

## Power MOSFET



RoHS  
COMPLIANT  
HALOGEN  
**FREE**  
Available

| PRODUCT SUMMARY           |                               |
|---------------------------|-------------------------------|
| $V_{DS}$ (V)              | 60                            |
| $R_{DS(on)}$ ( $\Omega$ ) | $V_{GS} = 10\text{ V}$   0.10 |
| $Q_g$ (Max.) (nC)         | 25                            |
| $Q_{gs}$ (nC)             | 5.8                           |
| $Q_{gd}$ (nC)             | 11                            |
| Configuration             | Single                        |

### FEATURES

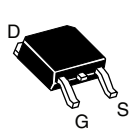
- Dynamic  $dV/dt$  Rating
- Surface Mount (IRFR024, SiHFR024)
- Straight Lead (IRFU024, SiHFU024)
- Available in Tape and Reel
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements
- Material categorization: For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

### DESCRIPTION

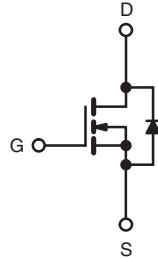
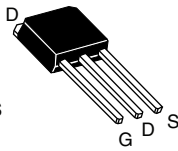
Third generation power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

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)



N-Channel MOSFET

| ORDERING INFORMATION            |               |                           |                 |               |
|---------------------------------|---------------|---------------------------|-----------------|---------------|
| Package                         | DPAK (TO-252) | DPAK (TO-252)             | DPAK (TO-252)   | IPAK (TO-251) |
| Lead (Pb)-free and Halogen-free | SiHFR024-GE3  | SiHFR024TR-GE3            | SiHFR024TRL-GE3 | SiHFU024-GE3  |
| Lead (Pb)-free                  | IRFR024PbF    | IRFR024TRPbF <sup>a</sup> | -               | IRFU024PbF    |
|                                 | SiHFR024-E3   | SiHFR024T-E3 <sup>a</sup> | -               | SiHFU024-E3   |

#### Note

- a. See device orientation.

| ABSOLUTE MAXIMUM RATINGS ( $T_C = 25\text{ }^\circ\text{C}$ , unless otherwise noted) |                                  |                                   |                |               |                     |
|---------------------------------------------------------------------------------------|----------------------------------|-----------------------------------|----------------|---------------|---------------------|
| PARAMETER                                                                             |                                  |                                   | SYMBOL         | LIMIT         | UNIT                |
| Drain-Source Voltage                                                                  |                                  |                                   | $V_{DS}$       | 60            | V                   |
| Gate-Source Voltage                                                                   |                                  |                                   | $V_{GS}$       | $\pm 20$      |                     |
| Continuous Drain Current                                                              | $V_{GS}$ at 10 V                 | $T_C = 25\text{ }^\circ\text{C}$  | $I_D$          | 14            | A                   |
|                                                                                       |                                  | $T_C = 100\text{ }^\circ\text{C}$ |                | 9.0           |                     |
| Pulsed Drain Current <sup>a</sup>                                                     |                                  |                                   | $I_{DM}$       | 56            | W/ $^\circ\text{C}$ |
| Linear Derating Factor                                                                |                                  |                                   |                | 0.33          |                     |
| Linear Derating Factor (PCB Mount) <sup>e</sup>                                       |                                  |                                   |                | 0.020         |                     |
| Single Pulse Avalanche Energy <sup>b</sup>                                            |                                  |                                   | $E_{AS}$       | 91            | mJ                  |
| Maximum Power Dissipation                                                             | $T_C = 25\text{ }^\circ\text{C}$ |                                   | $P_D$          | 42            | W                   |
|                                                                                       | $T_A = 25\text{ }^\circ\text{C}$ |                                   |                | 2.5           |                     |
| Peak Diode Recovery $dV/dt$ <sup>c</sup>                                              |                                  |                                   | $dV/dt$        | 5.5           | 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                         |                                   |                | 260           |                     |

#### Notes

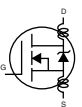

- Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
- $V_{DD} = 25\text{ V}$ , starting  $T_J = 25\text{ }^\circ\text{C}$ ,  $L = 541\text{ }\mu\text{H}$ ,  $R_g = 25\text{ }\Omega$ ,  $I_{AS} = 14\text{ A}$  (see fig. 12).
- $I_{SD} \leq 17\text{ A}$ ,  $dI/dt \leq 110\text{ A}/\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150\text{ }^\circ\text{C}$ .
- 1.6 mm from case.
- When mounted on 1" square PCB (FR-4 or G-10 material).



| 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)                     | $R_{thJC}$ | -    | -    | 3.0  |      |  |

**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          |
| <b>Static</b>                                                               |                     |                                                                                                                                                         |                                                                            |      |       |           |               |
| Drain-Source Breakdown Voltage                                              | $V_{DS}$            | $V_{GS} = 0\text{ V}, I_D = 250\text{ }\mu\text{A}$                                                                                                     |                                                                            | 60   | -     | -         | V             |
| $V_{DS}$ Temperature Coefficient                                            | $\Delta V_{DS}/T_J$ | Reference to $25\text{ }^\circ\text{C}, I_D = 1\text{ mA}$                                                                                              |                                                                            | -    | 0.073 | -         | V/°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                                                         | $I_{GSS}$           | $V_{GS} = \pm 20\text{ V}$                                                                                                                              |                                                                            | -    | -     | $\pm 100$ | nA            |
| Zero Gate Voltage Drain Current                                             | $I_{DSS}$           | $V_{DS} = 60\text{ V}, V_{GS} = 0\text{ V}$                                                                                                             |                                                                            | -    | -     | 25        | $\mu\text{A}$ |
|                                                                             |                     | $V_{DS} = 48\text{ V}, V_{GS} = 0\text{ V}, T_J = 125\text{ }^\circ\text{C}$                                                                            |                                                                            | -    | -     | 250       |               |
| Drain-Source On-State Resistance                                            | $R_{DS(on)}$        | $V_{GS} = 10\text{ V}$                                                                                                                                  | $I_D = 8.4\text{ A}^b$                                                     | -    | -     | 0.10      | $\Omega$      |
| Forward Transconductance                                                    | $g_{fs}$            | $V_{DS} = 25\text{ V}, I_D = 8.4\text{ A}^b$                                                                                                            |                                                                            | 6.2  | -     | -         | S             |
| <b>Dynamic</b>                                                              |                     |                                                                                                                                                         |                                                                            |      |       |           |               |
| Input Capacitance                                                           | $C_{iss}$           | $V_{GS} = 0\text{ V}, V_{DS} = 25\text{ V}, f = 1.0\text{ MHz}$ , see fig. 5                                                                            |                                                                            | -    | 640   | -         | pF            |
| Output Capacitance                                                          | $C_{oss}$           |                                                                                                                                                         |                                                                            | -    | 360   | -         |               |
| Reverse Transfer Capacitance                                                | $C_{rss}$           |                                                                                                                                                         |                                                                            | -    | 79    | -         |               |
| Total Gate Charge                                                           | $Q_g$               | $V_{GS} = 10\text{ V}$                                                                                                                                  | $I_D = 17\text{ A}, V_{DS} = 48\text{ V}$ , see fig. 6 and 13 <sup>b</sup> | -    | -     | 25        | nC            |
| Gate-Source Charge                                                          | $Q_{gs}$            |                                                                                                                                                         |                                                                            | -    | -     | 5.8       |               |
| Gate-Drain Charge                                                           | $Q_{gd}$            |                                                                                                                                                         |                                                                            | -    | -     | 11        |               |
| Turn-On Delay Time                                                          | $t_{d(on)}$         | $V_{DD} = 30\text{ V}, I_D = 17\text{ A}, R_G = 18\text{ }\Omega, R_D = 1.7\text{ }\Omega$ , see fig. 10 <sup>b</sup>                                   |                                                                            | -    | 13    | -         | ns            |
| Rise Time                                                                   | $t_r$               |                                                                                                                                                         |                                                                            | -    | 58    | -         |               |
| Turn-Off Delay Time                                                         | $t_{d(off)}$        |                                                                                                                                                         |                                                                            | -    | 25    | -         |               |
| Fall Time                                                                   | $t_f$               |                                                                                                                                                         |                                                                            | -    | 42    | -         |               |
| Internal Drain Inductance                                                   | $L_D$               | Between lead, 6 mm (0.25") from package and center of die contact  |                                                                            | -    | 4.5   | -         | nH            |
| Internal Source Inductance                                                  | $L_S$               |                                                                                                                                                         |                                                                            | -    | 7.5   | -         |               |
| <b>Drain-Source Body Diode Characteristics</b>                              |                     |                                                                                                                                                         |                                                                            |      |       |           |               |
| Continuous Source-Drain Diode Current                                       | $I_S$               | MOSFET symbol showing the integral reverse p - n junction diode    |                                                                            | -    | -     | 14        | A             |
| Pulsed Diode Forward Current <sup>a</sup>                                   | $I_{SM}$            |                                                                                                                                                         |                                                                            | -    | -     | 56        |               |
| Body Diode Voltage                                                          | $V_{SD}$            | $T_J = 25\text{ }^\circ\text{C}, I_S = 14\text{ A}, V_{GS} = 0\text{ V}^b$                                                                              |                                                                            | -    | -     | 1.5       | V             |
| Body Diode Reverse Recovery Time                                            | $t_{rr}$            | $T_J = 25\text{ }^\circ\text{C}, I_F = 17\text{ A}, di/dt = 100\text{ A}/\mu\text{s}^b$                                                                 |                                                                            | -    | 88    | 180       | ns            |
| Body Diode Reverse Recovery Charge                                          | $Q_{rr}$            |                                                                                                                                                         |                                                                            | -    | 0.29  | 0.64      |               |
| 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  $\leq 2\text{ }\%$ .



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

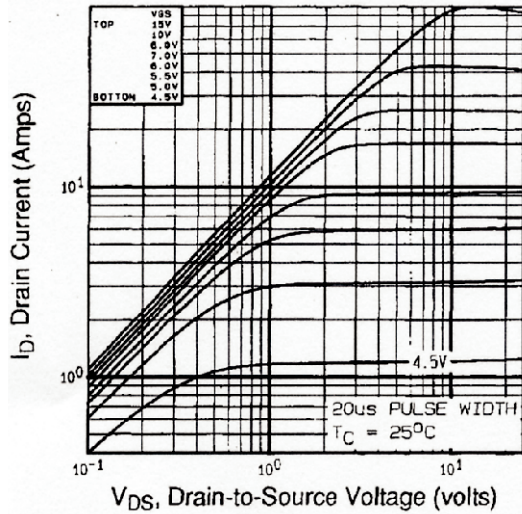


Fig. 1 - Typical Output Characteristics,  $T_C = 25\text{ }^\circ\text{C}$

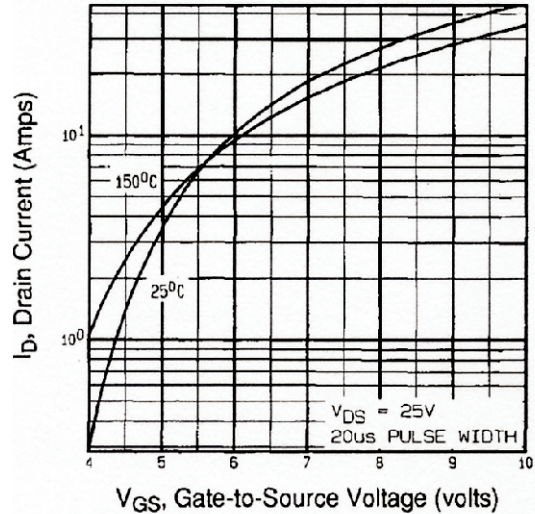


Fig. 3 - Typical Transfer Characteristics

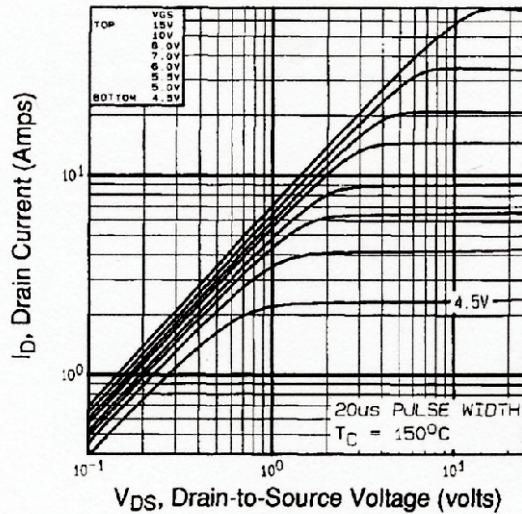


Fig. 2 - Typical Output Characteristics,  $T_C = 150\text{ }^\circ\text{C}$

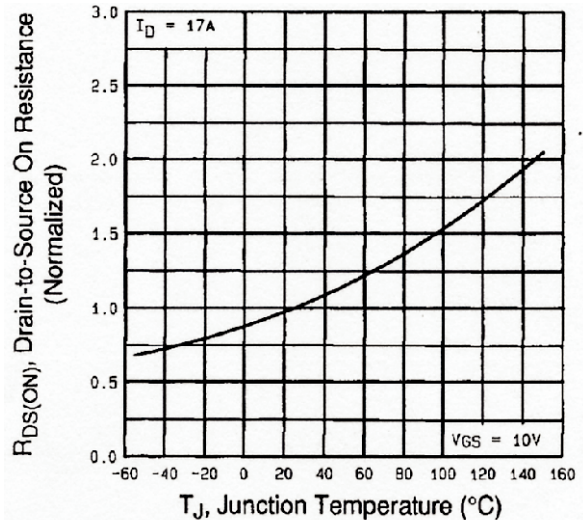


Fig. 4 - Normalized On-Resistance vs. Temperature

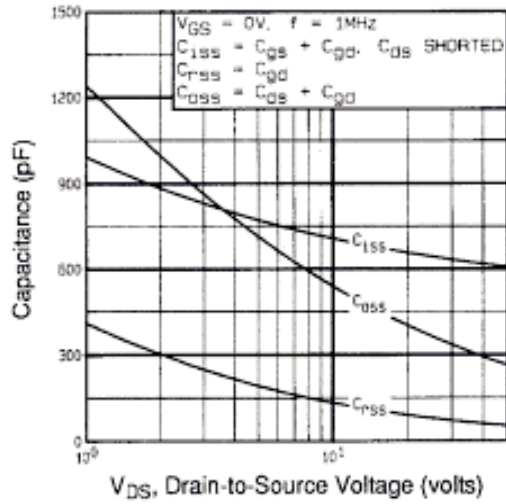


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

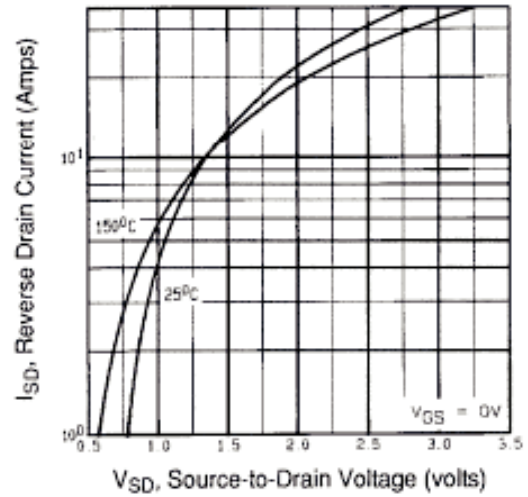


Fig. 7 - Typical Source-Drain Diode Forward Voltage

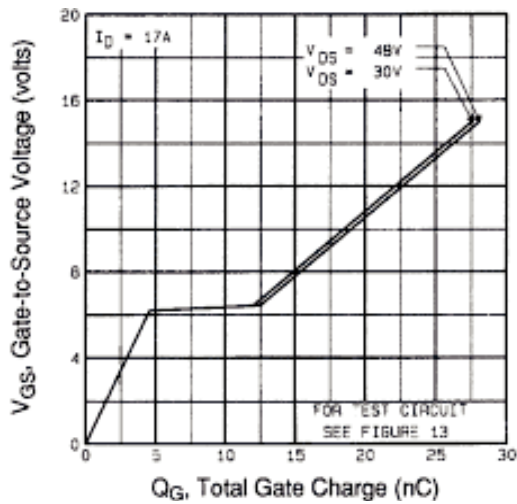


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

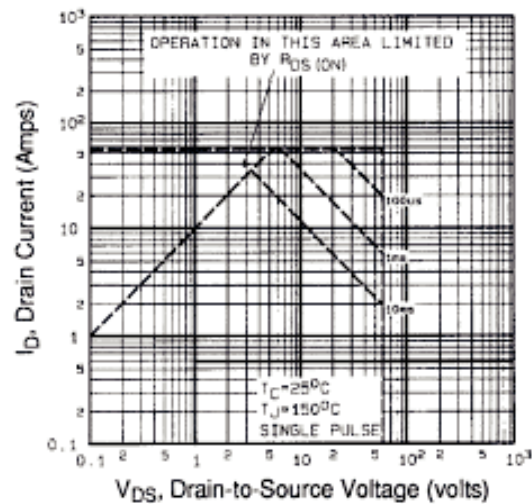


Fig. 8 - Maximum Safe Operating Area



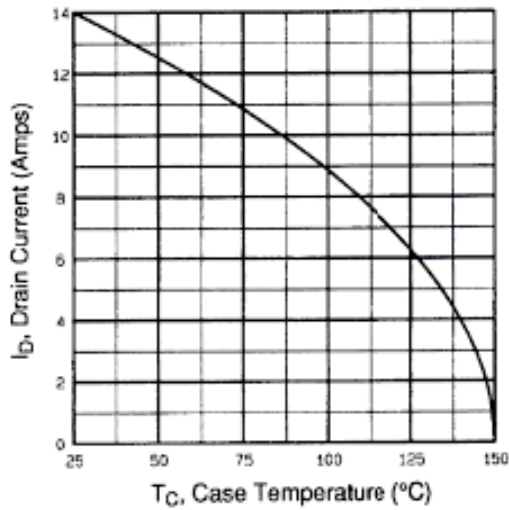


Fig. 9 - Maximum Drain Current vs. Case Temperature

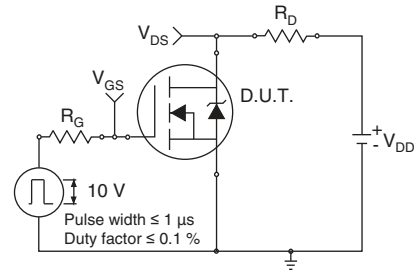


Fig. 10a - Switching Time Test Circuit

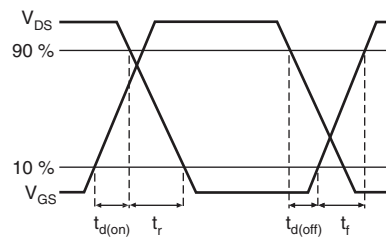


Fig. 10b - Switching Time Waveforms

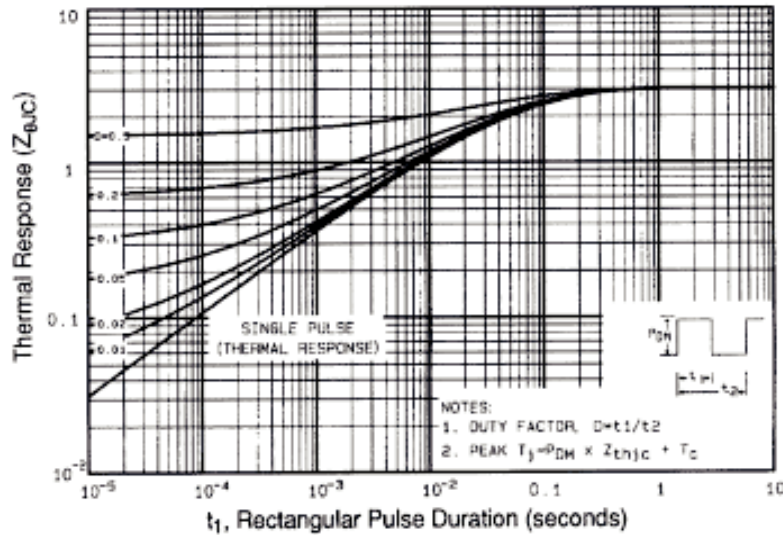
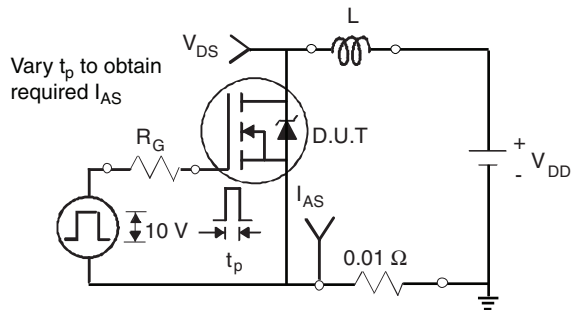
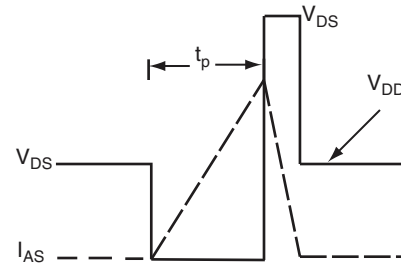
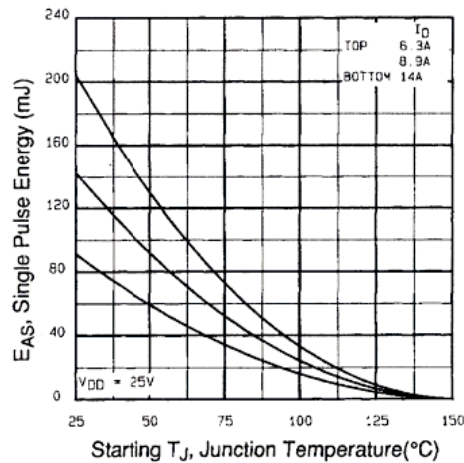
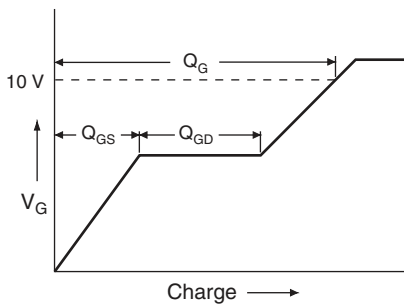
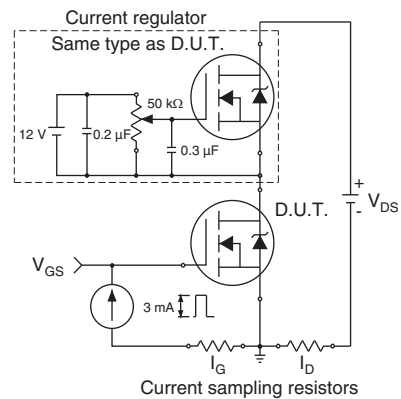


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case


**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**

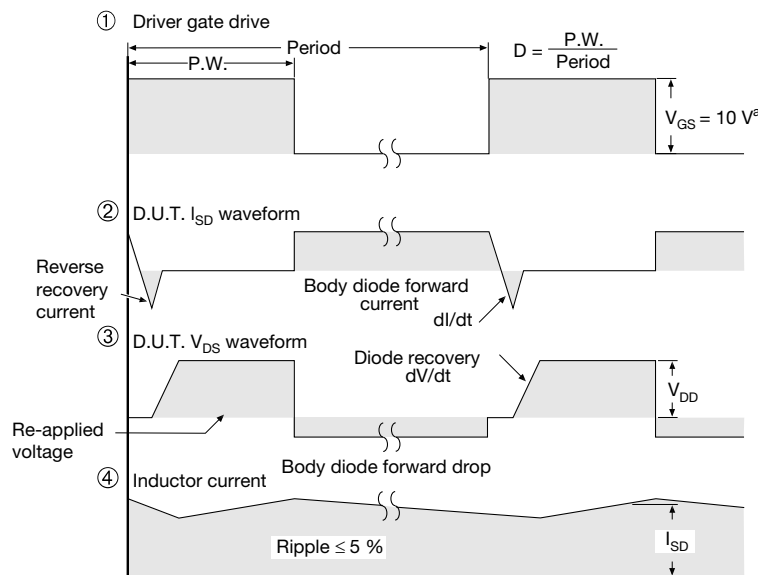
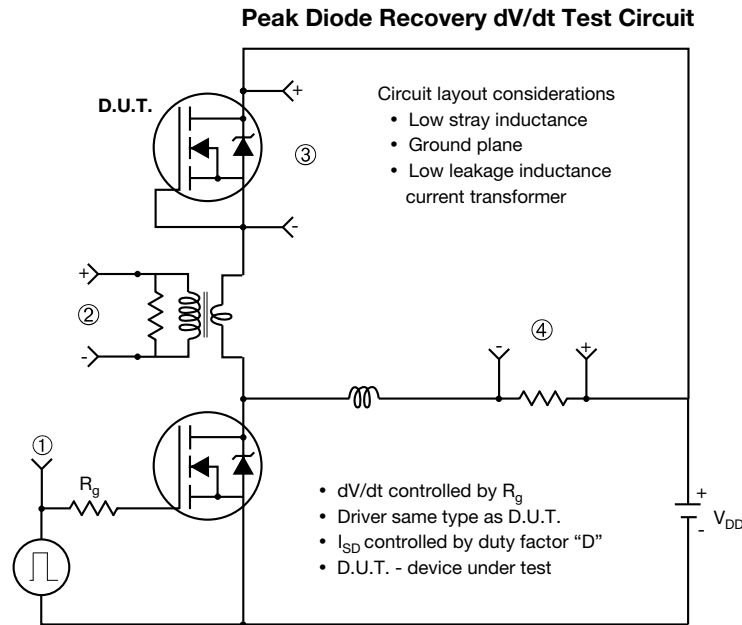


Fig. 14 - For N-Channel

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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 |
| theta1 | 0'          | 15'  | 0'       | 15'   |
| theta2 | 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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