |      |       |           |                        |

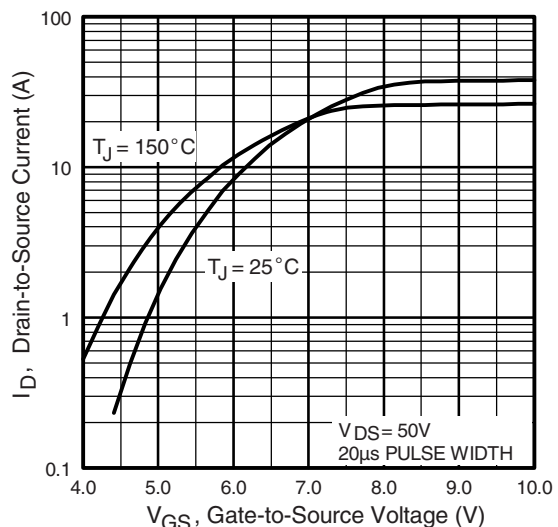
**Notes**

- 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.  $C_{oss\text{ eff.}}$  effective is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DS}$ .

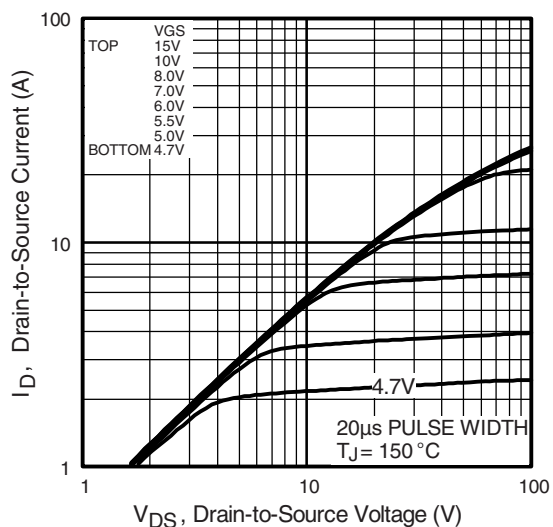
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



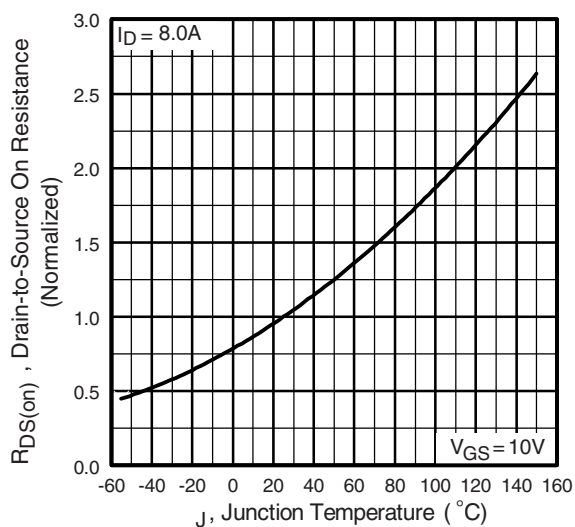
**Fig. 1 - Typical Output Characteristics**



**Fig. 3 - Typical Transfer Characteristics**



**Fig. 2 - Typical Output Characteristics**



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

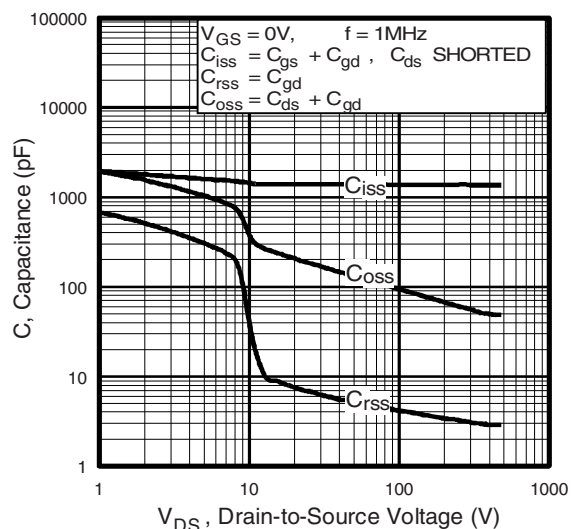


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

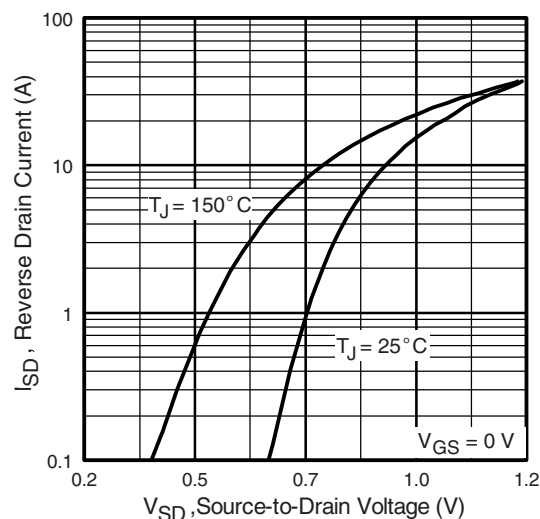


Fig. 7 - Typical Source-Drain Diode Forward Voltage

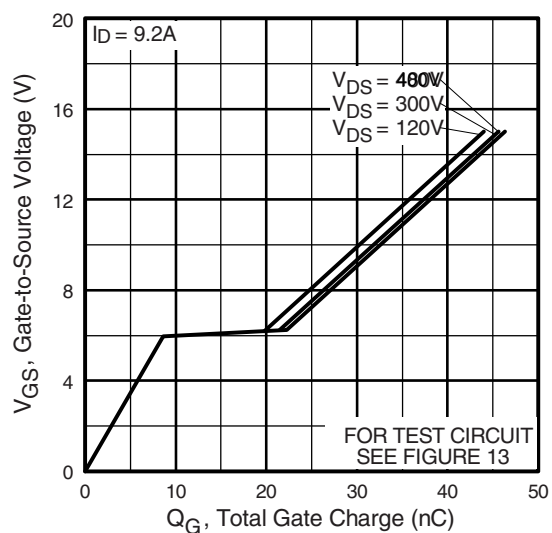


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

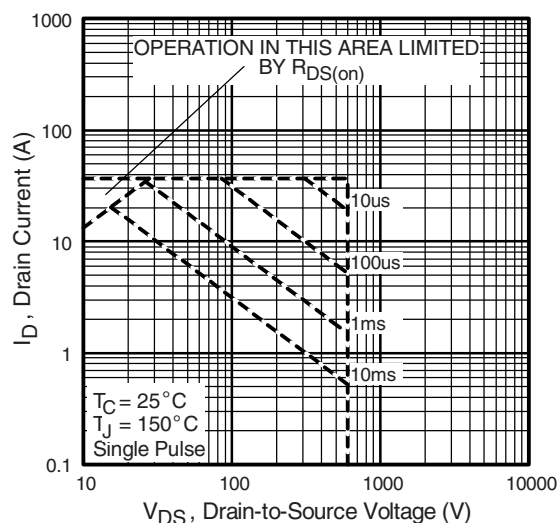


Fig. 8 - Maximum Safe Operating Area

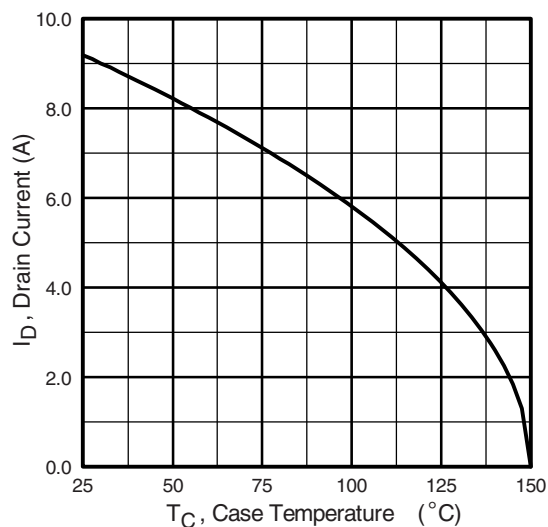


Fig. 9 - Maximum Drain Current vs. Case Temperature

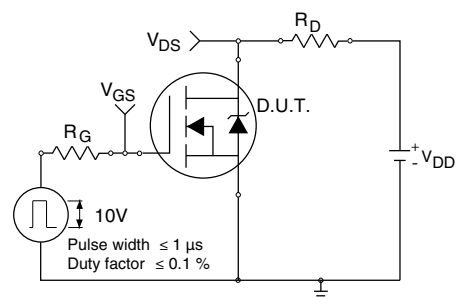


Fig. 10a - Switching Time Test Circuit

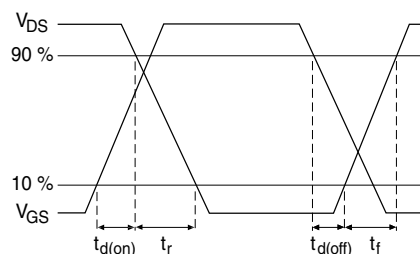


Fig. 10b - Switching Time Waveforms

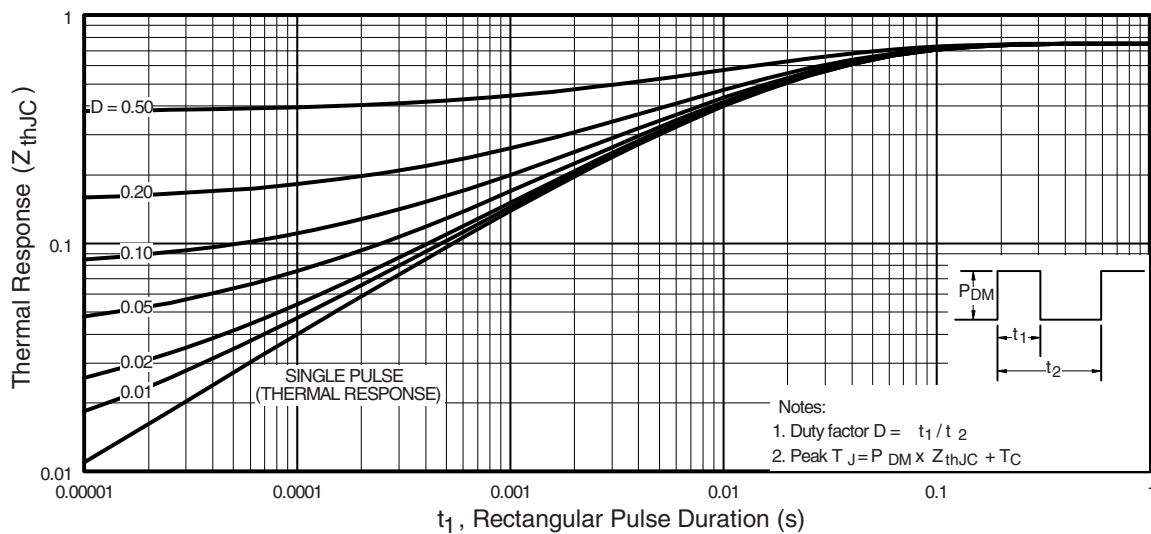


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

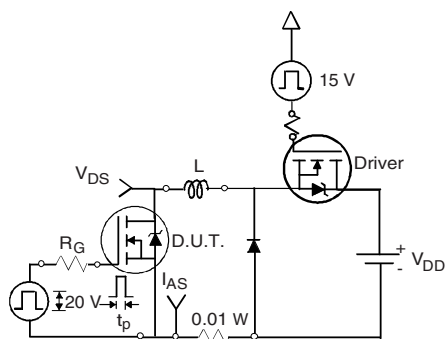


Fig. 12a - Unclamped Inductive Test Circuit

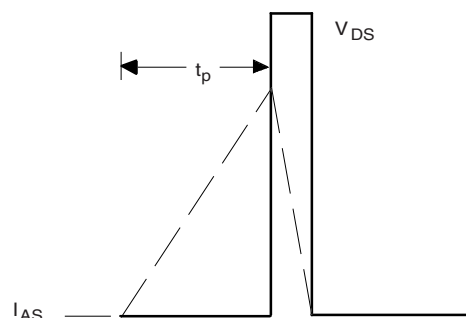


Fig. 12b - Unclamped Inductive Waveforms

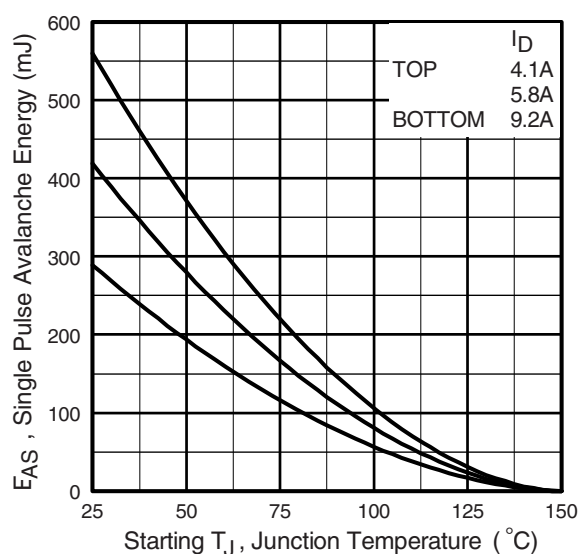


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

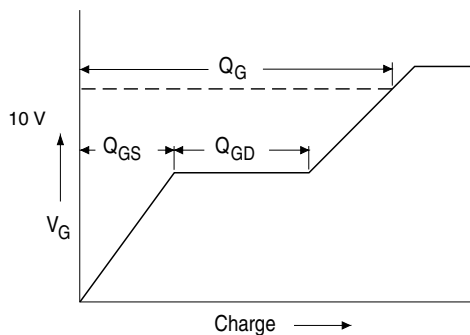


Fig. 13a - Basic Gate Charge Waveform

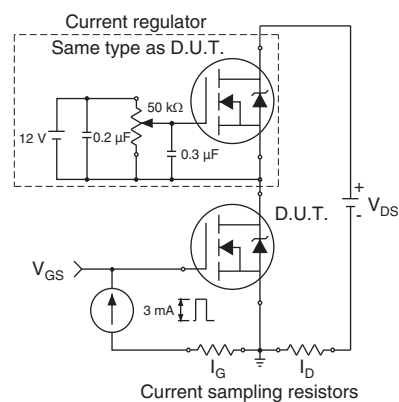
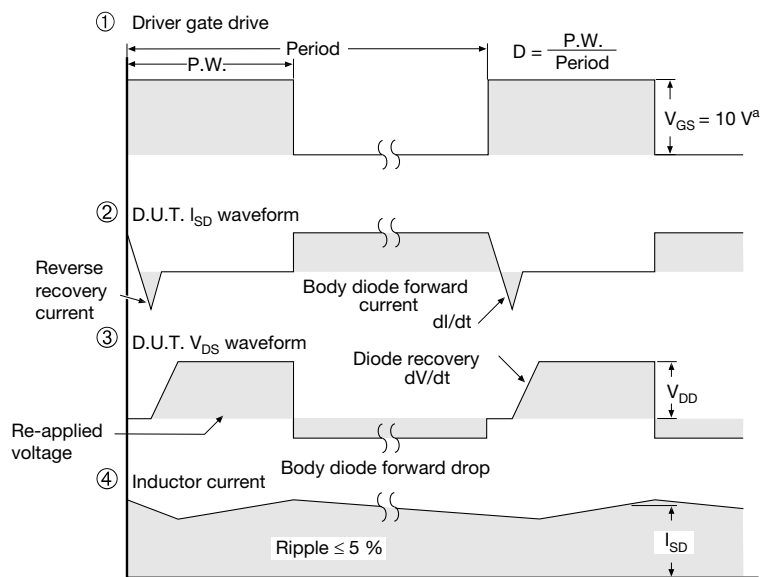
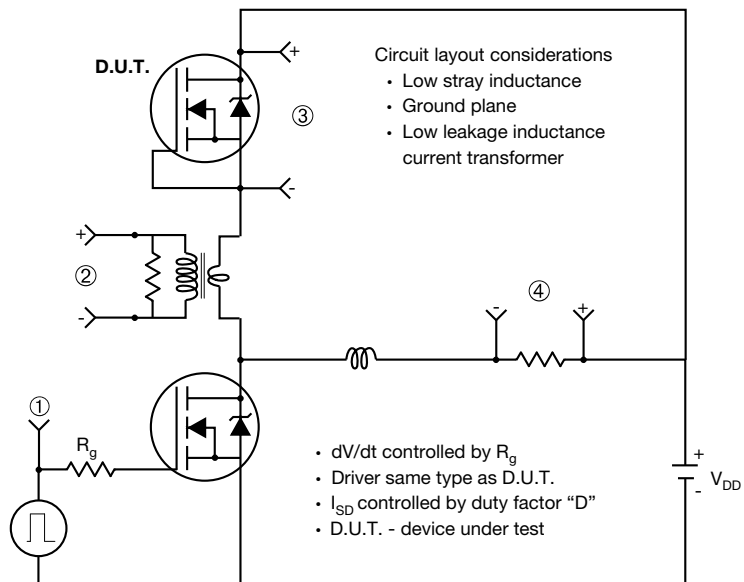


Fig. 13b - Gate Charge Test Circuit

**Peak Diode Recovery dV/dt Test Circuit**

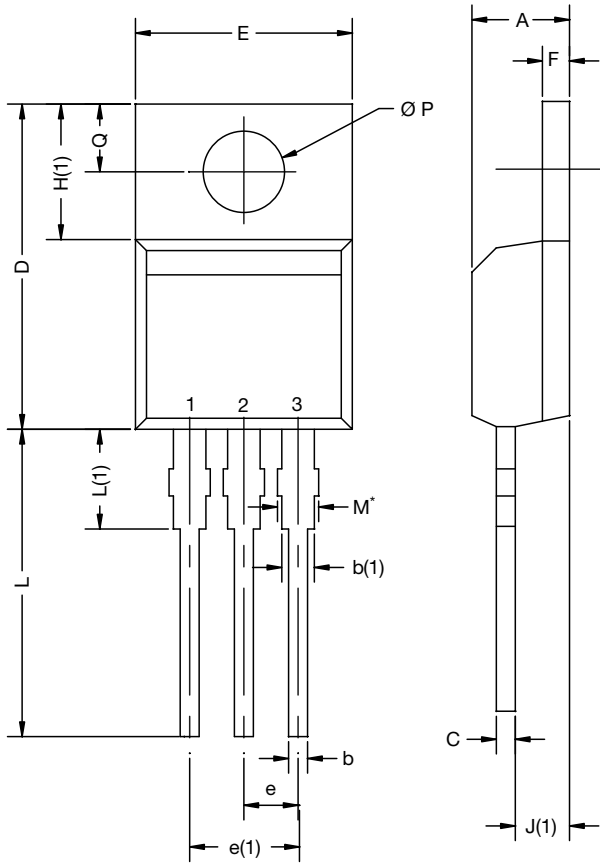


**Note**

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

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

## TO-220AB



| DIM.            | MILLIMETERS |       | INCHES |       |
|-----------------|-------------|-------|--------|-------|
|                 | MIN.        | MAX.  | MIN.   | MAX.  |
| A               | 4.24        | 4.65  | 0.167  | 0.183 |
| b               | 0.69        | 1.02  | 0.027  | 0.040 |
| b(1)            | 1.14        | 1.78  | 0.045  | 0.070 |
| c               | 0.36        | 0.61  | 0.014  | 0.024 |
| D               | 14.33       | 15.85 | 0.564  | 0.624 |
| E               | 9.96        | 10.52 | 0.392  | 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)            | 6.10        | 6.71  | 0.240  | 0.264 |
| J(1)            | 2.41        | 2.92  | 0.095  | 0.115 |
| L               | 13.36       | 14.40 | 0.526  | 0.567 |
| L(1)            | 3.33        | 4.04  | 0.131  | 0.159 |
| $\varnothing P$ | 3.53        | 3.94  | 0.139  | 0.155 |
| Q               | 2.54        | 3.00  | 0.100  | 0.118 |

ECN: X15-0364-Rev. C, 14-Dec-15  
DWG: 6031

**Note**

- $M^*$  = 0.052 inches to 0.064 inches (dimension including protrusion), heatsink hole for HVM



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