

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

### PRODUCT SUMMARY

|                                         |                        |      |
|-----------------------------------------|------------------------|------|
| $V_{DS}$ (V) at $T_J$ max.              | 650                    |      |
| $R_{DS(on)}$ max. at 25 °C ( $\Omega$ ) | $V_{GS} = 10\text{ V}$ | 0.82 |
| $Q_g$ max. (nC)                         | 57                     |      |
| $Q_{gs}$ (nC)                           | 4.0                    |      |
| $Q_{gd}$ (nC)                           | 5.4                    |      |
| Configuration                           | Single                 |      |

### FEATURES

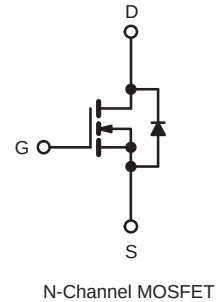
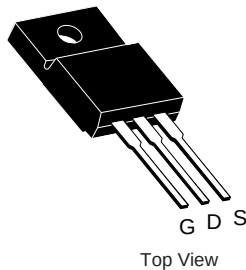
- Low figure-of-merit (FOM)  $R_{on} \times Q_g$
- Low input capacitance ( $C_{iss}$ )
- Reduced switching and conduction losses
- Ultra low gate charge ( $Q_g$ )
- Avalanche energy rated (UIS)



### APPLICATIONS

- Server and telecom power supplies
- Switch mode power supplies (SMPS)
- Power factor correction power supplies (PFC)
- Lighting
  - High-intensity discharge (HID)
  - Fluorescent ballast lighting
- Industrial

TO-220 FULLPAK



### ABSOLUTE MAXIMUM RATINGS ( $T_C = 25\text{ °C}$ , unless otherwise noted)

| PARAMETER                                                        |                                     |                                     | SYMBOL         | LIMIT        | UNIT |
|------------------------------------------------------------------|-------------------------------------|-------------------------------------|----------------|--------------|------|
| Drain-Source Voltage                                             |                                     |                                     | $V_{DS}$       | 650          | V    |
| Gate-Source Voltage                                              |                                     |                                     | $V_{GS}$       | ± 30         |      |
| Continuous Drain Current ( $T_J = 150\text{ }^{\circ}\text{C}$ ) | $V_{GS}$ at 10 V                    | $T_C = 25\text{ }^{\circ}\text{C}$  | $I_D$          | 10           | A    |
|                                                                  |                                     | $T_C = 100\text{ }^{\circ}\text{C}$ |                | 8            |      |
| Pulsed Drain Current <sup>a</sup>                                |                                     |                                     | $I_{DM}$       | 35           |      |
| Linear Derating Factor                                           |                                     |                                     |                | 1.67/1.5/0.3 | W/°C |
| Single Pulse Avalanche Energy <sup>b</sup>                       |                                     |                                     | $E_{AS}$       | 86           | mJ   |
| Maximum Power Dissipation                                        |                                     |                                     | $P_D$          | 178/156/53   | W    |
| Operating Junction and Storage Temperature Range                 |                                     |                                     | $T_J, T_{stg}$ | -55 to +150  | °C   |
| Drain-Source Voltage Slope                                       | $T_J = 125\text{ }^{\circ}\text{C}$ |                                     | dV/dt          | 50           | V/ns |
| Reverse Diode dV/dt <sup>d</sup>                                 |                                     | 4.5                                 |                |              |      |
| Soldering Recommendations (Peak Temperature) <sup>c</sup>        | for 10 s                            |                                     |                | 300          | °C   |

#### Notes

- a. Repetitive rating; pulse width limited by maximum junction temperature.  
 b.  $V_{DS} = 50\text{ V}$ , starting  $T_J = 25\text{ °C}$ ,  $L = 28.2\text{ mH}$ ,  $R_g = 25\text{ }\Omega$ ,  $I_{AS} = 3.5\text{ A}$ .  
 c. 1.6 mm from case.  
 d.  $I_{SD} \leq I_D$ ,  $dI/dt = 100\text{ A}/\mu\text{s}$ , starting  $T_J = 25\text{ °C}$ .

**THERMAL RESISTANCE RATINGS**

| PARAMETER                        | SYMBOL     | TYP. | MAX. | UNIT |
|----------------------------------|------------|------|------|------|
| Maximum Junction-to-Ambient      | $R_{thJA}$ | -    | 63   | °C/W |
| Maximum Junction-to-Case (Drain) | $R_{thJC}$ | -    | 0.6  |      |

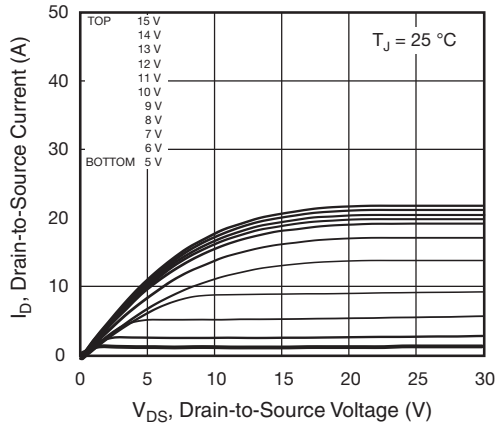
**SPECIFICATIONS** ( $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted)

| 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                                                                                                               |                                               | -    | 0.65 | -     | V/°C |
| Gate-Source Threshold Voltage (N)                         | V <sub>GS(th)</sub>              | V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 250 μA                                                                                             |                                               | 2    | -    | 4     | V    |
| Gate-Source Leakage                                       | I <sub>GSS</sub>                 | V <sub>GS</sub> = ± 20 V                                                                                                                                |                                               | -    | -    | ± 100 | nA   |
|                                                           |                                  | V <sub>GS</sub> = ± 30 V                                                                                                                                |                                               | -    | -    | ± 1   | μA   |
| Zero Gate Voltage Drain Current                           | I <sub>DSS</sub>                 | V <sub>DS</sub> = 650 V, V <sub>GS</sub> = 0 V                                                                                                          |                                               | -    | -    | 1     | μA   |
|                                                           |                                  | V <sub>DS</sub> = 520 V, V <sub>GS</sub> = 0 V, T <sub>J</sub> = 125 °C                                                                                 |                                               | -    | -    | 10    |      |
| Drain-Source On-State Resistance                          | R <sub>DS(on)</sub>              | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 4 A                          | -    | 0.82 | -     | Ω    |
| Forward Transconductance                                  | g <sub>fs</sub>                  | V <sub>DS</sub> = 30 V, I <sub>D</sub> = 4 A                                                                                                            |                                               | -    | 16   | -     | S    |
| Dynamic                                                   |                                  |                                                                                                                                                         |                                               |      |      |       |      |
| Input Capacitance                                         | C <sub>iss</sub>                 | V <sub>GS</sub> = 0 V,<br>V <sub>DS</sub> = 100 V,<br>f = 1 MHz                                                                                         |                                               | -    | 1900 | -     | pF   |
| Output Capacitance                                        | C <sub>oss</sub>                 |                                                                                                                                                         |                                               | -    | 400  | -     |      |
| Reverse Transfer Capacitance                              | C <sub>rss</sub>                 |                                                                                                                                                         |                                               | -    | 240  | -     |      |
| Effective Output Capacitance, Energy Related <sup>a</sup> | C <sub>o(er)</sub>               | V <sub>DS</sub> = 0 V to 520 V, V <sub>GS</sub> = 0 V                                                                                                   |                                               | -    | 45   | -     |      |
| Effective Output Capacitance, Time Related <sup>b</sup>   | C <sub>o(tr)</sub>               |                                                                                                                                                         |                                               | -    | 62   | -     |      |
| Total Gate Charge                                         | Q <sub>g</sub>                   | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 4 A, V <sub>DS</sub> = 520 V | -    | 40   | 57    | nC   |
| Gate-Source Charge                                        | Q <sub>gs</sub>                  |                                                                                                                                                         |                                               | -    | 4.0  | -     |      |
| Gate-Drain Charge                                         | Q <sub>gd</sub>                  |                                                                                                                                                         |                                               | -    | 5.4  | -     |      |
| Turn-On Delay Time                                        | t <sub>d(on)</sub>               | V <sub>DD</sub> = 520 V, I <sub>D</sub> = 4 A,<br>V <sub>GS</sub> = 10 V, R <sub>g</sub> = 9.1 Ω                                                        |                                               | -    | 25   | -     | ns   |
| Rise Time                                                 | t <sub>r</sub>                   |                                                                                                                                                         |                                               | -    | 55   | -     |      |
| Turn-Off Delay Time                                       | t <sub>d(off)</sub>              |                                                                                                                                                         |                                               | -    | 70   | -     |      |
| Fall Time                                                 | t <sub>f</sub>                   |                                                                                                                                                         |                                               | -    | 40   | -     |      |
| Gate Input Resistance                                     | R <sub>g</sub>                   | f = 1 MHz, open drain                                                                                                                                   |                                               | -    | 3.5  | -     | Ω    |
| 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> |                                               | -    | -    | 7     | A    |
| Pulsed Diode Forward Current                              | I <sub>SM</sub>                  |                                                                                                                                                         |                                               | -    | -    | 18    |      |
| Diode Forward Voltage                                     | V <sub>SD</sub>                  | T <sub>J</sub> = 25 °C, I <sub>S</sub> = 4 A, V <sub>GS</sub> = 0 V                                                                                     |                                               | -    | -    | 1.5   | V    |
| Reverse Recovery Time                                     | t <sub>rr</sub>                  | T <sub>J</sub> = 25 °C, I <sub>F</sub> = I <sub>S</sub> = 4 A,<br>dI/dt = 100 A/μs, V <sub>R</sub> = 400 V                                              |                                               | -    | 190  | -     | ns   |
| Reverse Recovery Charge                                   | Q <sub>rr</sub>                  |                                                                                                                                                         |                                               | -    | 2.3  | -     | μC   |
| Reverse Recovery Current                                  | I <sub>RRM</sub>                 |                                                                                                                                                         |                                               | -    | 10   | -     | A    |

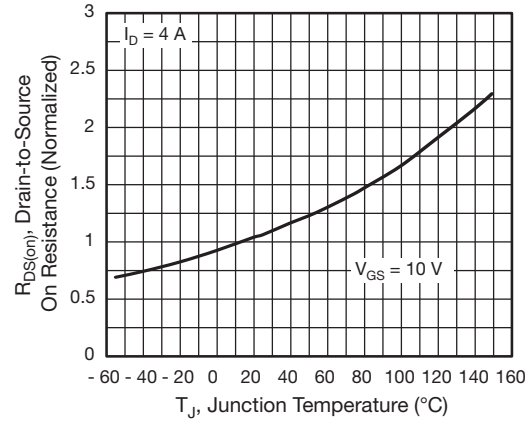
**Notes**

- a.  $C_{oss(er)}$  is a fixed capacitance that gives the same energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$ .  
 b.  $C_{oss(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$ .

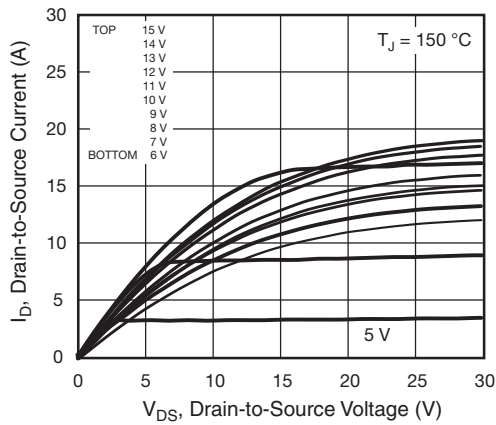
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



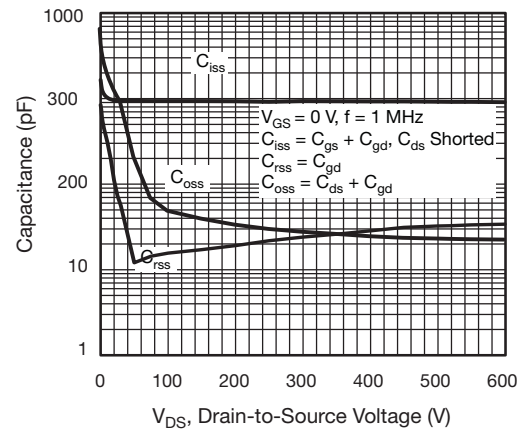
**Fig. 1 - Typical Output Characteristics**



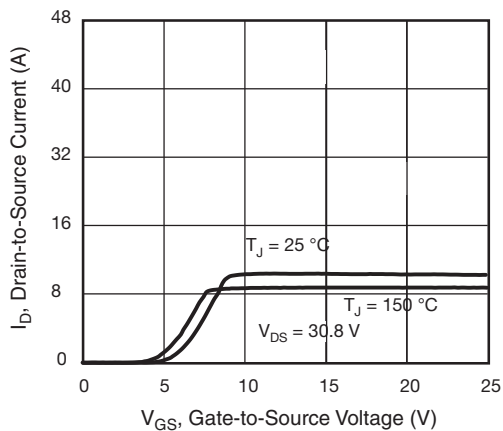
**Fig. 4 - Normalized On-Resistance vs. Temperature**



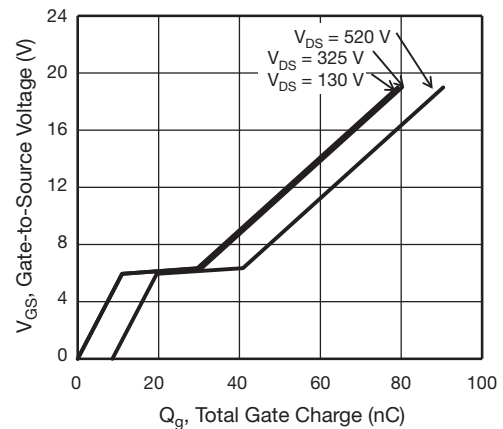
**Fig. 2 - Typical Output Characteristics**



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



**Fig. 3 - Typical Transfer Characteristics**



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

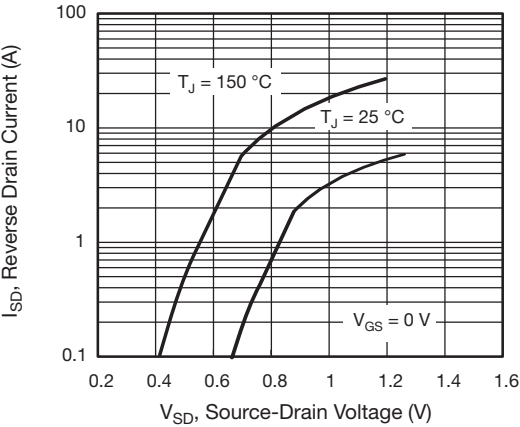


Fig. 7 - Typical Source-Drain Diode Forward Voltage

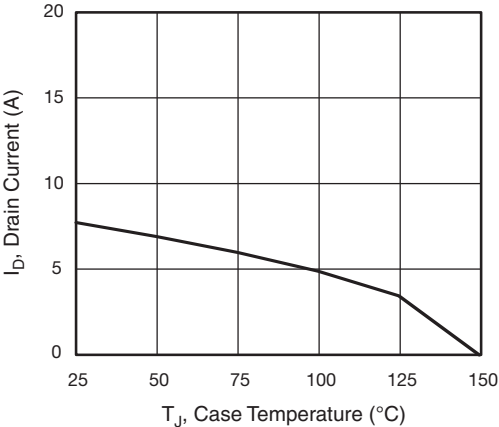


Fig. 9 - Maximum Drain Current vs. Case Temperature

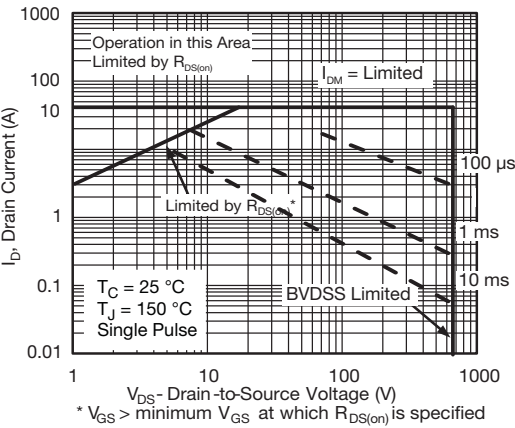


Fig. 8 - Maximum Safe Operating Area

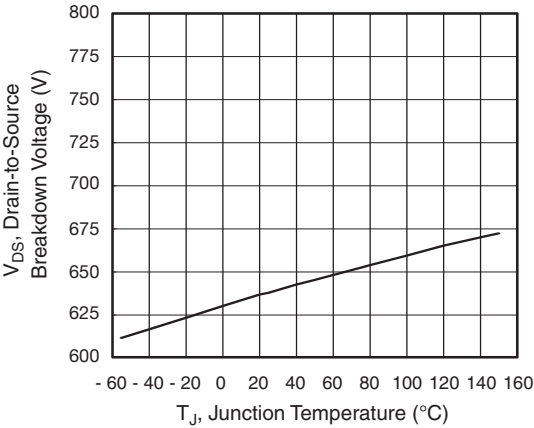


Fig. 10 - Temperature vs. Drain-to-Source Voltage

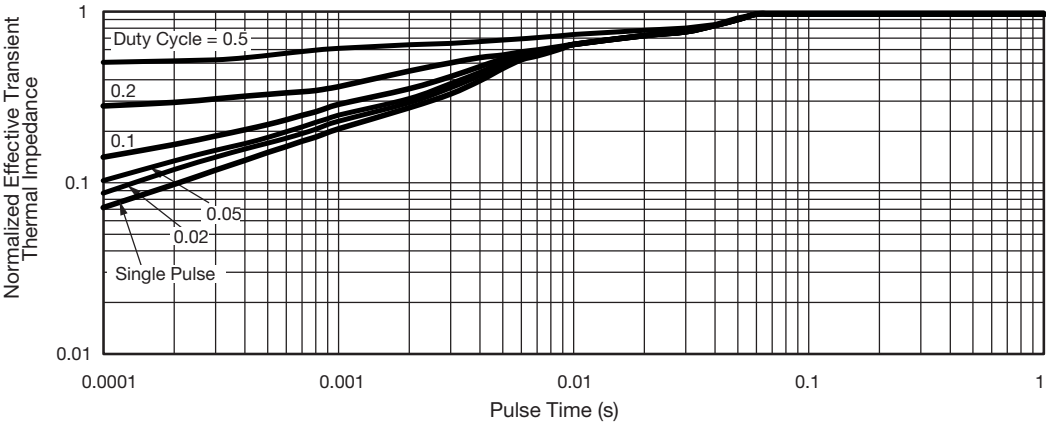


Fig. 11 - Normalized Thermal Transient Impedance, Junction-to-Case

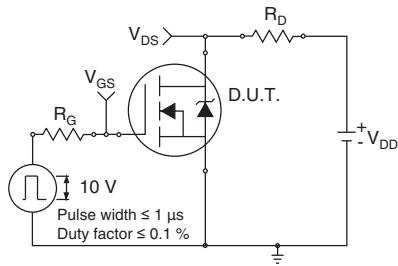


Fig. 12 - Switching Time Test Circuit

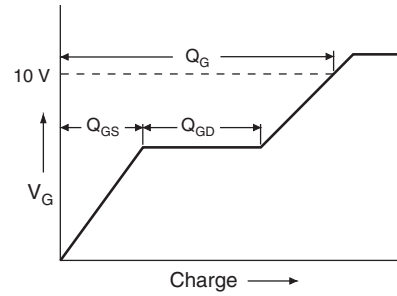


Fig. 16 - Basic Gate Charge Waveform

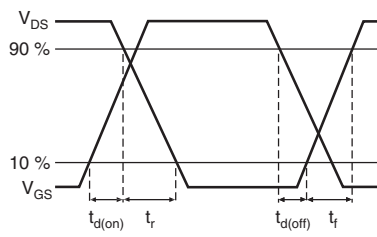


Fig. 13 - Switching Time Waveforms

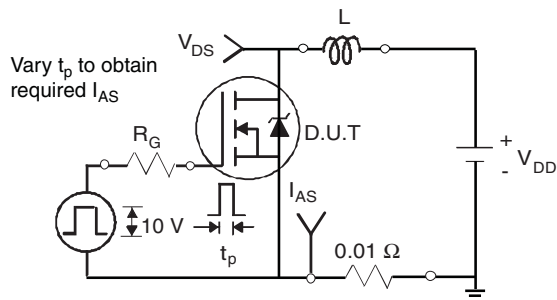


Fig. 14 - Unclamped Inductive Test Circuit

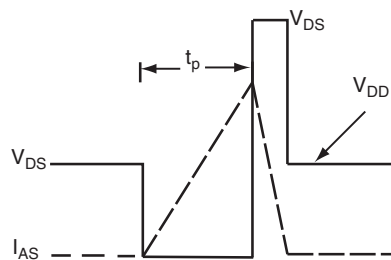


Fig. 15 - Unclamped Inductive Waveforms

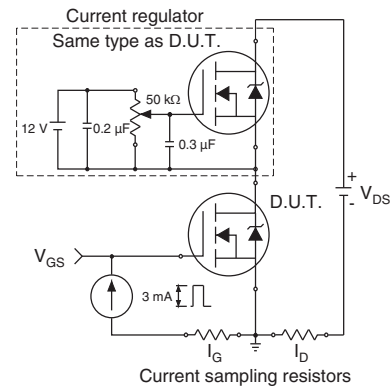
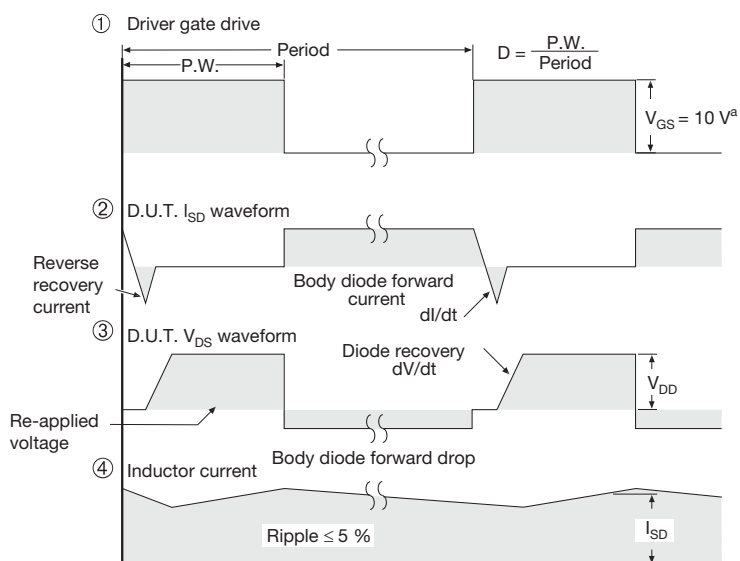
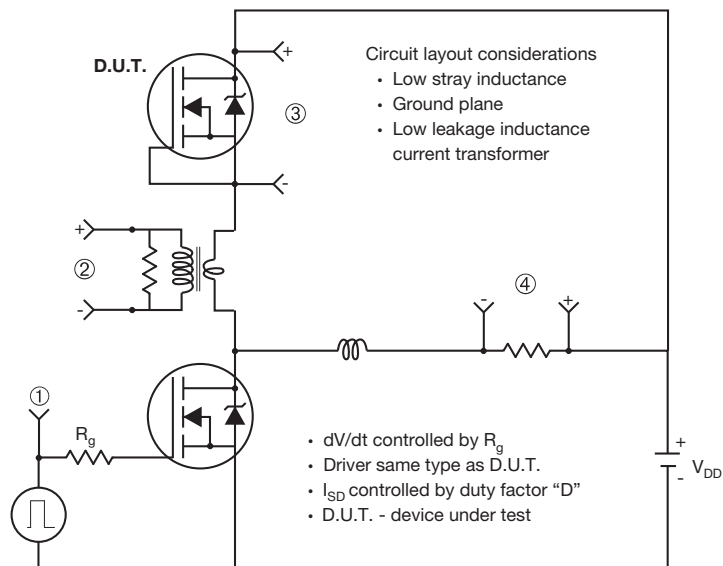


Fig. 17 - Gate Charge Test Circuit

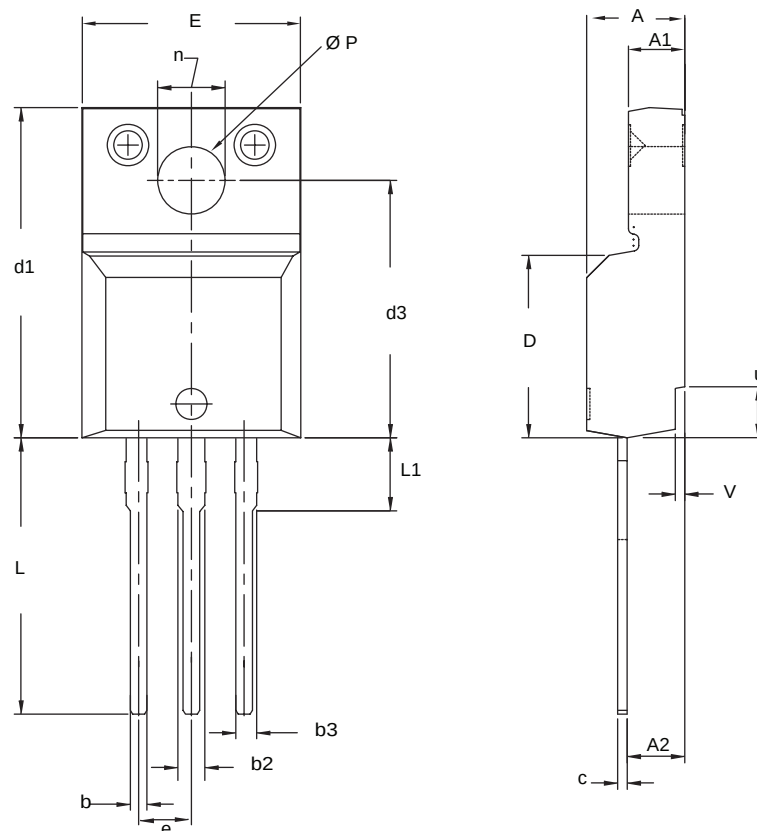
### Peak Diode Recovery $dV/dt$ Test Circuit



#### Note

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

**Fig. 18 - For N-Channel**

**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<br>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.

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