

## Automotive P-Channel 60 V (D-S) 175 °C MOSFET

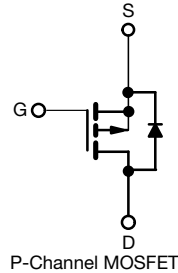
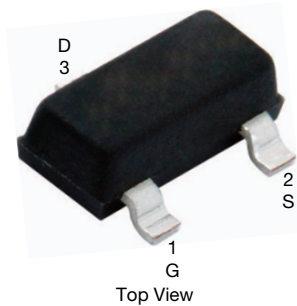
 AUTOMOTIVE  
GRADE

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

| PRODUCT SUMMARY                                |        |
|--|--------|
| $V_{DS}$ (V)                                   | -60    |
| $R_{DS(on)}$ ( $\Omega$ ) at $V_{GS} = -10$ V  | 0.177  |
| $R_{DS(on)}$ ( $\Omega$ ) at $V_{GS} = -4.5$ V | 0.246  |
| $I_D$ (A)                                      | -2.8   |
| Configuration                                  | Single |

### FEATURES

- TrenchFET® power MOSFET
- AEC-Q101 qualified
- 100 %  $R_g$  and UIS tested
- Material categorization:  
for definitions of compliance please see  
[www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

**SOT-23 (TO-236)**

**Marking Code:** 9Dxxx

| ORDERING INFORMATION            |                 |
|---------------------------------|-----------------|
| Package                         | SOT-23          |
| Lead (Pb)-free and Halogen-free | SQ2361ES-T1-GE3 |

| ABSOLUTE MAXIMUM RATINGS ( $T_C = 25$ °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  | $T_C = 25$ °C  | $I_D$          | -2.8        | A    |
|   | $T_C = 125$ °C |                | -1.6        |      |
| Continuous Source Current (Diode Conduction)                      |                | $I_S$          | -2.5        |      |
| Pulsed Drain Current <sup>a</sup>                                 |                | $I_{DM}$       | -11         |      |
| Single Pulse Avalanche Current                                    | L = 0.1 mH     | $I_{AS}$       | -12.5       |      |
| Single Pulse Avalanche Energy                                     |                |                | $E_{AS}$    |      |
| Maximum Power Dissipation <sup>a</sup>                            | $T_C = 25$ °C  | $P_D$          | 2           | W    |
|   | $T_C = 125$ °C |                | 0.67        |      |
| Operating Junction and Storage Temperature Range                  |                | $T_J, T_{stg}$ | -55 to +175 | °C   |

| THERMAL RESISTANCE RATINGS |                        |            |            |      |
|----------------------------|------------------------|------------|------------|------|
| PARAMETER                  |                        | SYMBOL     | LIMIT      | UNIT |
| Junction-to-Ambient        | PCB Mount <sup>b</sup> | $R_{thJA}$ | 175        | °C/W |
| Junction-to-Foot (Drain)   |                        |            | $R_{thJF}$ |      |

**Notes**

- Pulse test; pulse width  $\leq 300$   $\mu$ s, duty cycle  $\leq 2$  %.
- When mounted on 1" square PCB (FR4 material).



| SPECIFICATIONS ( $T_C = 25\text{ }^\circ\text{C}$ , 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     |               |
| Gate-Source Threshold Voltage   | $V_{GS(th)}$ | $V_{DS} = V_{GS}$ , $I_D = -250\text{ }\mu\text{A}$  | -1.5  | -    | -2.5      |       |               |
| Gate-Source Leakage   | $I_{GSS}$    | $V_{DS} = 0\text{ V}$ , $V_{GS} = \pm 20\text{ V}$   | -   | -    | $\pm 100$ | nA    |               |
| Zero Gate Voltage Drain Current   | $I_{DSS}$    | $V_{GS} = 0\text{ V}$  | $V_{DS} = -60\text{ V}$                                     | -    | -         | -1    | $\mu\text{A}$ |
|   |              | $V_{GS} = 0\text{ V}$  | $V_{DS} = -60\text{ V}$ , $T_J = 125\text{ }^\circ\text{C}$ | -    | -         | -50   |               |
|   |              | $V_{GS} = 0\text{ V}$  | $V_{DS} = -60\text{ V}$ , $T_J = 175\text{ }^\circ\text{C}$ | -    | -         | -150  |               |
| On-State Drain Current <sup>a</sup>   | $I_{D(on)}$  | $V_{GS} = -10\text{ V}$  | $V_{DS} \leq -5\text{ V}$                                   | -10  | -         | A     |               |
| Drain-Source On-State Resistance <sup>a</sup>                               | $R_{DS(on)}$ | $V_{GS} = -10\text{ V}$  | $I_D = -2.4\text{ A}$                                       | -    | 0.130     | 0.177 | $\Omega$      |
|   |              | $V_{GS} = -10\text{ V}$  | $I_D = -2.4\text{ A}$ , $T_J = 125\text{ }^\circ\text{C}$   | -    | -         | 0.310 |               |
|   |              | $V_{GS} = -10\text{ V}$  | $I_D = -2.4\text{ A}$ , $T_J = 175\text{ }^\circ\text{C}$   | -    | -         | 0.320 |               |
|   |              | $V_{GS} = -4.5\text{ V}$   | $I_D = -1.8\text{ A}$                                       | -    | 0.205     | 0.246 |               |
| Forward Transconductance <sup>b</sup>                                       | $g_{fs}$     | $V_{DS} = -10\text{ V}$ , $I_D = -2\text{ A}$  |   | -    | 5         | S     |               |
| <b>Dynamic <sup>b</sup></b>   |              |  |   |      |           |       |               |
| Input Capacitance   | $C_{iss}$    | $V_{GS} = 0\text{ V}$  | $V_{DS} = -30\text{ V}$ , $f = 1\text{ MHz}$                | -    | 380       | 550   | $\mu\text{F}$ |
| Output Capacitance  | $C_{oss}$    |  |   | -    | 50        | 75    |               |
| Reverse Transfer Capacitance  | $C_{rss}$    |  |   | -    | 30        | 42    |               |
| Total Gate Charge <sup>c</sup>  | $Q_g$        | $V_{GS} = -10\text{ V}$  | $V_{DS} = -30\text{ V}$ , $I_D = -6\text{ A}$               | -    | 9         | 12    | nC            |
| Gate-Source Charge <sup>c</sup>   | $Q_{gs}$     |  |   | -    | 1.6       | -     |               |
| Gate-Drain Charge <sup>c</sup>  | $Q_{gd}$     |  |   | -    | 3.3       | -     |               |
| Gate Resistance   | $R_g$        | f = 1 MHz  |   | 3.1  | 4.1       | 5.2   | $\Omega$      |
| Turn-On Delay Time <sup>c</sup>   | $t_{d(on)}$  | $V_{DD} = -30\text{ V}$ , $R_L = 20\text{ }\Omega$<br>$I_D \cong -1.5\text{ A}$ , $V_{GEN} = -10\text{ V}$ , $R_g = 1\text{ }\Omega$ |   | -    | 8         | 11    | ns            |
| Rise Time <sup>c</sup>  | $t_r$        |  |   | -    | 9         | 12    |               |
| Turn-Off Delay Time <sup>c</sup>  | $t_{d(off)}$ |  |   | -    | 22        | 26    |               |
| Fall Time <sup>c</sup>  | $t_f$        |  |   | -    | 4         | 6     |               |
| <b>Source-Drain Diode Ratings and Characteristics <sup>b</sup></b>          |              |  |   |      |           |       |               |
| Pulsed Current <sup>a</sup>   | $I_{SM}$     |  |   | -    | -         | -11   | A             |
| Forward Voltage   | $V_{SD}$     | $I_F = -1.5\text{ A}$ , $V_{GS} = 0\text{ V}$  |   | -    | -0.9      | -1.2  | V             |

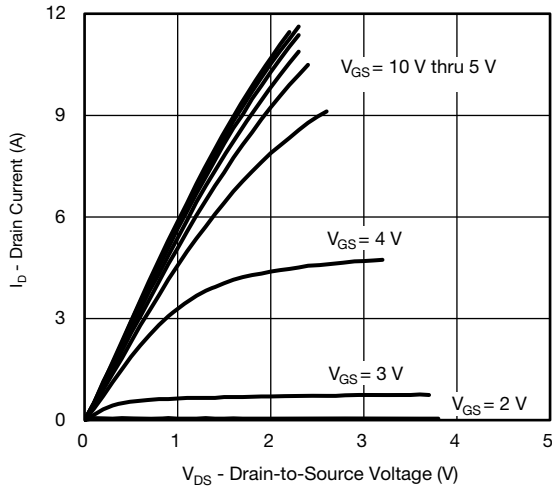
**Notes**

- a. Pulse test; pulse width  $\leq 300\text{ }\mu\text{s}$ , duty cycle  $\leq 2\%$ .  
b. Guaranteed by design, not subject to production testing.  
c. Independent of operating temperature.

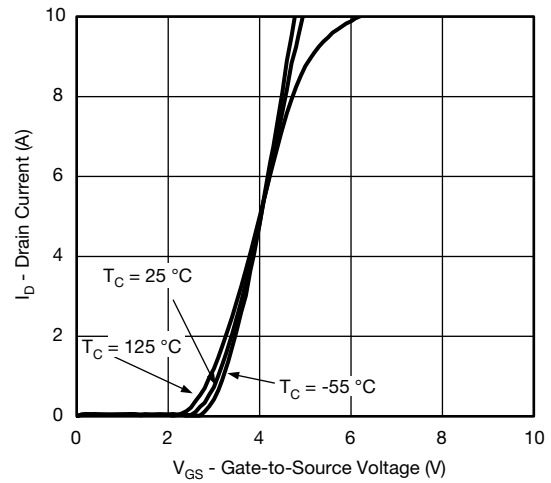
Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.



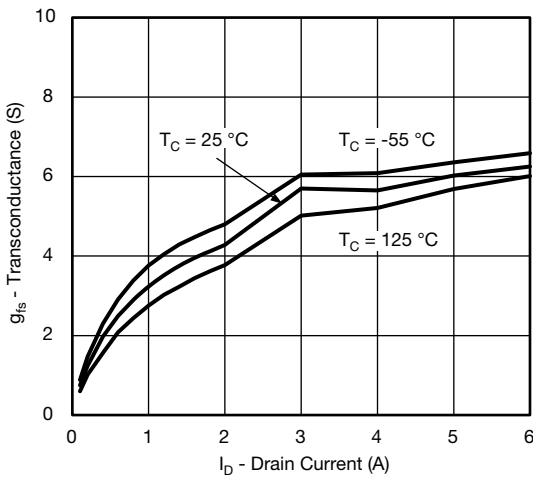
TYPICAL CHARACTERISTICS (T<sub>A</sub> = 25 °C, unless otherwise noted)



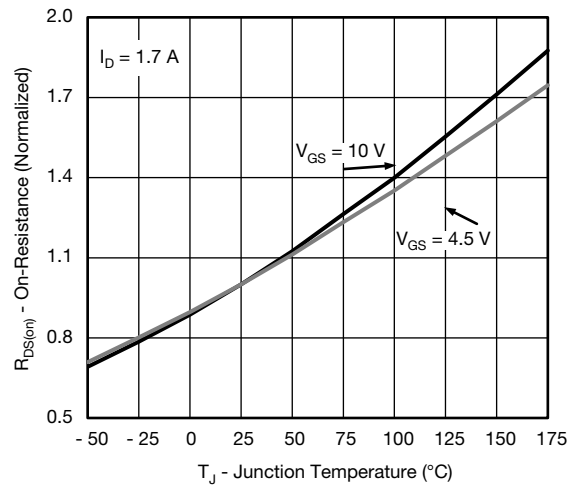
Output Characteristics



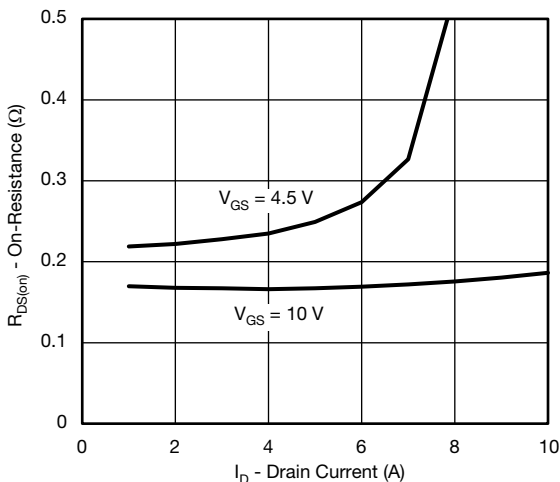
Transfer Characteristics



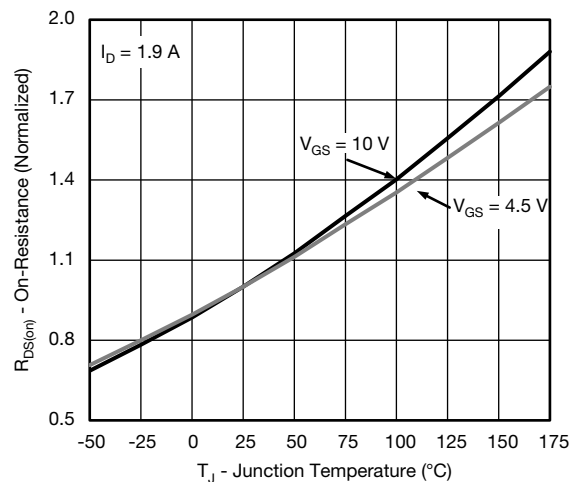
Transconductance



On-Resistance vs. Junction Temperature



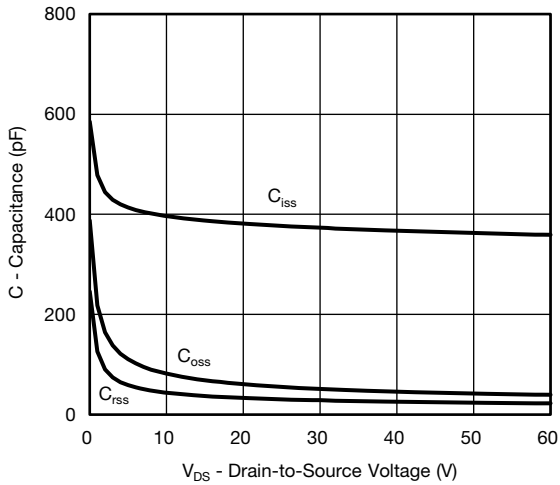
On-Resistance vs. Drain Current



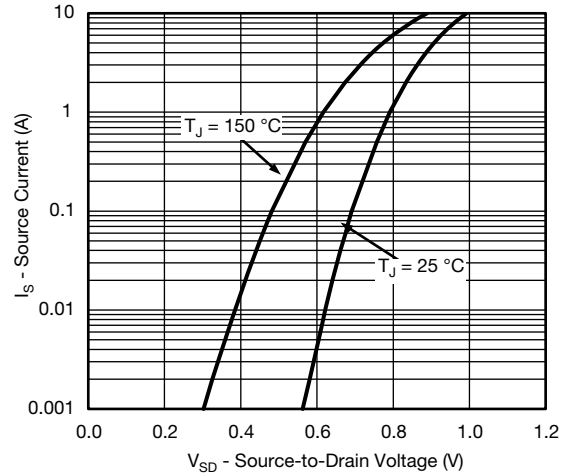
On-Resistance vs. Junction Temperature



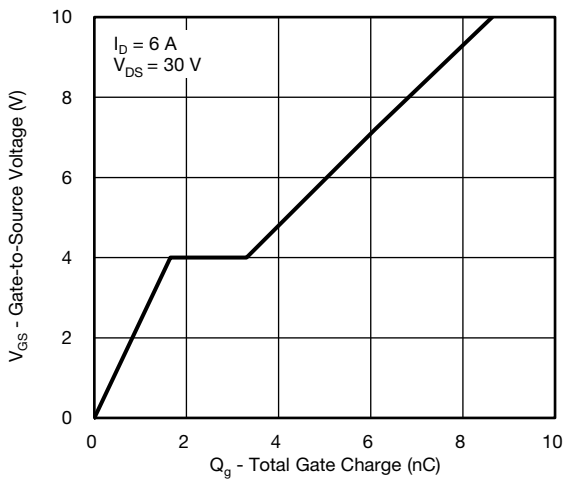
TYPICAL CHARACTERISTICS (T<sub>A</sub> = 25 °C, unless otherwise noted)



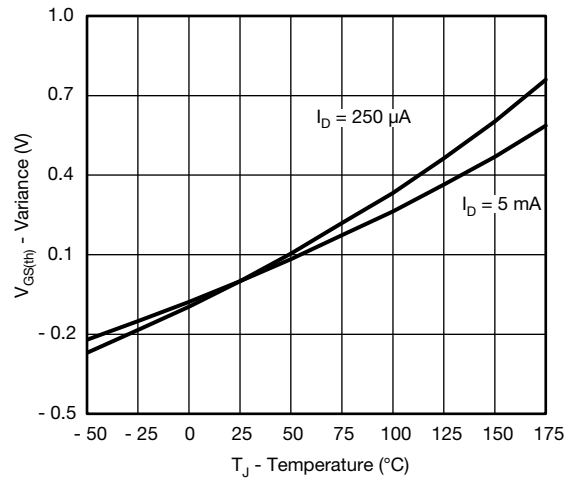
Capacitance



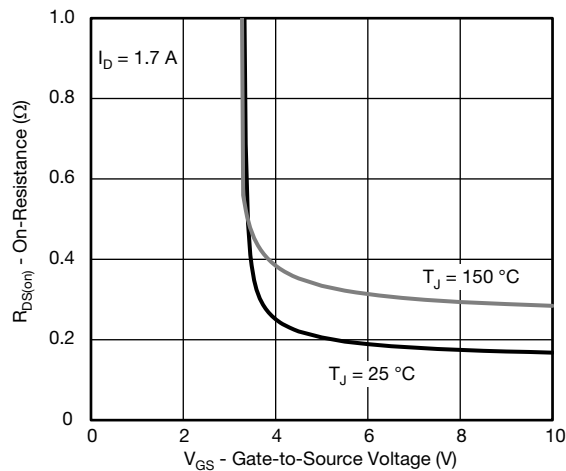
Source-Drain Diode Forward Voltage



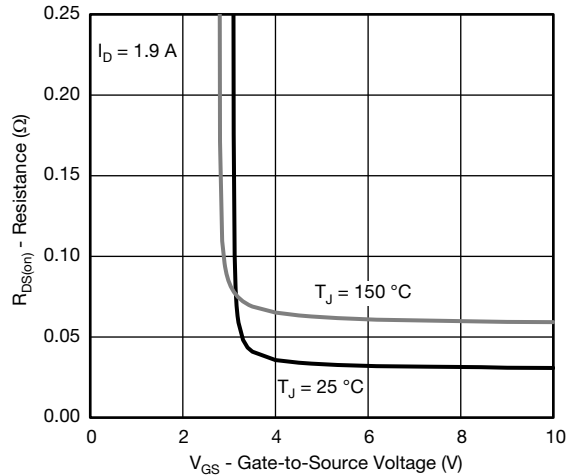
Gate Charge



Threshold Voltage

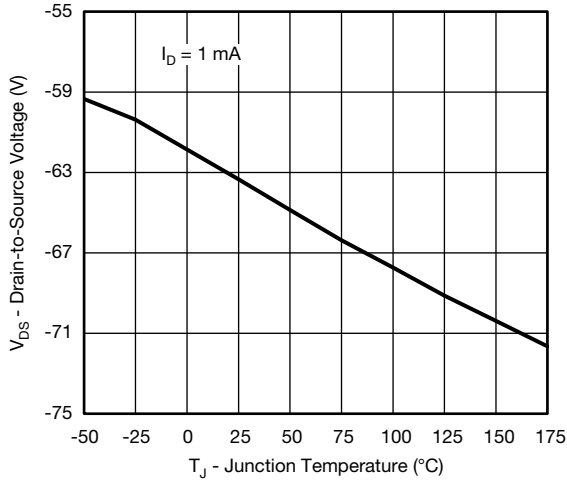


On-Resistance vs. Gate-Source Voltage

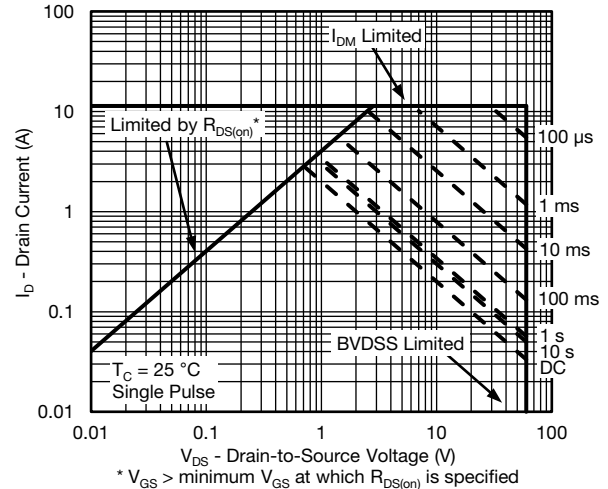


On-Resistance vs. Gate-Source Voltage

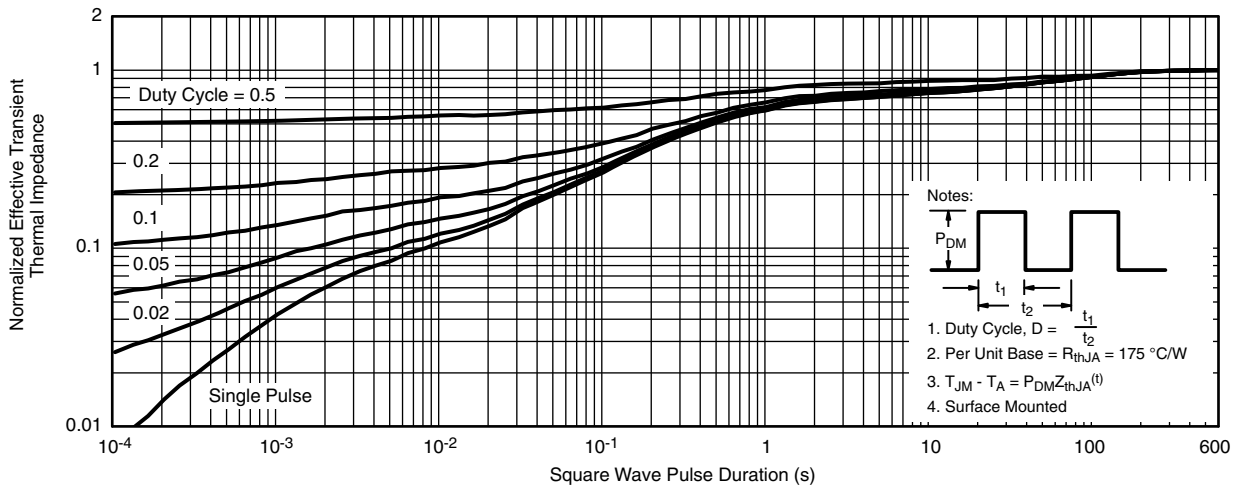
**THERMAL RATINGS** ( $T_A = 25\text{ }^\circ\text{C}$ , unless otherwise noted)



**Drain-Source Breakdown vs. Junction Temperature**



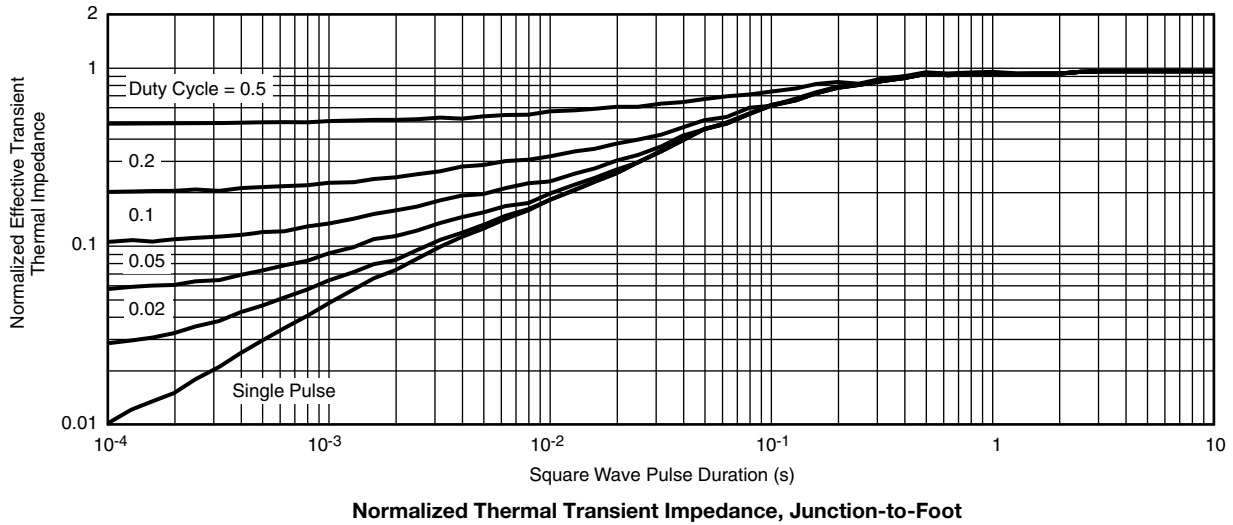
**Safe Operating Area**



**Normalized Thermal Transient Impedance, Junction-to-Ambient**



**THERMAL RATINGS** ( $T_A = 25\text{ }^\circ\text{C}$ , unless otherwise noted)



**Note**

- The characteristics shown in the two graphs
  - Normalized Transient Thermal Impedance Junction-to-Ambient ( $25\text{ }^\circ\text{C}$ )
  - Normalized Transient Thermal Impedance Junction-to-Foot ( $25\text{ }^\circ\text{C}$ )
 are given for general guidelines only to enable the user to get a “ball park” indication of part capabilities. The data are extracted from single pulse transient thermal impedance characteristics which are developed from empirical measurements. The latter is valid for the part mounted on printed circuit board - FR4, size 1" x 1" x 0.062", double sided with 2 oz. copper, 100 % on both sides. The part capabilities can widely vary depending on actual application parameters and operating conditions.

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?66894](http://www.vishay.com/ppg?66894).

## SOT-23 (TO-236): 3-LEAD



| Dim            | MILLIMETERS |      | INCHES     |       |
|----------------|-------------|------|------------|-------|
|                | Min         | Max  | Min        | Max   |
| A              | 0.89        | 1.12 | 0.035      | 0.044 |
| A <sub>1</sub> | 0.01        | 0.10 | 0.0004     | 0.004 |
| A <sub>2</sub> | 0.88        | 1.02 | 0.0346     | 0.040 |
| b              | 0.35        | 0.50 | 0.014      | 0.020 |
| c              | 0.085       | 0.18 | 0.003      | 0.007 |
| D              | 2.80        | 3.04 | 0.110      | 0.120 |
| E              | 2.10        | 2.64 | 0.083      | 0.104 |
| E <sub>1</sub> | 1.20        | 1.40 | 0.047      | 0.055 |
| e              | 0.95 BSC    |      | 0.0374 Ref |       |
| e <sub>1</sub> | 1.90 BSC    |      | 0.0748 Ref |       |
| L              | 0.40        | 0.60 | 0.016      | 0.024 |
| L <sub>1</sub> | 0.64 Ref    |      | 0.025 Ref  |       |
| S              | 0.50 Ref    |      | 0.020 Ref  |       |
| q              | 3°          | 8°   | 3°         | 8°    |

ECN: S-03946-Rev. K, 09-Jul-01  
 DWG: 5479

## Mounting LITTLE FOOT<sup>®</sup> SOT-23 Power MOSFETs

Wharton McDaniel

Surface-mounted LITTLE FOOT power MOSFETs use integrated circuit and small-signal packages which have been modified to provide the heat transfer capabilities required by power devices. Leadframe materials and design, molding compounds, and die attach materials have been changed, while the footprint of the packages remains the same.

See Application Note 826, *Recommended Minimum Pad Patterns With Outline Drawing Access for Vishay Siliconix MOSFETs*, (<http://www.vishay.com/doc?72286>), for the basis of the pad design for a LITTLE FOOT SOT-23 power MOSFET footprint. In converting this footprint to the pad set for a power device, designers must make two connections: an electrical connection and a thermal connection, to draw heat away from the package.

The electrical connections for the SOT-23 are very simple. Pin 1 is the gate, pin 2 is the source, and pin 3 is the drain. As in the other LITTLE FOOT packages, the drain pin serves the additional function of providing the thermal connection from the package to the PC board. The total cross section of a copper trace connected to the drain may be adequate to carry the current required for the application, but it may be inadequate thermally. Also, heat spreads in a circular fashion from the heat source. In this case the drain pin is the heat source when looking at heat spread on the PC board.

Figure 1 shows the footprint with copper spreading for the SOT-23 package. This pattern shows the starting point for utilizing the board area available for the heat spreading copper. To create this pattern, a plane of copper overlies the drain pin and provides planar copper to draw heat from the drain lead and start the process of spreading the heat so it can be dissipated into the

ambient air. This pattern uses all the available area underneath the body for this purpose.



**FIGURE 1.** Footprint With Copper Spreading

Since surface-mounted packages are small, and reflow soldering is the most common way in which these are affixed to the PC board, “thermal” connections from the planar copper to the pads have not been used. Even if additional planar copper area is used, there should be no problems in the soldering process. The actual solder connections are defined by the solder mask openings. By combining the basic footprint with the copper plane on the drain pins, the solder mask generation occurs automatically.

A final item to keep in mind is the width of the power traces. The absolute minimum power trace width must be determined by the amount of current it has to carry. For thermal reasons, this minimum width should be at least 0.020 inches. The use of wide traces connected to the drain plane provides a low-impedance path for heat to move away from the device.



## RECOMMENDED MINIMUM PADS FOR SOT-23



Recommended Minimum Pads  
Dimensions in Inches/(mm)

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