

## Load Switch with Level-Shift

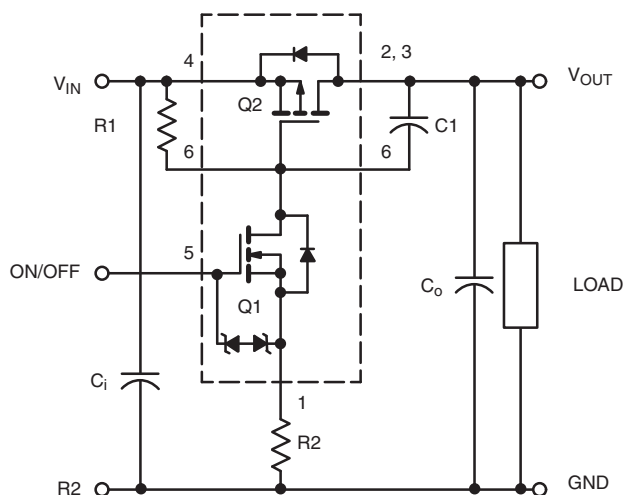
### PRODUCT SUMMARY

| V <sub>IN</sub> (V <sub>DS2</sub> ) (V) | R <sub>DS(on)</sub> (Ω)          | I <sub>D</sub> (A) |
|-----------------------------------------|----------------------------------|--------------------|
| 1.5 to 12                               | 0.054 at V <sub>IN</sub> = 4.5 V | 3.9                |
|                                         | 0.077 at V <sub>IN</sub> = 2.5 V | 3.2                |
|                                         | 0.106 at V <sub>IN</sub> = 1.8 V | 2.8                |
|                                         | 0.165 at V <sub>IN</sub> = 1.5 V | 2.2                |

### DESCRIPTION

The Si3865DDV includes a p- and n-channel MOSFET in a single TSOP-6 package. The low on-resistance p-channel TrenchFET is tailored for use as a load switch. The n-channel, with an external resistor, can be used as a level-shift to drive the p-channel load-switch. The n-channel MOSFET has internal ESD protection and can be driven by logic signals as low as 1.8 V. The Si3865DDV operates on supply lines from 1.5 V to 12 V, and can drive loads up to 2.8 A.

### APPLICATION CIRCUITS



### FEATURES

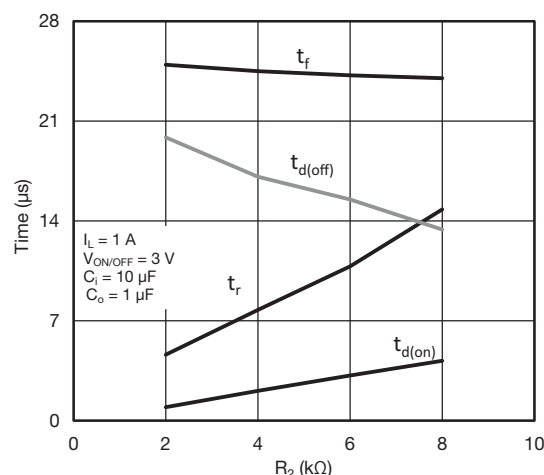
- Low R<sub>DS(on)</sub> TrenchFET®: 1.5 V rated
- 1.5 V to 12 V input
- 1.8 V to 8 V logic level control
- Low profile, small footprint TSOP-6 package
- 2100 V ESD protection on input switch, V<sub>ON/OFF</sub>
- Adjustable slew-rate
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



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

### APPLICATIONS

- Load switch with level-shift gate drive
- Slew-rate control
- Portable / consumer devices



Switching Variation R2 at V<sub>IN</sub> = 2.5 V, R1 = 20 kΩ

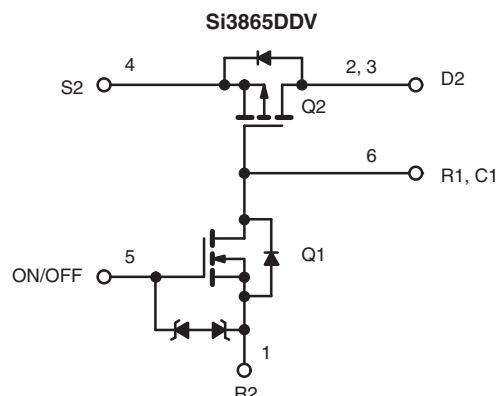
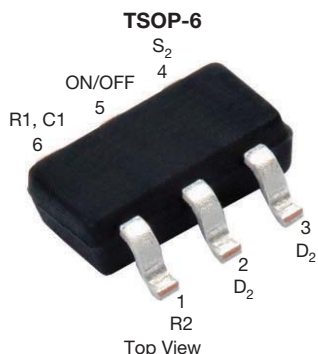
### COMPONENTS

|    |                            |                                    |
|----|----------------------------|------------------------------------|
| R1 | Pull-Up Resistor           | Typical 10 kΩ to 1 MΩ <sup>a</sup> |
| R2 | Optional Slew-Rate Control | Typical 0 to 100 kΩ <sup>a</sup>   |
| C1 | Optional Slew-Rate Control | Typical 1000 pF                    |

#### Note

- a. Minimum R1 value should be at least 10 x R2 to ensure Q1 turn-on.

The Si3865DDV is ideally suited for high-side load switching in portable applications. The integrated n-channel level-shift device saves space by reducing external components. The slew rate is set externally so that rise-times can be tailored to different load types.

**FUNCTIONAL BLOCK DIAGRAM**

**Marking Code:** IK

**Ordering Information:**

Si3865DDV-T1-GE3 (Lead (Pb)-free and Halogen-free)

| ABSOLUTE MAXIMUM RATINGS (T <sub>A</sub> = 25 °C, unless otherwise noted) |                            |                                     |             |      |
|---------------------------------------------------------------------------|----------------------------|-------------------------------------|-------------|------|
| PARAMETER                                                                 |                            | SYMBOL                              | LIMIT       | UNIT |
| Input Voltage                                                             |                            | V <sub>IN</sub> (V <sub>DS2</sub> ) | 12          | V    |
| On/Off Voltage                                                            |                            | V <sub>ON/OFF</sub>                 | 8           |      |
| Load Current                                                              | Continuous <sup>a, b</sup> | I <sub>L</sub>                      | ± 2.8       | A    |
|                                                                           | Pulsed <sup>b, c</sup>     |                                     | ± 6         |      |
| Continuous Intrinsic Diode Conduction <sup>a</sup>                        |                            | I <sub>S</sub>                      | -1          |      |
| Maximum Power Dissipation <sup>a</sup>                                    |                            | P <sub>D</sub>                      | 0.83        | W    |
| Operating Junction and Storage Temperature Range                          |                            | T <sub>J</sub> , T <sub>stg</sub>   | -55 to +150 | °C   |
| ESD Rating, MIL-STD-883D Human Body Model (100 pF, 1500 Ω)                |                            | ESD                                 | 2           | kV   |

| THERMAL RESISTANCE RATINGS                                    |                   |         |         |      |
|---------------------------------------------------------------|-------------------|---------|---------|------|
| PARAMETER                                                     | SYMBOL            | TYPICAL | MAXIMUM | UNIT |
| Maximum Junction-to-Ambient (Continuous Current) <sup>a</sup> | R <sub>thJA</sub> | 130     | 150     | °C/W |
| Maximum Junction-to-Foot (Q2)                                 | R <sub>thJF</sub> | 75      | 90      |      |

| SPECIFICATIONS (T <sub>J</sub> = 25 °C, unless otherwise noted) |                     |                                                                                 |                         |       |       |      |
|-----------------------------------------------------------------|---------------------|---------------------------------------------------------------------------------|-------------------------|-------|-------|------|
| PARAMETER                                                       | SYMBOL              | TEST CONDITIONS                                                                 | MIN.                    | TYP.  | MAX.  | UNIT |
| OFF Characteristics                                             |                     |                                                                                 |                         |       |       |      |
| Reverse Leakage Current                                         | I <sub>FL</sub>     | V <sub>IN</sub> = 12 V, V <sub>ON/OFF</sub> = 0 V                               | -                       | -     | 1     | μA   |
| Diode Forward Voltage                                           | V <sub>SD</sub>     | I <sub>S</sub> = -1 A                                                           | -                       | -0.77 | -1    | V    |
| ON Characteristics                                              |                     |                                                                                 |                         |       |       |      |
| Input Voltage Range                                             | V <sub>IN</sub>     |                                                                                 | 1.5                     | -     | 12    | V    |
| On-Resistance (P-Channel) at 1 A                                | R <sub>DS(on)</sub> | V <sub>ON/OFF</sub> = 1.8 V, I <sub>D</sub> = 1 A                               | V <sub>IN</sub> = 4.5 V | -     | 0.045 | Ω    |
|                                                                 |                     |                                                                                 | V <sub>IN</sub> = 2.5 V | -     | 0.063 |      |
|                                                                 |                     |                                                                                 | V <sub>IN</sub> = 1.8 V | -     | 0.085 |      |
|                                                                 |                     |                                                                                 | V <sub>IN</sub> = 1.5 V | -     | 0.110 |      |
| On-State (P-Channel) Drain-Current                              | I <sub>D(on)</sub>  | V <sub>IN-OUT</sub> ≤ 0.2 V, V <sub>IN</sub> = 5 V, V <sub>ON/OFF</sub> = 1.8 V | 1                       | -     | -     | A    |
|                                                                 |                     | V <sub>IN-OUT</sub> ≤ 0.3 V, V <sub>IN</sub> = 3 V, V <sub>ON/OFF</sub> = 1.8 V | 1                       | -     | -     |      |

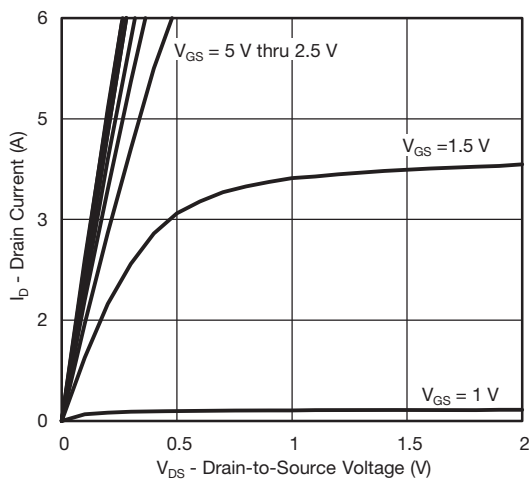
**Notes**

- Surface mounted on FR4 board.
- V<sub>IN</sub> = 12 V, V<sub>ON/OFF</sub> = 8 V, T<sub>A</sub> = 25 °C.
- Pulse test: pulse width ≤ 300 μs, duty cycle ≤ 2 %.

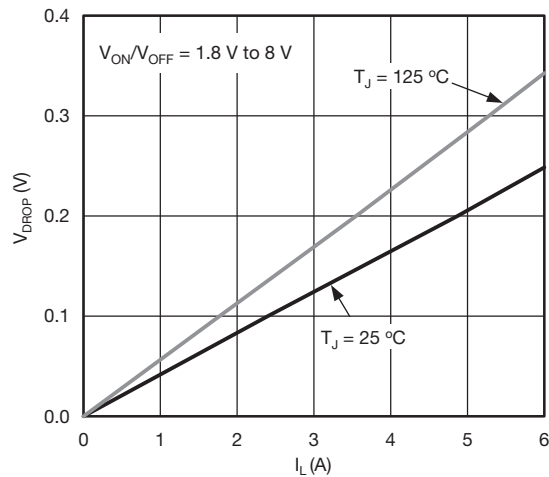
Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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



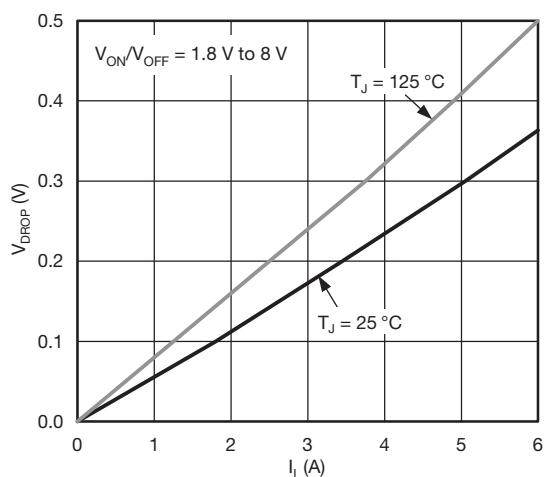
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



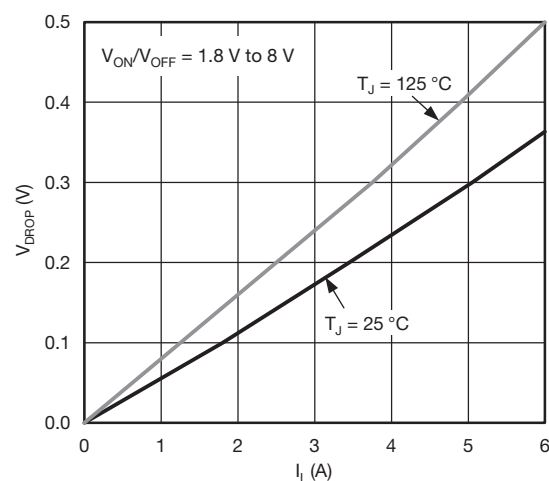
**Output Characteristics**



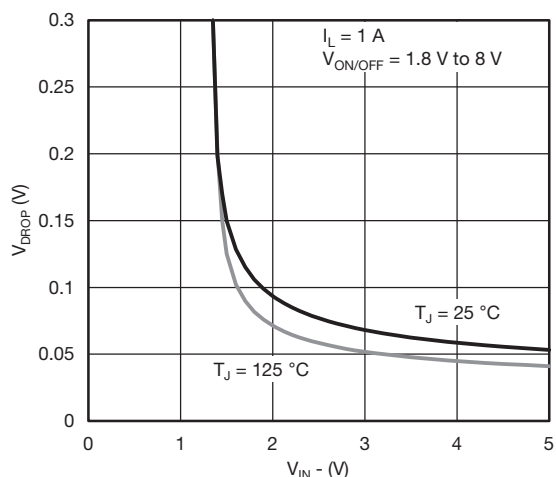
**$V_{DROP}$  vs.  $I_L$  at  $V_{IN} = 4.5\text{ V}$**



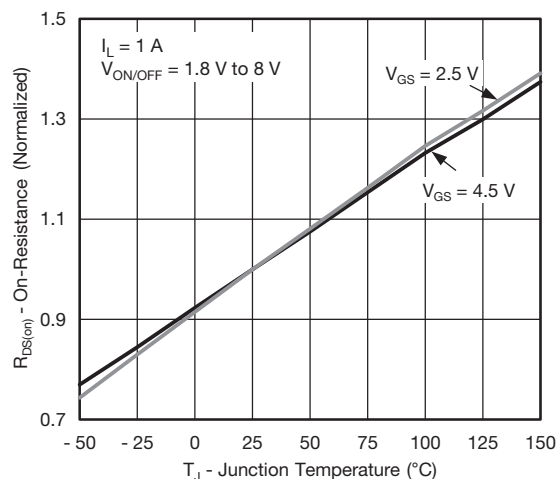
**$V_{DROP}$  vs.  $I_L$  at  $V_{IN} = 2.5\text{ V}$**



**$V_{DROP}$  vs.  $I_L$  at  $V_{IN} = 1.8\text{ V}$**



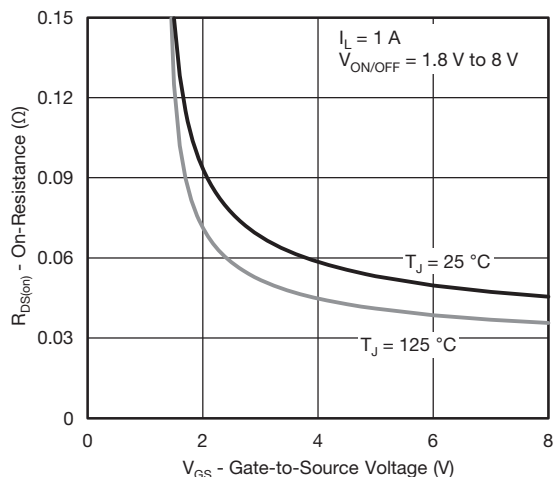
**$V_{DROP}$  vs.  $V_{IN}$  at  $I_L = 1\text{ A}$**



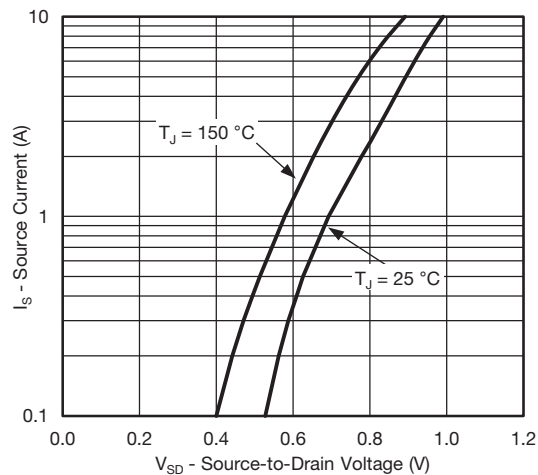
**Normalized On-Resistance vs. Junction Temperature**



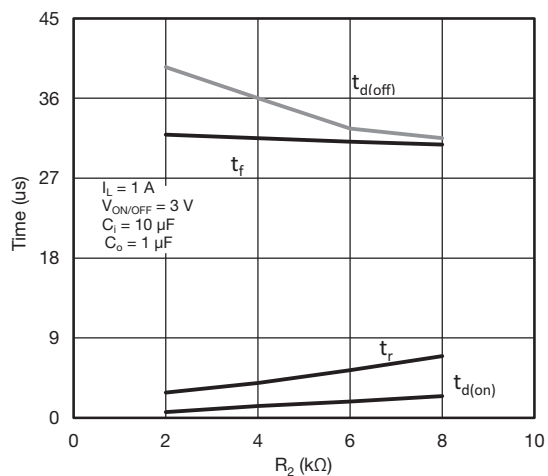
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



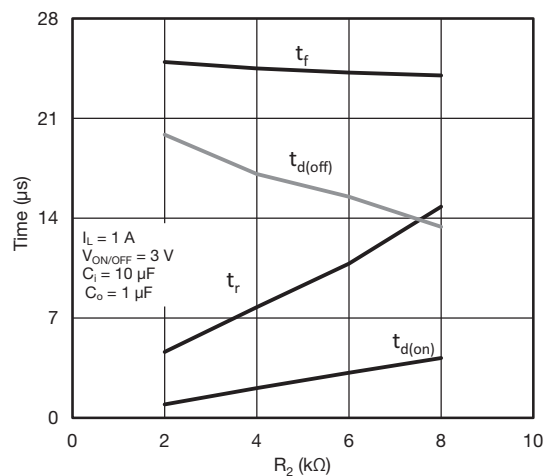
**On-Resistance vs. Input Voltage**



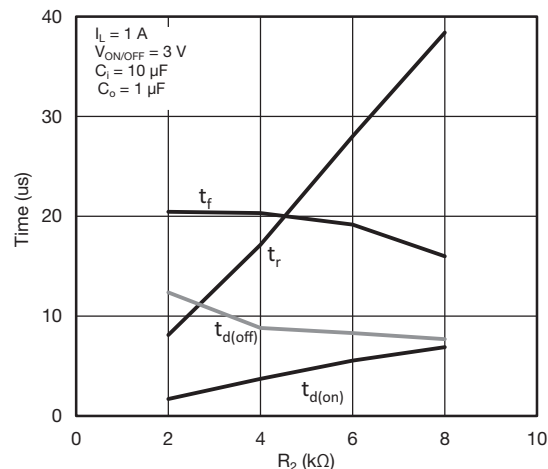
**Source-Drain Diode Forward Voltage**



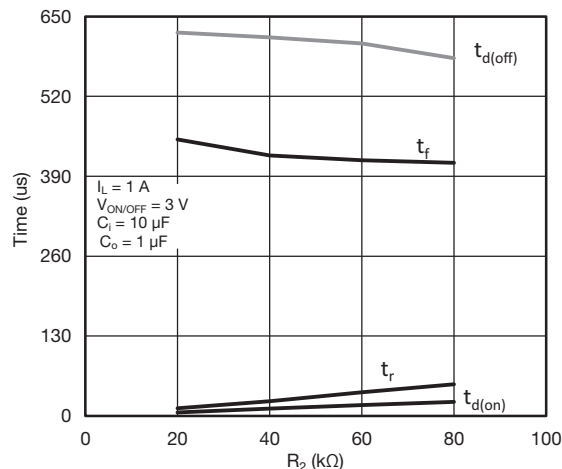
**Switching Variation  $R_2$  at  $V_{IN} = 4.5\text{ V}$ ,  $R_1 = 20\text{ k}\Omega$**



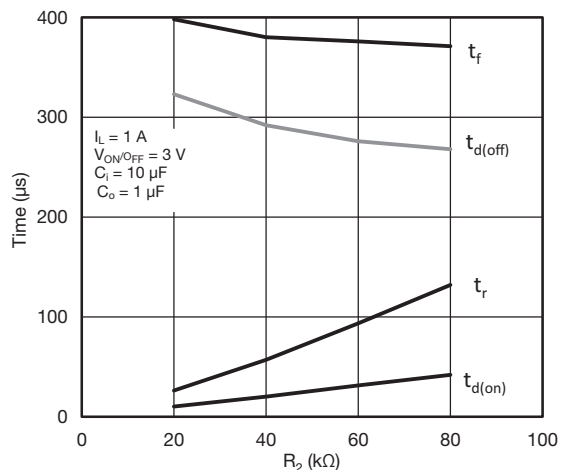
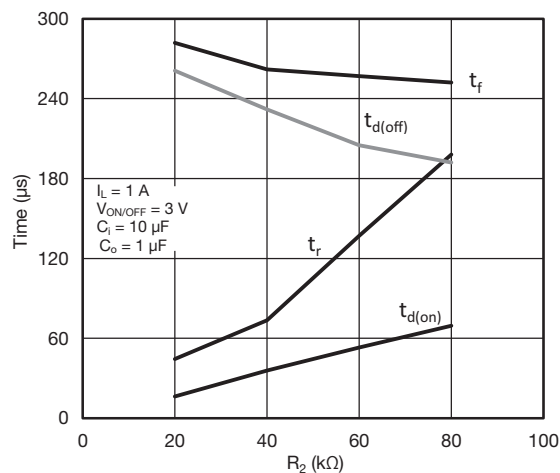
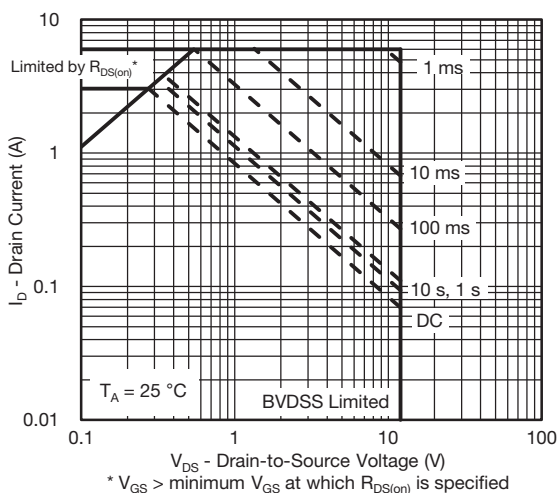
**Switching Variation  $R_2$  at  $V_{IN} = 2.5\text{ V}$ ,  $R_1 = 20\text{ k}\Omega$**



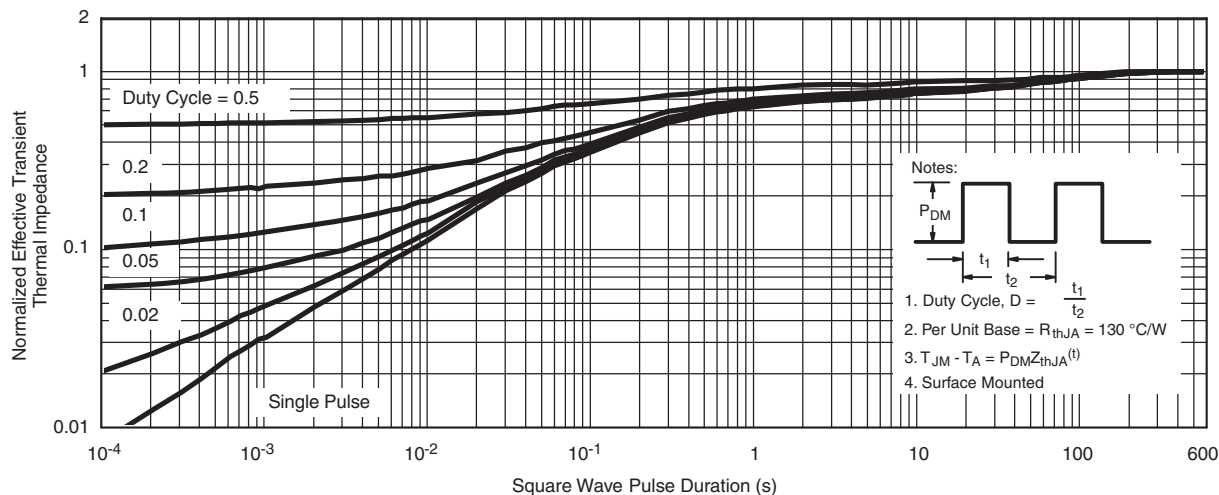
**Switching Variation  $R_2$  at  $V_{IN} = 1.8\text{ V}$ ,  $R_1 = 20\text{ k}\Omega$**



**Switching Variation  $R_2$  at  $V_{IN} = 4.5\text{ V}$ ,  $R_1 = 300\text{ k}\Omega$**

**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)Switching Variation  $R_2$  at  $V_{IN} = 2.5$  V,  $R_1 = 300$  k $\Omega$ Switching Variation  $R_2$  at  $V_{IN} = 1.8$  V,  $R_1 = 300$  k $\Omega$ 

Safe Operating Area, Junction-to-Foot

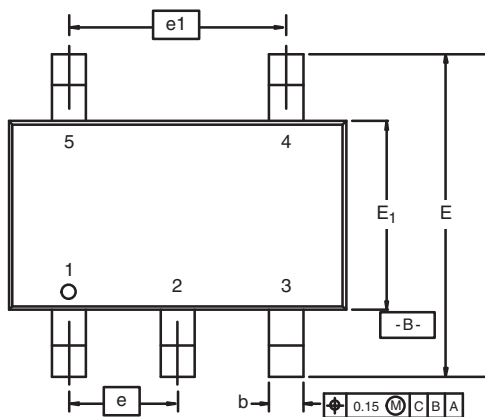


Normalized Thermal Transient Impedance, Junction-to-Ambient

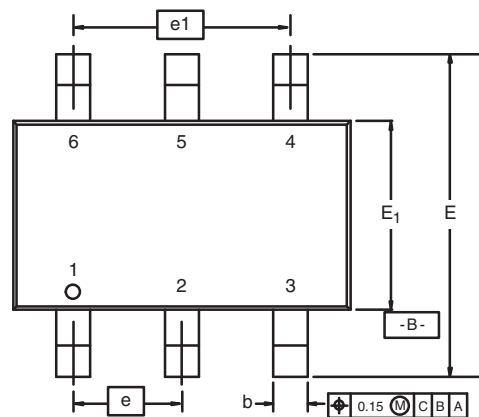
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## TSOP: 5/6-LEAD

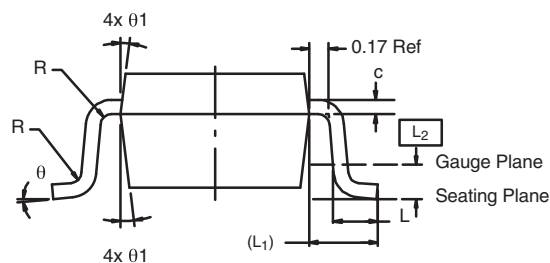
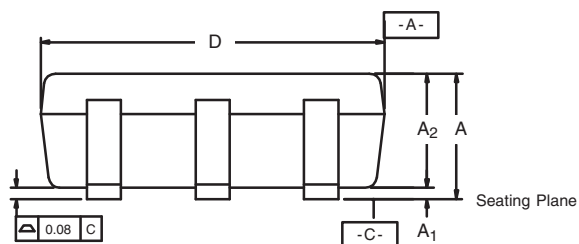
JEDEC Part Number: MO-193C



5-LEAD TSOP



6-LEAD TSOP



|                                | MILLIMETERS |      |      | INCHES     |       |       |
|--------------------------------|-------------|------|------|------------|-------|-------|
| Dim                            | Min         | Nom  | Max  | Min        | Nom   | Max   |
| A                              | 0.91        | -    | 1.10 | 0.036      | -     | 0.043 |
| A <sub>1</sub>                 | 0.01        | -    | 0.10 | 0.0004     | -     | 0.004 |
| A <sub>2</sub>                 | 0.90        | -    | 1.00 | 0.035      | 0.038 | 0.039 |
| b                              | 0.30        | 0.32 | 0.45 | 0.012      | 0.013 | 0.018 |
| c                              | 0.10        | 0.15 | 0.20 | 0.004      | 0.006 | 0.008 |
| D                              | 2.95        | 3.05 | 3.10 | 0.116      | 0.120 | 0.122 |
| E                              | 2.70        | 2.85 | 2.98 | 0.106      | 0.112 | 0.117 |
| E <sub>1</sub>                 | 1.55        | 1.65 | 1.70 | 0.061      | 0.065 | 0.067 |
| e                              | 0.95 BSC    |      |      | 0.0374 BSC |       |       |
| e <sub>1</sub>                 | 1.80        | 1.90 | 2.00 | 0.071      | 0.075 | 0.079 |
| L                              | 0.32        | -    | 0.50 | 0.012      | -     | 0.020 |
| L <sub>1</sub>                 | 0.60 Ref    |      |      | 0.024 Ref  |       |       |
| L <sub>2</sub>                 | 0.25 BSC    |      |      | 0.010 BSC  |       |       |
| R                              | 0.10        | -    | -    | 0.004      | -     | -     |
| θ                              | 0°          | 4°   | 8°   | 0°         | 4°    | 8°    |
| θ <sub>1</sub>                 | 7° Nom      |      |      | 7° Nom     |       |       |
| ECN: C-06593-Rev. I, 18-Dec-06 |             |      |      |            |       |       |
| DWG: 5540                      |             |      |      |            |       |       |

## Mounting LITTLE FOOT<sup>®</sup> TSOP-6 Power MOSFETs

Surface mounted power MOSFET packaging has been based on integrated circuit and small signal packages. Those packages have been modified to provide the improvements in heat transfer required by power MOSFETs. Leadframe materials and design, molding compounds, and die attach materials have been changed. What has remained the same is the footprint of the packages.

The basis of the pad design for surface mounted power MOSFET is the basic footprint for the package. For the TSOP-6 package outline drawing see <http://www.vishay.com/doc?71200> and see <http://www.vishay.com/doc?72610> for the minimum pad footprint. In converting the footprint to the pad set for a power MOSFET, you must remember that not only do you want to make electrical connection to the package, but you must make thermal connection and provide a means to draw heat from the package, and move it away from the package.

In the case of the TSOP-6 package, the electrical connections are very simple. Pins 1, 2, 5, and 6 are the drain of the MOSFET and are connected together. For a small signal device or integrated circuit, typical connections would be made with traces that are 0.020 inches wide. Since the drain pins serve the additional function of providing the thermal connection to the package, this level of connection is inadequate. The total cross section of the copper may be adequate to carry the current required for the application, but it presents a large thermal impedance. Also, heat spreads in a circular fashion from the heat source. In this case the drain pins are the heat sources when looking at heat spread on the PC board.

Figure 1 shows the copper spreading recommended footprint for the TSOP-6 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 overlays the basic pattern on pins 1,2,5, and 6. The copper plane connects the drain pins electrically, but more importantly provides planar copper to draw heat from the drain leads and start the process of spreading the heat so it can be dissipated into the ambient air. Notice that the planar copper is shaped like a "T" to move heat away from the drain leads in all directions. This pattern uses all the available area underneath the body for this purpose.

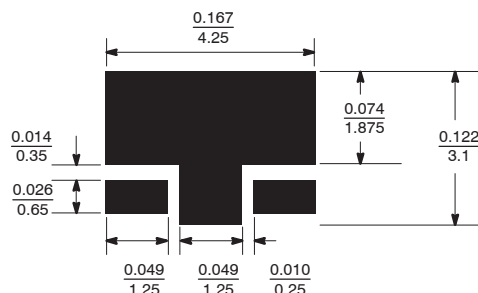


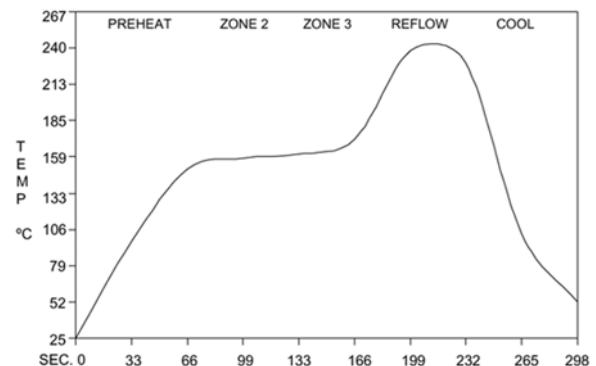
FIGURE 1. Recommended Copper Spreading Footprint

Since surface mounted packages are small, and reflow soldering is the most common form of soldering for surface mount components, "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.

### REFLOW SOLDERING

Vishay Siliconix surface-mount packages meet solder reflow reliability requirements. Devices are subjected to solder reflow as a test preconditioning and are then reliability-tested using temperature cycle, bias humidity, HAST, or pressure pot. The solder reflow temperature profile used, and the temperatures and time duration, are shown in Figures 2 and 3.



|                             |                     |
|-----------------------------|---------------------|
| Ramp-Up Rate                | +6°C/Second Maximum |
| Temperature @ 155 ± 15°C    | 120 Seconds Maximum |
| Temperature Above 180°C     | 70 – 180 Seconds    |
| Maximum Temperature         | 240 +5/-0°C         |
| Time at Maximum Temperature | 20 – 40 Seconds     |
| Ramp-Down Rate              | +6°C/Second Maximum |

FIGURE 2. Solder Reflow Temperature Profile

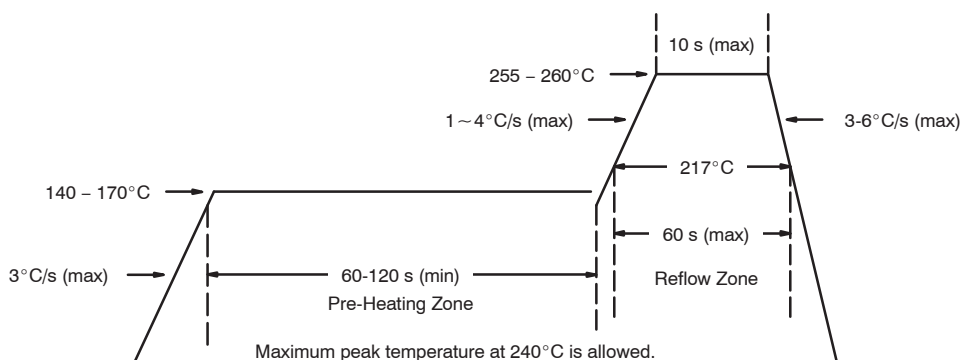


FIGURE 3. Solder Reflow Temperature and Time Durations

## THERMAL PERFORMANCE

A basic measure of a device's thermal performance is the junction-to-case thermal resistance,  $R\theta_{JC}$ , or the junction-to-foot thermal resistance,  $R\theta_{JF}$ . This parameter is measured for the device mounted to an infinite heat sink and is therefore a characterization of the device only, in other words, independent of the properties of the object to which the device is mounted. Table 1 shows the thermal performance of the TSOP-6.

| TABLE 1.                                   |        |
|--------------------------------------------|--------|
| Equivalent Steady State Performance—TSOP-6 |        |
| Thermal Resistance $R\theta_{JF}$          | 30°C/W |

## SYSTEM AND ELECTRICAL IMPACT OF TSOP-6

In any design, one must take into account the change in MOSFET  $r_{DS(on)}$  with temperature (Figure 4).

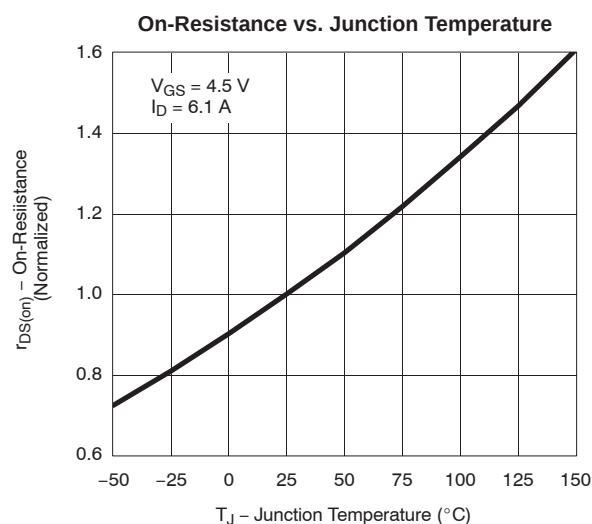
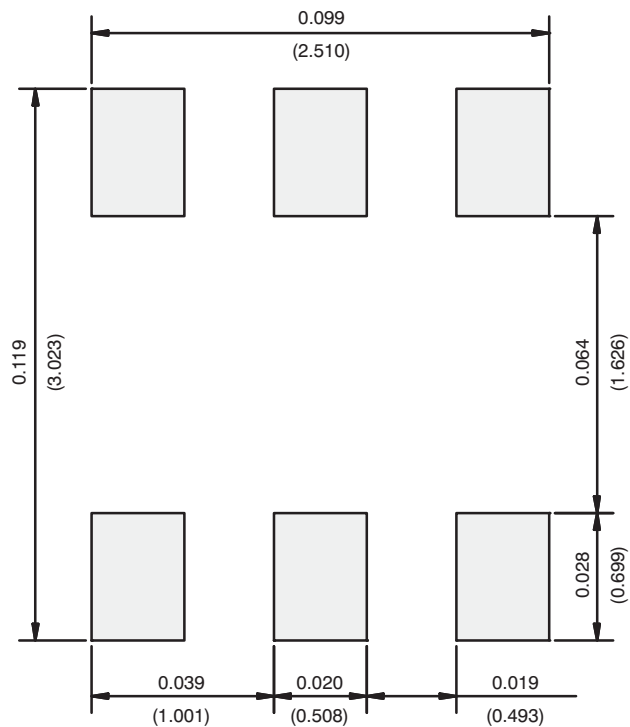


FIGURE 4. Si3434DV

## RECOMMENDED MINIMUM PADS FOR TSOP-6



Recommended Minimum Pads  
Dimensions in Inches/(mm)

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