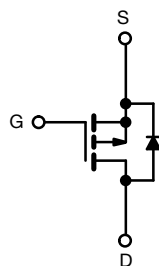
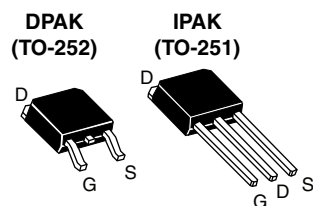


## Power MOSFET



P-Channel MOSFET

### FEATURES

- Dynamic dV/dt rating
- Repetitive avalanche rated
- Surface-mount (IRFR9024, SiHFR9024)
- Straight lead (IRFU9024, SiHFU9024)
- Available in tape and reel
- P-channel
- Fast switching
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



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

### PRODUCT SUMMARY

|                            |                         |      |
|----------------------------|-------------------------|------|
| V <sub>DS</sub> (V)        | -60                     |      |
| R <sub>DS(on)</sub> (Ω)    | V <sub>GS</sub> = -10 V | 0.28 |
| Q <sub>g</sub> (Max.) (nC) | 19                      |      |
| Q <sub>gs</sub> (nC)       | 5.4                     |      |
| Q <sub>gd</sub> (nC)       | 11                      |      |
| Configuration              | Single                  |      |

### 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.

### ORDERING INFORMATION

| Package                         | DPAK (TO-252)   | DPAK (TO-252)                | DPAK (TO-252)                 | DPAK (TO-252)                 | IPAK (TO-251) |
|---------------------------------|-----------------|------------------------------|-------------------------------|-------------------------------|---------------|
| Lead (Pb)-free and halogen-free | SiHFR9024-GE3   | SiHFR9024TR-GE3 <sup>a</sup> | SiHFR9024TRL-GE3 <sup>a</sup> | SiHFR9024TRR-GE3 <sup>a</sup> | SiHFU9024-GE3 |
|                                 | IRFR9024PbF-BE3 | IRFR9024TRPbF-BE3            | IRFR9024TRLPbF-BE3            |                               | -             |
| Lead (Pb)-free                  | IRFR9024PbF     | IRFR9024TRPbF <sup>a</sup>   | IRFR9024TRLPbF <sup>a</sup>   | -                             | IRFU9024PbF   |

#### Note

a. See device orientation

### ABSOLUTE MAXIMUM RATINGS (T<sub>C</sub> = 25 °C, unless otherwise noted)

| PARAMETER                                                 | SYMBOL                            | LIMIT                   | UNIT |
|-----------------------------------------------------------|-----------------------------------|-------------------------|------|
| Drain-source voltage                                      | V <sub>DS</sub>                   | -60                     | V    |
| Gate-source voltage                                       | V <sub>GS</sub>                   | ± 20                    |      |
| Continuous drain current                                  | V <sub>GS</sub> at -10 V          | T <sub>C</sub> = 25 °C  | A    |
|                                                           |                                   | T <sub>C</sub> = 100 °C |      |
| Pulsed drain current <sup>a</sup>                         | I <sub>DM</sub>                   | -35                     |      |
| Linear derating factor                                    |                                   | 0.33                    | W/°C |
| Linear derating factor (PCB mount) <sup>e</sup>           |                                   | 0.020                   |      |
| Single pulse avalanche energy <sup>b</sup>                | E <sub>AS</sub>                   | 300                     | mJ   |
| Repetitive avalanche current <sup>a</sup>                 | I <sub>AR</sub>                   | -8.8                    | A    |
| Repetitive avalanche energy <sup>a</sup>                  | E <sub>AR</sub>                   | 5.0                     | mJ   |
| Maximum power dissipation                                 | P <sub>D</sub>                    | T <sub>C</sub> = 25 °C  | W    |
| Maximum power dissipation (PCB mount) <sup>e</sup>        |                                   | T <sub>A</sub> = 25 °C  |      |
| Peak diode recovery dV/dt <sup>c</sup>                    | dV/dt                             | -4.5                    | V/ns |
| Operating junction and storage temperature range          | T <sub>J</sub> , T <sub>stg</sub> | -55 to +150             | °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<sub>DD</sub> = - 25 V, starting T<sub>J</sub> = 25 °C, L = 4.5 mH, R<sub>g</sub> = 25 Ω, I<sub>AS</sub> = - 8.8 A (see fig. 12)
- I<sub>SD</sub> ≤ - 11 A, dI/dt ≤ 140 A/μs, V<sub>DD</sub> ≤ V<sub>DS</sub>, T<sub>J</sub> ≤ 150 °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 |
|-------------------------------------------|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------|---------|-------|------|
| Static                                    |                                  |                                                                                                                               |                                                                                      |       |         |       |      |
| Drain-source breakdown voltage            | V <sub>DS</sub>                  | V <sub>GS</sub> = 0 V, I <sub>D</sub> = 250 μA                                                                                |                                                                                      | - 60  | -       | -     | 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                                                                                     |                                                                                      | -     | - 0.063 | -     | 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> = - 60 V, V <sub>GS</sub> = 0 V                                                                               |                                                                                      | -     | -       | - 100 | μA   |
|                                           |                                  | V <sub>DS</sub> = - 48 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> = - 5.3 A <sup>b</sup>                                                | -     | -       | 0.28  | Ω    |
| Forward transconductance                  | g <sub>fs</sub>                  | V <sub>DS</sub> = - 25 V, I <sub>D</sub> = - 5.3 A                                                                            |                                                                                      | 2.9   | -       | -     | 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                                                            |                                                                                      | -     | 570     | -     | pF   |
| Output capacitance                        | C <sub>oss</sub>                 |                                                                                                                               |                                                                                      | -     | 360     | -     |      |
| Reverse transfer capacitance              | C <sub>rss</sub>                 |                                                                                                                               |                                                                                      | -     | 65      | -     |      |
| Total gate charge                         | Q <sub>g</sub>                   | V <sub>GS</sub> = - 10 V                                                                                                      | I <sub>D</sub> = - 11 A, V <sub>DS</sub> = - 48 V,<br>see fig. 6 and 13 <sup>b</sup> | -     | -       | 19    | nC   |
| Gate-source charge                        | Q <sub>gs</sub>                  |                                                                                                                               |                                                                                      | -     | -       | 5.4   |      |
| Gate-drain charge                         | Q <sub>gd</sub>                  |                                                                                                                               |                                                                                      | -     | -       | 11    |      |
| Turn-on delay time                        | t <sub>d(on)</sub>               | V <sub>DD</sub> = - 30 V, I <sub>D</sub> = - 11 A,<br>R <sub>g</sub> = 18 Ω, R <sub>D</sub> = 2.5 Ω, see fig. 10 <sup>b</sup> |                                                                                      | -     | 13      | -     | ns   |
| Rise time                                 | t <sub>r</sub>                   |                                                                                                                               |                                                                                      | -     | 68      | -     |      |
| Turn-off delay time                       | t <sub>d(off)</sub>              |                                                                                                                               |                                                                                      | -     | 15      | -     |      |
| Fall time                                 | t <sub>f</sub>                   |                                                                                                                               |                                                                                      | -     | 29      | -     |      |
| Internal drain inductance                 | L <sub>D</sub>                   | Between lead,<br>6 mm (0.25") from<br>package and center of<br>die contact                                                    |                                                                                      | -     | 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                                                      |                                                                                      | -     | -       | - 8.8 | A    |
| Pulsed diode forward current <sup>a</sup> | I <sub>SM</sub>                  |                                                                                                                               |                                                                                      | -     | -       | - 35  |      |
| Body diode voltage                        | V <sub>SD</sub>                  | T <sub>J</sub> = 25 °C, I <sub>S</sub> = - 8.8 A, V <sub>GS</sub> = 0 V <sup>b</sup>                                          |                                                                                      | -     | -       | - 6.3 | V    |
| Body diode reverse recovery time          | t <sub>rr</sub>                  | T <sub>J</sub> = 25 °C, I <sub>F</sub> = - 11 A, dI/dt = 100 A/μs <sup>b</sup>                                                |                                                                                      | -     | 100     | 200   | ns   |
| Body diode reverse recovery charge        | Q <sub>rr</sub>                  |                                                                                                                               |                                                                                      | -     | 0.32    | 0.64  | 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  $\leq 2\%$



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

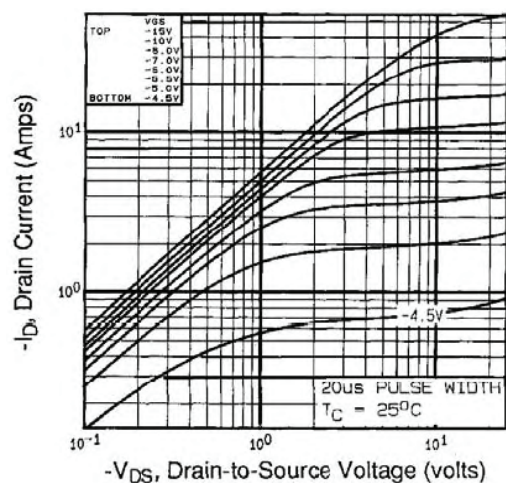


Fig. 1 - Typical Output Characteristics,  $T_C = 25^\circ\text{C}$

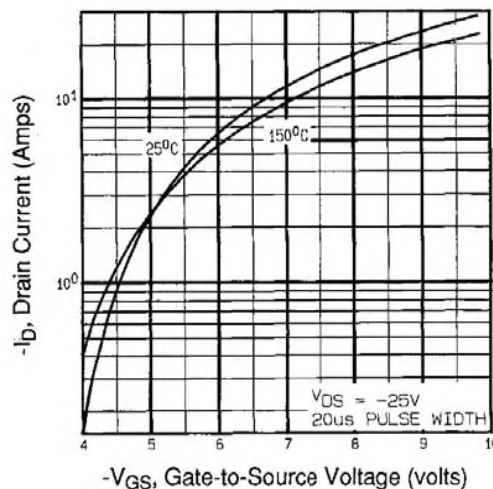


Fig. 3 - Typical Transfer Characteristics

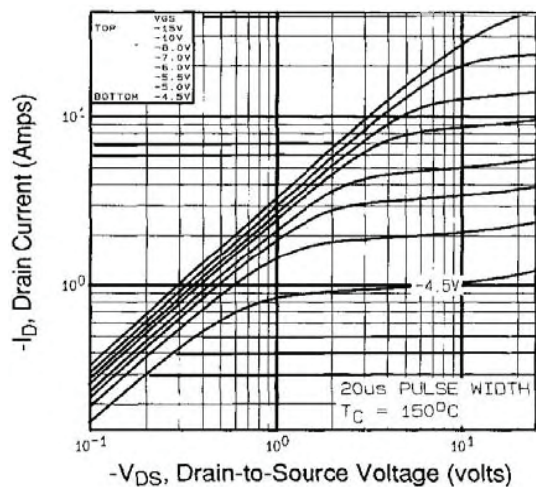


Fig. 2 - Typical Output Characteristics,  $T_C = 150^\circ\text{C}$

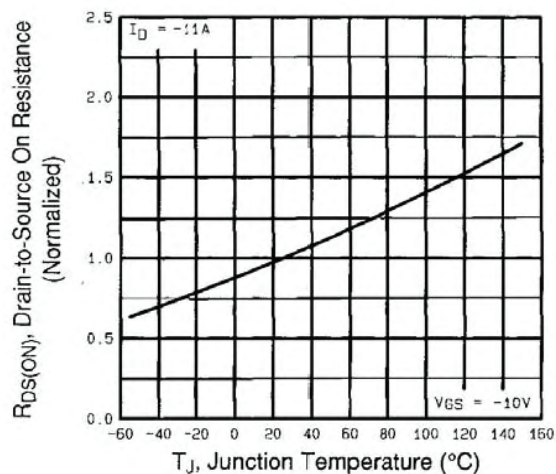
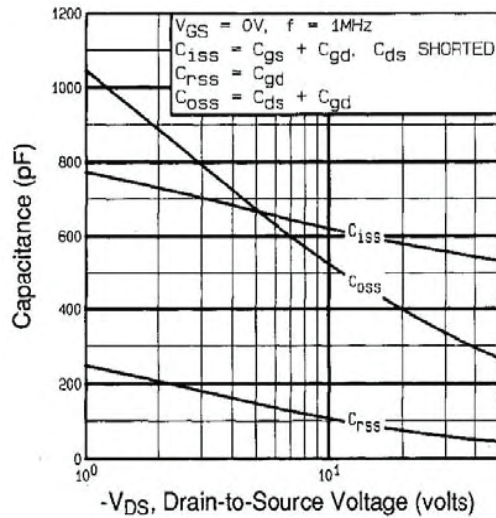
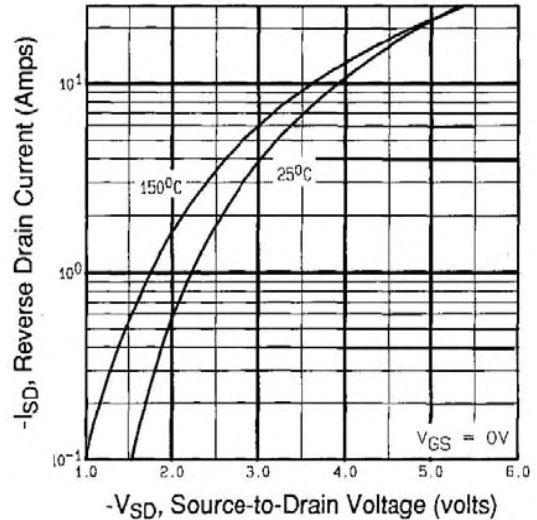
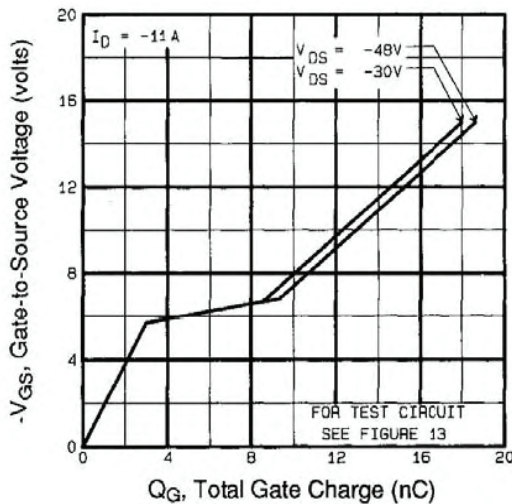
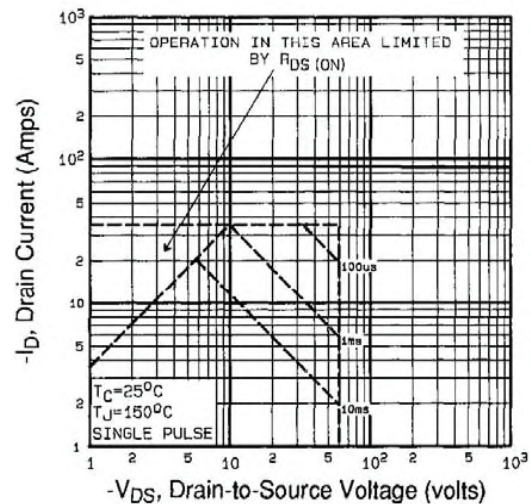


Fig. 4 - Normalized On-Resistance vs. Temperature


**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**



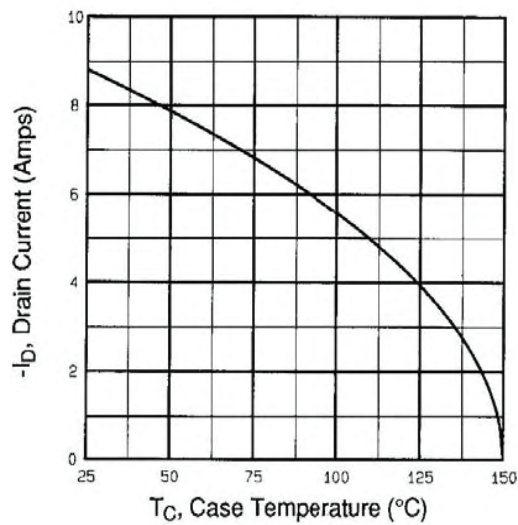


Fig. 9 - Maximum Drain Current vs. Case Temperature

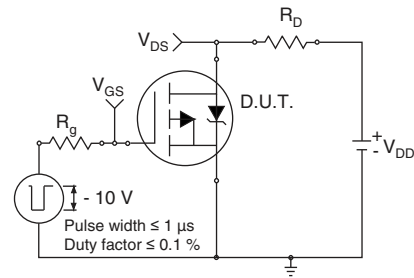


Fig. 10a - Switching Time Test Circuit

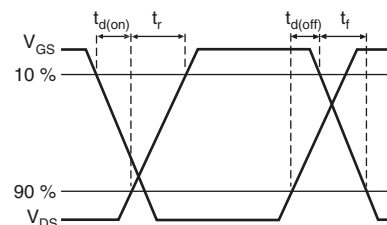


Fig. 10b - Switching Time Waveforms

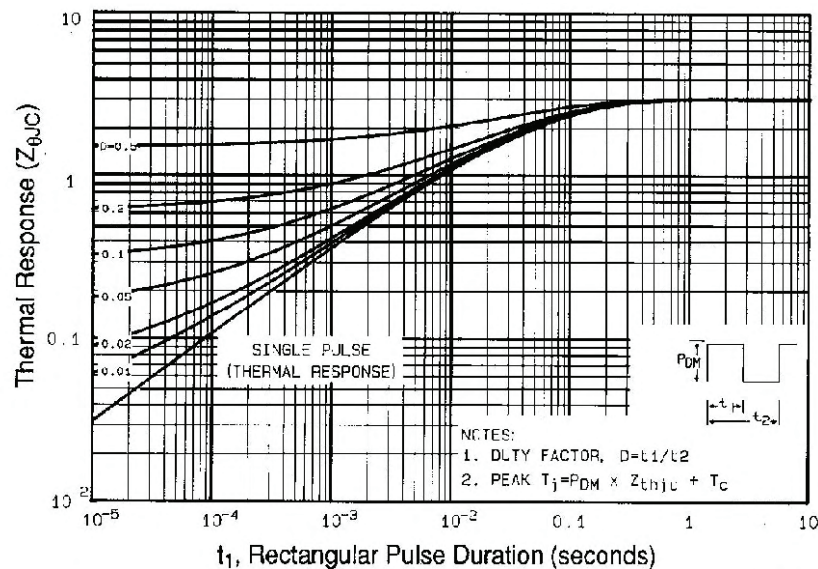


Fig. 11 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

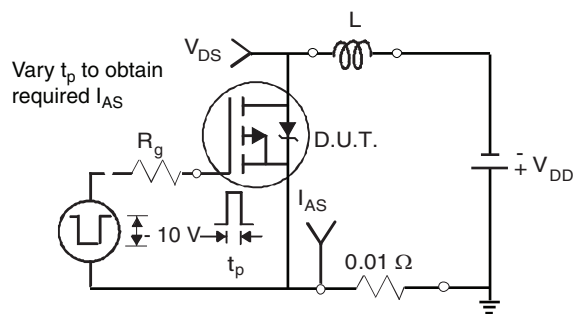


Fig. 12a - Unclamped Inductive Test Circuit

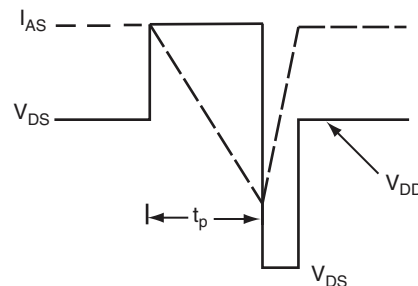


Fig. 12b - Unclamped Inductive Waveforms

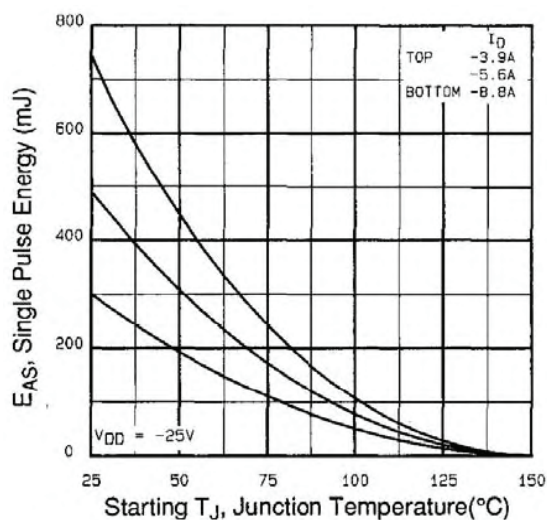


Fig. 12c - Maximum Avalanche Energy vs. Drain Current

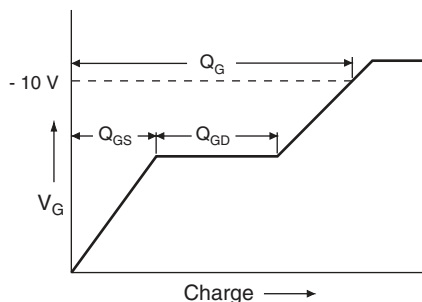


Fig. 13a - Basic Gate Charge Waveform

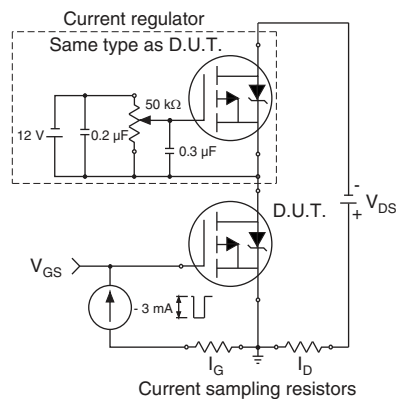
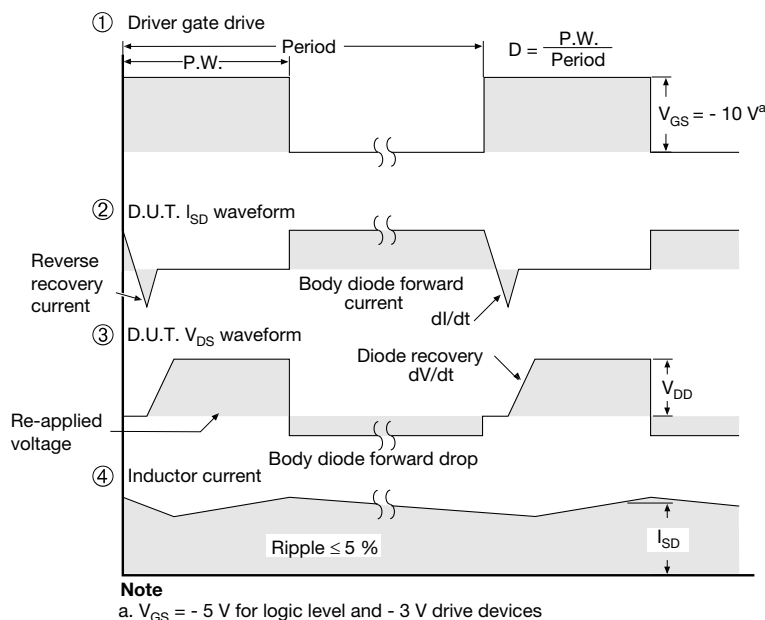
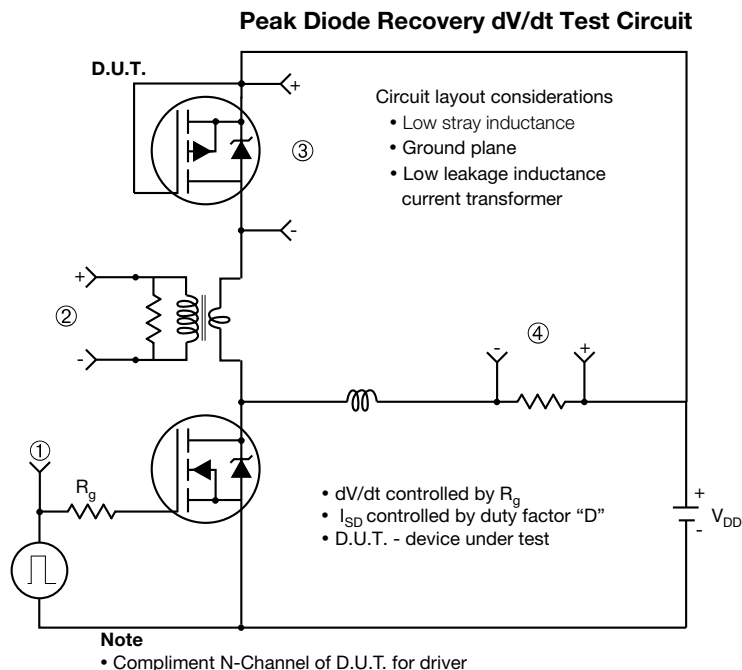


Fig. 13b - Gate Charge Test Circuit

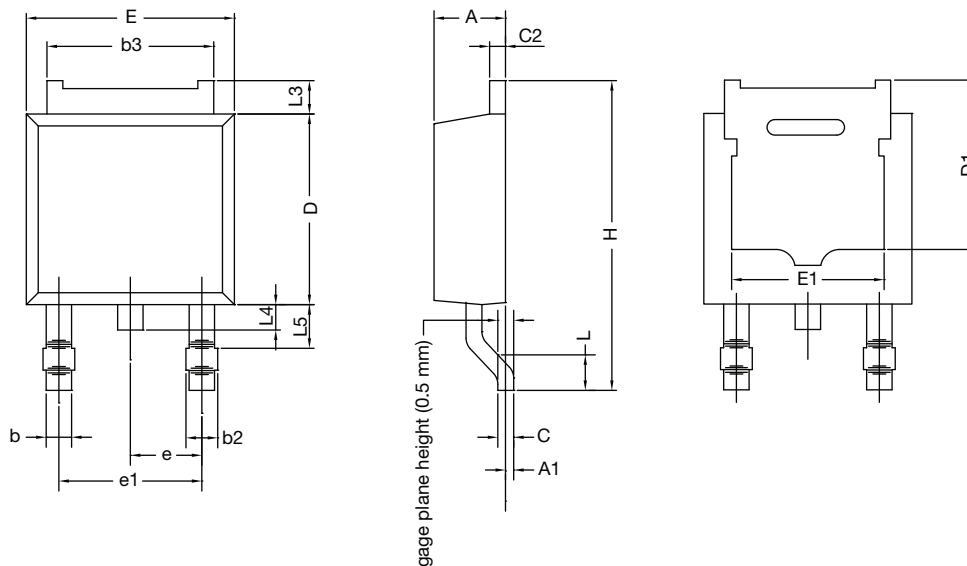


**Fig. 14 - For P-Channel**

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?91278](http://www.vishay.com/ppg?91278).

## 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  |

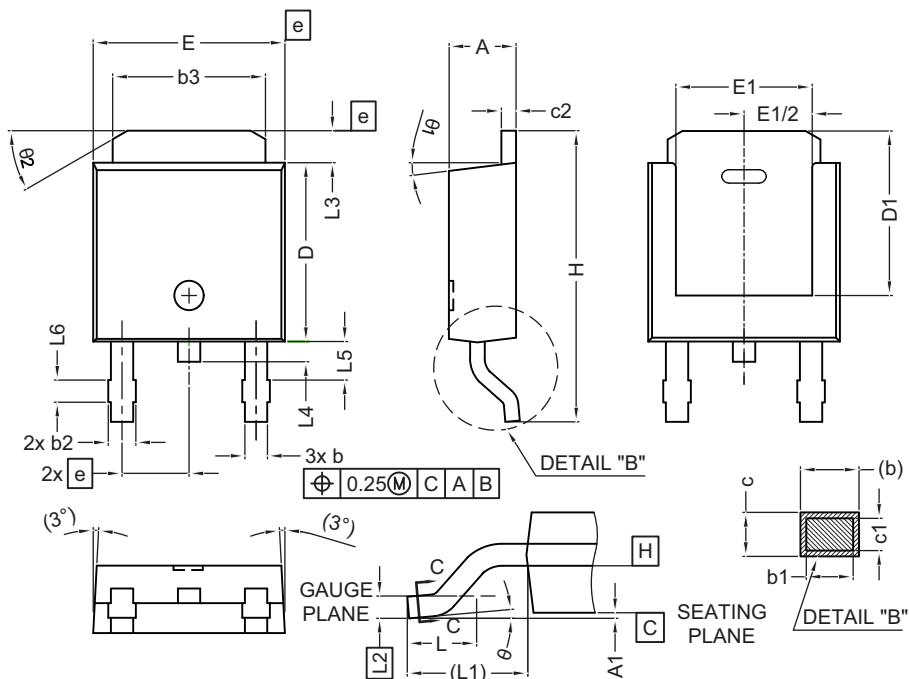
#### Note

- 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 |
| θ    | 0°          | 10°  |
| θ1   | 0°          | 15°  |
| θ2   | 25°         | 35°  |

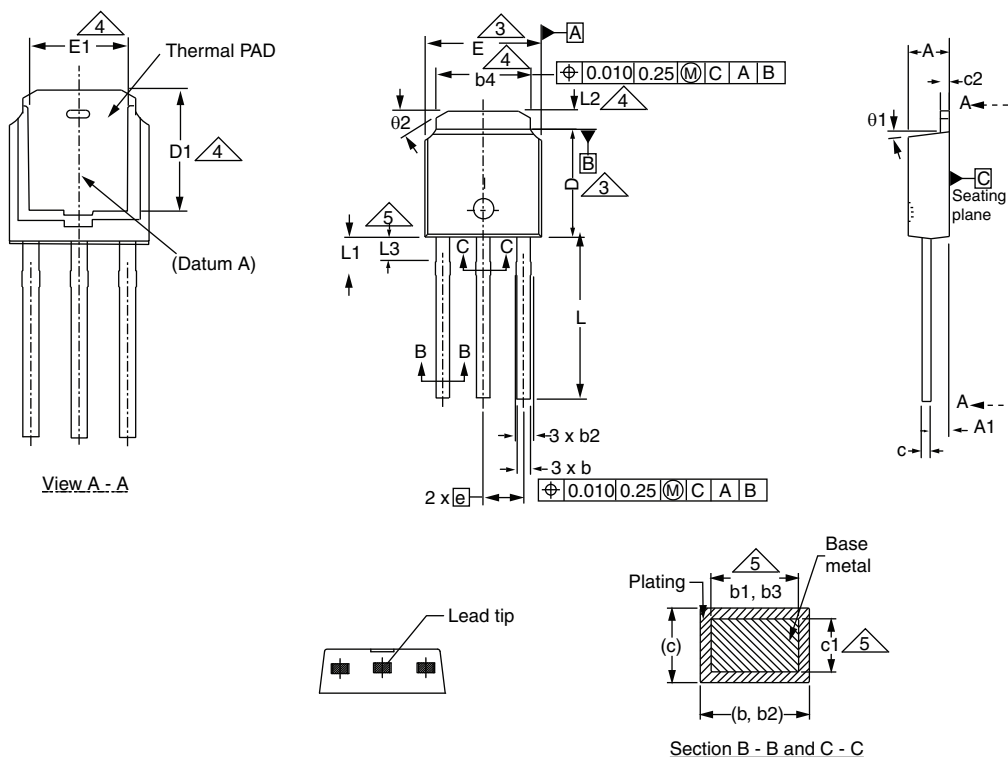
### Notes

- 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

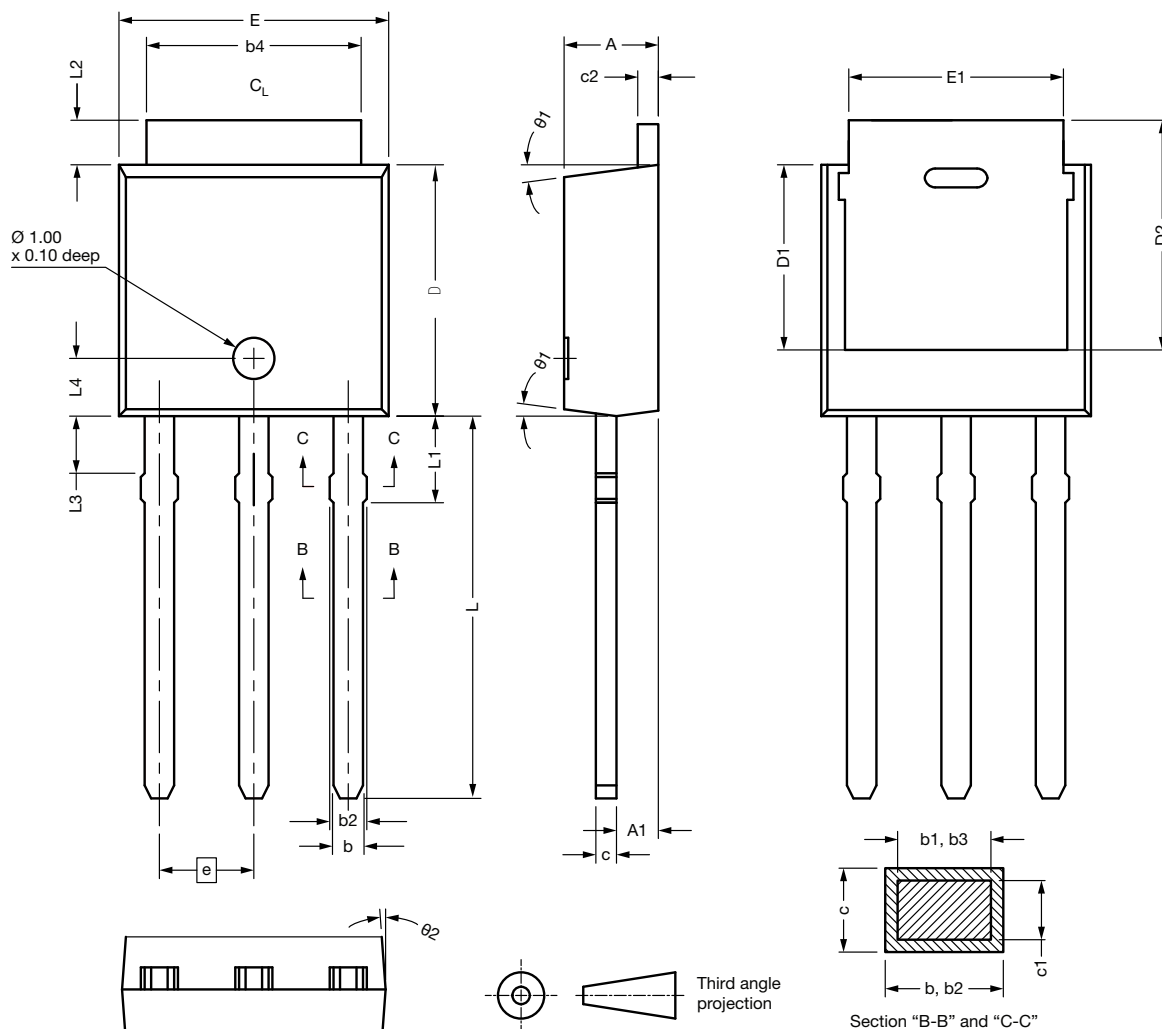
DWG: 5968

### 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 | -     | -     |

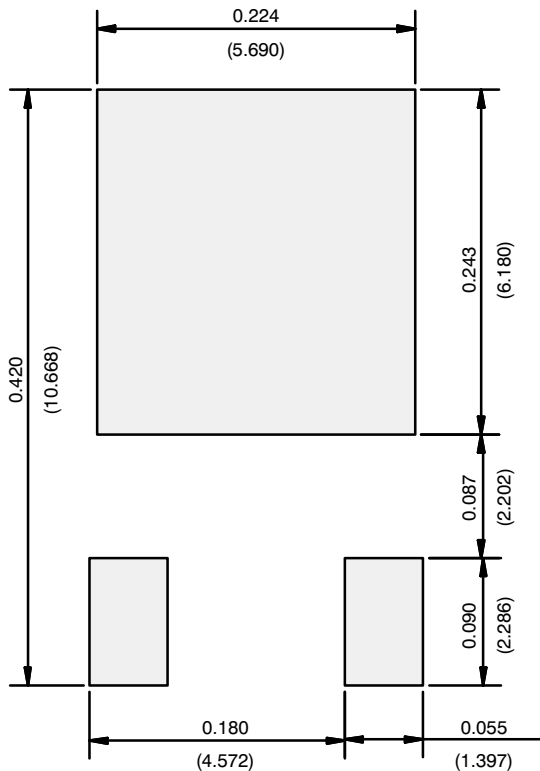
| DIM.   | MIN.     | NOM.  | MAX.  |
|--------|----------|-------|-------|
| D2     | 5.380    | -     | -     |
| E      | 6.350    | 6.540 | 6.730 |
| E1     | 4.32     | -     | -     |
| e      | 2.29 BSC |       |       |
| L      | 8.890    | 9.270 | 9.650 |
| L1     | 1.910    | 2.100 | 2.290 |
| 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°       | -     | -     |

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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)

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