



## Power MOSFET

## PRODUCT SUMMARY

|                           |                   |     |
|---------------------------|-------------------|-----|
| $V_{DS}$ (V)              | - 400             |     |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = - 10$ V | 7.0 |
| $Q_g$ (Max.) (nC)         | 13                |     |
| $Q_{gs}$ (nC)             | 3.2               |     |
| $Q_{gd}$ (nC)             | 5.0               |     |
| Configuration             | Single            |     |

## FEATURES

- P-Channel
- Surface Mount (IRFR9310, SiHFR9310)
- Straight Lead (IRFU9310, SiHFU9310)
- Advanced Process Technology
- Fast Switching
- Fully Avalanche Rated
- Material categorization: For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

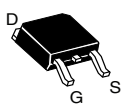
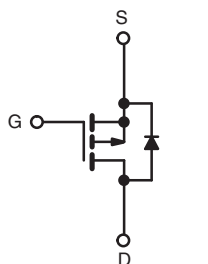
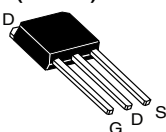


**RoHS**  
COMPLIANT  
HALOGEN  
**FREE**  
Available

## DESCRIPTION

Third generation power MOSFETs from Vishay utilize advanced processing techniques to achieve low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

The DPAK is designed for surface mounting using vapor phase, infrared, or wave soldering techniques. The straight lead version (IRFU/SiHFU series) is for through-hole mounting applications. Power dissipation levels up to 1.5 W are possible in typical surface mount applications.

DPAK  
(TO-252)IPAK  
(TO-251)

P-Channel MOSFET

## ORDERING INFORMATION

| Package                         | DPAK (TO-252) | DPAK (TO-252)                | DPAK (TO-252)               | DPAK (TO-252)                | IPAK (TO-251) |
|---------------------------------|---------------|------------------------------|-----------------------------|------------------------------|---------------|
| Lead (Pb)-free and Halogen-free | SiHFR9310-GE3 | SiHFR9310TRL-GE3             | SiHFR9310TR-GE3             | SiHFR9310TRR-GE3             | SiHFU9310-GE3 |
| Lead (Pb)-free                  | IRFR9310PbF   | IRFR9310TRL-PbF <sup>a</sup> | IRFR9310TR-PbF <sup>a</sup> | IRFR9310TRR-PbF <sup>a</sup> | IRFU9310PbF   |
|                                 | SiHFR9310-E3  | SiHFR9310TL-E3 <sup>a</sup>  | SiHFR9310T-E3 <sup>a</sup>  | SiHFR9310TR-E3 <sup>a</sup>  | SiHFU9310-E3  |

## Note

a. See device orientation.

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

| PARAMETER                                                 | SYMBOL         | LIMIT                     | UNIT                |
|-----------------------------------------------------------|----------------|---------------------------|---------------------|
| Drain-Source Voltage                                      | $V_{DS}$       | - 400                     | V                   |
| Gate-Source Voltage                                       | $V_{GS}$       | $\pm 20$                  |                     |
| Continuous Drain Current                                  | $I_D$          | $T_C = 25^\circ\text{C}$  | A                   |
|                                                           |                | $T_C = 100^\circ\text{C}$ |                     |
| Pulsed Drain Current <sup>a</sup>                         | $I_{DM}$       | - 7.2                     |                     |
| Linear Derating Factor                                    |                | 0.40                      | W/ $^\circ\text{C}$ |
| Single Pulse Avalanche Energy <sup>b</sup>                | $E_{AS}$       | 92                        | mJ                  |
| Repetitive Avalanche Current <sup>a</sup>                 | $I_{AR}$       | - 1.8                     | A                   |
| Repetitive Avalanche Energy <sup>a</sup>                  | $E_{AR}$       | 5.0                       | mJ                  |
| Maximum Power Dissipation                                 | $P_D$          | 50                        | W                   |
| Peak Diode Recovery $dV/dt$ <sup>c</sup>                  | $dV/dt$        | - 24                      | 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> | for 10 s       | 300                       |                     |

## Notes

a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).

b. Starting  $T_J = 25^\circ\text{C}$ ,  $L = 57$  mH,  $R_g = 25\ \Omega$ ,  $I_{AS} = - 1.8$  A (see fig. 12).

c.  $I_{SD} \leq - 1.1$  A,  $dI/dt \leq 450$  A/ $\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150^\circ\text{C}$ .

d. 1.6 mm from case.

**THERMAL RESISTANCE RATINGS**

| PARAMETER                                            | SYMBOL     | MIN. | TYP. | MAX. | UNIT |
|------------------------------------------------------|------------|------|------|------|------|
| Maximum Junction-to-Ambient                          | $R_{thJA}$ | -    | -    | 110  | °C/W |
| Maximum Junction-to-Ambient (PCB Mount) <sup>a</sup> | $R_{thJA}$ | -    | -    | 50   |      |
| Maximum Junction-to-Case (Drain)                     | $R_{thJC}$ | -    | -    | 2.5  |      |

**Note**

a. When mounted on 1" square PCB (FR-4 or G-10 material).

**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                                                                                                                              |                                                                                        | - 400 | -      | -     | 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                                                                                                                                   |                                                                                        | -     | - 0.41 | -     | V/°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> = ± 20 V                                                                                                                                                      |                                                                                        | -     | -      | ± 100 | nA   |
| Zero Gate Voltage Drain Current           | I <sub>DSS</sub>                 | V <sub>DS</sub> = - 400 V, V <sub>GS</sub> = 0 V                                                                                                                              |                                                                                        | -     | -      | - 100 | μA   |
|                                           |                                  | V <sub>DS</sub> = - 320 V, V <sub>GS</sub> = 0 V, T <sub>J</sub> = 125 °C                                                                                                     |                                                                                        | -     | -      | - 500 |      |
| Drain-Source On-State Resistance          | R <sub>DS(on)</sub>              | V <sub>GS</sub> = - 10 V                                                                                                                                                      | I <sub>D</sub> = - 1.1 A <sup>b</sup>                                                  | -     | -      | 7.0   | Ω    |
| Forward Transconductance                  | g <sub>fs</sub>                  | V <sub>DS</sub> = - 50 V, I <sub>D</sub> = - 1.1 A                                                                                                                            |                                                                                        | 0.91  | -      | -     | 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                                                                                                |                                                                                        | -     | 270    | -     | pF   |
| Output Capacitance                        | C <sub>oss</sub>                 |                                                                                                                                                                               |                                                                                        | -     | 50     | -     |      |
| Reverse Transfer Capacitance              | C <sub>rss</sub>                 |                                                                                                                                                                               |                                                                                        | -     | 8.0    | -     |      |
| Total Gate Charge                         | Q <sub>g</sub>                   | V <sub>GS</sub> = - 10 V                                                                                                                                                      | I <sub>D</sub> = - 1.1 A, V <sub>DS</sub> = - 320 V,<br>see fig. 6 and 13 <sup>b</sup> | -     | -      | 13    | nC   |
| Gate-Source Charge                        | Q <sub>gs</sub>                  |                                                                                                                                                                               |                                                                                        | -     | -      | 3.2   |      |
| Gate-Drain Charge                         | Q <sub>gd</sub>                  |                                                                                                                                                                               |                                                                                        | -     | -      | 5.0   |      |
| Turn-On Delay Time                        | t <sub>d(on)</sub>               | V <sub>DD</sub> = - 200 V, I <sub>D</sub> = - 1.1 A,<br>R <sub>g</sub> = 21 Ω, R <sub>D</sub> = 180 Ω, see fig. 10 <sup>b</sup>                                               |                                                                                        | -     | 11     | -     | ns   |
| Rise Time                                 | t <sub>r</sub>                   |                                                                                                                                                                               |                                                                                        | -     | 10     | -     |      |
| Turn-Off Delay Time                       | t <sub>d(off)</sub>              |                                                                                                                                                                               |                                                                                        | -     | 25     | -     |      |
| Fall Time                                 | t <sub>f</sub>                   |                                                                                                                                                                               |                                                                                        | -     | 24     | -     |      |
| Internal Drain Inductance                 | L <sub>D</sub>                   | Between lead,<br>6 mm (0.25") from<br>package and center of<br>die contact <sup>c</sup>  |                                                                                        | -     | 4.5    | -     | nH   |
| Internal Source Inductance                | L <sub>S</sub>                   |                                                                                                                                                                               |                                                                                        | -     | 7.5    | -     |      |
| Drain-Source Body Diode Characteristics   |                                  |                                                                                                                                                                               |                                                                                        |       |        |       |      |
| Continuous Source-Drain Diode Current     | I <sub>S</sub>                   | MOSFET symbol<br>showing the<br>integral reverse<br>p - n junction diode                 |                                                                                        | -     | -      | - 1.9 | A    |
| Pulsed Diode Forward Current <sup>a</sup> | I <sub>SM</sub>                  |                                                                                                                                                                               |                                                                                        | -     | -      | - 7.6 |      |
| Body Diode Voltage                        | V <sub>SD</sub>                  | T <sub>J</sub> = 25 °C, I <sub>S</sub> = - 1.1 A, V <sub>GS</sub> = 0 V <sup>b</sup>                                                                                          |                                                                                        | -     | -      | - 4.0 | V    |
| Body Diode Reverse Recovery Time          | t <sub>rr</sub>                  | T <sub>J</sub> = 25 °C, I <sub>F</sub> = -1.1 A, dI/dt = 100 A/μs <sup>b</sup>                                                                                                |                                                                                        | -     | 170    | 260   | ns   |
| Body Diode Reverse Recovery Charge        | Q <sub>rr</sub>                  |                                                                                                                                                                               |                                                                                        | -     | 640    | 960   | nC   |
| 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. This is applied for IPAK,  $L_S$  of DPAK is measured between lead and center of die contact.



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

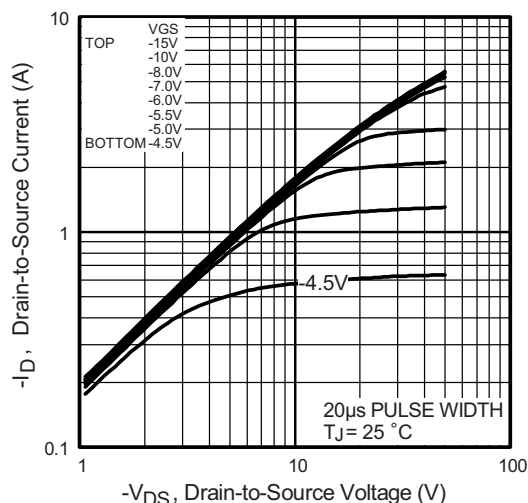


Fig. 1 - Typical Output Characteristics

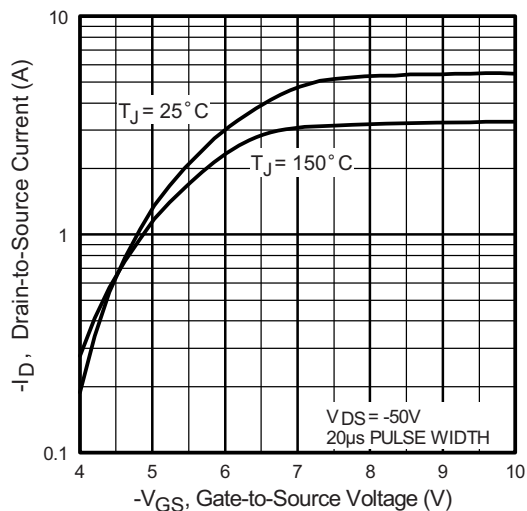


Fig. 3 - Typical Transfer Characteristics

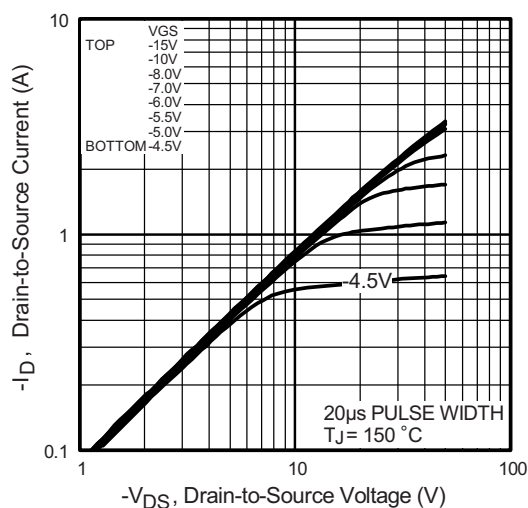


Fig. 2 - Typical Output Characteristics

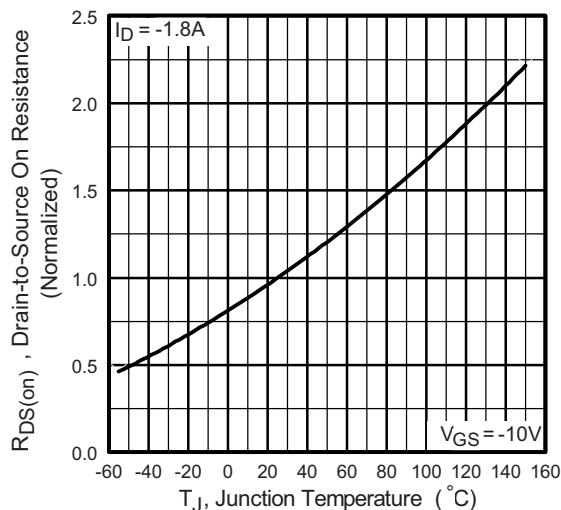
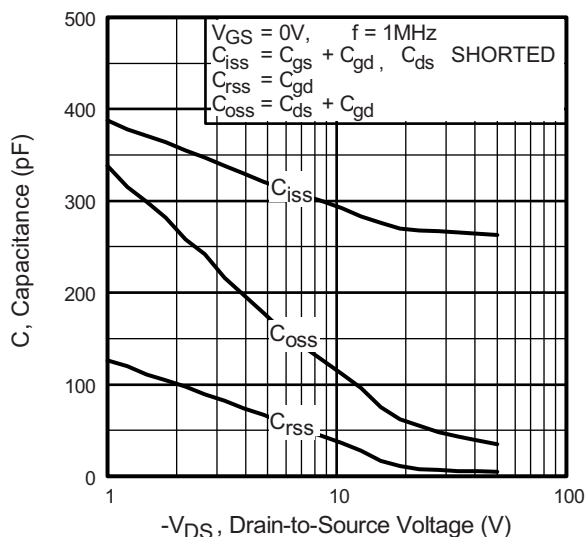
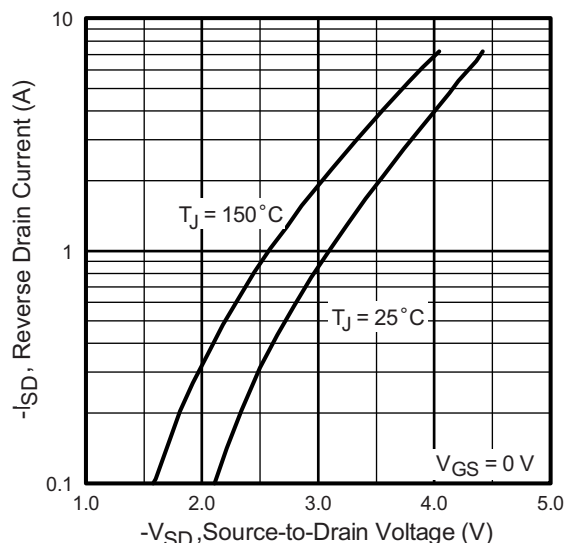
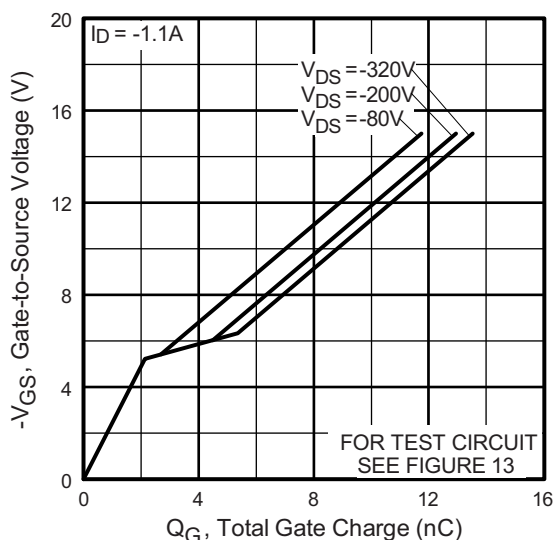
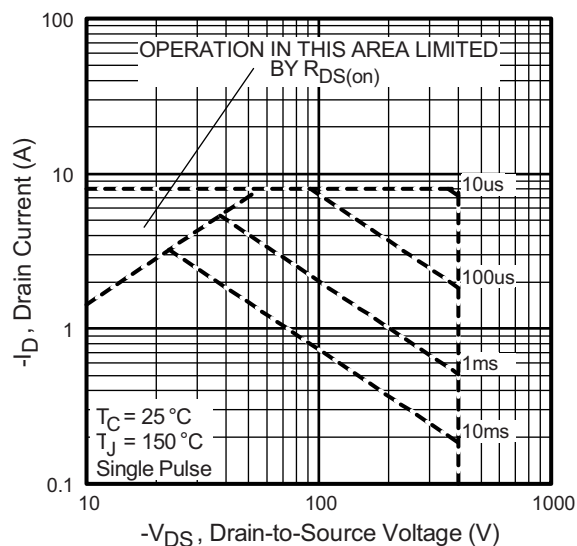
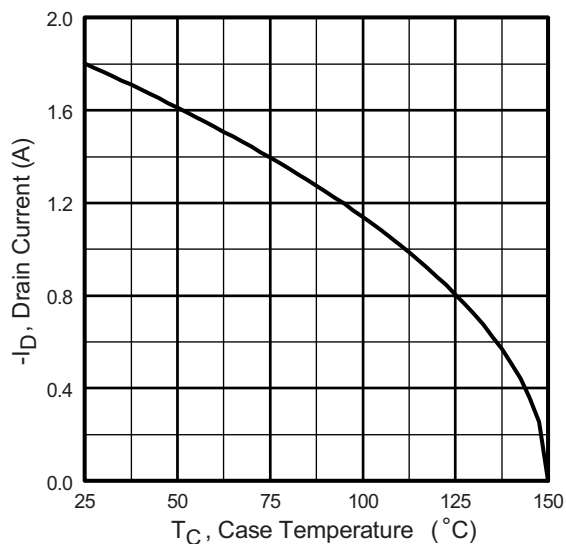
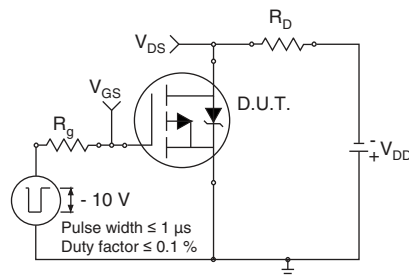


Fig. 4 - Normalized On-Resistance vs. Temperature

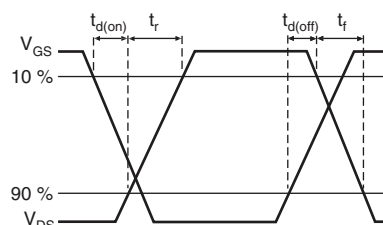

**Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage**

**Fig. 7 - Typical Source-Drain Diode Forward Voltage**

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

**Fig. 8 - Maximum Safe Operating Area**



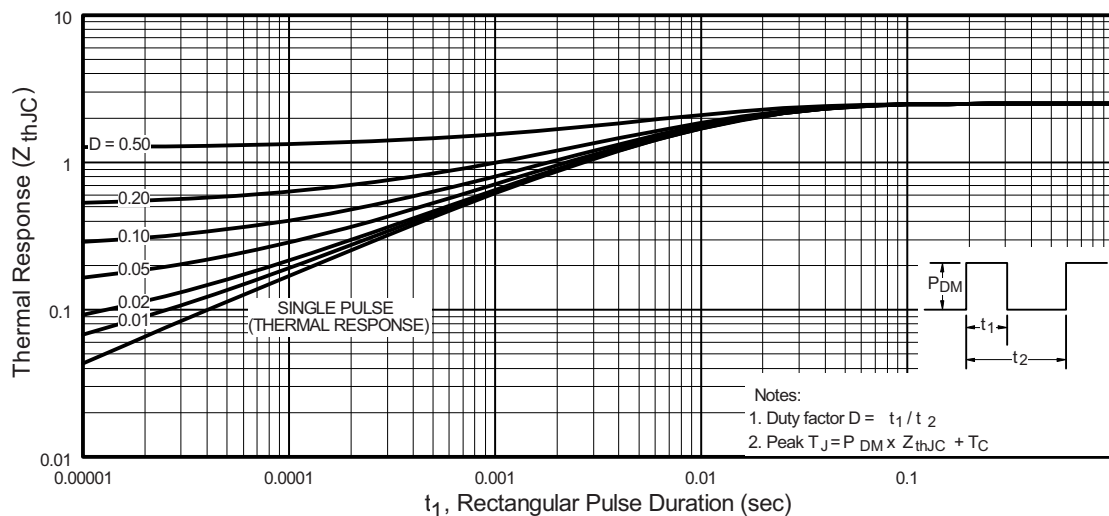
**Fig. 9 - Maximum Drain Current vs. Case Temperature**



**Fig. 10a - Switching Time Test Circuit**



**Fig. 10b - Switching Time Waveforms**



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

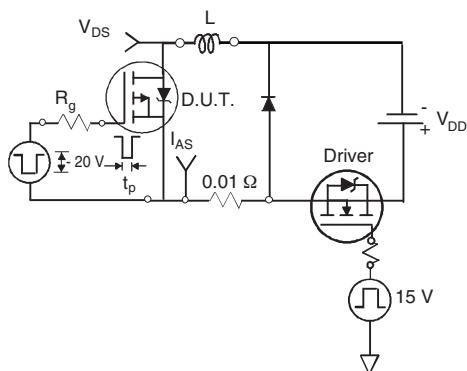


Fig. 12a - Unclamped Inductive Test Circuit

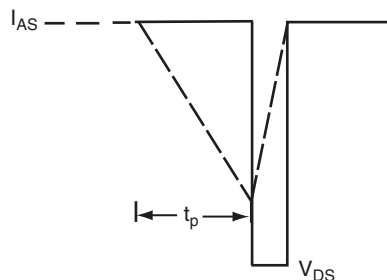


Fig. 12b - Unclamped Inductive Waveforms

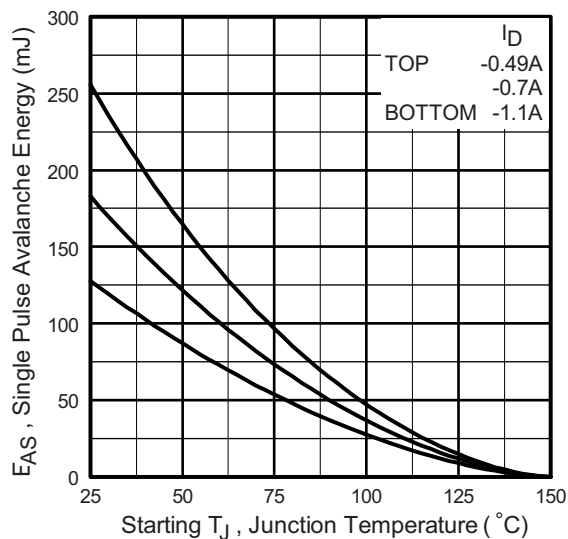


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

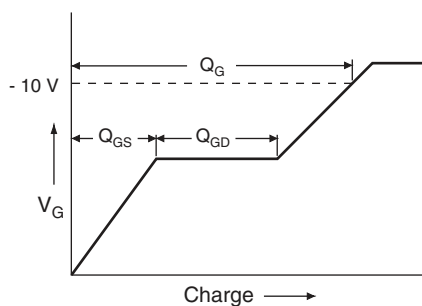


Fig. 13a - Basic Gate Charge Waveform

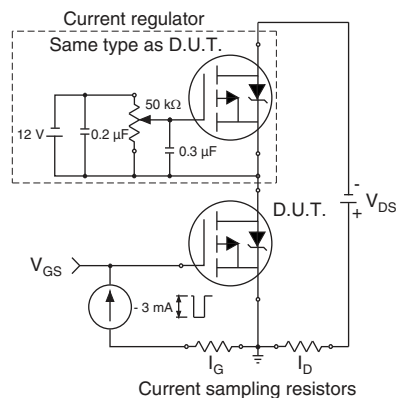


Fig. 13b - Gate Charge Test Circuit



**Fig. 14 - For P-Channel**

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## 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                                           | 4.10        | -     | 0.161     | -     |
| 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                                           | 1.01        | 1.52  | 0.040     | 0.060 |
| ECN: T16-0236-Rev. P, 16-May-16<br>DWG: 5347 |             |       |           |       |

### Notes

- Dimension L3 is for reference only.

## TO-251AA (HIGH VOLTAGE)



| DIM. | MILLIMETERS |      | INCHES |       |
|------|-------------|------|--------|-------|
|      | MIN.        | MAX. | MIN.   | MAX.  |
| A    | 2.18        | 2.39 | 0.086  | 0.094 |
| A1   | 0.89        | 1.14 | 0.035  | 0.045 |
| b    | 0.64        | 0.89 | 0.025  | 0.035 |
| b1   | 0.65        | 0.79 | 0.026  | 0.031 |
| b2   | 0.76        | 1.14 | 0.030  | 0.045 |
| b3   | 0.76        | 1.04 | 0.030  | 0.041 |
| b4   | 4.95        | 5.46 | 0.195  | 0.215 |
| c    | 0.46        | 0.61 | 0.018  | 0.024 |
| c1   | 0.41        | 0.56 | 0.016  | 0.022 |
| c2   | 0.46        | 0.86 | 0.018  | 0.034 |
| D    | 5.97        | 6.22 | 0.235  | 0.245 |

| DIM. | MILLIMETERS |      | INCHES   |       |
|------|-------------|------|----------|-------|
|      | MIN.        | MAX. | MIN.     | MAX.  |
| D1   | 5.21        | -    | 0.205    | -     |
| E    | 6.35        | 6.73 | 0.250    | 0.265 |
| E1   | 4.32        | -    | 0.170    | -     |
| e    | 2.29 BSC    |      | 2.29 BSC |       |
| L    | 8.89        | 9.65 | 0.350    | 0.380 |
| L1   | 1.91        | 2.29 | 0.075    | 0.090 |
| L2   | 0.89        | 1.27 | 0.035    | 0.050 |
| L3   | 1.14        | 1.52 | 0.045    | 0.060 |
| θ1   | 0°          | 15°  | 0°       | 15°   |
| θ2   | 25°         | 35°  | 25°      | 35°   |

ECN: S-82111-Rev. A, 15-Sep-08  
DWG: 5968

### Notes

1. Dimensioning and tolerancing per ASME Y14.5M-1994.
2. Dimension are shown in inches and millimeters.
3. Dimension D and E do not include mold flash. Mold flash shall not exceed 0.13 mm (0.005") per side. These dimensions are measured at the outermost extremes of the plastic body.
4. Thermal pad contour optional with dimensions b4, L2, E1 and D1.
5. Lead dimension uncontrolled in L3.
6. Dimension b1, b3 and c1 apply to base metal only.
7. Outline conforms to JEDEC outline TO-251AA.

## RECOMMENDED MINIMUM PADS FOR DPAK (TO-252)



Recommended Minimum Pads  
Dimensions in Inches/(mm)

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