

## 28 V, 56 mΩ, Load Switch with Programmable Current Limit and Slew Rate Control

### OPERATION DESCRIPTION

The SiP32429 is a load switch that integrates multiple control features that simplify the design and increase the reliability of the circuitry connected to the switch. The SiP32429 is a 56 mΩ switch designed to operate in the 6 V to 28 V range. An internally generated gate drive voltage ensures good  $R_{ON}$  linearity over the input voltage operating range.

The SiP32429 has a slew rate control circuit that controls the switch turn on time to the value set by an external capacitor. After soft start, an over current protection circuit (OCP) continuously monitors the current through the load switch, and controls the switch impedance to limit the current to the level programmed by an external resistor. If the overcurrent condition persists for more than 7 ms, the switch shuts off automatically. The SiP32429 has an over temperature protection circuit (OTP) which will shut the switch off if the junction temperature exceeds 137 °C. The OTP circuit will release the switch when the temperature has decreased by about 39 °C of hysteresis.

When an OCP or an OTP fault condition is detected the  $\overline{FLG}$  pin is pulled low. The fault flag will release 150 ms after the fault condition is cleared, and the switch will automatically turn on at the programmed slew rate.

The device features a low voltage control logic interface which can be controlled without the need for level shifting. The device also includes a power good flag.

SiP32429 is available in a space efficient DFN10 3 mm x 3 mm package.

### FEATURES

- 6 V to 28 V operation
- Programmable soft start
- Programmable current limit
- Over temperature protection
- ON resistance 56 mΩ
- Power good, when  $V_{OUT}$  reaches 90 % of  $V_{IN}$
- Fault flag
- Under voltage lockout: 4.8 V/5.4 V (typ./max.)
- Package: DFN10 3 mm x 3 mm
- SiP32429 will turn OFF the switch under fault conditions, and re-try to turn on through the full soft start procedure 150 ms after the switch is off and the fault removed.
- Material categorization: For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



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

### APPLICATIONS

- Personal Computers
- Lighting
- Flat panel displays
- Game Consoles
- Industrial
- Network communication
- Data storage

### TYPICAL APPLICATION CIRCUIT

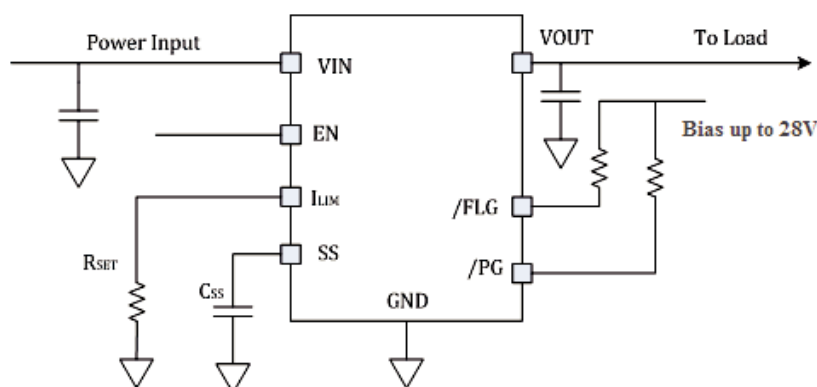


Figure 1 - SiP32429 Typical Application Circuit

**ORDERING INFORMATION**

| Temperature Range | Package           | Marking | Part Number        |
|-------------------|-------------------|---------|--------------------|
| - 40 °C to 85 °C  | DFN10 3 mm x 3 mm | 2429    | SiP32429DNP-T1-GE4 |

Note:

GE4 denotes halogen-free and RoHS-compliant

**ABSOLUTE MAXIMUM RATINGS**

| Parameter                                         | Limit                     | Unit |
|---------------------------------------------------|---------------------------|------|
| Input Voltage ( $V_{IN}$ )                        | - 0.3 to 30               | V    |
| Output Voltage ( $V_{OUT}$ )                      | - 0.3 to $V_{IN} + 0.3$ V |      |
| $\overline{PG}$ Voltage                           | - 0.3 to 30               |      |
| $\overline{FLG}$ Voltage                          | - 0.3 to 30               |      |
| EN Voltage                                        | - 0.3 to 6                |      |
| Maximum Continuous Switch Current                 | 4.5                       | A    |
| Maximum Junction Temperature                      | 150                       | °C   |
| Storage Temperature                               | - 55 to 150               |      |
| Thermal Resistance ( $\theta_{JA}$ ) <sup>a</sup> | 88                        | °C/W |
| Power Dissipation ( $P_D$ ) <sup>a,b</sup>        | 1.42                      | W    |

Notes:

a) Device mounted with all lead and power pad soldered or welded to PCB.

b) Derate 11.4 mW/°C above  $T_A = 25$  °C.

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 ( $V_{IN}$ )         | 6 to 28       | V    |
| $V_{SS}$                           | 0 to 6        |      |
| $V_{OUT}$                          | 0 V to 28     |      |
| EN                                 | 0 to 6        |      |
| $\overline{FLG}$ , $\overline{PG}$ | 0 to $V_{IN}$ |      |
| $I_{LIM}$                          | 0 to 6        |      |
| Current Limit                      | 0.75 to 3.5   | A    |
| Operating Temperature Range        | - 40 to 85    | °C   |

| SPECIFICATIONS                                                              |              |                                                                                                                             |                                                    |      |                      |      |                    |
|-----------------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------|----------------------|------|--------------------|
| Parameter                                                                   | Symbol       | Test Conditions Unless Specified<br>$V_{IN} = 12\text{ V}$ , $V_{EN} = 2.4\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$   | Temp.                                              | Min. | Typ.                 | Max. | Unit               |
| Power Input Voltage                                                         | $V_{IN}$     |                                                                                                                             | -                                                  | 6    | -                    | 28   | V                  |
| Quiescent Current                                                           | $I_Q$        | $I_{OUT} = 0\text{ A}$ , and device enabled                                                                                 | -                                                  | -    | 170                  | 300  | $\mu\text{A}$      |
| Shutdown Current                                                            | $I_{SD}$     | $I_{OUT} = 0\text{ A}$ , and device disabled                                                                                | -                                                  | -    | 12                   | 20   |                    |
| Switch OFF Leakage                                                          | $I_{(OFF)}$  | $V_{IN} = 28\text{ V}$ , $V_{OUT} = 0\text{ V}$<br>(current measured at output)                                             | -                                                  | -    | -                    | 1    |                    |
| Current Limit Accuracy                                                      |              | $R_{SET} = 4.1\text{ k}\Omega$                                                                                              | -40 $^{\circ}\text{C}$<br>to 85 $^{\circ}\text{C}$ | 1.2  | 1.5                  | 1.8  | A                  |
| Switch On Resistance                                                        | $R_{DS(ON)}$ | $I_{SW} = 500\text{ mA}$                                                                                                    | -                                                  | -    | 56                   | 72   | m $\Omega$         |
| Soft Start Charge Current                                                   | $I_{SS}$     | Constant current source                                                                                                     | -                                                  | -    | 4.5                  | -    | $\mu\text{A}$      |
| Turn ON Delay Time                                                          | $T_{ONDLY}$  | 50 % $V_{EN}$ to 50 % $V_{OUT}$<br>$C_{SS} = \text{open}$ , $R_L = 10\text{ }\Omega$ ,<br>$C_{OUT} = 10\text{ }\mu\text{F}$ | -                                                  | -    | 550                  | -    | $\mu\text{s}$      |
| Turn ON Rise Time                                                           | $T_R$        | $C_{SS} = \text{open}$ , $R_L = 10\text{ }\Omega$ ,<br>$C_{OUT} = 10\text{ }\mu\text{F}$                                    | -                                                  | -    | 400                  | -    |                    |
|                                                                             |              | $C_{SS} = 47\text{ nF}$ , $R_L = 10\text{ }\Omega$ ,<br>$C_{OUT} = 10\text{ }\mu\text{F}$                                   | -                                                  | -    | 7                    | -    | ms                 |
|                                                                             |              | $C_{SS} = 47\text{ nF}$ , no $R_L$ ,<br>$C_{OUT} = 10\text{ }\mu\text{F}$                                                   | -                                                  | -    | 2                    | -    |                    |
| Turn Off Delay                                                              | $T_{OFFDLY}$ |                                                                                                                             | -                                                  | -    | 1                    | -    | $\mu\text{s}$      |
| Current Limit Response Time                                                 |              |                                                                                                                             | -                                                  | -    | 20                   | -    |                    |
| Short Circuit Response Time                                                 |              |                                                                                                                             | -                                                  | -    | 1                    | -    |                    |
| OC Flag Blanking Time/Switch OFF delay under OC                             |              |                                                                                                                             | -40 $^{\circ}\text{C}$<br>to 85 $^{\circ}\text{C}$ | 4    | -                    | -    | ms                 |
| Auto re-try time                                                            |              |                                                                                                                             | -                                                  | -    | 150                  | -    |                    |
| Input Logic High Voltage                                                    | $V_{ENH}$    | $V_{IN} = 6\text{ V to }28\text{ V}$                                                                                        | -40 $^{\circ}\text{C}$<br>to 85 $^{\circ}\text{C}$ | 1.5  | -                    | -    | V                  |
| Input Logic Low Voltage                                                     | $V_{ENL}$    |                                                                                                                             | -40 $^{\circ}\text{C}$<br>to 85 $^{\circ}\text{C}$ | -    | -                    | 0.6  |                    |
| Input Pull Down Resistor                                                    | $R_{EN}$     | $V_{EN} = 5\text{ V}$                                                                                                       | -                                                  | -    | 2.5                  | -    | M $\Omega$         |
| Power Good Trip Voltage                                                     |              |                                                                                                                             | -                                                  | -    | 90 % $\times V_{IN}$ | -    | V                  |
| Power Good Hysteresis                                                       |              |                                                                                                                             | -                                                  | -    | 3 % $\times V_{IN}$  | -    |                    |
| $\overline{\text{PG}}$ and $\overline{\text{FLG}}$ Output Logic Low Voltage |              | $I_{SINK} = 1\text{ mA}$                                                                                                    | -                                                  | -    | < 0.1                | -    |                    |
| $\overline{\text{PG}}$ and $\overline{\text{FLG}}$ Output High Leakage      |              | $V_{PG}$ , $V_{FLG} = 28\text{ V}$                                                                                          | -                                                  | -    | -                    | 1    | $\mu\text{A}$      |
| UVLO Threshold                                                              |              |                                                                                                                             | -                                                  | -    | 4.8                  | 5.4  | V                  |
| UVLO Hysteresis                                                             |              |                                                                                                                             | -                                                  | -    | 0.28                 | -    |                    |
| Thermal Shutdown Threshold                                                  |              |                                                                                                                             | -                                                  | -    | 137                  | -    | $^{\circ}\text{C}$ |
| Thermal Shut down Hysteresis                                                |              |                                                                                                                             | -                                                  | -    | 39                   | -    |                    |

## PIN CONFIGURATION

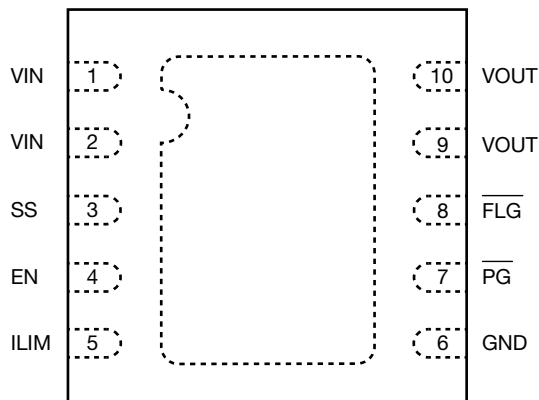


Figure 2 - DFN10 3 mm x 3 mm Package  
Top View

| PIN DESCRIPTION |                  |                                                                                                                                                     |
|-----------------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Pin Number      | Name             | Function                                                                                                                                            |
| 1               | $V_{IN}$         | Power Input                                                                                                                                         |
| 2               | $V_{IN}$         | Power Input                                                                                                                                         |
| 3               | SS               | Soft-Start Pin. Connect a Capacitor from SS to GND to Program the Soft-Start Time. Leave SS open to set the Default Soft-Start Time of 400 $\mu$ s. |
| 4               | EN               | Enable Input. Logic High Enabled                                                                                                                    |
| 5               | $I_{LIM}$        | Current Limit Setting Pin. Connect $R_{SET}$ Resistor to GND                                                                                        |
| 6               | GND              | Ground                                                                                                                                              |
| 7               | $\overline{PG}$  | Power Good                                                                                                                                          |
| 8               | $\overline{FLG}$ | Fault Condition Flag                                                                                                                                |
| 9               | $V_{OUT}$        | Switch Output                                                                                                                                       |
| 10              | $V_{OUT}$        | Switch Output                                                                                                                                       |
| Central Pad     |                  | Connect this Pad to GND or leave it floating                                                                                                        |

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

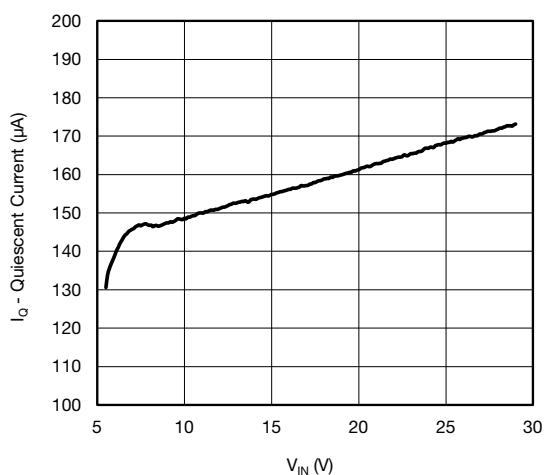


Figure 3 - Quiescent Current vs. Input Voltage

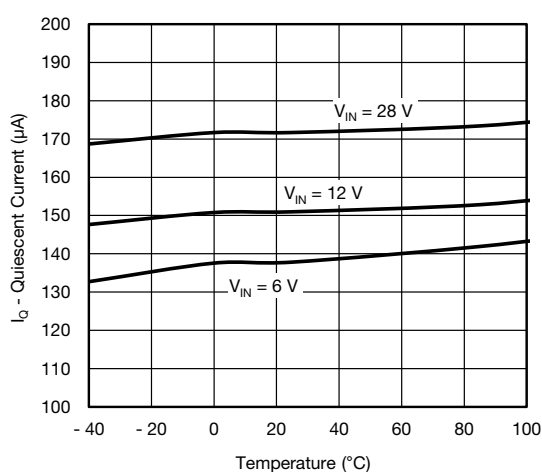
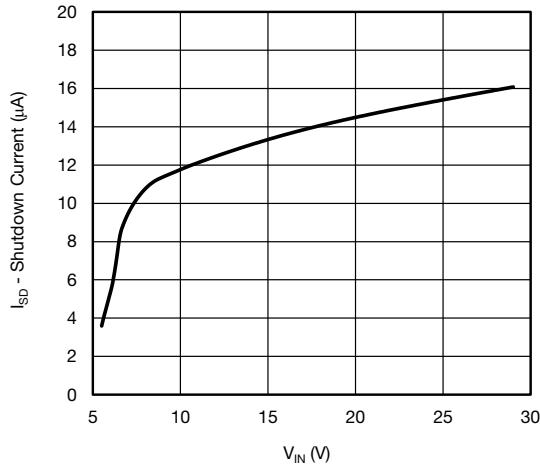
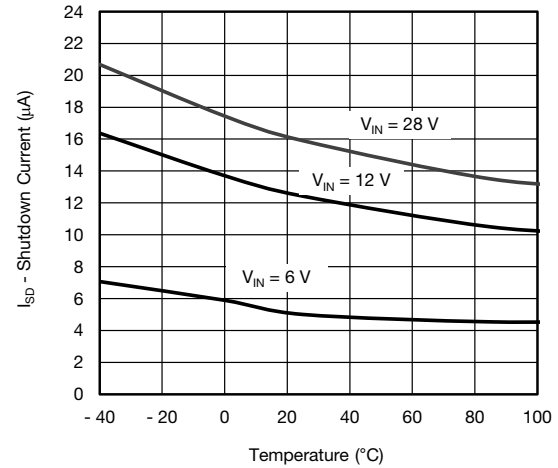


Figure 4 - Quiescent Current vs. Temperature

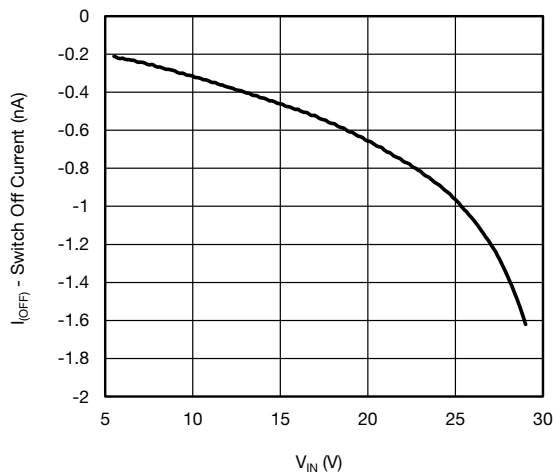
**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)



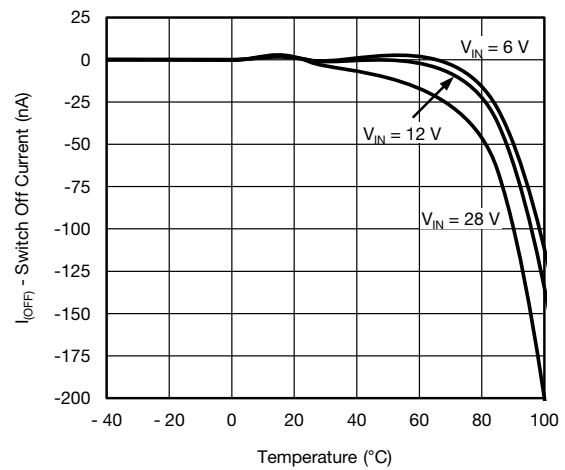
**Figure 5 - Shutdown Current vs. Input Voltage**



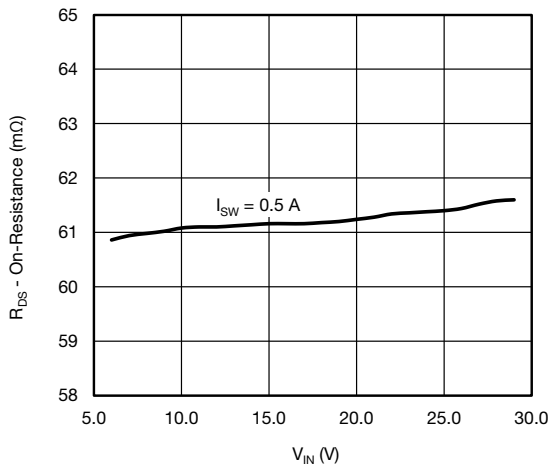
**Figure 8 - Shutdown Current vs. Temperature**



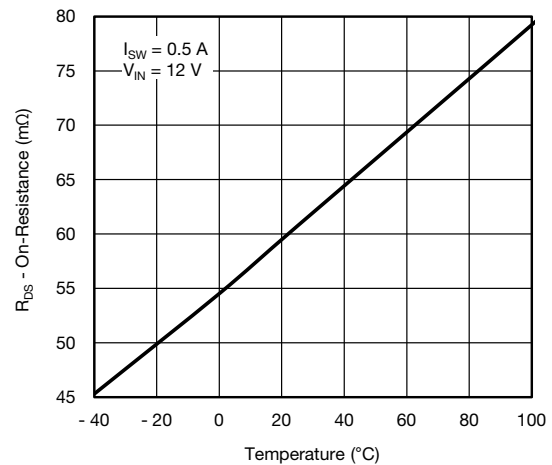
**Figure 6 - Shutdown Current vs. Input Voltage**



**Figure 9 - Switch Off Current vs. Temperature**



**Figure 7 - On Resistance vs. Input Voltage**



**Figure 10 - On Resistance vs. Temperature**

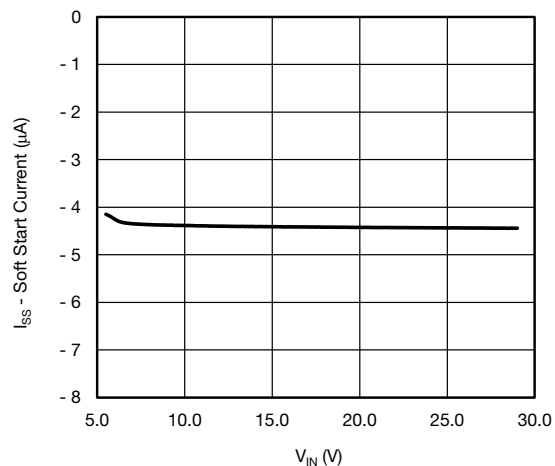
**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)

Figure 11 - Soft Start Current vs. Input Voltage

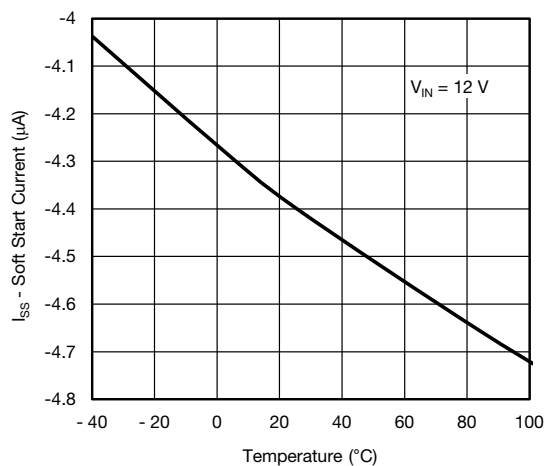


Figure 13 - Soft Start Current vs. Temperature

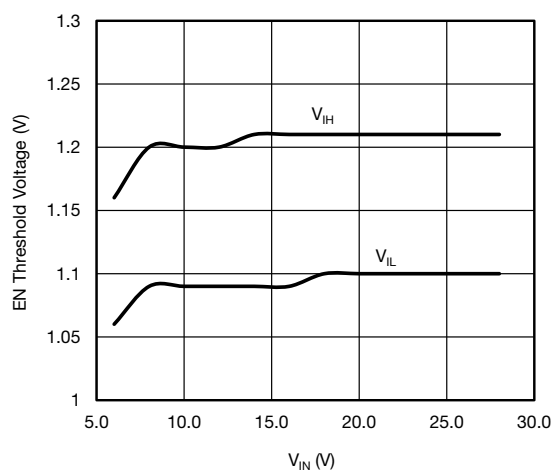
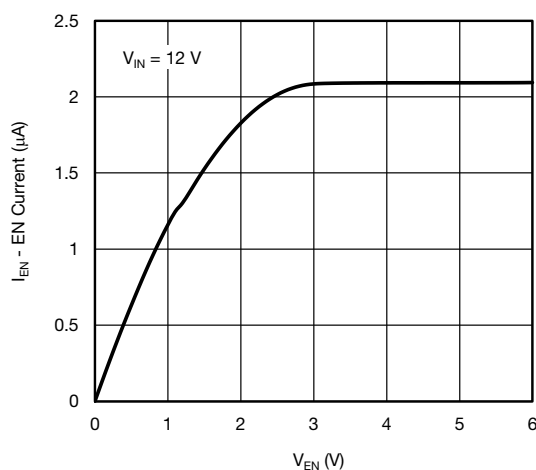
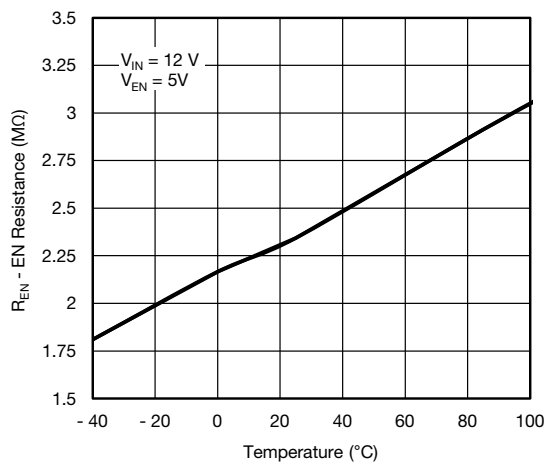
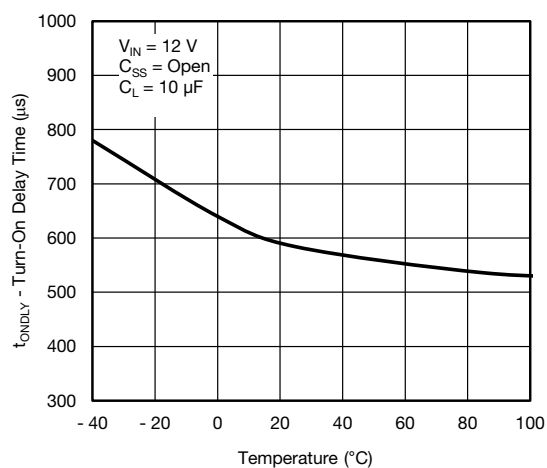
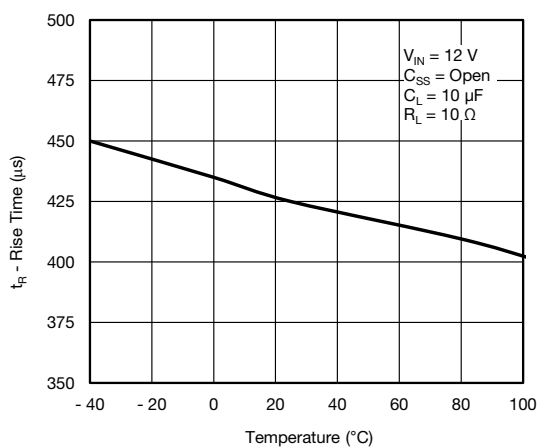
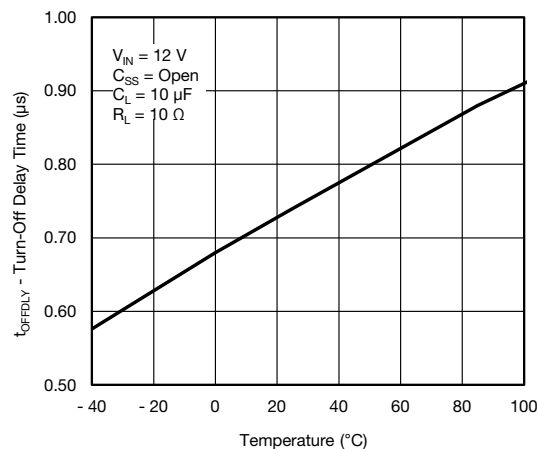
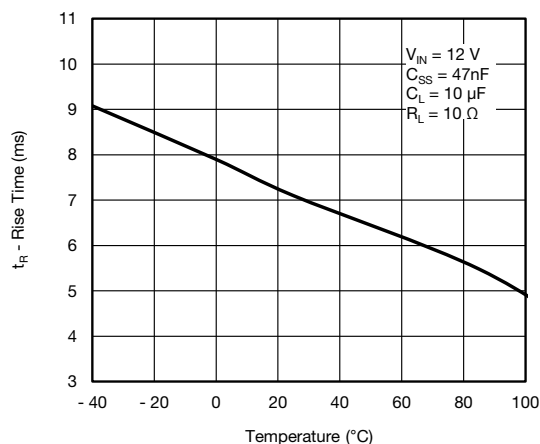


Figure 12 - Threshold Voltage vs. Input Voltage

Figure 14 - EN Current vs. V<sub>EN</sub>

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

**Figure 15 - EN Resistance vs. Temperature**

**Figure 17 - Turn-On Delay Time vs. Temperature**

**Figure 16 - Rise Time vs. Temperature**

**Figure 18 - Turn-Off Delay Time vs. Temperature**

**Figure 19 - Rise Time vs. Temperature**

## TYPICAL WAVEFORMS

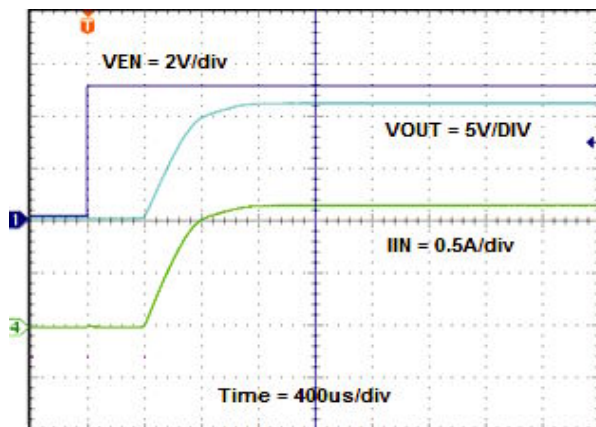


Figure 20 - Turn On Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = \text{open}$ ,  $R_L = 10\ \Omega$ ,  $C_L = 10\ \mu\text{F}$

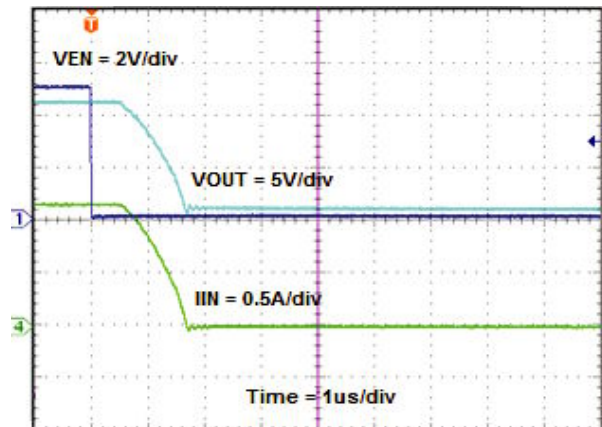


Figure 23 - Turn Off Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = \text{open}$ ,  $R_L = 10\ \Omega$ ,  $C_L = 10\ \mu\text{F}$

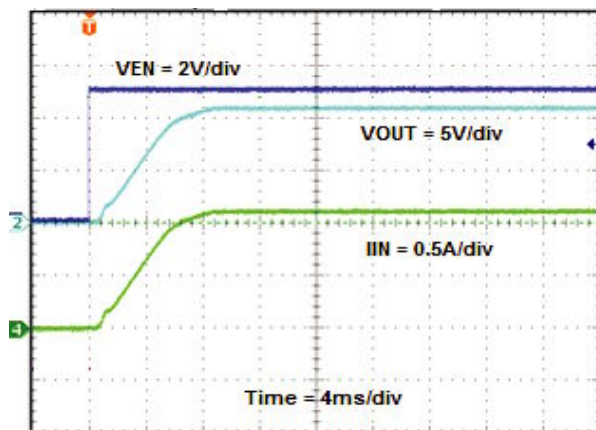


Figure 21 - Turn On Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 47\text{ nF}$ ,  $R_L = 10\ \Omega$ ,  $C_L = 10\ \mu\text{F}$

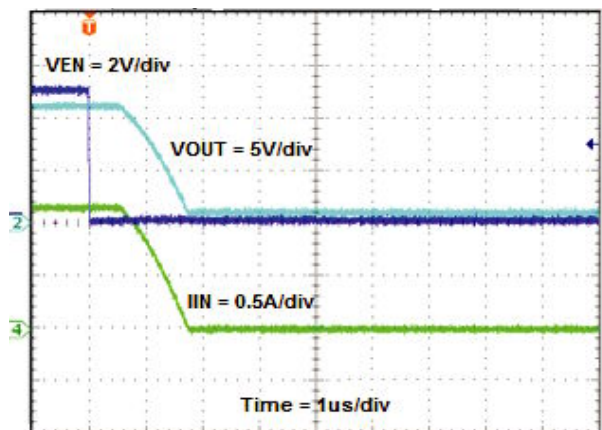


Figure 24 - Turn Off Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 47\text{ nF}$ ,  $R_L = 10\ \Omega$ ,  $C_L = 10\ \mu\text{F}$

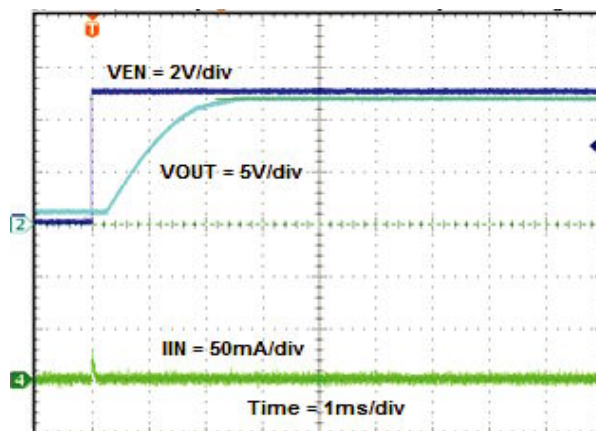


Figure 22 - Turn On Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 47\text{ nF}$ ,  $R_L = \text{open}$ ,  $C_L = 10\ \mu\text{F}$

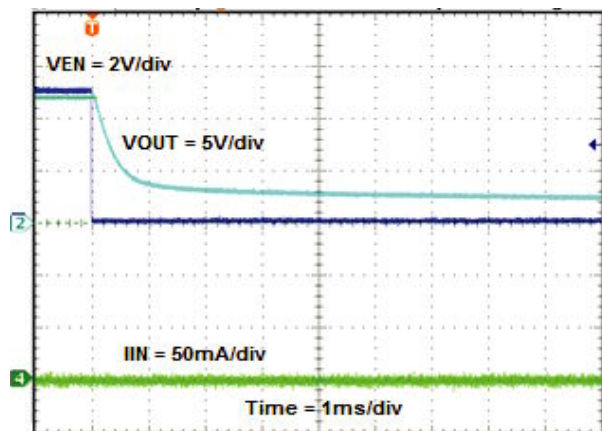
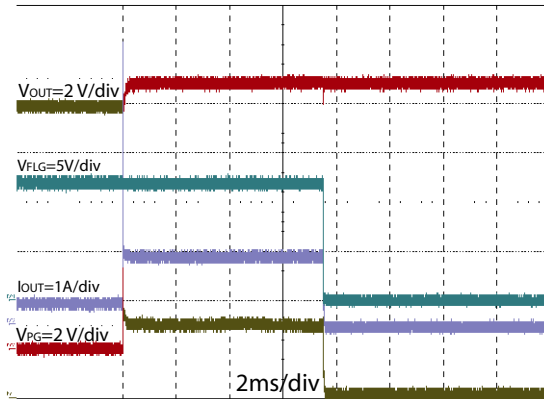
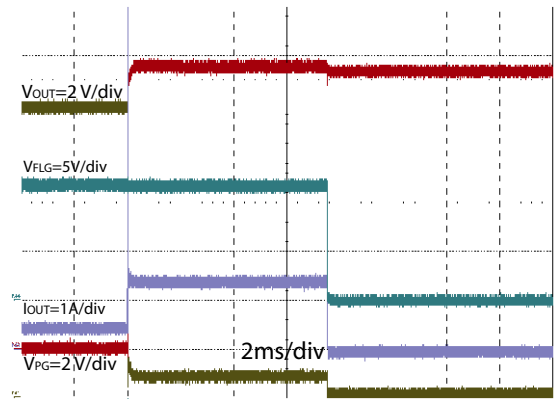


Figure 25 - Turn Off Time,  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 47\text{ nF}$ ,  $R_L = \text{open}$ ,  $C_L = 10\ \mu\text{F}$

## TYPICAL WAVEFORMS



**Figure 26 - Current Limit**  
from 25  $\Omega$  to 2  $\Omega$  Load,  $V_{IN} = 12$  V



**Figure 27 - Current Limit**  
from 25  $\Omega$  to 0.5  $\Omega$  Load,  $V_{IN} = 12$  V

## DETAILED DESCRIPTION

### OVER CURRENT LIMIT

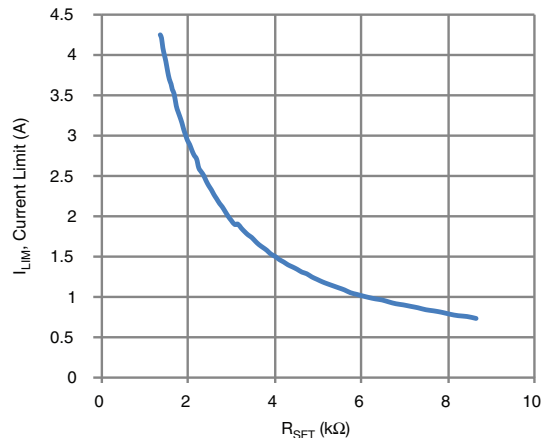
When an over-current event occurs, the SiP32429 will current limit immediately. If the event exceeds 7 ms the switch is turned OFF and the FLG pin is pulled low. The device remains off for 150 ms and after this time if the signal on EN pin is in a high state, the switch will enable.

The current limit is set by connecting a resistor between the  $I_{LIM}$  pin and GND.  $R_{SET}$  can be calculated by the following formula:

$$I_{lim} = \frac{1.24 \text{ V}}{R_{SET}} \times 5000$$

Where:

$I_{LIM}$  = is the target current limit setting.



**Figure 28 - Current Limit vs.  $R_{SET}$**

| <b><math>R_{SET}</math> SELECTION TABLE</b>        |                          |             |             |                 |
|----------------------------------------------------|--------------------------|-------------|-------------|-----------------|
| <b><math>R_{SET}</math> (k<math>\Omega</math>)</b> | <b>Current Limit (A)</b> |             |             | <b>Tol. (%)</b> |
|                                                    | <b>Min.</b>              | <b>Typ.</b> | <b>Max.</b> |                 |
| 1.74                                               | 2.85                     | 3.56        | 4.28        | 20              |
| 1.78                                               | 2.78                     | 3.48        | 4.18        | 20              |
| 1.82                                               | 2.73                     | 3.41        | 4.09        | 20              |
| 2.21                                               | 2.25                     | 2.81        | 3.37        | 20              |
| 2.80                                               | 1.77                     | 2.21        | 2.66        | 20              |
| 3.57                                               | 1.39                     | 1.74        | 2.08        | 20              |
| 4.12                                               | 1.20                     | 1.50        | 1.81        | 20              |
| 4.53                                               | 1.03                     | 1.37        | 1.71        | 25              |
| 5.76                                               | 0.81                     | 1.08        | 1.35        | 25              |
| 7.32                                               | 0.64                     | 0.85        | 1.06        | 25              |
| 8.25                                               | 0.56                     | 0.75        | 0.94        | 25              |

### SOFT START

The soft start time can be calculated by the following formula:

$$\frac{\Delta V_{OUT}}{\Delta T} = \frac{I_{SS}}{C_{SS}} \times \frac{R_{OUT} \times 5000}{R_{SET}}$$

Where:

$\Delta T$  is the soft start time

$\Delta V_{OUT}$  is the output voltage range

$I_{SS}$  is the built-in current source charging the soft start capacitor  $C_{SS}$ .  $I_{SS}$  value is 5  $\mu$ A typical.

$C_{SS}$  is the soft start time setting capacitor.

$R_{SET}$  is the current limit setting resistor.

$R_{OUT}$  is the output load.

## ENABLE

The enable pin needs to be high for the device to become active. This can be accomplished by applying a logic high signal to the EN pin. Alternatively this pin can be hardwired through a resistor divider to the  $V_{IN}$ , thus keeping the switch permanently ON as long as the supply is present.

## FLG

The  $\overline{FLG}$  is an open drain output and will be pulled low in fault condition. This pin can be pulled up through a 100K resistor.

## PG

The  $\overline{PG}$  is an open drain output that will be pulled low when output voltage passes 90 % of the  $V_{IN}$ . This pin can be pulled up through a 100K resistor.

## APPLICATION INFORMATION

### INPUT CAPACITOR

While bypass capacitors at the inputs pins are not required, a 2.2  $\mu F$  or larger capacitors for  $C_{IN}$  is recommended in almost all applications. The bypass capacitors should be placed as physically close to the device's input pins to be effective to minimize 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.

### OUTPUT CAPACITOR

The device does not require an output capacitor for proper operation. A proper value  $C_{OUT}$  is recommended to accommodate load transient per circuit design requirements. There are no ESR or capacitor type requirements.

### OVER TEMPERATURE SHUTDOWN

In case an over temperature event happens, the SiP32429 will turn the switch off immediately. It will then retry to start 150 ms after the temperature is back to normal; during this period,  $\overline{FLG}$  will be pulled low. The SiP32429  $\overline{FLG}$  will be pulled high 150 ms after the OT event has finished.

### THERMAL CONSIDERATION

The SiP32429 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 should be kept at reasonably safe level. However, another limiting characteristic of the safe operating load current is the thermal power dissipation.

## SOA

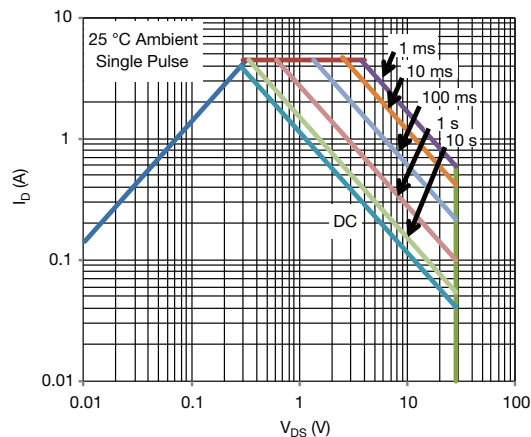


Figure 29 - SOA on Application Board

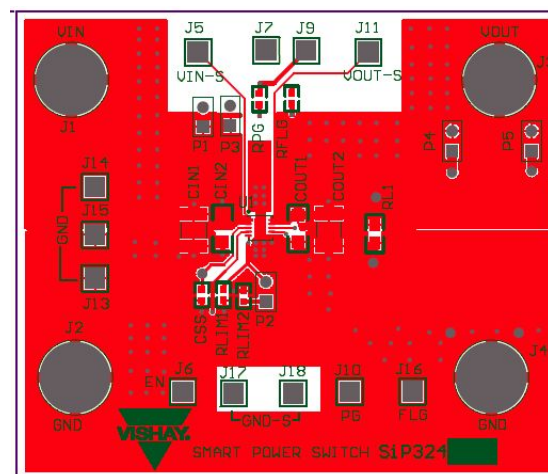


Figure 30 - Application Board Layout



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