

## P4NK60FP-VB Datasheet

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

## PRODUCT SUMMARY

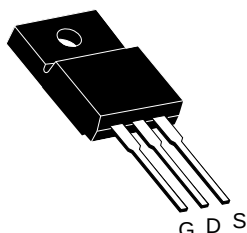
|                           |                        |     |
|---------------------------|------------------------|-----|
| $V_{DS}$ (V)              | 650                    |     |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10\text{ V}$ | 2.5 |
| $Q_g$ (Max.) (nC)         | 48                     |     |
| $Q_{gs}$ (nC)             | 12                     |     |
| $Q_{gd}$ (nC)             | 19                     |     |
| Configuration             | Single                 |     |

## FEATURES

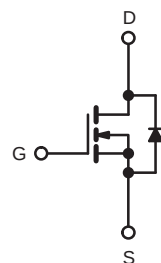
- Low Gate Charge  $Q_g$  Results in Simple Drive Requirement
- Improved Gate, Avalanche and Dynamic  $dV/dt$  Ruggedness
- Fully Characterized Capacitance and Avalanche Voltage and Current
- Compliant to RoHS directive 2002/95/EC


**RoHS\***  
 COMPLIANT

TO-220 FULLPAK



Top View



N-Channel MOSFET

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>                     | $I_D$            | 4             | A                   |
| Continuous Drain Current                                  |                  | 3.8           |                     |
| Pulsed Drain Current <sup>a</sup>                         | $I_{DM}$         | 18            |                     |
| Linear Derating Factor                                    |                  | 0.48          | W/ $^\circ\text{C}$ |
| Single Pulse Avalanche Energy <sup>b</sup>                | $E_{AS}$         | 325           | mJ                  |
| Repetitive Avalanche Current <sup>a</sup>                 | $I_{AR}$         | 4             | A                   |
| Repetitive Avalanche Energy <sup>a</sup>                  | $E_{AR}$         | 6             | mJ                  |
| Maximum Power Dissipation                                 | $P_D$            | 30            | 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> |                  | 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  |      |

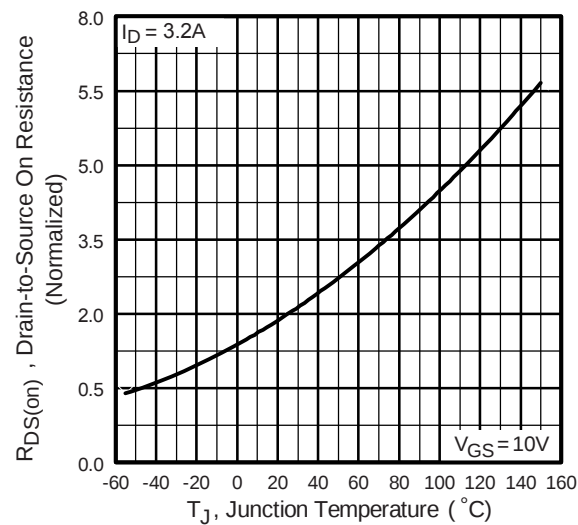
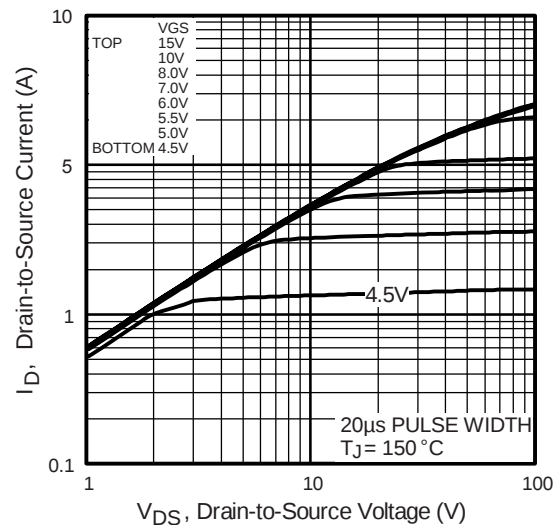
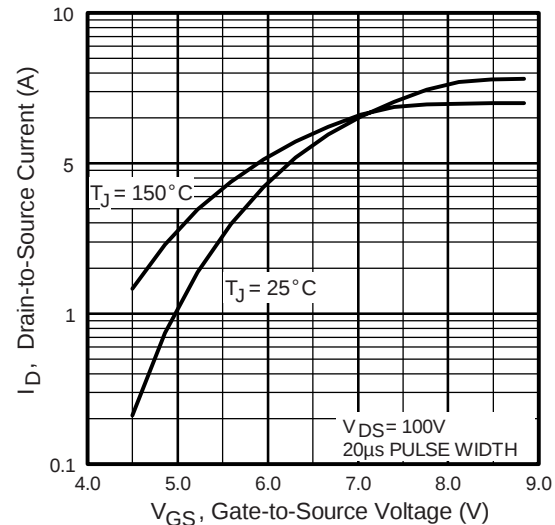
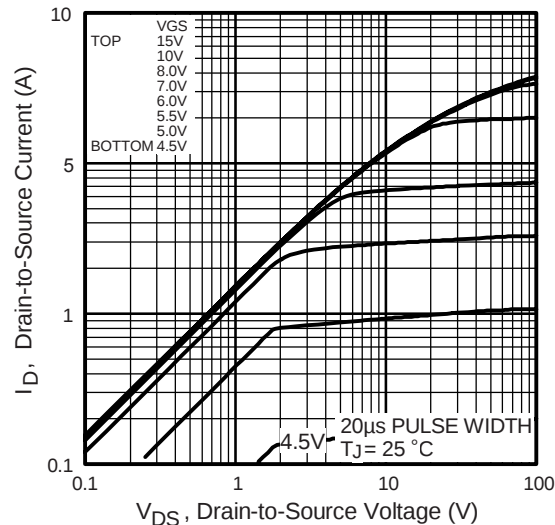
**SPECIFICATIONS**  $T_J = 25\text{ °C}$ , unless otherwise noted

| 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>                                                                                                  |                                                                                   | -    | 670  | -     | 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                                                                                                          |                                                                                   | -    | -    | 25    | μA    |
|                                           |                                  | V <sub>DS</sub> = 520 V, V <sub>GS</sub> = 0 V, T <sub>J</sub> = 125 °C                                                                                 |                                                                                   | -    | -    | 250   |       |
| Drain-Source On-State Resistance          | R <sub>DS(on)</sub>              | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 3.1 A <sup>b</sup>                                               | -    | 2.5  | -     | Ω     |
| Forward Transconductance                  | g <sub>fs</sub>                  | V <sub>DS</sub> = 50 V, I <sub>D</sub> = 3.1 A                                                                                                          |                                                                                   | 3.9  | -    | -     | 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                                                                            |                                                                                   | -    | 1080 | -     | pF    |
| Output Capacitance                        | C <sub>oss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 177  | -     |       |
| Reverse Transfer Capacitance              | C <sub>rss</sub>                 |                                                                                                                                                         |                                                                                   | -    | 7.0  | -     |       |
| Output Capacitance                        | C <sub>oss</sub>                 | V <sub>GS</sub> = 0 V                                                                                                                                   | V <sub>DS</sub> = 1.0 V, f = 1.0 MHz                                              | -    | 1912 | -     |       |
|                                           |                                  |                                                                                                                                                         | V <sub>DS</sub> = 520 V, f = 1.0 MHz                                              | -    | 48   | -     |       |
| Effective Output Capacitance              | C <sub>oss eff.</sub>            |                                                                                                                                                         | V <sub>DS</sub> = 0 V to 520 V <sup>c</sup>                                       | -    | 84   | -     |       |
| Total Gate Charge                         | Q <sub>g</sub>                   | V <sub>GS</sub> = 10 V                                                                                                                                  | I <sub>D</sub> = 3.2 A, V <sub>DS</sub> = 400 V<br>see fig. 6 and 13 <sup>b</sup> | -    | -    | 48    | nC    |
| Gate-Source Charge                        | Q <sub>gs</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 12    |       |
| Gate-Drain Charge                         | Q <sub>gd</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 19    |       |
| 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>                           |                                                                                   | -    | 14   | -     | ns    |
| Rise Time                                 | t <sub>r</sub>                   |                                                                                                                                                         |                                                                                   | -    | 20   | -     |       |
| Turn-Off Delay Time                       | t <sub>d(off)</sub>              |                                                                                                                                                         |                                                                                   | -    | 34   | -     |       |
| Fall Time                                 | t <sub>f</sub>                   |                                                                                                                                                         |                                                                                   | -    | 18   | -     |       |
| 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> |                                                                                   | -    | -    | 4     | A     |
| Pulsed Diode Forward Current <sup>a</sup> | I <sub>SM</sub>                  |                                                                                                                                                         |                                                                                   | -    | -    | 21    |       |
| 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>                                                                           |                                                                                   | -    | 493  | 739   | 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



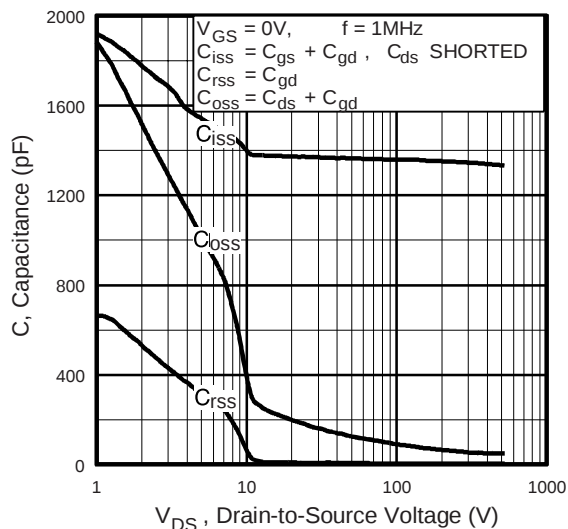


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

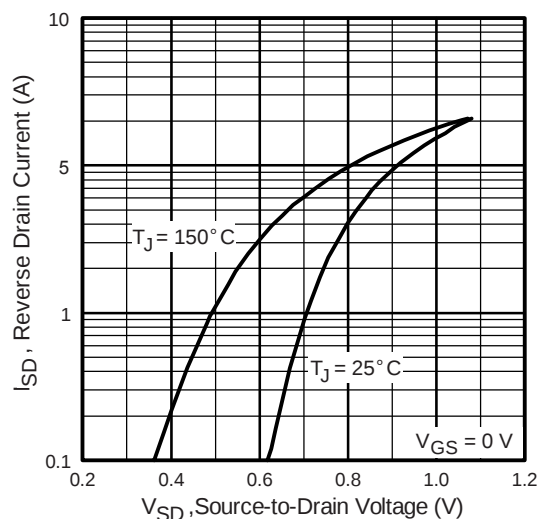


Fig. 7 - Typical Source-Drain Diode Forward Voltage

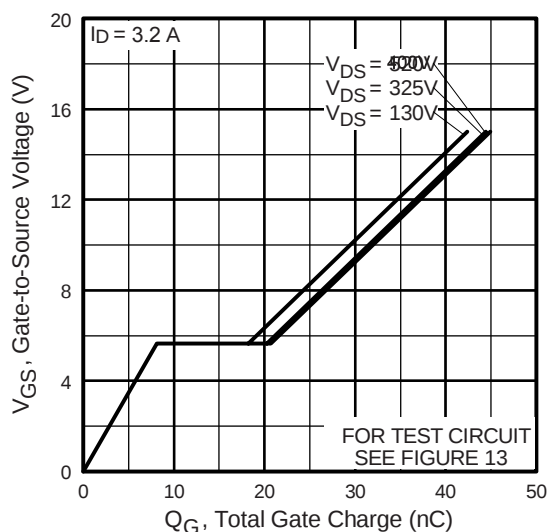


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

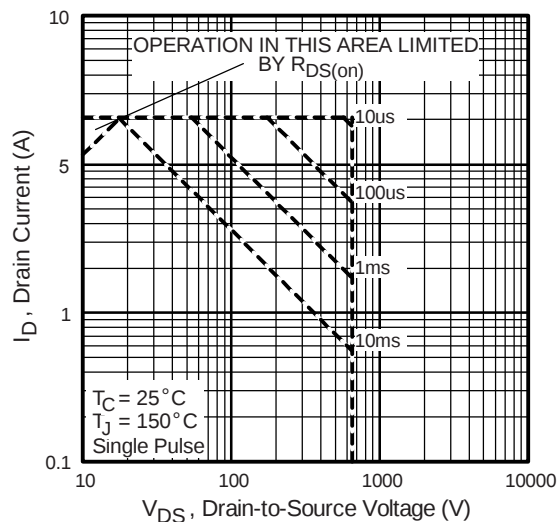


Fig. 8 - Maximum Safe Operating Area

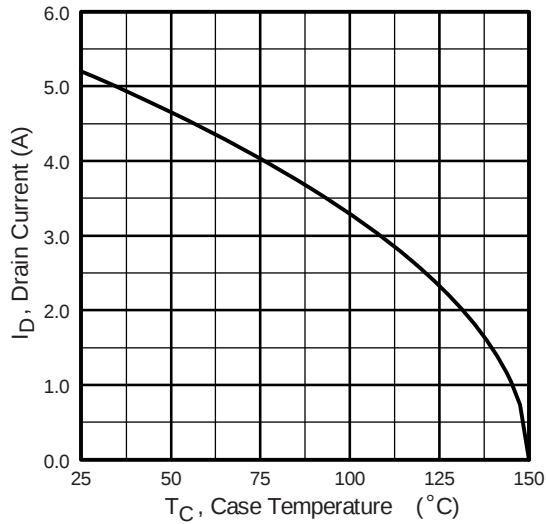


Fig. 9 - Maximum Drain Current vs. Case Temperature



Fig. 10a - Switching Time Test Circuit



Fig. 10b - Switching Time Waveforms

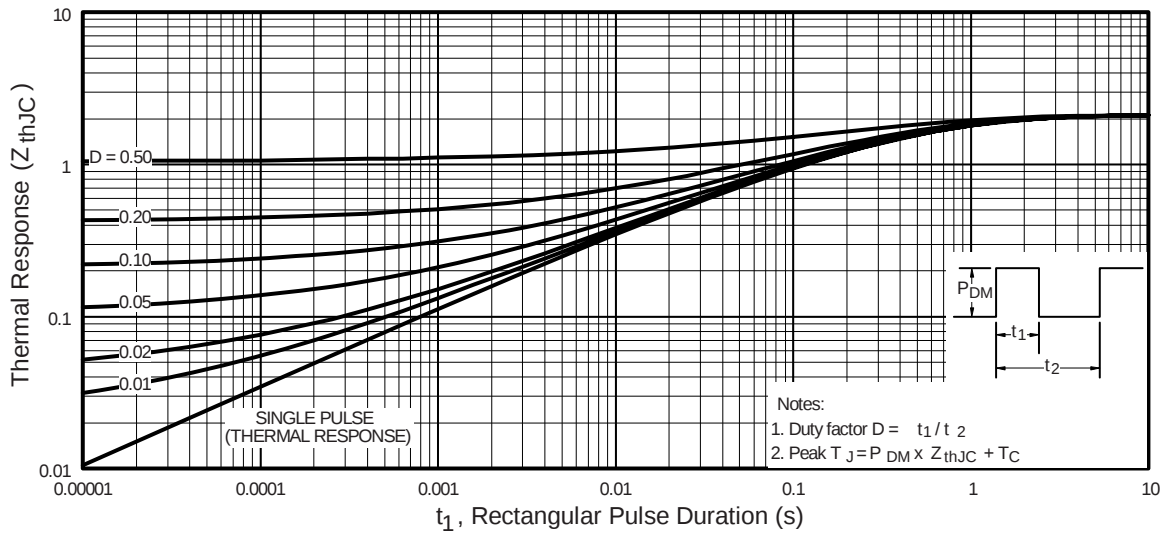


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

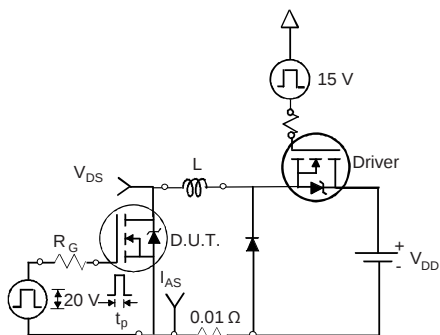


Fig. 12a - Unclamped Inductive Test Circuit



Fig. 12b - Unclamped Inductive Waveforms



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



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

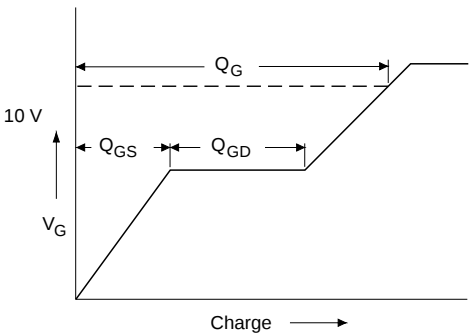


Fig. 13a - Basic Gate Charge Waveform

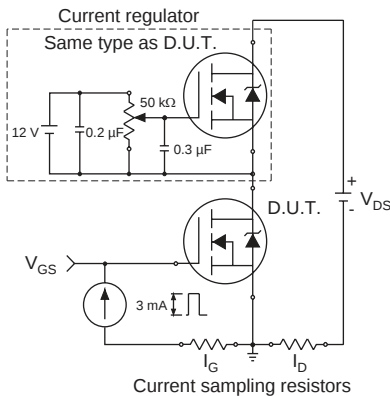


Fig. 13b - Gate Charge Test Circuit

The diagram illustrates a switching circuit for a Device Under Test (D.U.T.). The circuit includes a MOSFET driver stage (labeled ②) with a transformer-coupled gate driver, a MOSFET (labeled ③), and a load inductor (labeled ④). The D.U.T. is represented by a MOSFET symbol (labeled ①) connected to the gate of the MOSFET (labeled ③). The gate of the MOSFET (labeled ③) is connected to the secondary winding of the transformer, which is also connected to the gate of the MOSFET (labeled ①). The drain of the MOSFET (labeled ③) is connected to the load inductor (labeled ④), which is connected to the positive supply voltage  $V_{DD}$ . The source of the MOSFET (labeled ③) is connected to ground. The gate of the MOSFET (labeled ①) is connected to ground through a resistor  $R_G$ . The D.U.T. is represented by a MOSFET symbol (labeled ①) connected to the gate of the MOSFET (labeled ③). The gate of the MOSFET (labeled ③) is connected to the secondary winding of the transformer, which is also connected to the gate of the MOSFET (labeled ①). The drain of the MOSFET (labeled ③) is connected to the load inductor (labeled ④), which is connected to the positive supply voltage  $V_{DD}$ . The source of the MOSFET (labeled ③) is connected to ground. The gate of the MOSFET (labeled ①) is connected to ground through a resistor  $R_G$ .

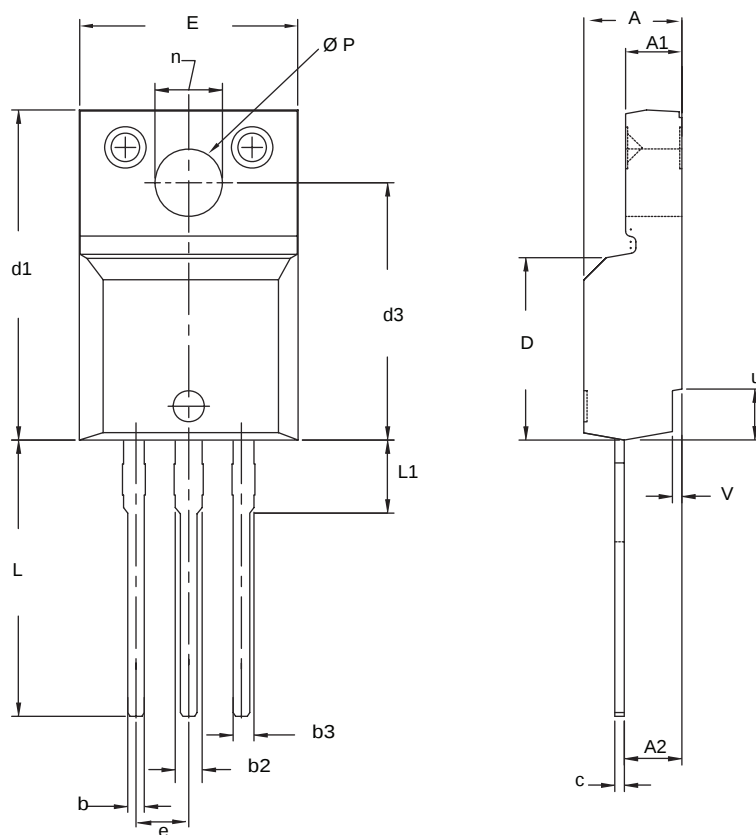
**Circuit layout considerations**

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

**Device characteristics 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



**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  
 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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