

# 1.0 A Slew Rate Controlled Load Switch with Reverse Blocking in SC70-6, and TDFN4 1.2 mm x 1.6 mm

## DESCRIPTION

The SiP32431 is a slew rate controlled high side switch with reverse blocking capability. The switch is of a low ON resistance p-channel MOSFET that supports continuous current up to 1.0 A.

The SiP32431 operates with an input voltage from 1.5 V to 5.5 V.

The SiP32431 features low input logic level to interface with low control voltage from microprocessors. This device has a very low operating current, typically 50 pA.

The SiP32431 is available in lead (Pb)-free package options including 6 pin SC70-6, and 4 pin TDFN4 1.2 mm x 1.6 mm DFN4 packages. The operation temperature range is specified from - 40 °C to + 85 °C.

The SiP32431 compact package options, operation voltage range, and low operating current make it a good fit for battery power applications.

## FEATURES

- 1.5 V to 5.5 V input voltage range
- Very low  $R_{DS(on)}$ , typically 105 mΩ at 5 V and 135 mΩ at 3 V for TDFN4 1.2 mm x 1.6 mm package
- Typical 147 mΩ at 5 V and 178 mΩ at 3 V for SC70-6 package
- Slew rate controlled turn-on time: 100 μs
- Low quiescent current < 1 μA
- Low shutdown current < 1 μA
- Reverse blocking capability
- SC70-6 and TDFN4 1.2 mm x 1.6 mm packages
- **Compliant to RoHS Directive 2002/95/EC**
- **Halogen-free according to IEC 61249-2-21 definition**



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

## APPLICATIONS

- Cellular telephones
- Digital still cameras
- Personal digital assistants (PDA)
- Hot swap supplies
- Notebook computers
- Personal communication devices
- Portable Instruments

## TYPICAL APPLICATION CIRCUIT

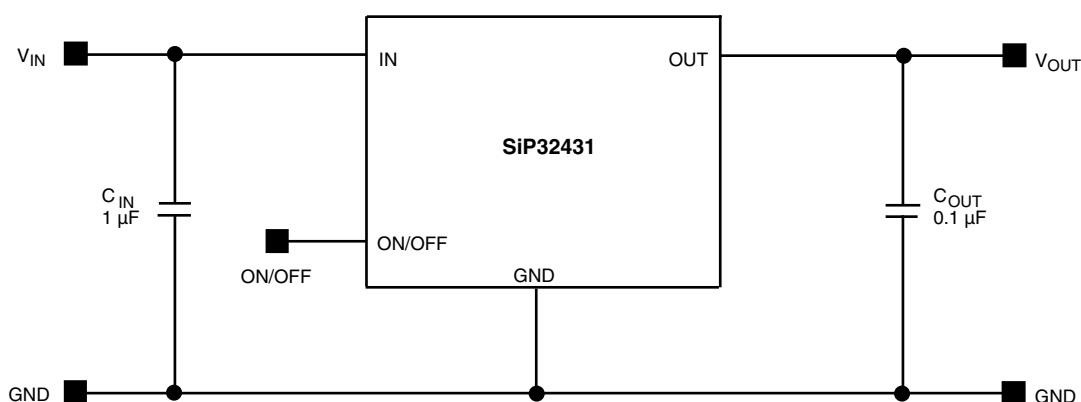


Figure 1 - SiP32431 Typical Application Circuit

**ORDERING INFORMATION**

| Temperature Range | Package               | Marking | Part Number        |
|-------------------|-----------------------|---------|--------------------|
| - 40 °C to 85 °C  | SC70-6                | MAxx    | SiP32431DR3-T1GE3  |
|                   | TDFN4 1.2 mm x 1.6 mm | ADx     | SiP32431DNP3-T1GE4 |

Notes:

x = Lot Code

-GE3 denotes halogen-free and RoHS compliant

Please use the SiP32431DR3-T1GE3 to replace SiP32431DR3-T1-E3

**ABSOLUTE MAXIMUM RATINGS**

| Parameter                                                                         |                                          | Limit                   | Unit |
|-----------------------------------------------------------------------------------|------------------------------------------|-------------------------|------|
| Supply Input Voltage ( $V_{IN}$ )                                                 |                                          | - 0.3 to 6              | V    |
| Enable Input Voltage ( $V_{ON/OFF}$ )                                             |                                          | - 0.3 to 6              |      |
| Output Voltage ( $V_{OUT}$ )                                                      |                                          | - 0.3 to $V_{IN} + 0.3$ |      |
| Maximum Continuous Switch Current ( $I_{MAX}$ )                                   | SC70-6 package                           | 1.2                     | A    |
|                                                                                   | TDFN4 1.2 mm x 1.6 mm                    | 1.4                     |      |
| Maximum Pulsed Current ( $I_{DM}$ ) $V_{IN}$<br>(Pulsed at 1 ms, 10 % Duty Cycle) | $V_{IN} \geq 2.5$ V                      | 3                       |      |
|                                                                                   | $V_{IN} < 2.5$ V                         | 1.6                     |      |
| ESD Rating (HBM)                                                                  |                                          | 4000                    | V    |
| Junction Temperature ( $T_J$ )                                                    |                                          | - 40 to 125             | °C   |
| Thermal Resistance ( $\theta_{JA}$ ) <sup>a</sup>                                 | 6 pin SC70-6 <sup>b</sup>                | 220                     | °C/W |
|                                                                                   | 4 pin TDFN4 1.2 mm x 1.6 mm <sup>c</sup> | 170                     |      |
| Power Dissipation ( $P_D$ ) <sup>a</sup>                                          | 6 pin SC70-6 <sup>b</sup>                | 250                     | mW   |
|                                                                                   | 4 pin TDFN4 1.2 mm x 1.6 mm <sup>c</sup> | 324                     |      |

Notes:

a. Device mounted with all leads and power pad soldered or welded to PC board.

b. Derate 4.5 mW/°C above  $T_A = 70$  °C.c. Derate 5.9 mW/°C above  $T_A = 70$  °C, see PCB layout.

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.

**RECOMMENDED OPERATING RANGE**

| Parameter                        | Limit      | Unit |
|----------------------------------|------------|------|
| Input Voltage Range ( $V_{IN}$ ) | 1.5 to 5.5 | V    |
| Operating Temperature Range      | - 40 to 85 | °C   |

| SPECIFICATIONS                        |                      |                                                                                                                                                |        |                            |                   |                   |        |
|---------------------------------------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------|--------|----------------------------|-------------------|-------------------|--------|
| Parameter                             | Symbol               | Test Conditions Unless Specified<br>V <sub>IN</sub> = 5.0, T <sub>A</sub> = - 40 °C to 85 °C<br>(Typical values are at T <sub>A</sub> = 25 °C) |        | Limits<br>- 40 °C to 85 °C |                   |                   | Unit   |
|                                       |                      |                                                                                                                                                |        | Min. <sup>a</sup>          | Typ. <sup>b</sup> | Max. <sup>a</sup> |        |
| Operating Voltage <sup>c</sup>        | V <sub>IN</sub>      |                                                                                                                                                |        | 1.5                        | -                 | 5.5               | V      |
| Quiescent Current                     | I <sub>Q</sub>       | On/Off = active                                                                                                                                |        | -                          | 0.00005           | 1                 | μA     |
| Off Supply Current                    | I <sub>Q(off)</sub>  | On/Off = inactive, Out = open                                                                                                                  |        | -                          | -                 | 1                 |        |
| Off Switch Current                    | I <sub>SD(off)</sub> | On/Off = inactive, Out = 0                                                                                                                     |        | -                          | -                 | 1                 |        |
| Reverse Blocking Current              | I <sub>RB</sub>      | V <sub>OUT</sub> = 5.5 V, V <sub>IN</sub> = 0, V <sub>on/off</sub> = inactive                                                                  |        | -                          | 0.13              | 1                 |        |
| On-Resistance                         | R <sub>DS(on)</sub>  | V <sub>IN</sub> = 5 V, I <sub>L</sub> = 500 mA, T <sub>A</sub> = 25 °C                                                                         | SC70-6 | -                          | 147               | 230               | mΩ     |
|                                       |                      |                                                                                                                                                | TDFN4  | -                          | 105               |                   |        |
|                                       |                      | V <sub>IN</sub> = 4.2 V, I <sub>L</sub> = 500 mA, T <sub>A</sub> = 25 °C                                                                       | SC70-6 | -                          | 155               | 250               |        |
|                                       |                      |                                                                                                                                                | TDFN4  | -                          | 110               |                   |        |
|                                       |                      | V <sub>IN</sub> = 3 V, I <sub>L</sub> = 500 mA, T <sub>A</sub> = 25 °C                                                                         | SC70-6 | -                          | 178               | 290               |        |
|                                       |                      |                                                                                                                                                | TDFN4  | -                          | 135               |                   |        |
|                                       |                      | V <sub>IN</sub> = 1.8 V, I <sub>L</sub> = 500 mA, T <sub>A</sub> = 25 °C                                                                       | SC70-6 | -                          | 275               | 480               |        |
|                                       |                      |                                                                                                                                                | TDFN4  | -                          | 230               |                   |        |
|                                       |                      | V <sub>IN</sub> = 1.5 V, I <sub>L</sub> = 500 mA, T <sub>A</sub> = 25 °C                                                                       | SC70-6 | -                          | 395               | 520               |        |
|                                       |                      |                                                                                                                                                | TDFN4  | -                          | 350               |                   |        |
| On-Resistance Temp.-Coefficient       | TD <sub>RDS</sub>    |                                                                                                                                                |        | -                          | 2800              | -                 | ppm/°C |
| On/Off Input Low Voltage <sup>c</sup> | V <sub>IL</sub>      | V <sub>IN</sub> ≥ 1.5 V to < 1.8 V                                                                                                             |        | -                          | -                 | 0.3               | V      |
|                                       |                      | V <sub>IN</sub> ≥ 1.8 V to < 2.7 V                                                                                                             |        | -                          | -                 | 0.4               |        |
|                                       |                      | V <sub>IN</sub> ≥ 2.7 V to ≤ 5.5 V                                                                                                             |        | -                          | -                 | 0.6               |        |
| On/Off Input Low Voltage <sup>c</sup> | V <sub>IH</sub>      | V <sub>IN</sub> ≥ 1.5 V to < 2.7 V                                                                                                             |        | 1.3                        | -                 | -                 |        |
|                                       |                      | V <sub>IN</sub> ≥ 2.7 V to < 4.2 V                                                                                                             |        | 1.5                        | -                 | -                 |        |
|                                       |                      | V <sub>IN</sub> ≥ 4.2 V to ≤ 5.5 V                                                                                                             |        | 1.8                        | -                 | -                 |        |
| On/Off Input Leakage                  | I <sub>SINK</sub>    | V <sub>On/Off</sub> = 5.5 V                                                                                                                    |        | -                          | -                 | 1                 | μA     |
| Output Turn-On Delay Time             | t <sub>d(on)</sub>   | V <sub>IN</sub> = 5 V, R <sub>LOAD</sub> = 10 Ω, T <sub>A</sub> = 25 °C                                                                        |        | -                          | 20                | 40                | μs     |
| Output Turn-On Rise Time              | t <sub>(on)</sub>    |                                                                                                                                                |        | -                          | 140               | 180               |        |
| Output Turn-Off Delay Time            | t <sub>d(off)</sub>  |                                                                                                                                                |        | -                          | 4                 | 10                |        |

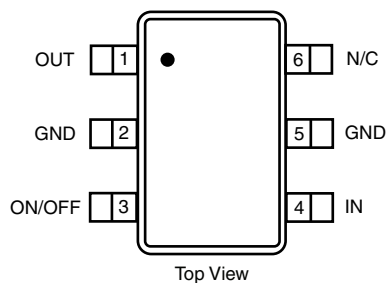
Notes:

a. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum.

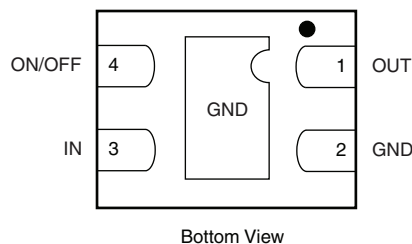
b. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing

c. For  $V_{IN}$  outside this range consult typical ON/OFF threshold curve.

## PIN CONFIGURATION



Top View  
Figure 2 - SC70-6 Package



Bottom View  
Figure 3 - TDFN4 1.2 mm x 1.6 mm Package

## PIN DESCRIPTION

| Pin Number |       | Name   | Function                                                                                             |
|------------|-------|--------|------------------------------------------------------------------------------------------------------|
| SC70-6     | TDFN4 |        |                                                                                                      |
| 4          | 3     | IN     | This pin is the p-channel MOSFET source connection. Bypass to ground through a 1 $\mu$ F capacitor.  |
| 2, 5       | 2     | GND    | Ground connection                                                                                    |
| 3          | 4     | ON/OFF | Enable input                                                                                         |
| 1          | 1     | OUT    | This pin is the p-channel MOSFET drain connection. Bypass to ground through a 0.1 $\mu$ F capacitor. |

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

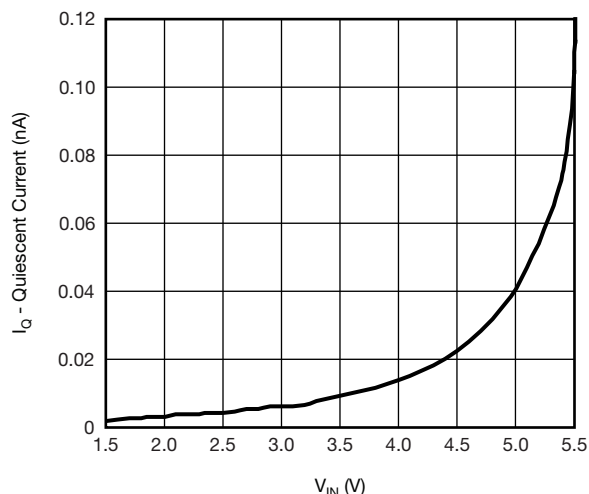


Figure 4 - Quiescent Current vs. Input Voltage

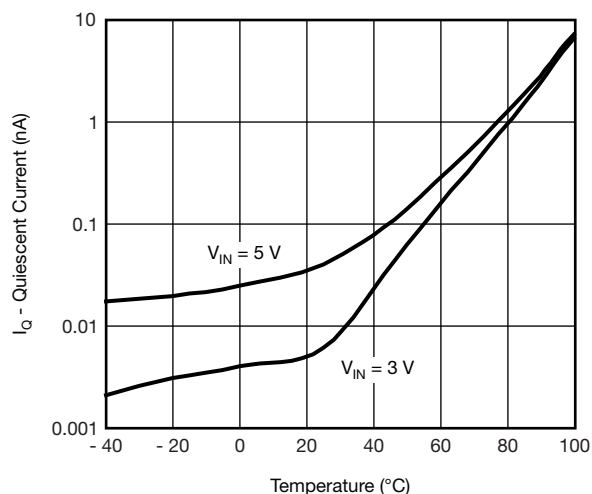


Figure 5 - Quiescent Current vs. Temperature

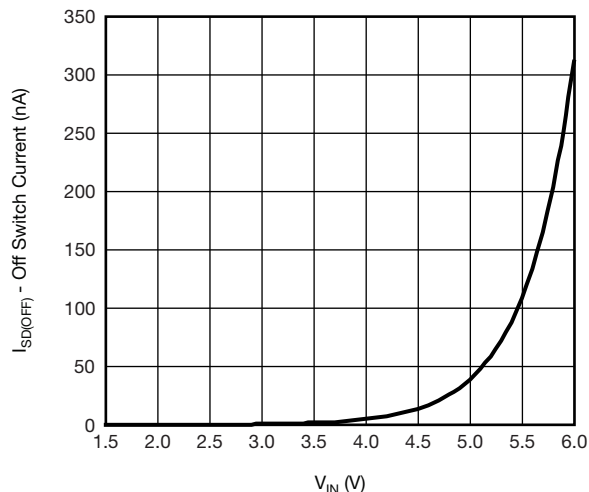


Figure 6 - Off Switch Current vs. Input Voltage

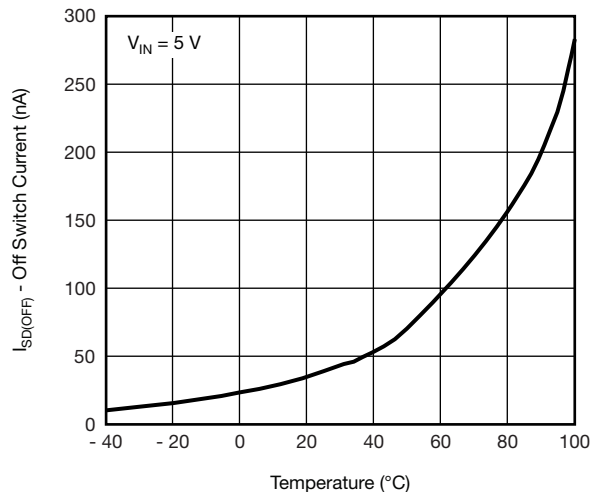


Figure 7 - Off Switch Current vs. Temperature

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

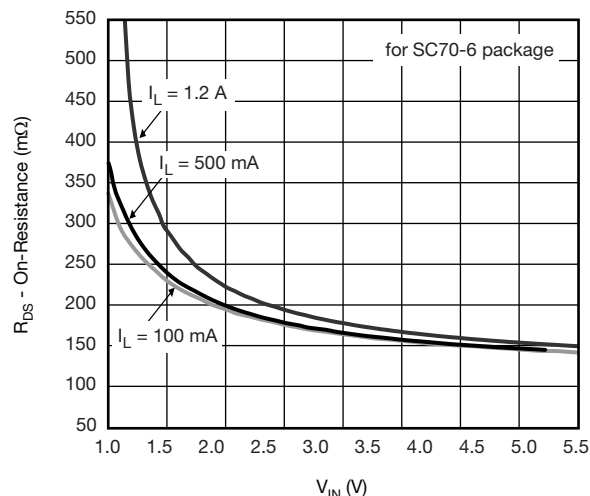


Figure 8 -  $R_{DS(on)}$  vs.  $V_{IN}$  for SC70-6 Package

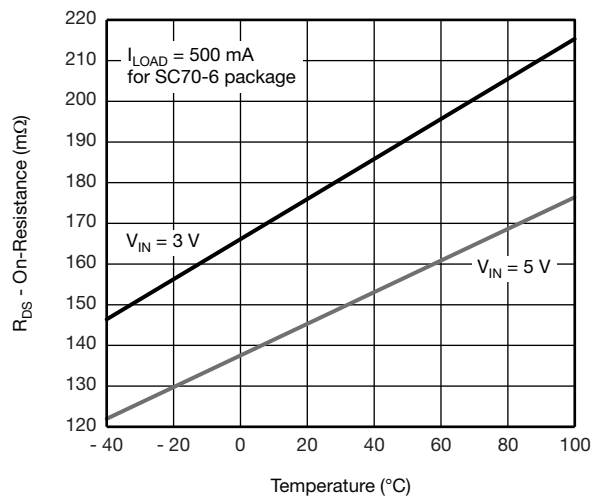


Figure 9 -  $R_{DS(on)}$  vs. Temperature

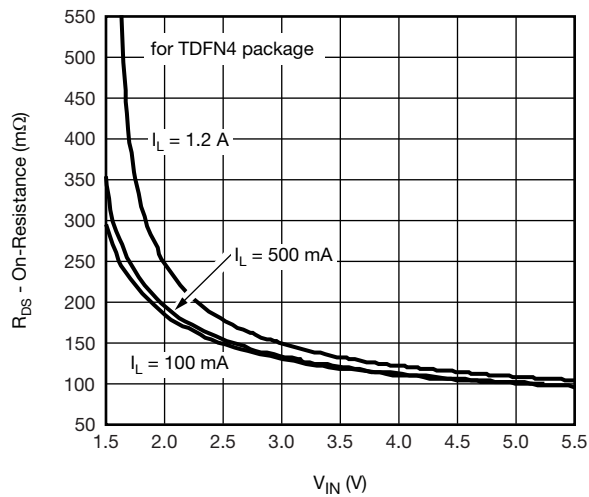


Figure 10 -  $R_{DS(on)}$  vs. Input Voltage

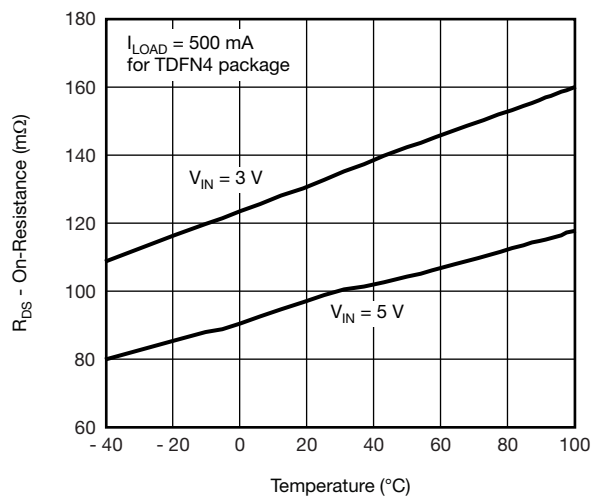


Figure 11 -  $R_{DS(on)}$  vs. Temperature

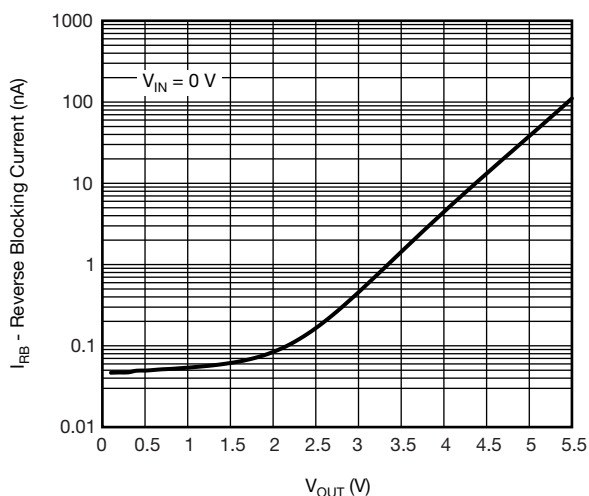


Figure 12 - Reverse Blocking Current vs.  $V_{OUT}$

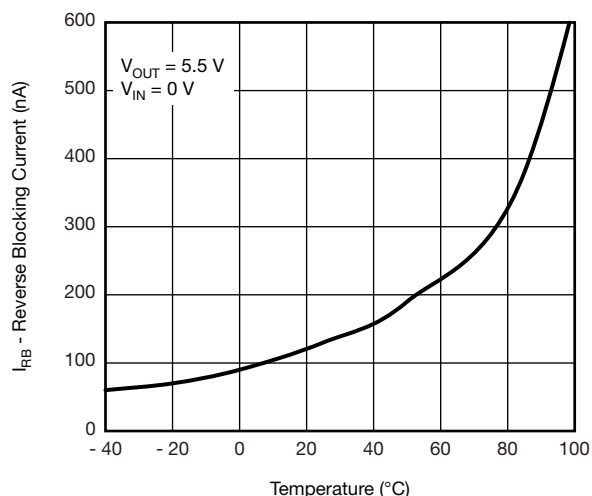


Figure 13 - Reverse Blocking Current vs. Temperature

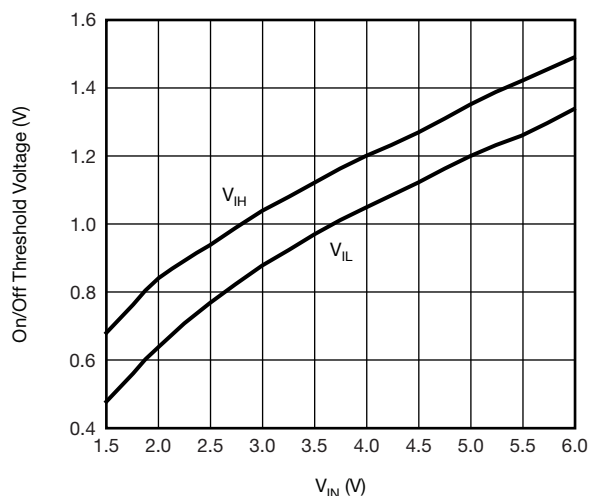
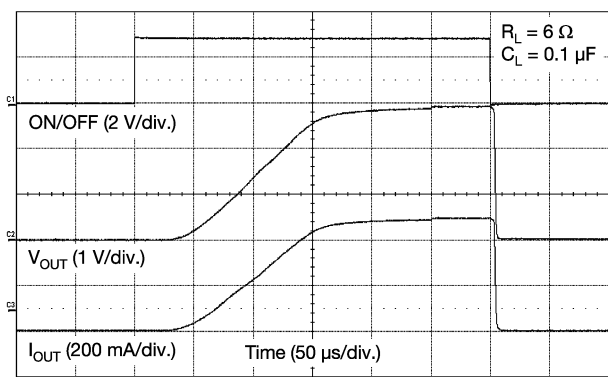
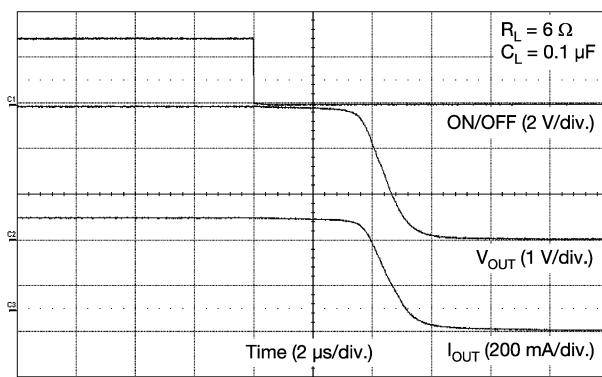
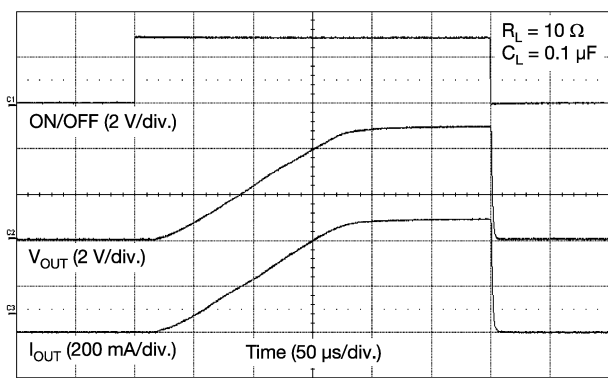
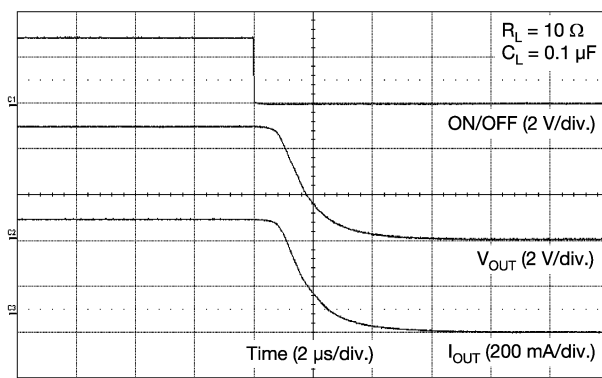
**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)


Figure 14 - ON/OFF Threshold vs. Input Voltage

**TYPICAL WAVEFORMS**
Figure 15 - Switching ( $V_{IN} = 3$  V)Figure 16 - Turn-Off ( $V_{IN} = 3$  V)Figure 17 - Switching ( $V_{IN} = 5$  V)Figure 18 - Turn-Off ( $V_{IN} = 5$  V)

## BLOCK DIAGRAM

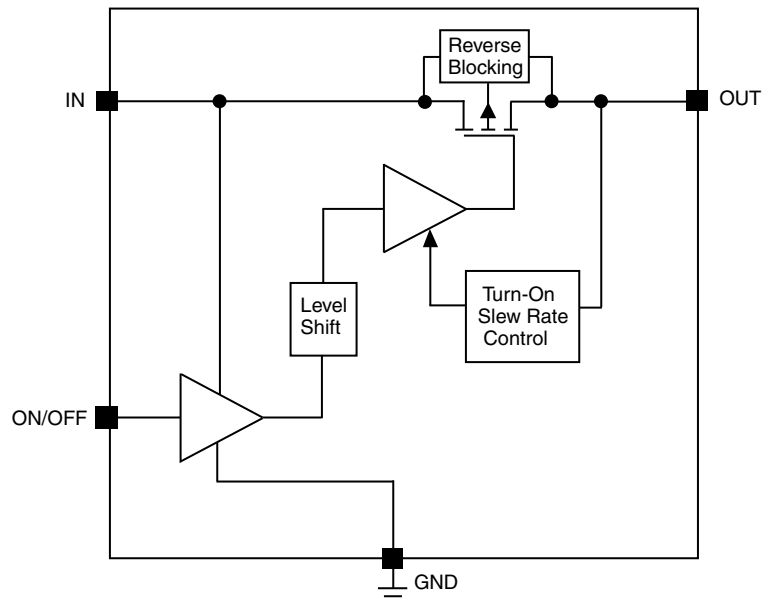
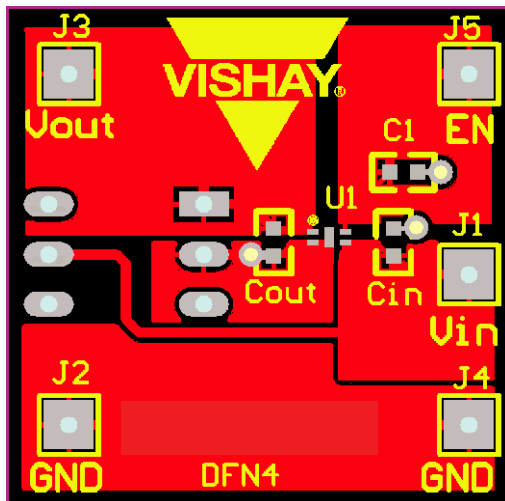
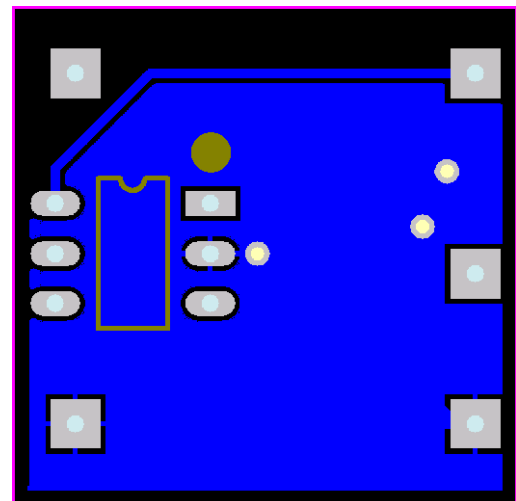


Figure 19 - Functional Block Diagram

## PCB LAYOUT



Top



Bottom

Figure 20 - TDFN4 1.2 mm x 1.6 mm PCB Layout

## DETAILED DESCRIPTION

The SiP32431 is a P-Channel MOSFET power switches designed for high-side slew rate controlled load-switching applications. Once turned on, the slew-rate control circuitry is activated and current is ramped in a linear fashion until it reaches the level required for the output load condition. This is accomplished by first elevating the gate voltage of the MOSFET up to its threshold voltage and then by linearly increasing the gate voltage until the MOSFET becomes fully enhanced. At this point, the gate voltage is then quickly increased to the full input voltage to reduce  $R_{DS(on)}$  of the MOSFET switch and minimize any associated power losses.

## APPLICATION INFORMATION

### Input Capacitor

While a bypass capacitor on the input is not required, a 1  $\mu\text{F}$  or larger capacitor for  $C_{IN}$  is recommended in almost all applications. The bypass capacitor should be placed as physically close as possible to the SiP32431 to be effective in minimizing transients on the input. Ceramic capacitors are recommended over tantalum because of their ability to withstand input current surges from low impedance sources such as batteries in portable devices.

### Output Capacitor

A 0.1  $\mu\text{F}$  capacitor or larger across  $V_{OUT}$  and GND is recommended to insure proper slew operation.  $C_{OUT}$  may be increased without limit to accommodate any load transient condition with only minimal affect on the SiP32431 turn on slew rate time. There are no ESR or capacitor type requirement.

### Enable

The On/Off pin is compatible with both TTL and CMOS logic voltage levels.

### Protection Against Reverse Voltage Condition

The SiP32431 contains a body snatcher that normally connect the body to the Source (IN) when the device is enable. In case where the device is disabled but the  $V_{OUT}$  is higher than the  $V_{IN}$ , the n-type body is switched to OUT, reverse bias the body diode to prevent the current from going back to the input.

### Thermal Considerations

The SiP32431 is designed to maintain a constant output load current. Due to physical limitations of the layout and assembly of the device the maximum switch current is 1.0 A, as stated in the Absolute Maximum Ratings table. However, another limiting characteristic for the safe operating load current is the thermal power dissipation of the package. To obtain the highest power dissipation (and a thermal resistance of 170  $^{\circ}\text{C}/\text{W}$ ) the power pad of the device should be connected to a heat sink on the printed circuit board.

The maximum power dissipation in any application is dependant on the maximum junction temperature,  $T_{J(MAX)} = 125^{\circ}\text{C}$ , the junction-to-ambient thermal resistance for the TDFN4 1.2 mm x 1.6 mm package,  $\theta_{JA} = 170^{\circ}\text{C}/\text{W}$ , and the ambient temperature,  $T_A$ , which may be formulaically expressed as:

$$P(\text{max.}) = \frac{T_J(\text{max.}) - T_A}{\theta_{JA}} = \frac{125 - T_A}{170}$$

It then follows that, assuming an ambient temperature of 70  $^{\circ}\text{C}$ , the maximum power dissipation will be limited to about 324 mW.

So long as the load current is below the 1.0 A limit, the maximum continuous switch current becomes a function two things: the package power dissipation and the  $R_{DS(on)}$  at the ambient temperature.

As an example let us calculate the worst case maximum load current at  $T_A = 70^{\circ}\text{C}$ . The worst case  $R_{DS(on)}$  at 25  $^{\circ}\text{C}$  occurs at an input voltage of 1.5 V and is equal to 520 m $\Omega$ . The  $R_{DS(on)}$  at 70  $^{\circ}\text{C}$  can be extrapolated from this data using the following formula

$$R_{DS(on)}(\text{at } 70^{\circ}\text{C}) = R_{DS(on)}(\text{at } 25^{\circ}\text{C}) \times (1 + T_C \times \Delta T)$$

Where  $T_C$  is 3300 ppm/ $^{\circ}\text{C}$ . Continuing with the calculation we have

$$R_{DS(on)}(\text{at } 70^{\circ}\text{C}) = 520 \text{ m}\Omega \times (1 + 0.0033 \times (70^{\circ}\text{C} - 25^{\circ}\text{C})) = 597 \text{ m}\Omega$$

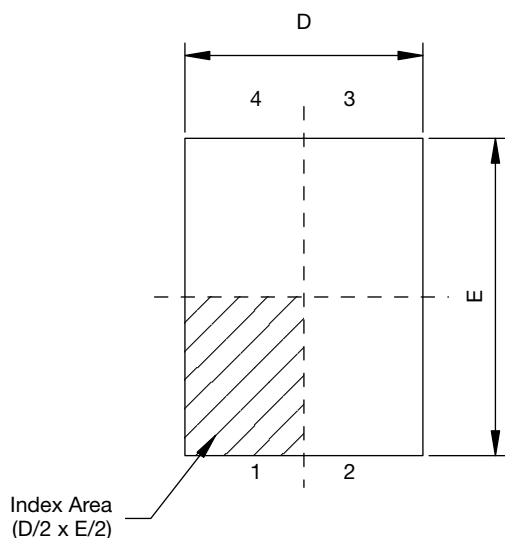
The maximum current limit is then determined by

$$I_{LOAD}(\text{max.}) < \sqrt{\frac{P(\text{max.})}{R_{DS(on)}}}$$

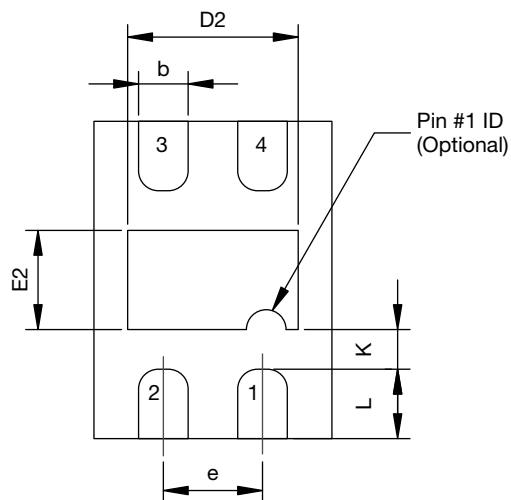
which in case is 0.74 A. Under the stated input voltage condition, if the 0.74 A current limit is exceeded the internal die temperature will rise and eventually, possibly damage the device.



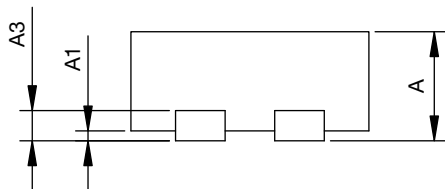
## TDFN4 1.2 x 1.6 Case Outline



Top View



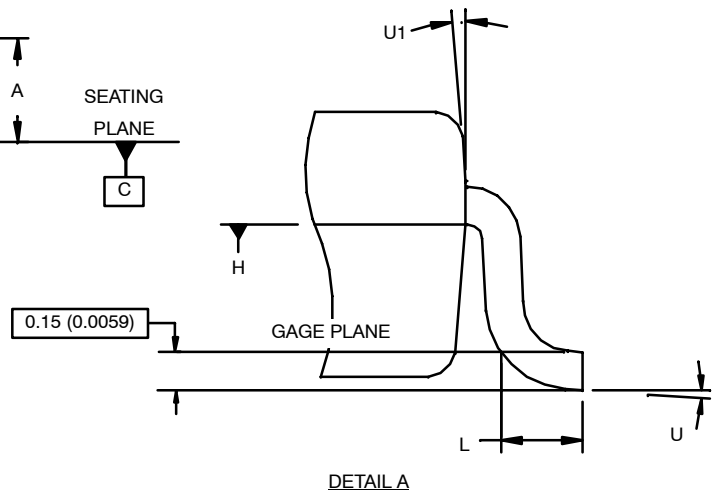
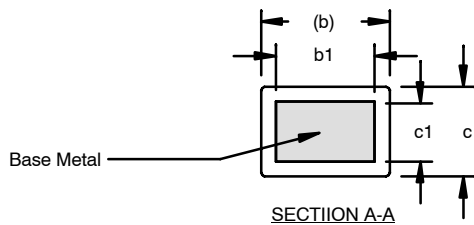
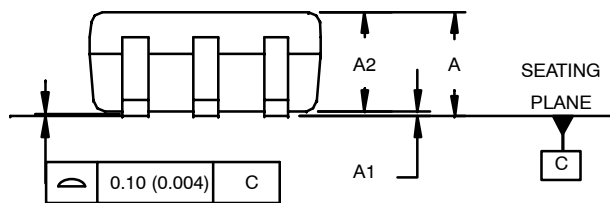
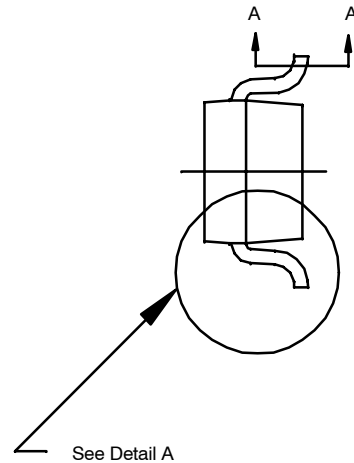
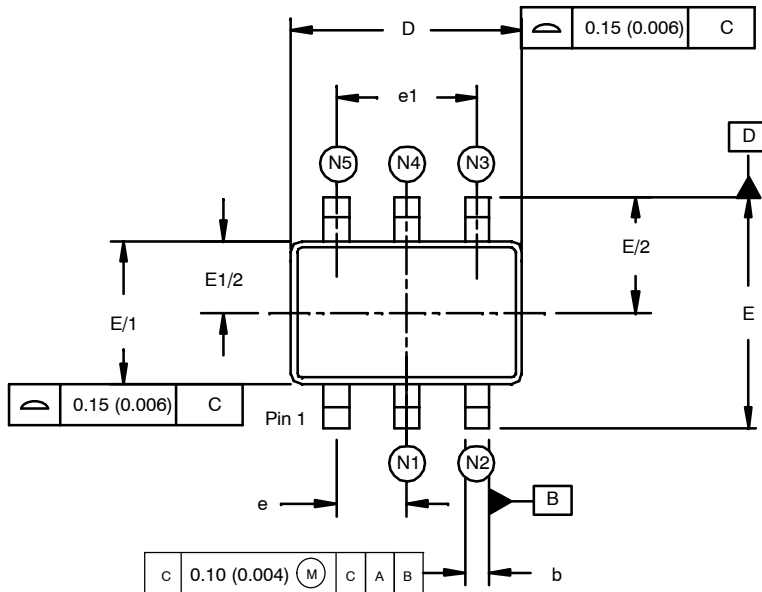
Bottom View



Side View

| DIM.                            | MILLIMETERS |      |      | INCHES     |       |       |
|---------------------------------|-------------|------|------|------------|-------|-------|
|                                 | MIN.        | NOM. | MAX. | MIN.       | NOM.  | MAX.  |
| A                               | 0.50        | 0.55 | 0.60 | 0.020      | 0.022 | 0.024 |
| A1                              | 0.00        | -    | 0.05 | 0.00       | -     | 0.002 |
| A3                              | 0.15 REF.   |      |      | 0.006      |       |       |
| b                               | 0.20        | 0.25 | 0.30 | 0.008      | 0.010 | 0.012 |
| D                               | 1.15        | 1.20 | 1.25 | 0.045      | 0.047 | 0.049 |
| D2                              | 0.81        | 0.86 | 0.91 | 0.032      | 0.034 | 0.036 |
| e                               | 0.50 BSC    |      |      | 0.020      |       |       |
| E                               | 1.55        | 1.60 | 1.65 | 0.061      | 0.063 | 0.065 |
| E2                              | 0.45        | 0.50 | 0.55 | 0.018      | 0.020 | 0.022 |
| K                               | 0.25 TYP.   |      |      | 0.010 TYP. |       |       |
| L                               | 0.25        | 0.30 | 0.35 | 0.010      | 0.012 | 0.014 |
| ECN: S11-2099-Rev. B, 07-Nov-11 |             |      |      |            |       |       |
| DWG: 5995                       |             |      |      |            |       |       |

### SC-70: 3/4/5/6-LEADS (PIC ONLY)



| Pin Code | LEAD COUNT |   |   |   |
|----------|------------|---|---|---|
|          | 3          | 4 | 5 | 6 |
| N1       | –          | – | 2 | 2 |
| N2       | 2          | 2 | 3 | 3 |
| N3       | –          | 3 | 4 | 4 |
| N4       | 3          | – | – | 5 |
| N5       | –          | 4 | 5 | 6 |

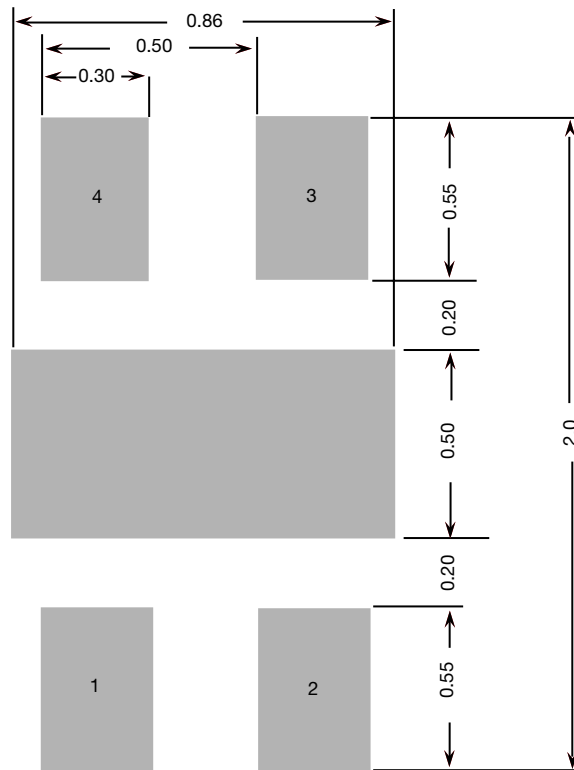
#### NOTES:

1. Dimensioning and tolerancing per ANSI Y14.5M-1994.
2. Controlling dimensions: millimeters converted to inch dimensions are not necessarily exact.
3. Dimension "D" does not include mold flash, protrusion or gate burr. Mold flash, protrusion or gate burr shall not exceed 0.15 mm (0.006 inch) per side.
4. The package top shall be smaller than the package bottom. Dimension "D" and "E1" are determined at the outer most extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs and interlead flash, but including any mismatch between the top and bottom of the plastic body.



| Dim                                         | MILLIMETERS |      |      | INCHES     |       |       |
|---------------------------------------------|-------------|------|------|------------|-------|-------|
|                                             | Min         | Nom  | Max  | Min        | Nom   | Max   |
| <b>A</b>                                    | 0.80        | –    | 1.10 | 0.031      | –     | 0.043 |
| <b>A1</b>                                   | 0.00        | –    | 0.10 | 0.000      | –     | 0.004 |
| <b>A2</b>                                   | 0.80        | 0.90 | 1.00 | 0.031      | 0.035 | 0.040 |
| <b>b</b>                                    | 0.15        | –    | 0.30 | 0.006      | –     | 0.012 |
| <b>b1</b>                                   | 0.15        | 0.20 | 0.25 | 0.006      | 0.008 | 0.010 |
| <b>c</b>                                    | 0.08        | –    | 0.25 | 0.003      | –     | 0.010 |
| <b>c1</b>                                   | 0.08        | 0.13 | 0.20 | 0.003      | 0.005 | 0.008 |
| <b>D</b>                                    | 1.90        | 2.10 | 2.15 | 0.074      | 0.082 | 0.084 |
| <b>E</b>                                    | 2.00        | 2.10 | 2.20 | 0.078      | 0.082 | 0.086 |
| <b>E<sub>1</sub></b>                        | 1.15        | 1.25 | 1.35 | 0.045      | 0.050 | 0.055 |
| <b>e</b>                                    | 0.65 BSC    |      |      | 0.0255 BSC |       |       |
| <b>e<sub>1</sub></b>                        | 1.30 BSC    |      |      | 0.0512 BSC |       |       |
| <b>L</b>                                    | 0.26        | 0.36 | 0.46 | 0.010      | 0.014 | 0.018 |
| <b>U</b>                                    | 0°          | –    | 8°   | 0°         | –     | 8°    |
| <b>U1</b>                                   | 4°          |      | 10°  | 4°         |       | 10°   |
| ECN: S-42145—Rev. A, 22-Nov-04<br>DWG: 5941 |             |      |      |            |       |       |

## RECOMMENDED MINIMUM PADS FOR TDFN4 1.2 x 1.6



Recommended Minimum Pads  
Dimensions in mm



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