



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

OPERATION DESCRIPTION

SiP32419 and SiP32429 are load switches that integrate multiple control features that simplify the design and increase the reliability of the circuitry connected to the switch. Both devices are 56 mΩ switches 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 SiP32419 and SiP32429 have 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 over-current condition persists for more than 7 ms, the switch shuts off automatically. The SiP32419 and SiP32429 has an over temperature protection circuit (OTP) which will shut the switch off if the junction temperature exceeds about 135 °C. The OTP circuit will release the switch when the temperature has decreased by about 40 °C of hysteresis.

When an OCP or an OTP fault condition is detected the FLG pin is pulled low. For the SiP32429, 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. For the SiP32419, the switch will remain off and the fault flag will remain on. The switch will be reset by toggling either control signal on EN pin or the input power if it is not under over temperature fault condition.

These devices feature a low voltage control logic interface which can be controlled without the need for level shifting. These devices also include a power good flag.

SiP32419 and SiP32429 are available in a space efficient DFN10 3 mm x 3 mm package.

FEATURES

- 6 V to 28 V operation voltage
- 56 mΩ typical on resistance
- Programmable soft start
- Programmable current limit
- Programmable soft start control
- Over temperature protection
- Power good, when V_{OUT} reaches 90 % of V_{IN}
- Fault flag on for thermal shutdown and OCP
- Under voltage lockout: 4.8 V / 5.4 V (typ. / max.)
- Auto-retry SiP32429 and latch-off SiP32419 versions
- Package: DFN-10 3 mm x 3 mm
- IEC 62368-1 certified
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912



APPLICATIONS

- eFuse, smart load switch
- White goods, appliances
- Flat panel displays
- Set top boxes, game consoles
- Smart meters, medical analyzers
- Industrial 4.0 IoT
- Telecom network
- RF LNA power
- SSD drive, data storage

TYPICAL APPLICATION CIRCUIT

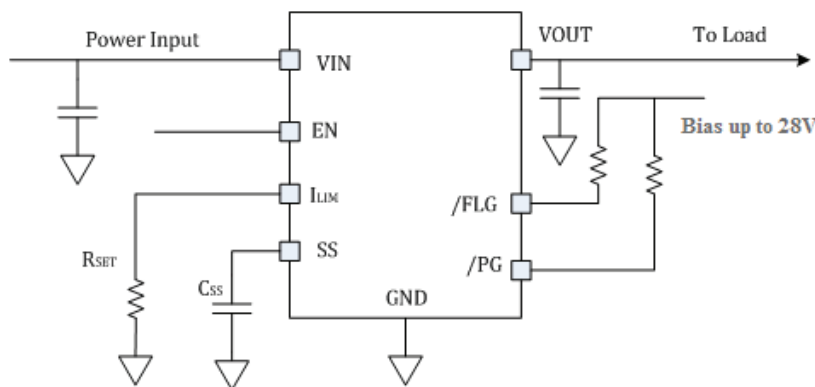


Fig. 1 - SiP32419, SiP32429 Typical Application Circuit



| ORDERING INFORMATION | | | | |
|----------------------|-------------------|---------|-------------------|------------|
| TEMPERATURE RANGE | PACKAGE | MARKING | PART NUMBER | OCP |
| -40 °C to +85 °C | DFN10 3 mm x 3 mm | 2429 | SiP32429DN-T1-GE4 | Auto-retry |
| | | 2419 | SiP32419DN-T1-GE4 | Latch-off |

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 | |
| | -5 V for 5 μ s | |
| PG voltage | -0.3 to +30 | |
| FLG voltage | -0.3 to +30 | |
| EN voltage | -0.3 to +6 | |
| Maximum continuous switch current | 4.5 | A |
| ESD rating (HBM) | 4000 | V |
| Maximum junction temperature | 150 | °C |
| Storage temperature | -55 to +150 | |
| Thermal resistance (θ_{thJA}) ^a | 88 | °C/W |
| Power dissipation (P_D) ^{a, b} | 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 to 28 | |
| EN | 0 to 6 | |
| 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 $V_{IN} = 12\text{ V}$, $V_{EN} = 2.4\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$ | 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 | μA |
| Shutdown current | I_{SD} | $I_{OUT} = 0\text{ A}$ and device disabled | - | - | 12 | 20 | |
| Switch off leakage | $I_{(OFF)}$ | $V_{IN} = 28\text{ V}$, $V_{OUT} = 0\text{ V}$ (current measured at output) | - | - | - | 1 | |
| Current limit accuracy | | $R_{SET} = 4.1\text{ k}\Omega$ | $-40\text{ }^\circ\text{C}$ to $+85\text{ }^\circ\text{C}$ | 1.2 | 1.5 | 1.8 | A |
| Switch on resistance | $R_{DS(on)}$ | $I_{SW} = 500\text{ mA}$ | - | - | 56 | 72 | $\text{m}\Omega$ |
| Soft start charge current | I_{SS} | Constant current source | - | - | 4.5 | - | μA |
| Turn on delay time | T_{ON_DLY} | 50 % V_{EN} to 50 % V_{OUT} , $C_{SS} = \text{open}$, $R_L = 10\text{ }\Omega$, $C_{OUT} = 10\text{ }\mu\text{F}$ | - | - | 550 | - | μs |
| Turn on rise time | T_R | $C_{SS} = \text{open}$, $R_L = 10\text{ }\Omega$, $C_{OUT} = 10\text{ }\mu\text{F}$ | - | - | 400 | - | |
| | | $C_{SS} = 47\text{ nF}$, $R_L = 10\text{ }\Omega$, $C_{OUT} = 10\text{ }\mu\text{F}$ | - | - | 7 | - | |
| | | $C_{SS} = 47\text{ nF}$, no R_L , $C_{OUT} = 10\text{ }\mu\text{F}$ | - | - | 2 | - | |
| Turn off delay | T_{OFF_DLY} | | - | - | 1 | - | μs |
| Current limit response time | | | - | - | 20 | - | |
| Short circuit response time | | | - | - | 1 | - | |
| OC flag blanking time / switch off delay under OC | | | $-40\text{ }^\circ\text{C}$ to $+85\text{ }^\circ\text{C}$ | 4 | - | - | ms |
| Auto-retry time (SiP32429 only) | | | - | - | 150 | - | |
| Input logic high voltage | V_{ENH} | $V_{IN} = 6\text{ V}$ to 28 V | $-40\text{ }^\circ\text{C}$ to $+85\text{ }^\circ\text{C}$ | 1.5 | - | - | V |
| Input logic low voltage | V_{ENL} | | $-40\text{ }^\circ\text{C}$ to $+85\text{ }^\circ\text{C}$ | - | - | 0.6 | |
| Input pull down resistor | R_{EN} | $V_{EN} = 5\text{ V}$ | $25\text{ }^\circ\text{C}$ | 1.5 | 2.5 | 3.9 | $\text{M}\Omega$ |
| | | | $-40\text{ }^\circ\text{C}$ to $+85\text{ }^\circ\text{C}$ | 0.7 | - | 4.5 | |
| 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 | μA |
| UVLO threshold | | | - | - | 4.8 | 5.4 | V |
| UVLO hysteresis | | | - | - | 0.28 | - | |
| Thermal shutdown threshold | | | - | - | 137 | - | $^\circ\text{C}$ |
| Thermal shutdown hysteresis | | | - | - | 39 | - | |

TIMING DIAGRAM

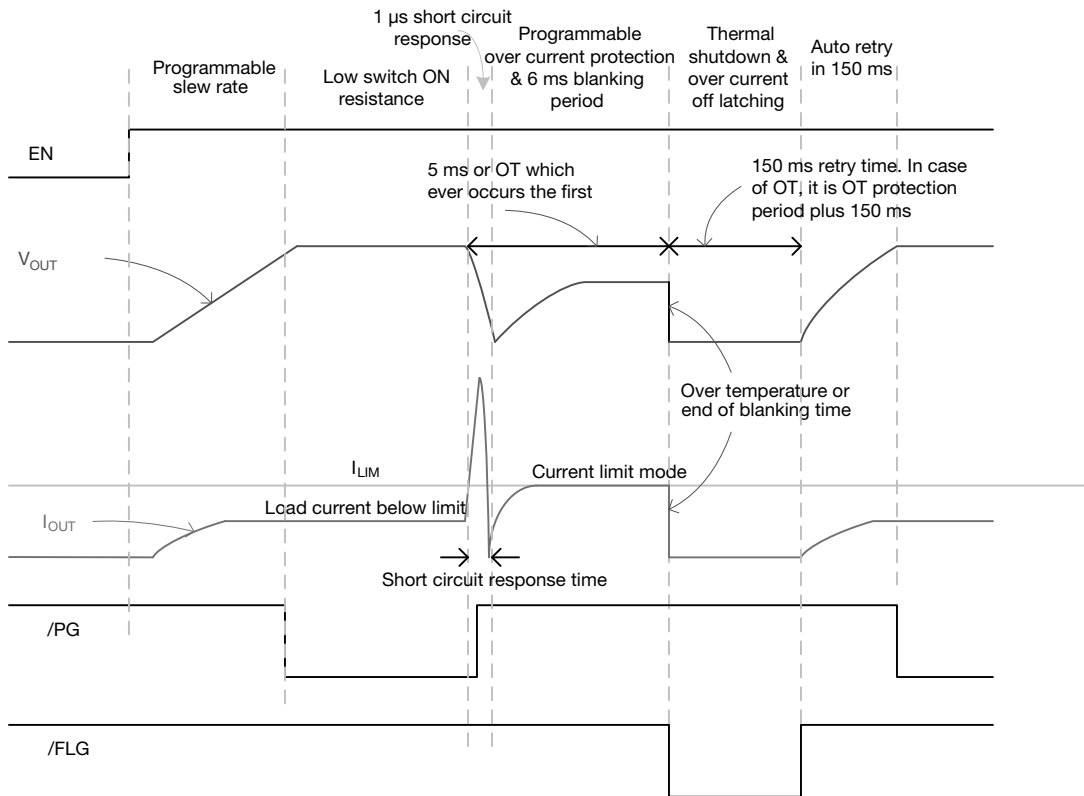


Fig. 2 - Timing Diagram

PIN CONFIGURATION

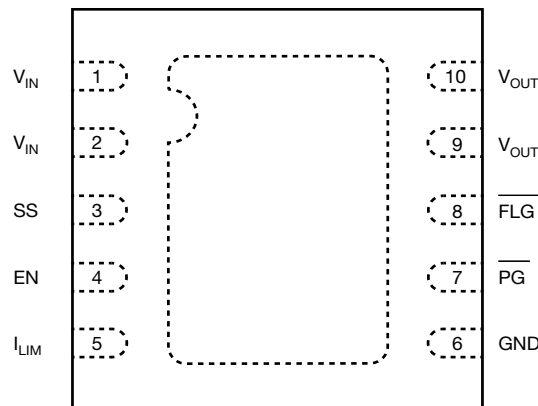


Fig. 3 - DFN10 3 mm x 3 mm Package
Top View

| 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 μ 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 |

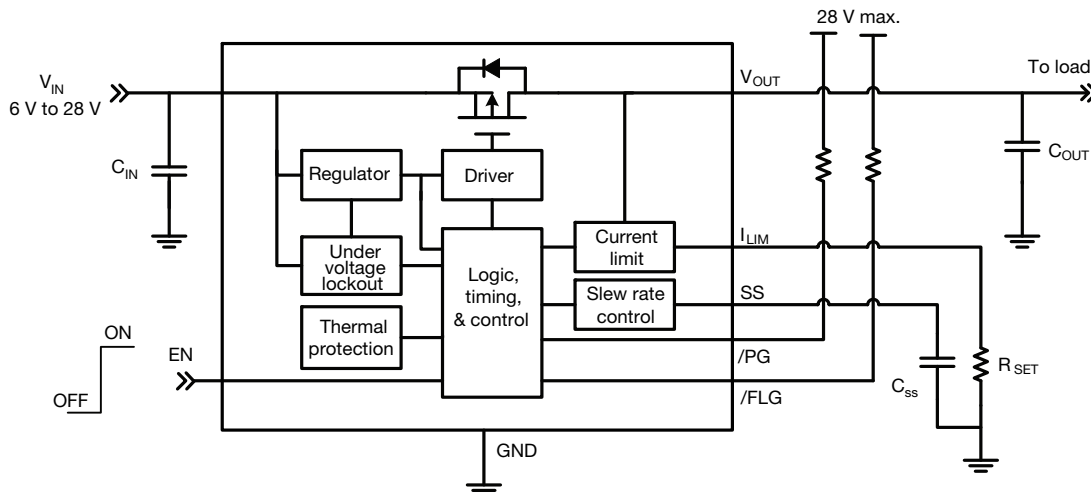
BLOCK DIAGRAM


Fig. 4 - Block Diagram

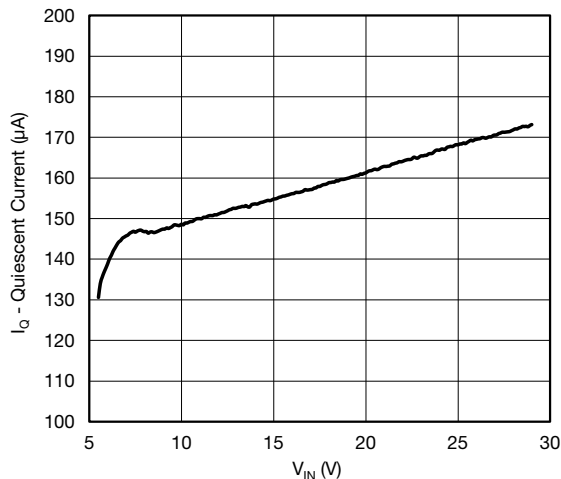
TYPICAL CHARACTERISTICS (internally regulated, 25 °C, unless otherwise noted)


Fig. 5 - Quiescent Current vs. Input Voltage

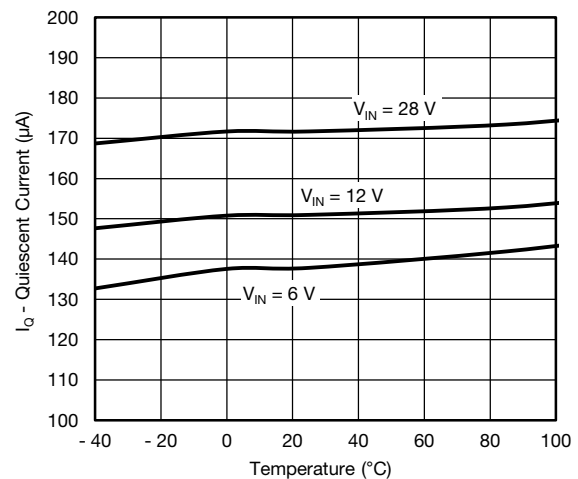


Fig. 6 - Quiescent Current vs. Temperature



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

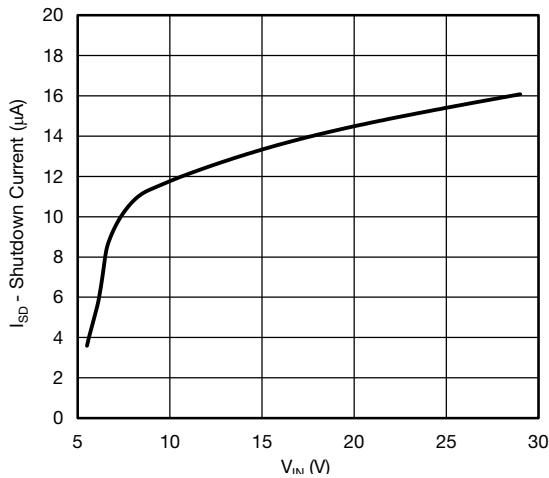


Fig. 7 - Shutdown Current vs. Input Voltage

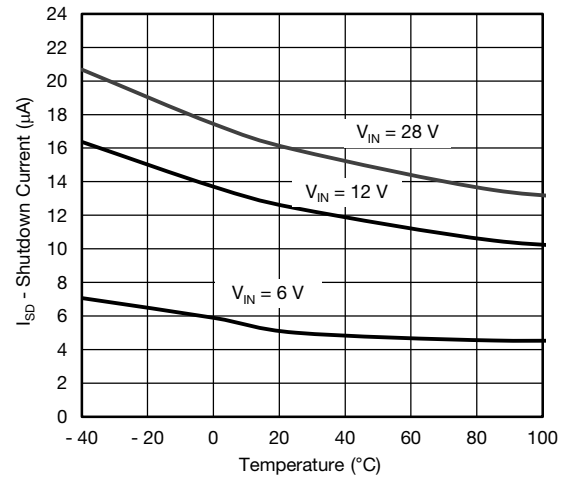


Fig. 10 - Shutdown Current vs. Temperature

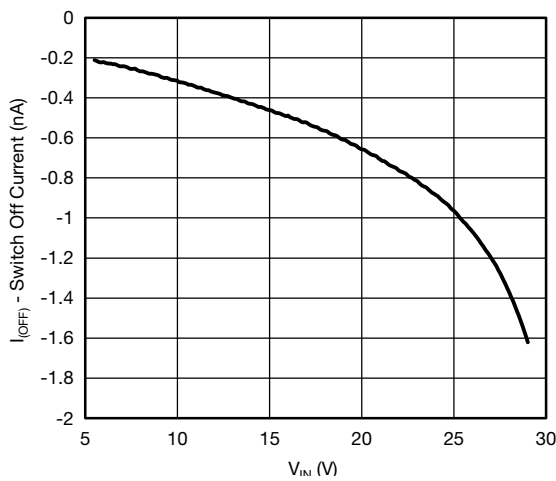


Fig. 8 - Shutdown Current vs. Input Voltage

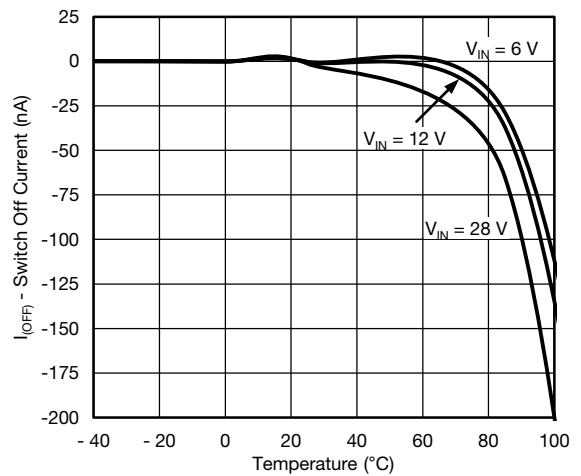


Fig. 11 - Switch Off Current vs. Temperature

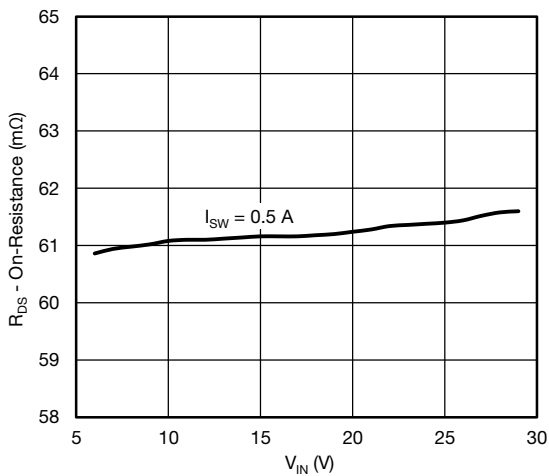


Fig. 9 - On Resistance vs. Input Voltage

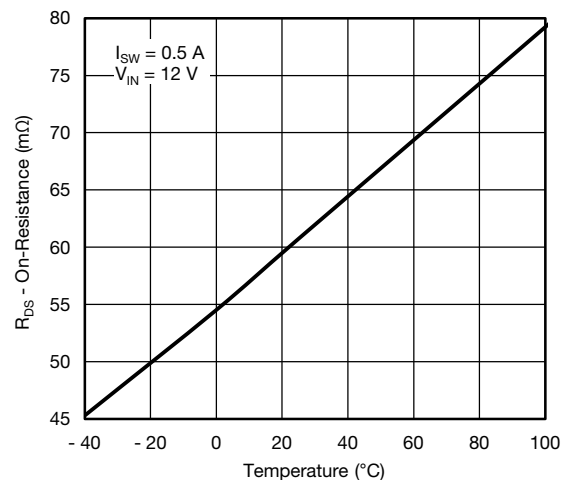


Fig. 12 - On Resistance vs. Temperature

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

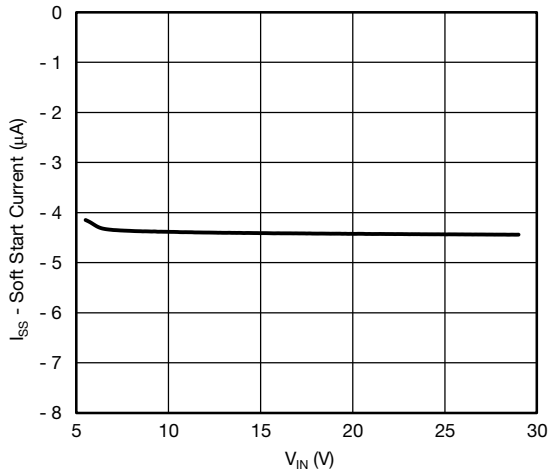


Fig. 13 - Soft Start Current vs. Input Voltage

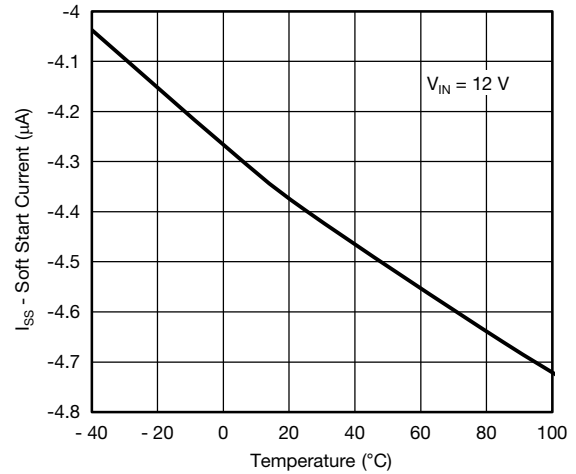


Fig. 15 - Soft Start Current vs. Temperature

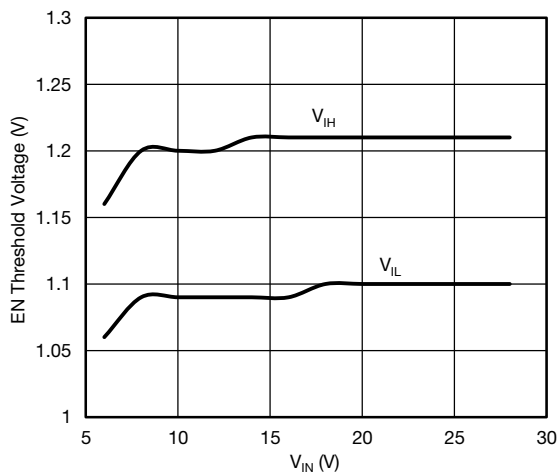


Fig. 14 - Threshold Voltage vs. Input Voltage

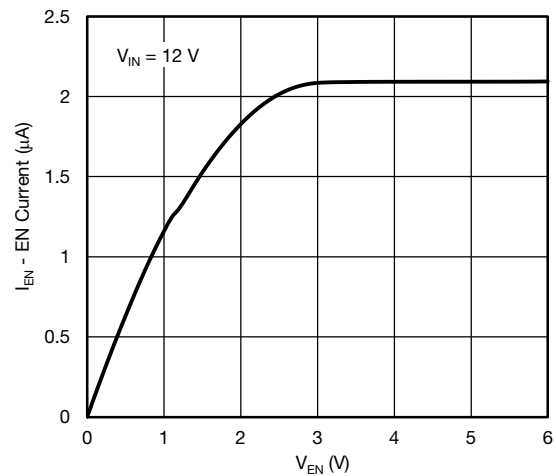
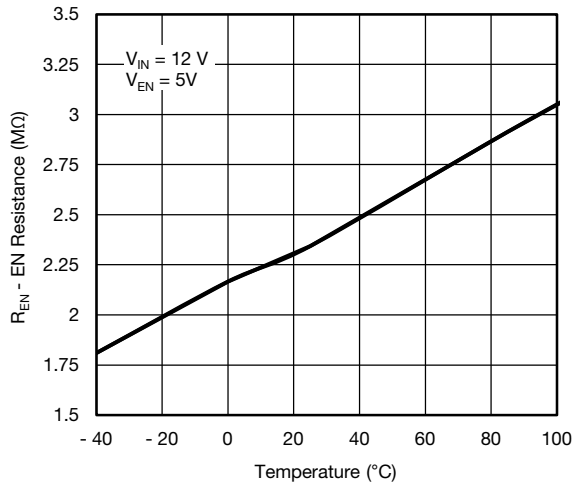
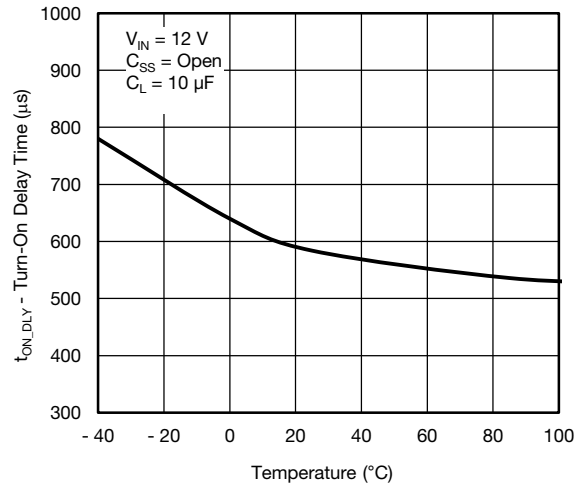
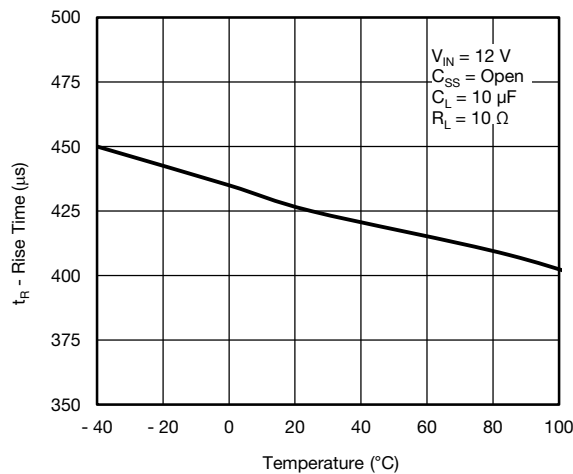
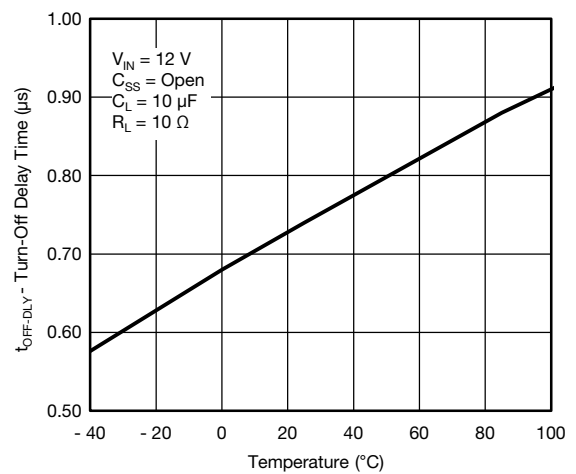
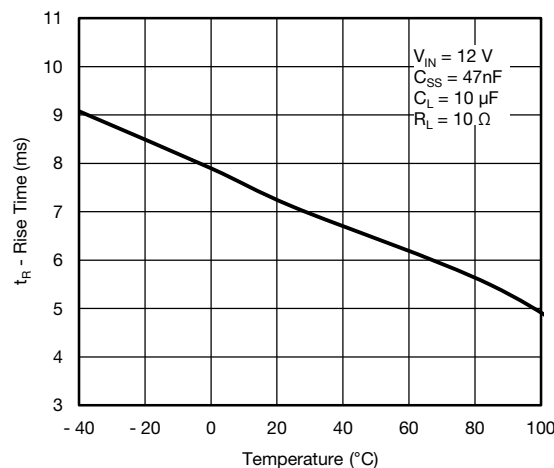


Fig. 16 - EN Current vs. V_{EN}

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

Fig. 17 - EN Resistance vs. Temperature

Fig. 19 - Turn-On Delay Time vs. Temperature

Fig. 18 - Rise Time vs. Temperature

Fig. 20 - Turn-Off Delay Time vs. Temperature

Fig. 21 - Rise Time vs. Temperature

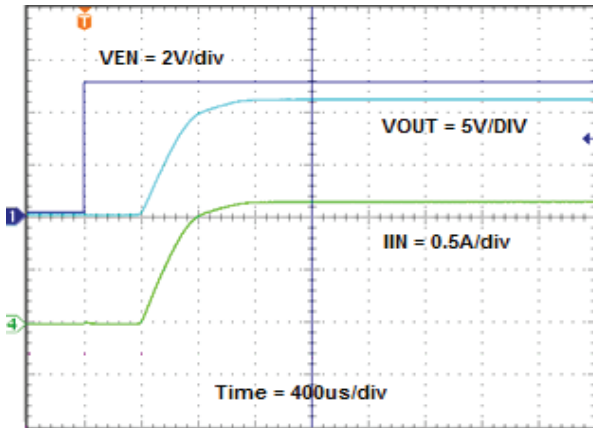
TYPICAL WAVEFORMS


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

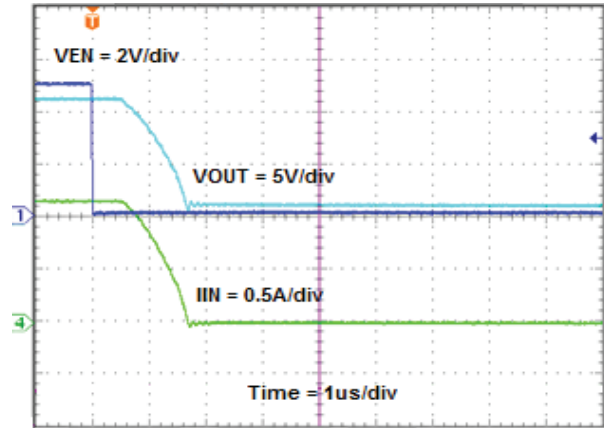


Fig. 25 - Turn-Off Time,
 $V_{IN} = 12\text{ V}$, $C_{SS} = \text{open}$, $R_L = 10\ \Omega$, $C_L = 10\ \mu\text{F}$

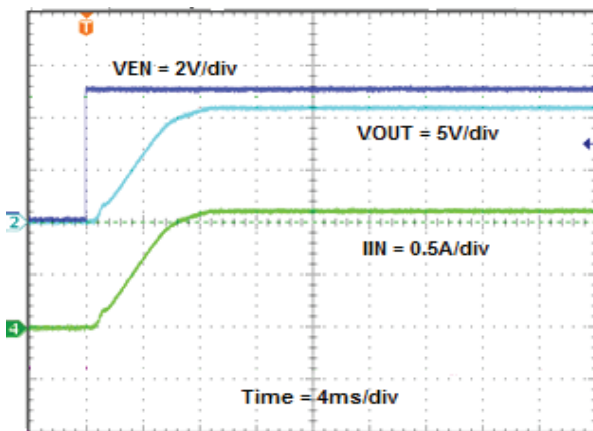


Fig. 23 - Turn-On Time,
 $V_{IN} = 12\text{ V}$, $C_{SS} = 47\text{ nF}$, $R_L = 10\ \Omega$, $C_L = 10\ \mu\text{F}$

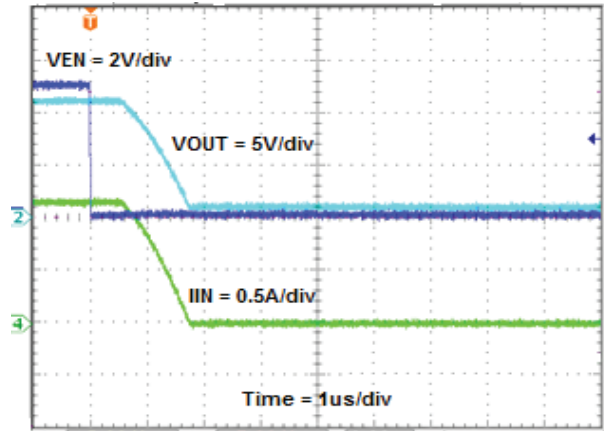


Fig. 26 - Turn-Off Time,
 $V_{IN} = 12\text{ V}$, $C_{SS} = 47\text{ nF}$, $R_L = 10\ \Omega$, $C_L = 10\ \mu\text{F}$

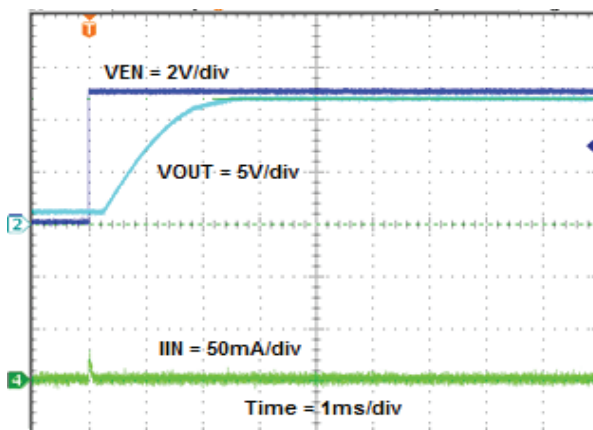


Fig. 24 - Turn-On Time,
 $V_{IN} = 12\text{ V}$, $C_{SS} = 47\text{ nF}$, $R_L = \text{open}$, $C_L = 10\ \mu\text{F}$

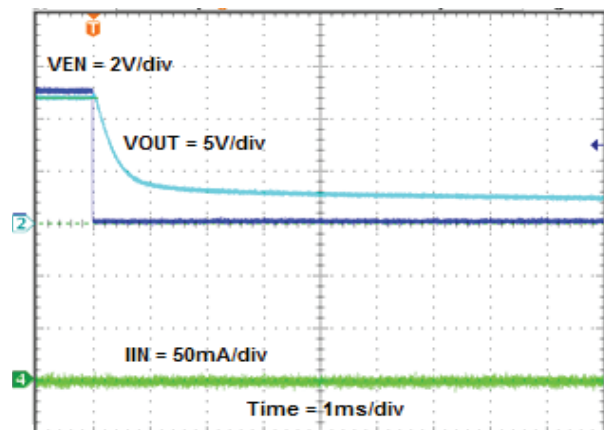


Fig. 27 - Turn-Off Time,
 $V_{IN} = 12\text{ V}$, $C_{SS} = 47\text{ nF}$, $R_L = \text{open}$, $C_L = 10\ \mu\text{F}$

TYPICAL WAVEFORMS

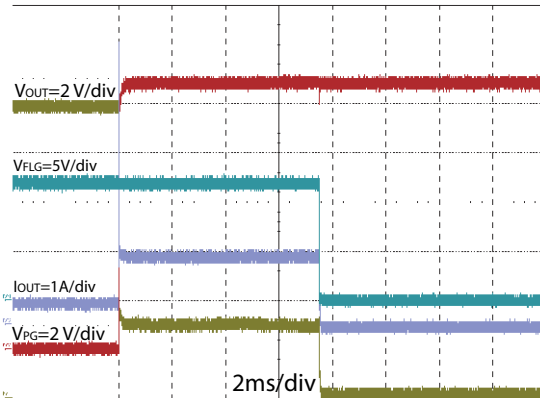


Fig. 28 - Current Limit
from 25 Ω to 2 Ω Load, $V_{IN} = 12\text{ V}$

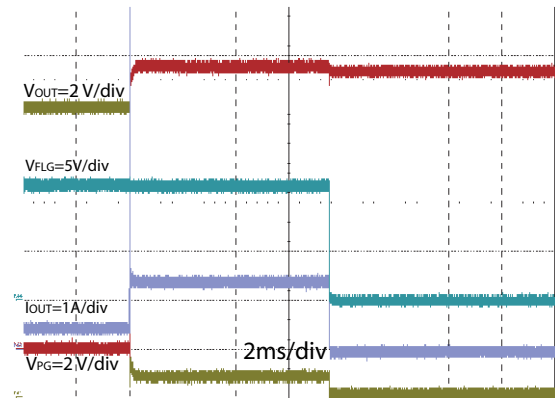


Fig. 30 - Current Limit
from 25 Ω to 0.5 Ω Load, $V_{IN} = 12\text{ V}$

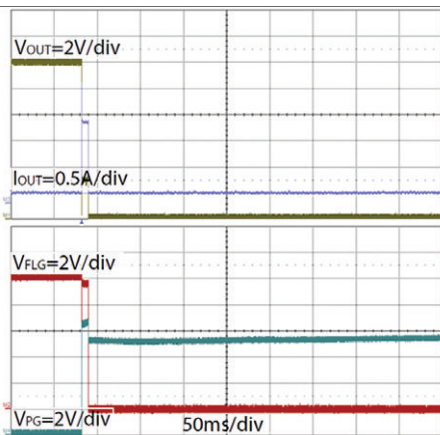


Fig. 29 - SiP32419
Remains OFF after seeing Fault Condition

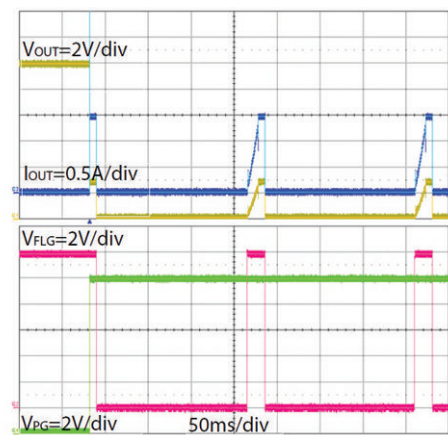


Fig. 31 - SiP32429
Re-Starts after ~ 150 ms during Fault Condition

DETAILED DESCRIPTION

Over Current Limit

The SiP32419 and SiP32429 current limit control circuit responds within 1 μ s (typ.) when an over current event occurs. During this brief period before the over current protection circuit is engaged, the parts will see a surge current especially under a severe output short condition. The magnitude of the surge current developed during the period when the overcurrent protection is not engaged is determined by impedance in the loop from the input current source to ground and the response time. This impedance is the sum total of the current source impedance, the path resistance and inductance and the load impedance. It is recommended to design the circuit to keep the peak current under 50 A by ensuring that there is sufficient impedance in the path to limit current to this recommended maximum of 50 A. Once the current limit circuit is engaged, the SiP32419 / SiP32429 will limit the current to the programmed set point. If the over current event exceeds 7 ms, the switch is turned off and the FLG pin is pulled low.

The SiP32429 features auto retry logic design and as long as enable is high, the part will restart after a 150 ms time out. The SiP32419 will remain off and can be reset by toggling V_{IN} or EN.

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.

| R_{SET} SELECTION TABLE | | | | |
|---|-------------------|------|------|----------|
| R_{SET} (k Ω) | CURRENT LIMIT (A) | | | TOL. (%) |
| | MIN. | TYP. | MAX. | |
| 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 |

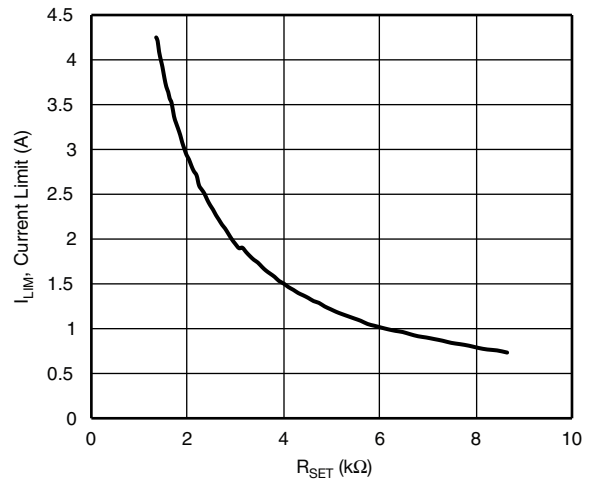


Fig. 32 - Current Limit vs. R_{SET}

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:

Δt is the soft start time

ΔV_{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 μ 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 μF 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 SiP32419 and SiP32429 will turn the switch off immediately. The SiP32429 will then retry to start 150 ms after the temperature is back to normal; during this period, $\overline{\text{FLG}}$ will be pulled low. The SiP32419 $\overline{\text{FLG}}$ will be pulled high 150 ms after the OT event has finished. The SiP32419 will remain off and not retry to start, $\overline{\text{FLG}}$ will remain to be pulled low.

Thermal Consideration

SiP32419 and SiP32429 are 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

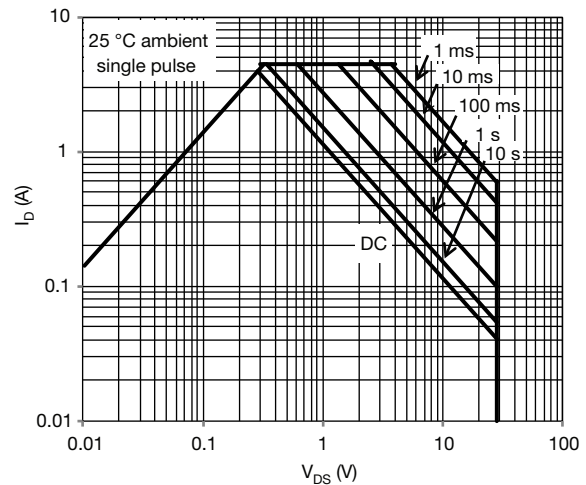


Fig. 33 - SOA on Application Board

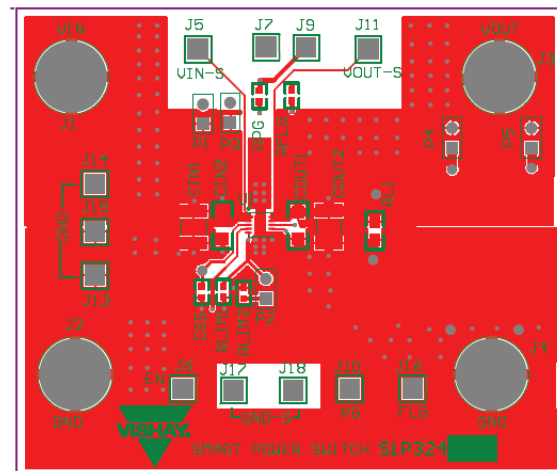


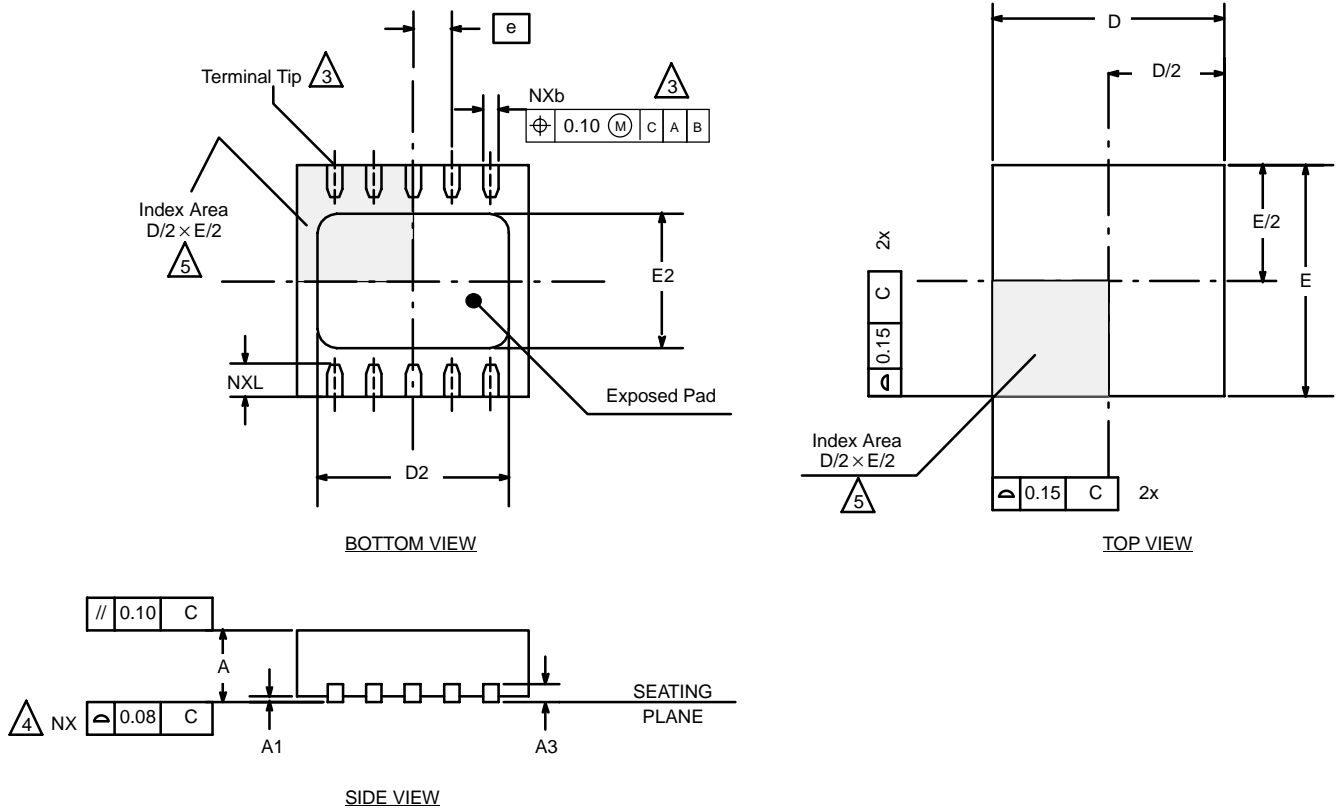
Fig. 34 - Application Board Layout



| PRODUCT SUMMARY | | |
|--|--|---|
| Part number | SiP32419 | SiP32429 |
| Description | 6 V to 28 V, 56 mΩ, programmable current limit and slew rate, latch-off on fault | 6 V to 28 V, 56 mΩ, programmable current limit and slew rate, auto-retry on fault |
| Configuration | Single | Single |
| Slew rate time (μs) | Adjustable | Adjustable |
| On delay time (μs) | 550 | 550 |
| Input voltage min. (V) | 6 | 6 |
| Input voltage max. (V) | 28 | 28 |
| On-resistance at input voltage min. (mΩ) | 56 | 56 |
| On-resistance at input voltage max. (mΩ) | 56 | 56 |
| Quiescent current at input voltage min. (μA) | 139 | 139 |
| Quiescent current at input voltage max. (μA) | 172 | 172 |
| Output discharge (yes / no) | No | No |
| Reverse blocking (yes / no) | No | No |
| Continuous current (A) | 4.5 | 4.5 |
| Current limit min. (A) | 0.75 | 0.75 |
| Current limit max. (A) | 3.5 | 3.5 |
| Absolute maximum input voltage (V) | 30 | 30 |
| Package type | DFN33-10L | DFN33-10L |
| Package size (W, L, H) (mm) | 3.0 x 3.0 x 0.9 | 3.0 x 3.0 x 0.9 |
| Status code | 2 | 2 |
| Product type | Slew rate, current limit | Slew rate, current limit |
| Applications | Computers, consumer, industrial, healthcare, networking, portable | Computers, consumer, industrial, healthcare, networking, portable |

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DFN-10 LEAD (3 X 3)



NOTES:

- All dimensions are in millimeters and inches.
- N is the total number of terminals.
- (3) Dimension b applies to metallized terminal and is measured between 0.15 and 0.30 mm from terminal tip.
- (4) Coplanarity applies to the exposed heat sink slug as well as the terminal.
- (5) The pin #1 identifier may be either a mold or marked feature, it must be located within the zone indicated.

| Dim | MILLIMETERS | | | INCHES | | |
|-----------|-------------|------|------|-----------|-------|-------|
| | Min | Nom | Max | Min | Nom | Max |
| A | 0.80 | 0.90 | 1.00 | 0.031 | 0.035 | 0.039 |
| A1 | 0.00 | 0.02 | 0.05 | 0.000 | 0.001 | 0.002 |
| A3 | 0.20 BSC | | | 0.008 BSC | | |
| b | 0.18 | 0.23 | 0.30 | 0.007 | 0.009 | 0.012 |
| D | 3.00 BSC | | | 0.118 BSC | | |
| D2 | 2.20 | 2.38 | 2.48 | 0.087 | 0.094 | 0.098 |
| E | 3.00 BSC | | | 0.118 BSC | | |
| E2 | 1.49 | 1.64 | 1.74 | 0.059 | 0.065 | 0.069 |
| e | 0.50 BSC | | | 0.020 BSC | | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |

*Use millimeters as the primary measurement.

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