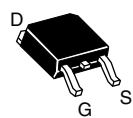
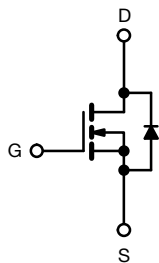
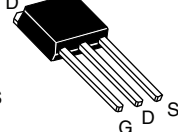


## Power MOSFET

**PAK (TO-252)**

**IPAK (TO-251)**


N-Channel MOSFET

### 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)



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

### 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 PAK 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.

### 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                 |      |

### ORDERING INFORMATION

| PACKAGE                         | PAK (TO-252) | PAK (TO-252)              | PAK (TO-252)    | PAK (TO-252)                   | IPAK (TO-251) |
|---------------------------------|--------------|---------------------------|-----------------|--------------------------------|---------------|
| Lead (Pb)-free and halogen-free | SiHFR024-GE3 | SiHFR024TR-GE3            | SiHFR024TRL-GE3 | IRFR024TRPbF-BE3 <sup>ab</sup> | SiHFU024-GE3  |
| Lead (Pb)-free                  | IRFR024PbF   | IRFR024TRPbF <sup>a</sup> | IRFR024TRLPbF   | IRFR024TRRPbF <sup>a</sup>     | IRFU024PbF    |

#### Notes

- a. See device orientation  
b. “-BE3” denotes alternate manufacturing location

### 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 | $T_C = 25\text{ }^\circ\text{C}$  | A                   |
|                                                           |                  | $T_C = 100\text{ }^\circ\text{C}$ |                     |
| Pulsed drain current <sup>a</sup>                         | $I_{DM}$         | 56                                |                     |
| Linear derating factor                                    |                  | 0.33                              | W/ $^\circ\text{C}$ |
| Linear derating factor (PCB mount) <sup>e</sup>           |                  | 0.020                             |                     |
| Single pulse avalanche energy <sup>b</sup>                | $E_{AS}$         | 91                                | mJ                  |
| Maximum power dissipation                                 | $P_D$            | $T_C = 25\text{ }^\circ\text{C}$  | W                   |
| Maximum power dissipation (PCB mount) <sup>e</sup>        |                  | $T_A = 25\text{ }^\circ\text{C}$  |                     |
| 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

- a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11)  
b.  $V_{DD} = 25\text{ V}$ , 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)  
c.  $I_{SD} \leq 17\text{ A}$ ,  $dI/dt \leq 110\text{ A}/\mu\text{s}$ ,  $V_{DD} \leq V_{DS}$ ,  $T_J \leq 150\text{ }^\circ\text{C}$   
d. 1.6 mm from case  
e. 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                |
|-------------------------------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------|-------|-----------|---------------------|
| Static                                    |                     |                                                                                                                                   |                                                                                  |      |       |           |                     |
| 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/ $^\circ\text{C}$ |
| Gate-source threshold voltage             | $V_{GS(th)}$        | $V_{DS} = V_{GS}$ , $I_D = 250\text{ }\mu\text{A}$                                                                                |                                                                                  | 2.0  | -     | 4.0       | V                   |
| Gate-source leakage                       | $I_{GSS}$           | $V_{GS} = \pm 20\text{ V}$                                                                                                        |                                                                                  | -    | -     | $\pm 100$ | 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                   |
| Dynamic                                   |                     |                                                                                                                                   |                                                                                  |      |       |           |                     |
| Input capacitance                         | $C_{iss}$           | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 25\text{ V}$ ,<br>$f = 1.0\text{ MHz}$ , see fig. 5                                          |                                                                                  | -    | 640   | -         | pF                  |
| Output capacitance                        | $C_{oss}$           |                                                                                                                                   |                                                                                  | -    | 360   | -         |                     |
| Reverse transfer capacitance              | $C_{rss}$           |                                                                                                                                   |                                                                                  | -    | 79    | -         |                     |
| Total gate charge                         | $Q_g$               | $V_{GS} = 10\text{ V}$                                                                                                            | $I_D = 17\text{ A}$ , $V_{DS} = 48\text{ V}$ ,<br>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                        | $t_{d(on)}$         | $V_{DD} = 30\text{ V}$ , $I_D = 17\text{ A}$ ,<br>$R_G = 18\text{ }\Omega$ , $R_D = 1.7\text{ }\Omega$ , 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,<br>6 mm (0.25") from<br>package and center of<br>die contact                                                        |                                                                                  | -    | 4.5   | -         | nH                  |
| Internal source inductance                | $L_S$               |                                                                                                                                   |                                                                                  | -    | 7.5   | -         |                     |
| Drain-source body diode characteristics   |                     |                                                                                                                                   |                                                                                  |      |       |           |                     |
| Continuous source-drain diode current     | $I_S$               | MOSFET symbol<br>showing the<br>integral reverse<br>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      | $\mu\text{C}$       |
| Forward turn-on time                      | $t_{on}$            | Intrinsic turn-on time is negligible (turn-on is dominated by $L_S$ and $L_D$ )                                                   |                                                                                  |      |       |           |                     |

**Notes**

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

b. Pulse width  $\leq 300\text{ }\mu\text{s}$ ; duty cycle  $\leq 2\%$



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

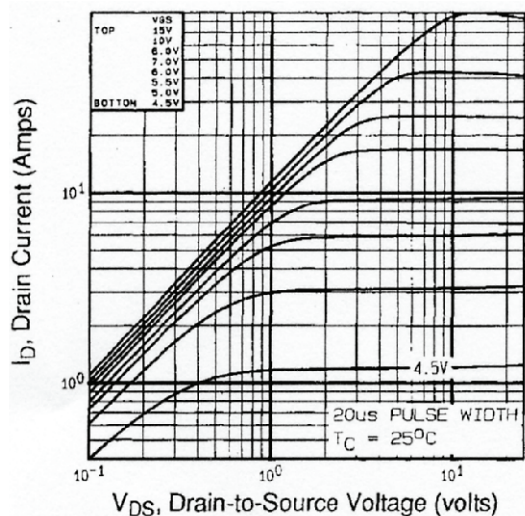


Fig. 1 - Typical Output Characteristics,  $T_C = 25^\circ C$

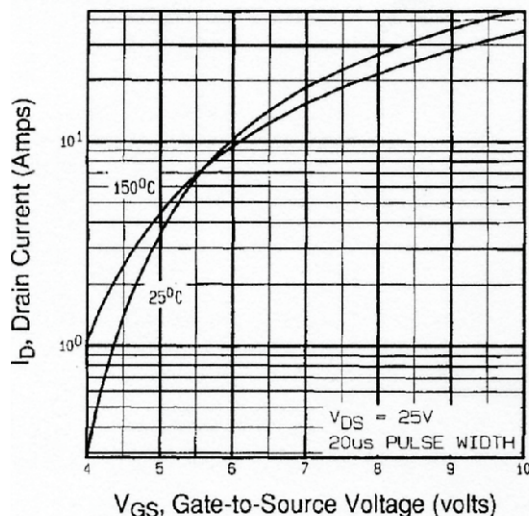


Fig. 2 - Typical Transfer Characteristics

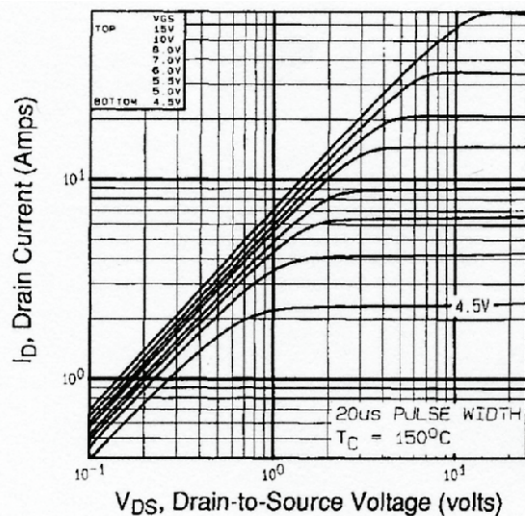


Fig. 1 - Typical Output Characteristics,  $T_C = 150^\circ C$

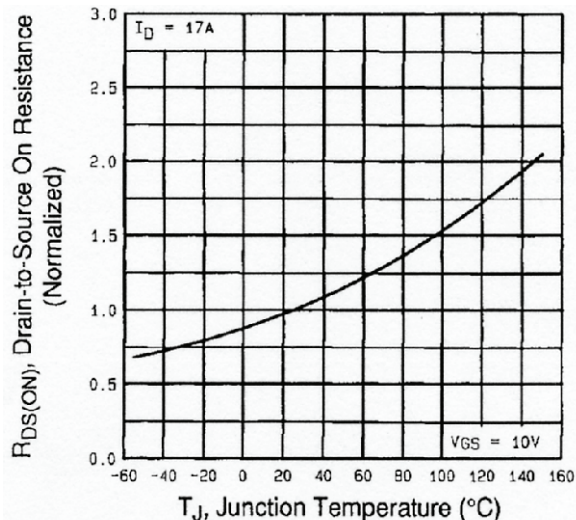
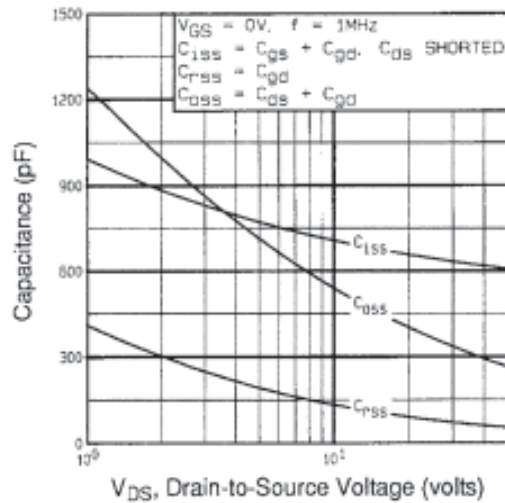
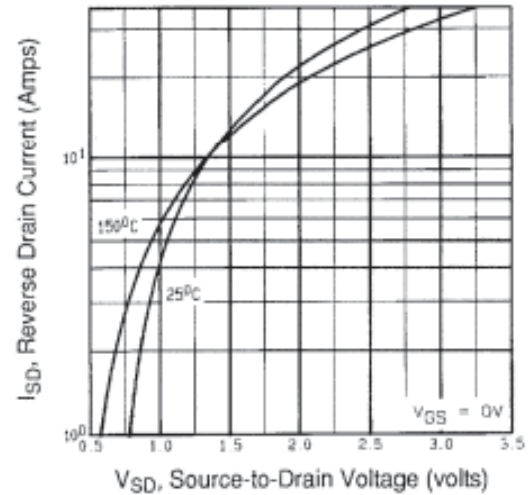
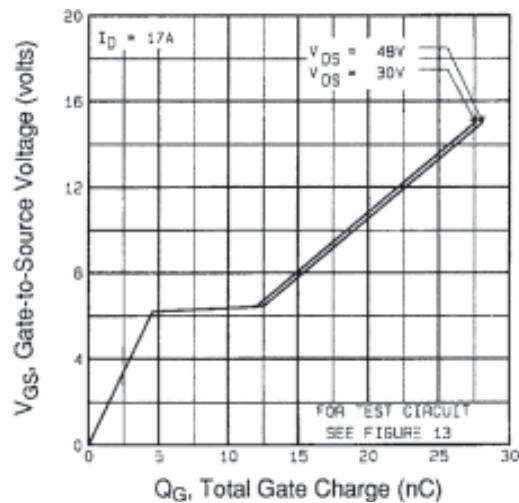
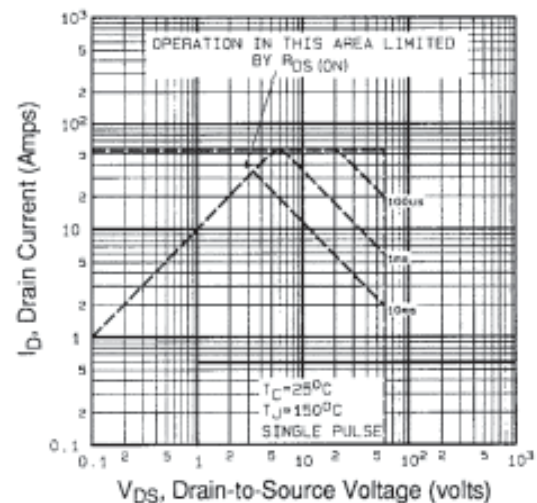


Fig. 3 - Normalized On-Resistance vs. Temperature


**Fig. 4 - Typical Capacitance vs. Drain-to-Source Voltage**

**Fig. 6 - Typical Source-Drain Diode Forward Voltage**

**Fig. 5 - Typical Gate Charge vs. Gate-to-Source Voltage**

**Fig. 7 - Maximum Safe Operating Area**

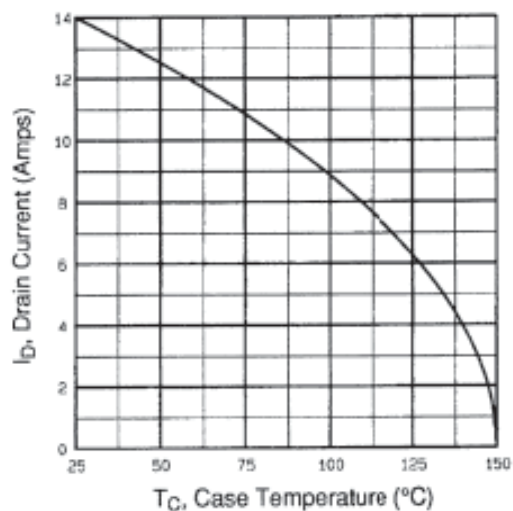


Fig. 8 - Maximum Drain Current vs. Case Temperature

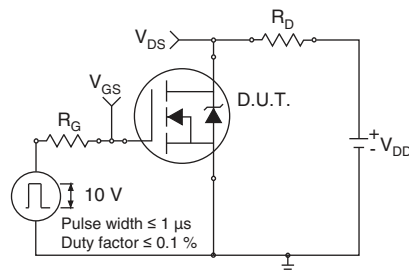


Fig. 10a - Switching Time Test Circuit

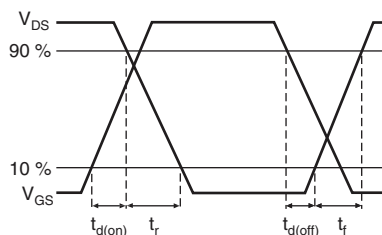


Fig. 10b - Switching Time Waveforms

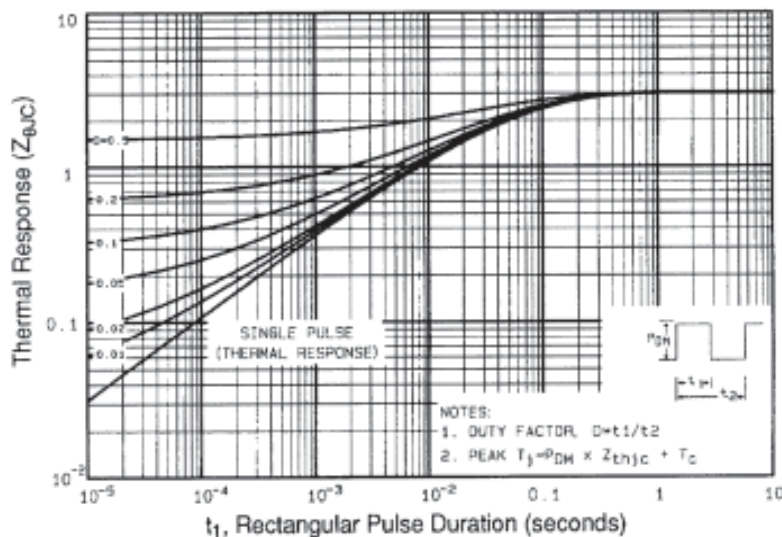


Fig. 9 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

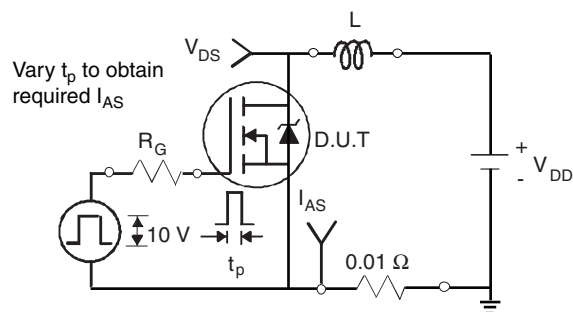


Fig. 12a - Unclamped Inductive Test Circuit



Fig. 12b - Unclamped Inductive Waveforms

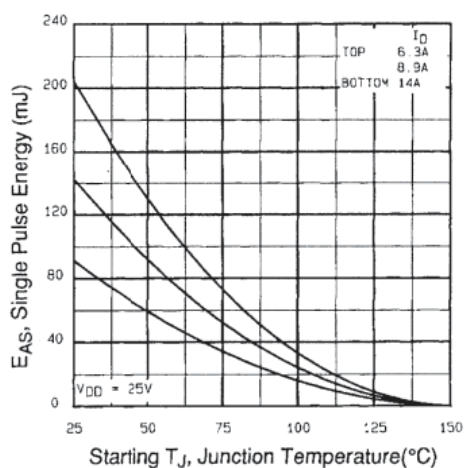


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

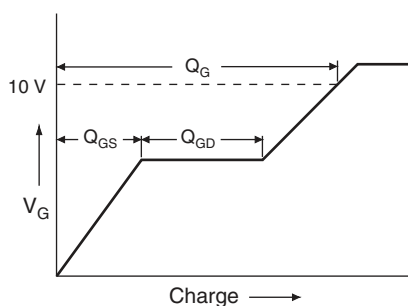


Fig. 13a - Basic Gate Charge Waveform

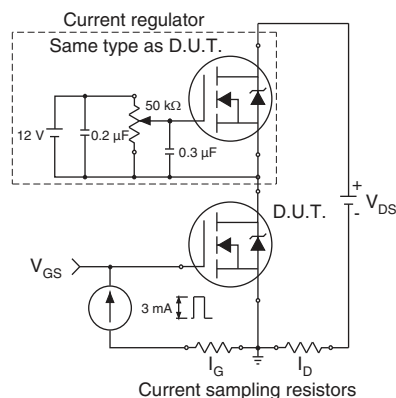
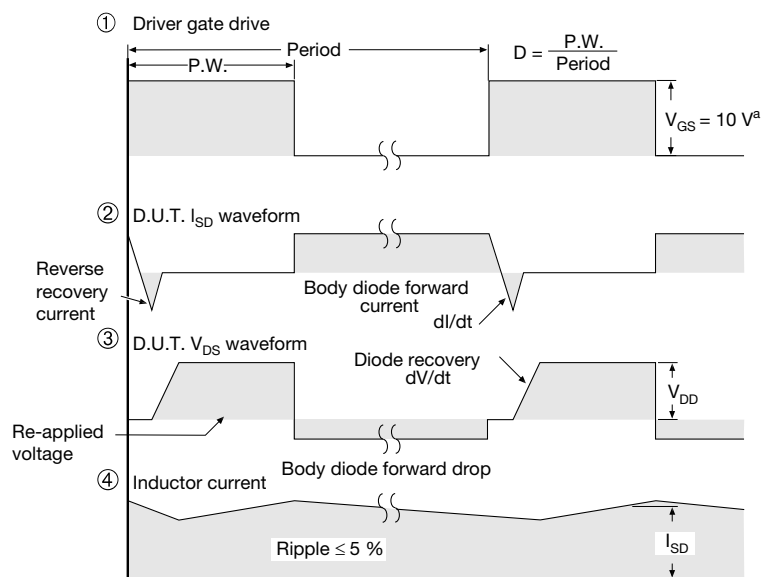
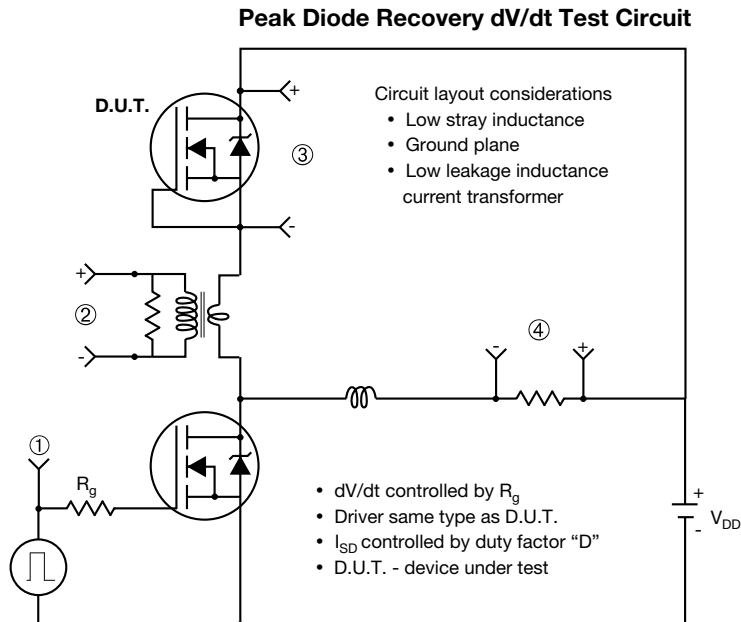


Fig. 13b - Gate Charge Test Circuit



**Fig. 10 - For N-Channel**

Vishay Siliconix maintains worldwide manufacturing capability. Products may be manufactured at one of several qualified locations. Reliability data for Silicon Technology and Package Reliability represent a composite of all qualified locations. For related documents such as package/tape drawings, part marking, and reliability data, see [www.vishay.com/ppg?91264](http://www.vishay.com/ppg?91264).

## TO-252AA Case Outline

### VERSION 1: FACILITY CODE = Y



| MILLIMETERS |          |       |
|-------------|----------|-------|
| DIM.        | MIN.     | MAX.  |
| A           | 2.18     | 2.38  |
| A1          | -        | 0.127 |
| b           | 0.64     | 0.88  |
| b2          | 0.76     | 1.14  |
| b3          | 4.95     | 5.46  |
| C           | 0.46     | 0.61  |
| C2          | 0.46     | 0.89  |
| D           | 5.97     | 6.22  |
| D1          | 4.10     | -     |
| E           | 6.35     | 6.73  |
| E1          | 4.32     | -     |
| H           | 9.40     | 10.41 |
| e           | 2.28 BSC |       |
| e1          | 4.56 BSC |       |
| L           | 1.40     | 1.78  |
| L3          | 0.89     | 1.27  |
| L4          | -        | 1.02  |
| L5          | 1.01     | 1.52  |

#### Note

- Dimension L3 is for reference only



## VERSION 2: FACILITY CODE = N



| DIM. | MILLIMETERS |       |
|------|-------------|-------|
|      | MIN.        | MAX.  |
| A    | 2.18        | 2.39  |
| A1   | -           | 0.13  |
| b    | 0.65        | 0.89  |
| b1   | 0.64        | 0.79  |
| b2   | 0.76        | 1.13  |
| b3   | 4.95        | 5.46  |
| c    | 0.46        | 0.61  |
| c1   | 0.41        | 0.56  |
| c2   | 0.46        | 0.60  |
| D    | 5.97        | 6.22  |
| D1   | 5.21        | -     |
| E    | 6.35        | 6.73  |
| E1   | 4.32        | -     |
| e    | 2.29 BSC    |       |
| H    | 9.94        | 10.34 |

| DIM.   | MILLIMETERS |      |
|--------|-------------|------|
|        | MIN.        | MAX. |
| L      | 1.50        | 1.78 |
| L1     | 2.74 ref.   |      |
| L2     | 0.51 BSC    |      |
| L3     | 0.89        | 1.27 |
| L4     | -           | 1.02 |
| L5     | 1.14        | 1.49 |
| L6     | 0.65        | 0.85 |
| theta  | 0°          | 10°  |
| theta1 | 0°          | 15°  |
| theta2 | 25°         | 35°  |

### Notes

- Dimensioning and tolerance confirm to ASME Y14.5M-1994
- All dimensions are in millimeters. Angles are in degrees
- Heat sink side flash is max. 0.8 mm
- Radius on terminal is optional

ECN: E22-0399-Rev. R, 03-Oct-2022  
DWG: 5347

## Case Outline for TO-251AA (High Voltage)

### OPTION 1:



| 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: E21-0682-Rev. C, 27-Dec-2021

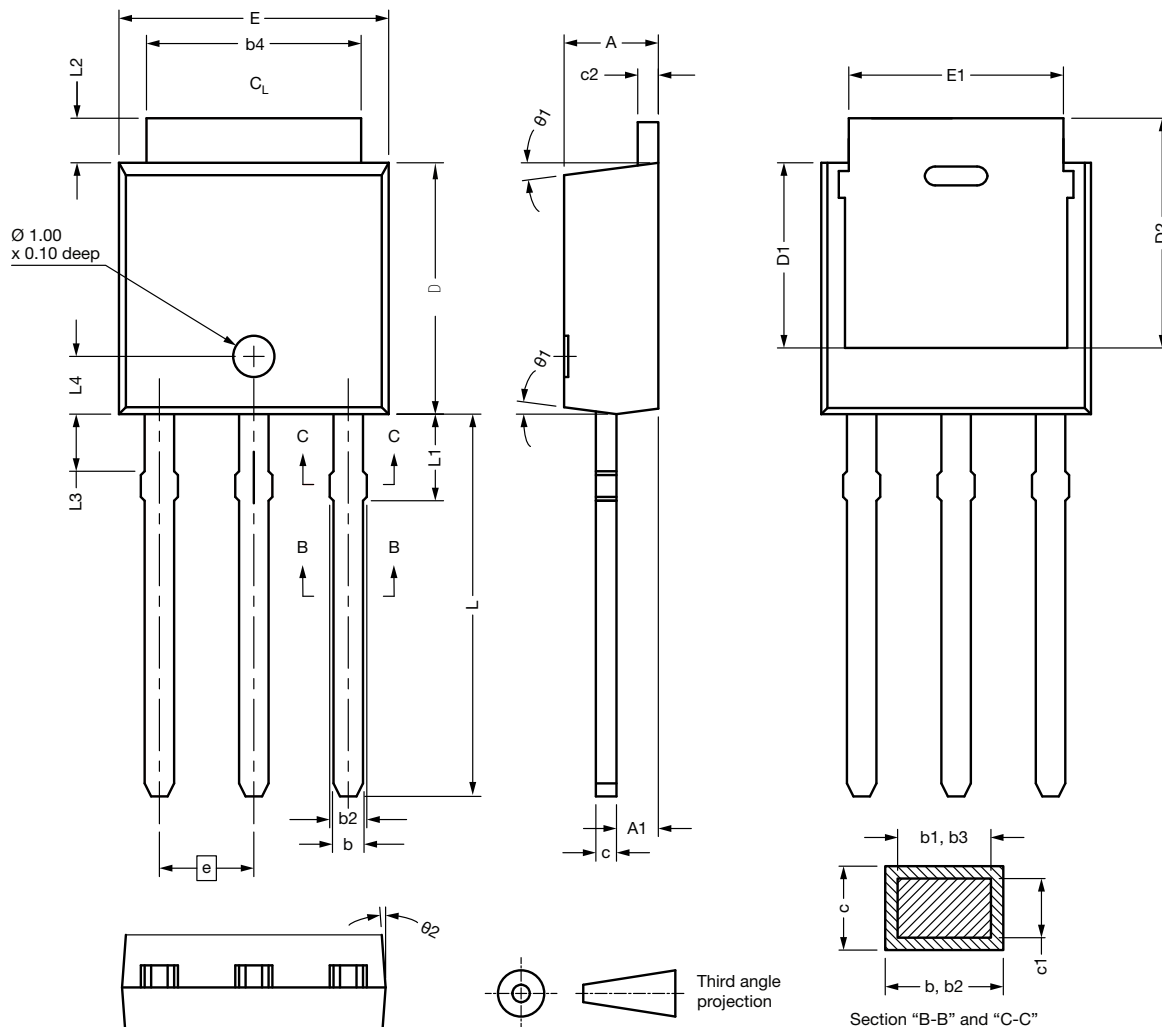
DWG: 5968

#### Notes

- Dimensioning and tolerancing per ASME Y14.5M-1994
- Dimension are shown in inches and millimeters
- 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
- Thermal pad contour optional with dimensions b4, L2, E1 and D1
- Lead dimension uncontrolled in L3
- Dimension b1, b3 and c1 apply to base metal only
- Outline conforms to JEDEC® outline TO-251AA



## OPTION 2: FACILITY CODE = N



| DIM. | MIN.  | NOM.  | MAX.  |
|------|-------|-------|-------|
| A    | 2.180 | 2.285 | 2.390 |
| A1   | 0.890 | 1.015 | 1.140 |
| b    | 0.640 | 0.765 | 0.890 |
| b1   | 0.640 | 0.715 | 0.790 |
| b2   | 0.760 | 0.950 | 1.140 |
| b3   | 0.760 | 0.900 | 1.040 |
| b4   | 4.950 | 5.205 | 5.460 |
| c    | 0.460 | -     | 0.610 |
| c1   | 0.410 | -     | 0.560 |
| c2   | 0.460 | -     | 0.610 |
| D    | 5.970 | 6.095 | 6.220 |
| D1   | 4.300 | -     | -     |

| DIM.   | MIN.     | NOM.  | MAX.  |
|--------|----------|-------|-------|
| D2     | 5.380    | -     | -     |
| E      | 6.350    | 6.540 | 6.730 |
| E1     | 4.32     | -     | -     |
| e      | 2.29 BSC |       |       |
| L      | 8.890    | 9.270 | 9.650 |
| L1     | 1.910    | 2.100 | 2.290 |
| L2     | 0.890    | 1.080 | 1.270 |
| L3     | 1.140    | 1.330 | 1.520 |
| L4     | 1.300    | 1.400 | 1.500 |
| theta1 | 0°       | 7.5°  | 15°   |
| theta2 | 4°       | -     | -     |

ECN: E21-0682-Rev. C, 27-Dec-2021  
DWG: 5968

### Notes

- Dimensioning and tolerancing per ASME Y14.5M-1994
- All dimension are in millimeters, angles are in degrees
- Heat sink side flash is max. 0.8 mm

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



Recommended Minimum Pads  
Dimensions in Inches/(mm)

[Return to Index](#)



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