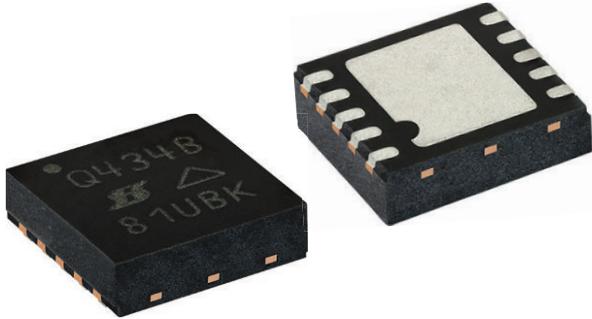


# 3.5 A, 78 mΩ, 2.8 V to 22 V eFuse With Accurate Current Limit, OVP, and Active Reverse Current Blocking



## DESCRIPTION

The SIPQ32433A and SIPQ32433B are single channel eFuses protect both power sources and downstream circuitry from excessive inrush currents, overloads, short circuits, over voltage, and Active Reverse Current Blocking which actively suppresses current flowing from the output to the input. They provide increased controllability, reliability, with simplified designs with minimal external components.

$V_{IN}$  overvoltage protection and undervoltage lockout threshold levels can be set with an external resistor network.  $V_{IN}$  inrush current can be set with a soft start capacitor. The output current limit can be set by a resistor connected to  $I_{LIM}$  pin.  $I_{LIM}$  pin voltage can also serve as switch current reporting.

Upon switch-off due to latchable faults, the SIPQ32433A will latch the power switch off and the PGD will remain low. The switch can restart by resetting the EN or  $V_{IN}$ . The SIPQ32433B will auto retry if there is no OTP or OVP fault. The retry delay time is 32 times the soft start time set by the CSS.

The switch is characterized for operation over a junction temperature range of  $-40\text{ }^{\circ}\text{C}$  to  $+125\text{ }^{\circ}\text{C}$ .

## FEATURES

- Qualified for automotive applications
- AEC-Q100 qualified:
  - Device temperature grade 1
  - Device HBM ESD classification level 2
  - Device CDM ESD classification level C4B method 2
- 2.8 V to 22 V operation voltage
- 28 V max. DC tolerance on  $V_{IN}$
- 78 mΩ typical switch resistance
- 0.3 A to 4.5 A current limit setting range
- Current limit accuracy of  $\pm 8\%$
- Fast short circuit protection response
- OCP triggering without overhead current
- Programmable turn-on slew rate
- Active reverse current blocking
- Adjustable OVP (and fixed 24 V OVP at  $V_{IN}$ )
- Adjustable UVLO
- Over-temperature protection
- PGD: power good indicator output
- IEC 62368-1 2018, CB certified, E531343-A6001-CB-1
- Compact TDFN10 3 mm x 3 mm package wettable flank
- 6 A uni-directional parts available with [SIPQ32434](#)
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

## APPLICATIONS

- Automotive infotainment
- ADAS and auto-pilot
- Cameras and sensors
- USB hubs
- Holdup power switching
- Power muxing

## TYPICAL APPLICATION CIRCUIT

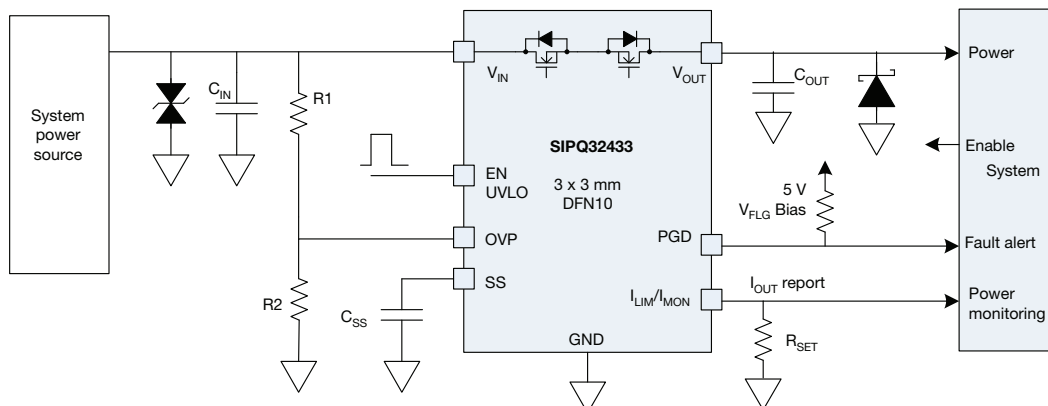


Fig. 1 - Application Circuit



ORDERING INFORMATION							
PART NUMBER	OCP RESPONSE	R <sub>DS(on)</sub> (mΩ)	ACTIVE REVERSE CURRENT BLOCKING	REPORT	MARKING CODE	PACKAGE	LEAD FINISH
SIPQ32433ADN-T1E3	Latch	78	Yes	PG	Q433A	DFN10 3 mm x 3 mm	Matte tin
SIPQ32433BDN-T1E3	Auto-retry	78	Yes	PG	Q433B	DFN10 3 mm x 3 mm	
SIP32433AEVB	Evaluation board						
SIP32433BEVB							

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	CONDITION	LIMIT	UNIT	
Input voltage (V <sub>IN</sub> )	Reference to GND	-0.3 to +28	V	
Output voltage (V <sub>OUT</sub> )	Reference to GND	-0.3 to +28		
		-5 V for +5 μs		
EN voltage	Reference to GND	-0.3 to +24		
OVP	Reference to GND	-0.3 to +6		
SS	Reference to GND	-0.3 to +6		
I <sub>LIM</sub>		-0.3 to +6		
PGD		-0.3 to +6		
Maximum continuous switch current		3.5		A
Thermal resistance (θ <sub>JJA</sub> )		44.8		°C/W
ESD rating	HBM	± 1		kV
ESD rating	CDM	± 1		
Latch up current	Per JEDEC78E, Class II	100	mA	
MSL rating		MSL1		
Temperature				
Operating junction temperature		-40 to +150	°C	
Storage temperature		-65 to +150		

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.

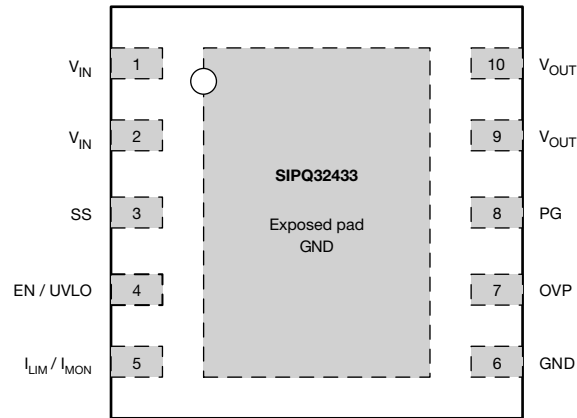
RECOMMENDED OPERATING RANGE		
ELECTRICAL	LIMIT	UNIT
Input voltage (V <sub>IN</sub> )	2.8 to 22	V
Operating junction temperature	-40 to +125	°C



<b>ELECTRICAL SPECIFICATIONS</b>						
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS SPECIFIED $V_{IN} = 12\text{ V}$ , $T_J = -40\text{ }^\circ\text{C}$ to $+125\text{ }^\circ\text{C}$ , $V_{EN(H)} = 2.4\text{ V}$ , $C_{OUT} = 0.1\text{ }\mu\text{F}$ , $R_{LIM} = 4.1\text{ k}\Omega$	LIMITS			UNIT
			MIN.	TYP.	MAX.	
<b>Power Supply</b>						
$V_{IN}$ max. DC tolerance	$V_{IN(max)}$		-	-	28	V
$V_{IN}$ operation voltage	$V_{IN}$	Operating input voltage range	2.8	-	22	V
Quiescent current	$I_{Q(ON)}$	$EN = 1.8\text{ V}$ , $V_{IN} = 2.8\text{ V}$ to $28\text{ V}$ , $V_{OUT}$ open	-	250	340	$\mu\text{A}$
Shutdown current	$I_{Q(SD)}$	$V_{IN} = 2.8\text{ V}$ to $28\text{ V}$ , $EN = 0\text{ V}$ , $T_A = 25\text{ }^\circ\text{C}$	-	0.6	5	
OVP switch-off current	$I_{Q(OVP)}$	$V_{IN} = 2.8\text{ V}$ to $28\text{ V}$ , $EN = 2.4\text{ V}$ , $OVP = 1.4\text{ V}$	-	1	-	
<b><math>V_{IN}</math> UVLO</b>						
Switch $V_{OUT}$ leakage	$I_{UVLO\_OUT}$		-500	-	+500	nA
Switch $V_{IN}$ leakage	$I_{UVLO\_IN}$		-	27	50	$\mu\text{A}$
<b>Overvoltage Protection</b>						
OVP threshold	$V_{OVP}$	$V_{IN} = 12\text{ V}$ , OVP rising	1.14	1.2	1.26	V
OVP hysteresis	$OVP_{HST}$		45	105	140	mV
OVP leakage	$I_{OVP}$	$V_{OVP} = 1.2\text{ V}$ on the pin, $T_A = 25\text{ }^\circ\text{C}$	-	40	100	nA
$V_{IN}$ pin internal fixed OVP	$IN_{OVP}$	$T_A = 25\text{ }^\circ\text{C}$	22.1	24	25.6	V
<b>EN / UVLO</b>						
EN on threshold	$V_{UVPR}$	$V_{EN}$ rising	-	1.25	-	V
EN off threshold	$V_{UVPF}$	$V_{EN}$ falling	-	1.05	-	
EN / UVLO leakage		$V_{EN} = 1.2\text{ V}$	-0.25	-	+0.25	$\mu\text{A}$
Soft start bias current	$I_{SS}$		-	5	-	
<b>Overcurrent Protection</b>						
Current limit voltage threshold	$V_{OCP}$	Voltage that triggers the OCP shown on $I_{LIM}$ pin	-	0.6	-	V
Current limit accuracy	$I_{OCP}$	$V_{IN} - V_{OUT} = 1\text{ V}$ , $R_{SET} = 20.6\text{ k}\Omega$	0.255	0.3	0.345	A
		$V_{IN} - V_{OUT} = 1\text{ V}$ , $R_{SET} = 4.1\text{ k}\Omega$	1.39	1.5	1.6	
		$V_{IN} - V_{OUT} = 1\text{ V}$ , $R_{SET} = 1.8\text{ k}\Omega$	3.32	3.5	3.68	
Current limit setting range			0.25	-	4.5	
Current limit hold-up time	$t_{LIM}$	Current limiting timeout, if no OTP	4	6	8	ms
<b>Active ReverseCurrent Blocking</b>						
$V_{IN} - V_{OUT}$ reverse blocking falling threshold	$V_{REVTH}$	$V_{IN} - V_{OUT}$ , $V_{IN}$ falling	-30	-20	-5	mV
$V_{IN} - V_{OUT}$ reverse blocking rising threshold	$V_{FWDTH}$	$V_{IN} - V_{OUT}$ , $V_{IN}$ rising	5	20	30	
<b>Power Switch</b>						
On resistance	$R_{DS(ON)}$	$V_{IN} = 3\text{ V}$ to $22\text{ V}$ , $I_{OUT} = 1\text{ A}$ , $T_J = 25\text{ }^\circ\text{C}$	-	78	100	m $\Omega$
		$V_{IN} = 3\text{ V}$ to $22\text{ V}$ , $I_{OUT} = 1\text{ A}$ , $T_J = 85\text{ }^\circ\text{C}$	-	-	130	
Output leakage at switch off		$V_{IN} = 28\text{ V}$ , $V_{EN} = 0\text{ V}$ , $V_{OUT} = 0\text{ V}$ , sourcing	-	-	5	$\mu\text{A}$
<b>PGD, Power Good</b>						
PGD pull-down resistance	$R_{PG}$	$V_{IN} = 5\text{ V}$ , output pin = $0.1\text{ V}$	-	5.2	10	$\Omega$
PGD oII leakage	$I_{PG}$	Biased with $5\text{ V}_{DC}$	-	0.01	1	$\mu\text{A}$



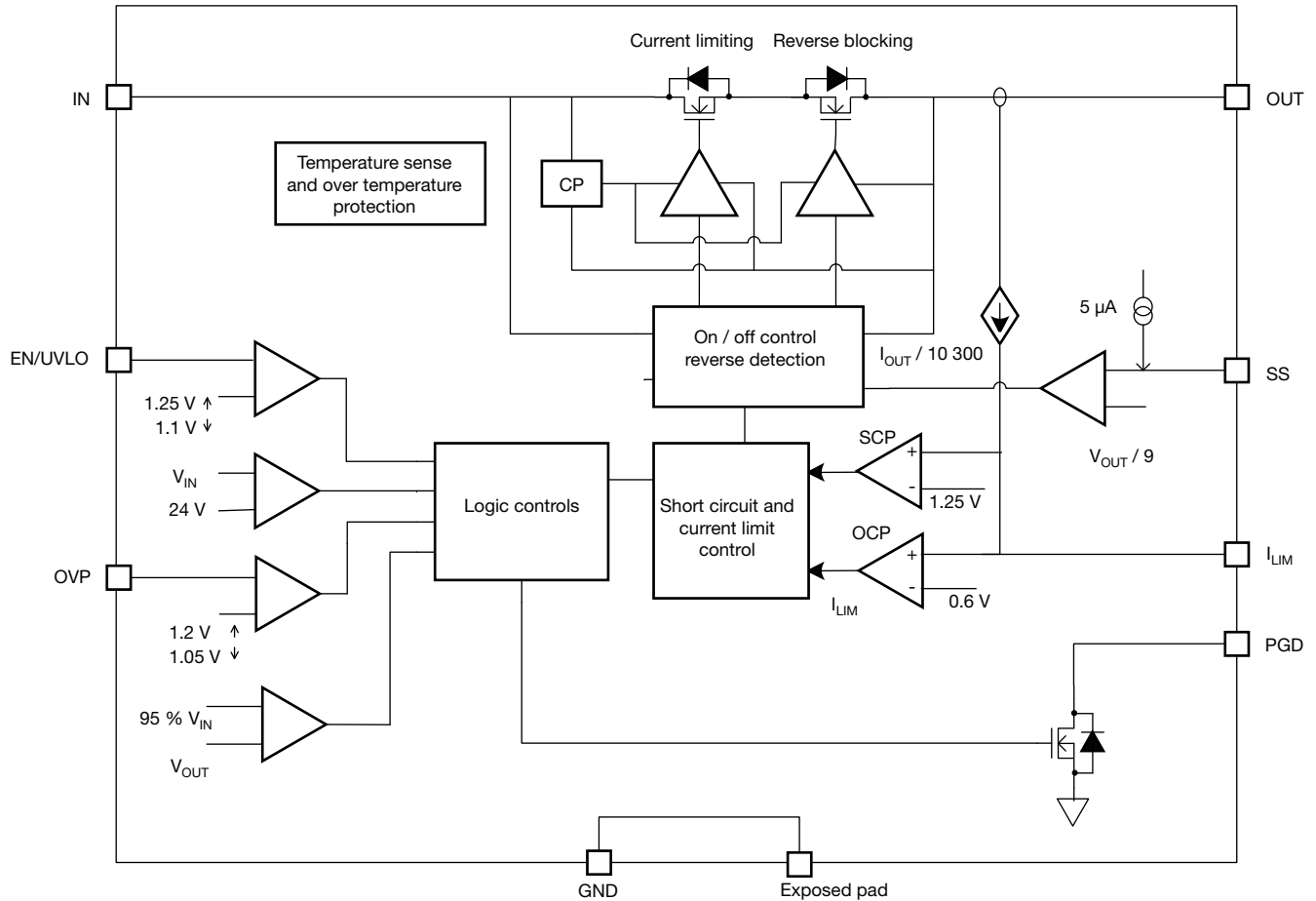
SWITCHING CHARACTERISTICS						
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS SPECIFIED $V_{IN} = 12\text{ V}$ , $T_J = -40\text{ }^\circ\text{C}$ to $+125\text{ }^\circ\text{C}$ , $V_{EN(H)} = 2.4\text{ V}$ , $C_{OUT} = 0.1\text{ }\mu\text{F}$ , $R_{LIM} = 4.1\text{ k}\Omega$	LIMITS			UNIT
			MIN.	TYP.	MAX.	
<b>EN / UVLO</b>						
Switch turn-on delay time	$T_{ON\_DLY}$	From EN / UVLO voltage, $V_{UVPR}$ to $V_{OUT}$ reaches 10 % $V_{IN}$ , $R_L = 10\text{ }\Omega$ , $C_L = 10\text{ }\mu\text{F}$ , $C_{SS}$ open	-	190	-	$\mu\text{s}$
Shutdown delay	$T_{OFF\_DLY}$	From EN / UVLO low to $V_{OUT} = 0.9 \times V_{IN}$ , $R_L = 10\text{ }\Omega$ , $C_L = 10\text{ }\mu\text{F}$ , $C_{SS}$ open	-	10	-	$\mu\text{s}$
<b>OVP Timing</b>						
OVP off time	$t_{OVP}$	$R_L = 100\text{ }\Omega$ , $C_L = 0\text{ }\mu\text{F}$ , OVP steps from 1 V to 1.4 V; measured from OVP pin voltage crossing 1.2 V threshold to $V_{OUT} = 0.9 \times V_{IN}$	-	0.3	1	$\mu\text{s}$
Internal OVP off time	$t_{OVP\_INT}$	$R_L = 100\text{ }\Omega$ , $C_L = 0\text{ }\mu\text{F}$ , $V_{IN}$ steps from 22 V to 26 V; measured from $V_{IN}$ pin voltage crossing 24 V threshold to $V_{OUT} = 0.9 \times V_{IN}$	-	1.5	-	$\mu\text{s}$
Flag reporting delay		PGD pull up to 5 V through a 100 k $\Omega$ ; delay time from OVP pin voltage step to PGD is below 0.5 V	-	-	2	$\mu\text{s}$
<b>Overcurrent protection</b>						
Moderate overcurrent protection	$t_{OCP}$	Load current is 120 % of current limit threshold	-	1.1	-	$\mu\text{s}$
<b>Soft Start Control</b>						
Output rise up time	$t_R$	$V_{IN} = 12\text{ V}$ , $R_L = 10\text{ }\Omega$ , $C_L = 10\text{ }\mu\text{F}$ , $V_{OUT}$ from 10 % to 90 % $V_{IN}$ , $C_{SS}$ open	-	350	-	$\mu\text{s}$
		$V_{IN} = 12\text{ V}$ , $R_L = 10\text{ }\Omega$ , $C_L = 10\text{ }\mu\text{F}$ , $V_{OUT}$ from 10 % to 90 % $V_{IN}$ , $C_{SS} = 22\text{ nF}$	-	4.7	-	ms
SS charge current			-	5	-	$\mu\text{A}$
<b>Auto Retry</b>						
Auto retry count	$RTY_{cnt}$	Delay time of restart after all faults are removed; this is defined as the number of cycles of soft start time set by $C_{SS}$	-	32	-	
<b>Thermal Shutdown</b>						
Thermal shutdown		Temperature increases	-	165	-	$^\circ\text{C}$
Thermal shutdown hysteresis			-	45	-	$^\circ\text{C}$

**PACKAGE OUTLINE**

**Fig. 2 - Pin Out Drawing (top view)**

PIN DESCRIPTION		
PIN #	NAME	FUNCTION
1, 2	$V_{IN}$	Power switch input pins; two pins are fused inside the package
3	SS	A capacitor from this pin to GND sets output voltage slew rate
4	EN / UVLO	Active high switch control input; $V_{THL} < 0.3\text{ V}$ , $V_{THH} > 1.4\text{ V}$
5	$I_{LIM} / I_{MON}$	A resistor from this pin to GND sets the over current and short-circuit current limit; the pin can be used for current reporting, referring to the voltage developed over the current limit setting resistor
6	GND	Ground (internally connected to central exposed pad)
7	OVP	Input for setting the programmable overvoltage protection threshold. An overvoltage event turns-off the internal FET and asserts FLT to indicate the overvoltage fault
8	PGD	Open drain output, asserted when $V_{OUT}$ is $\geq 95\%$ $V_{IN}$ , and none of the following faults are triggered: OT, OC, OV
9, 10	$V_{OUT}$	Power switch output pins; two pins are fused inside the package
Exposed pad	GND	The package's central exposed pad must be connected to the ground plane; optimal PCB thermal design will enhance device performance

**FUNCTIONAL BLOCK DIAGRAM AND TRUTH TABLE**

TRUTH TABLE	
EN	SWITCH
1	ON
0	OFF


**Fig. 3 - Device Block Diagram**

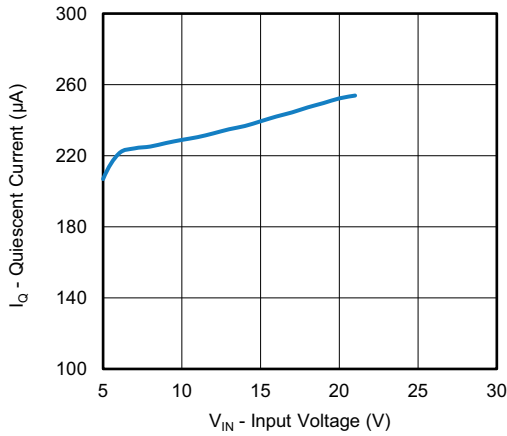


Fig. 4 - Quiescent Current vs. Input

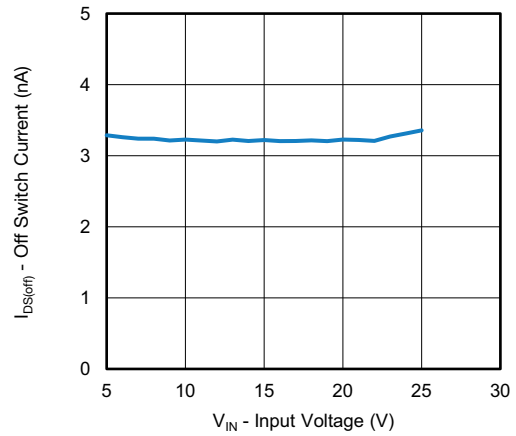


Fig. 7 - Switch Off Current vs. Input

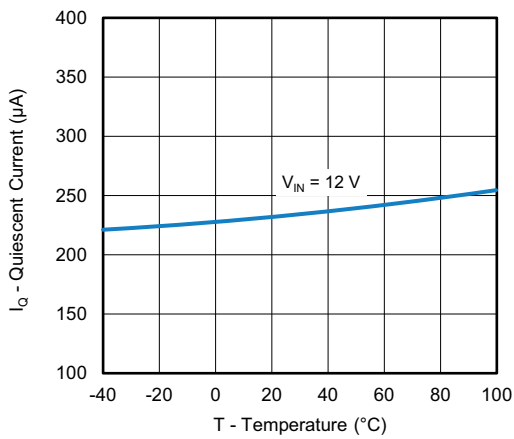


Fig. 5 - Quiescent Current vs. Temperature

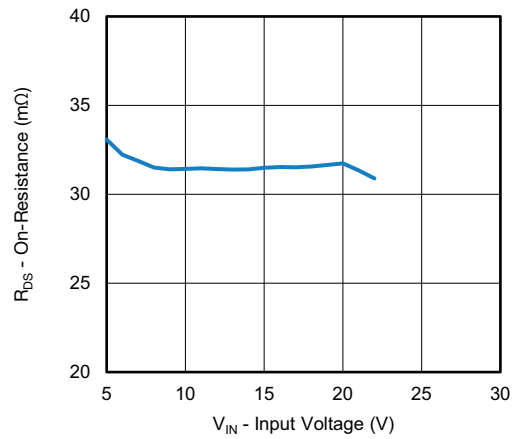


Fig. 8 - On Resistance vs. Input

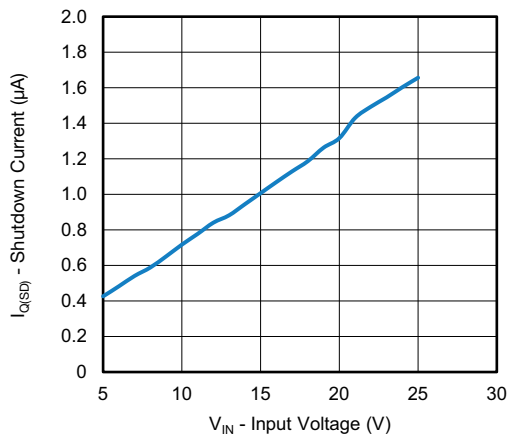


Fig. 6 - Shutdown Current vs. Input

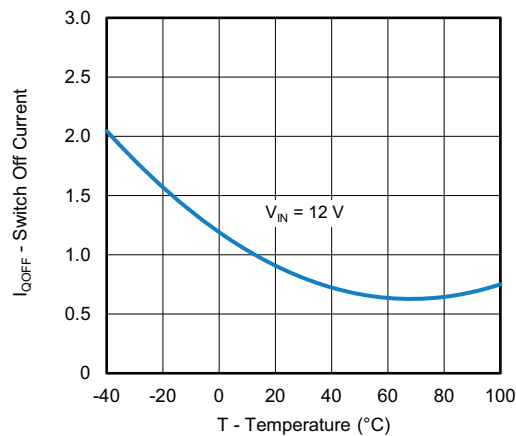


Fig. 9 - Shutdown Current vs. Temperature

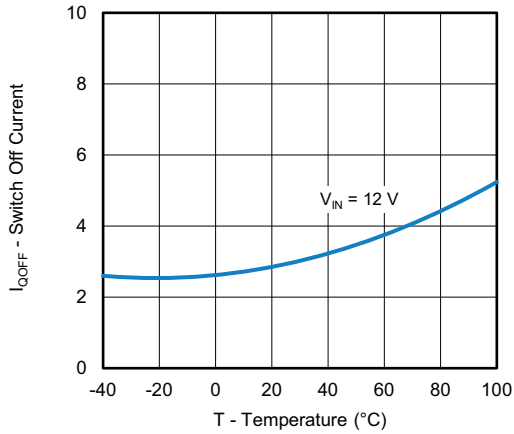


Fig. 10 - Switch Off Current vs. Temperature

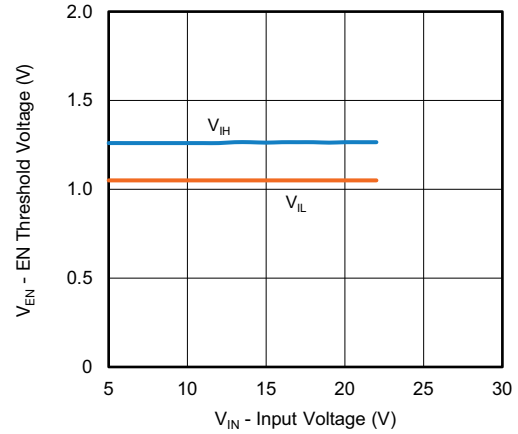


Fig. 13 - Threshold Voltage vs. Input Voltage V<sub>IN</sub>

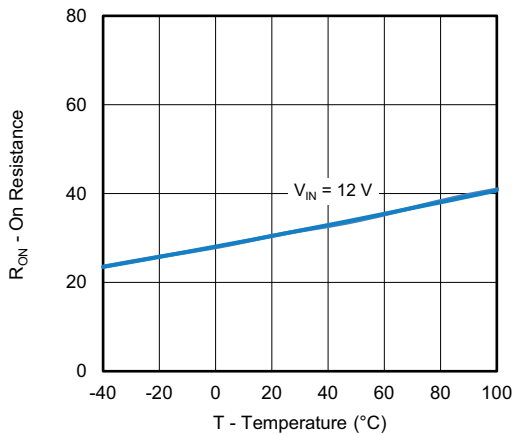


Fig. 11 - On Resistance vs. Temperature

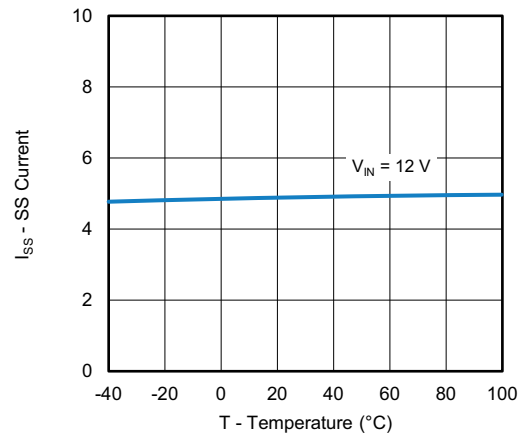


Fig. 14 - Soft Start Current vs. Temperature

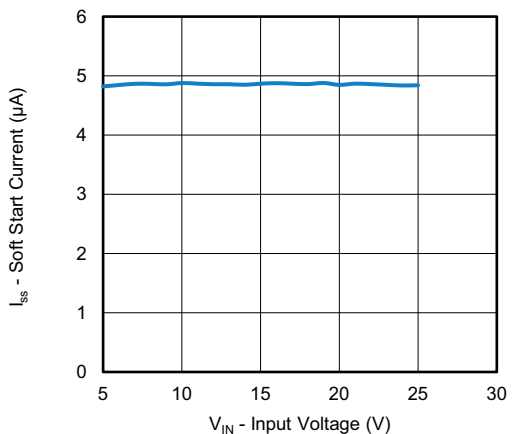


Fig. 12 - Soft Start Current vs. Input Voltage V<sub>IN</sub>

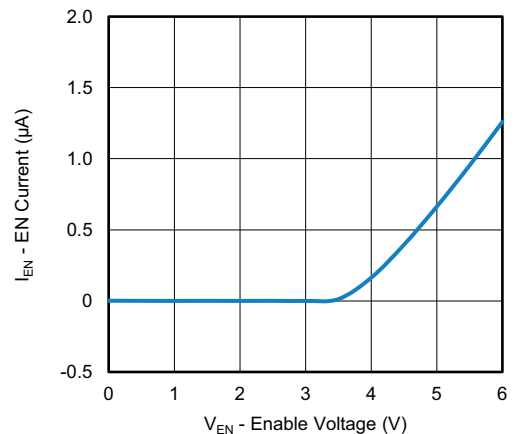


Fig. 15 - EN Current vs. EN Voltage



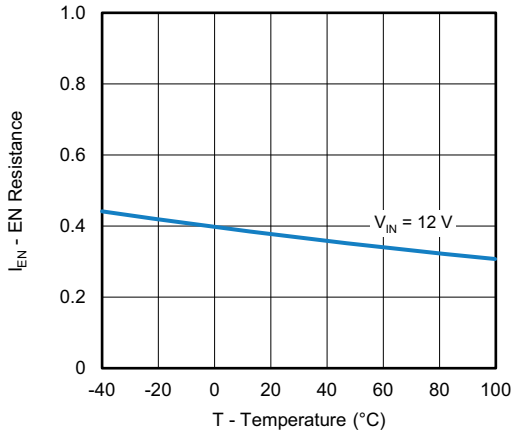


Fig. 16 - Enable Resistance vs. Temperature

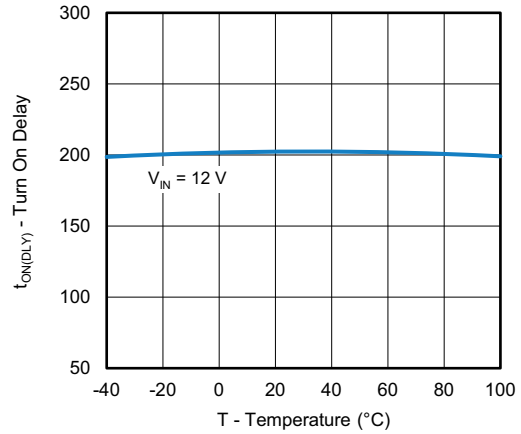


Fig. 18 - Turn On Delay Time vs. Temperature

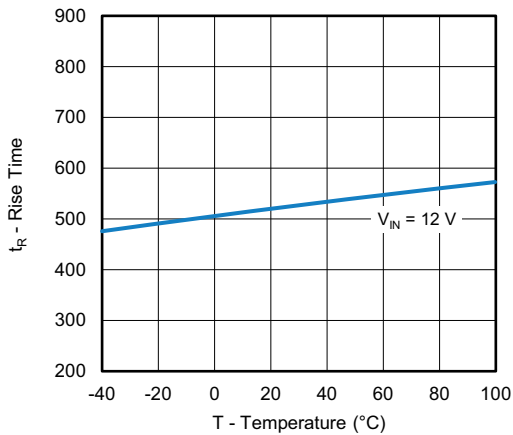


Fig. 17 - Rise Time vs. Temperature

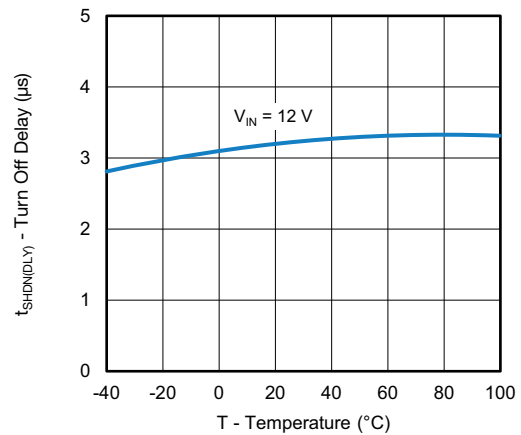
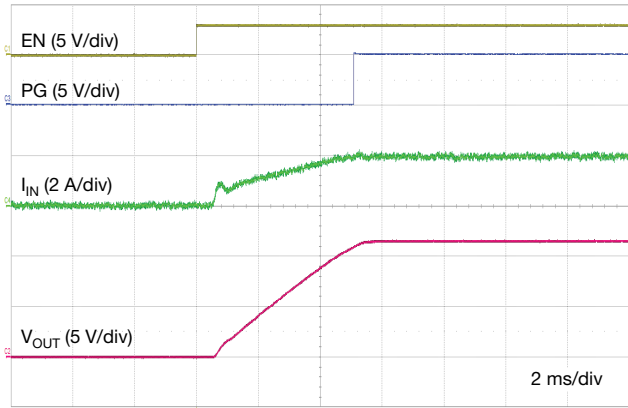
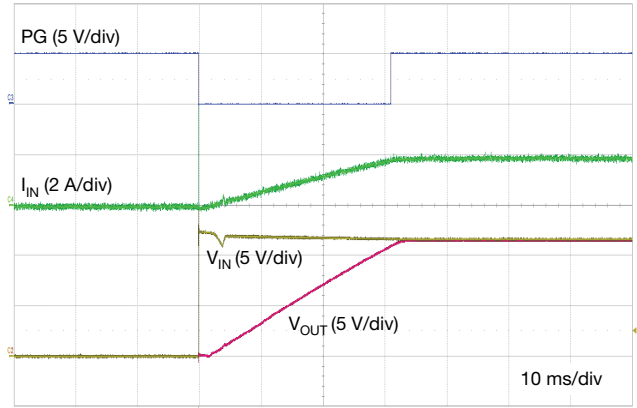


Fig. 19 - Turn Off Delay Time vs. Temperature

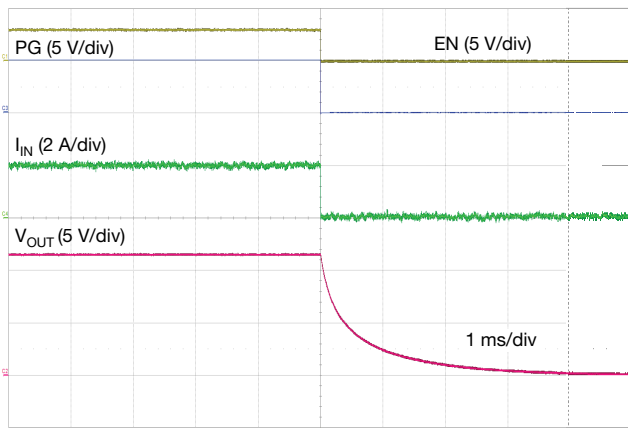
**TYPICAL CHARACTERISTICS**



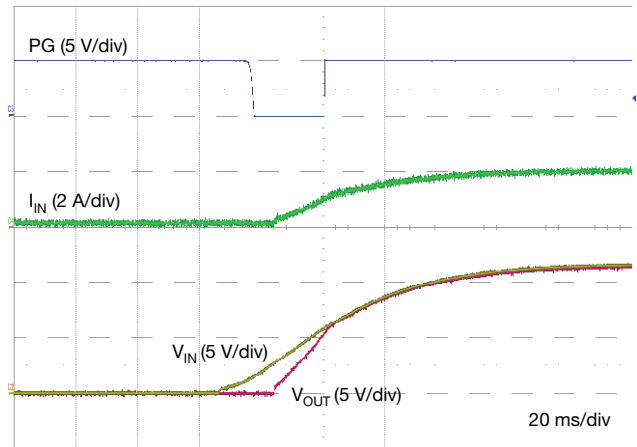
**Fig. 20 - Turn On by EN**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$



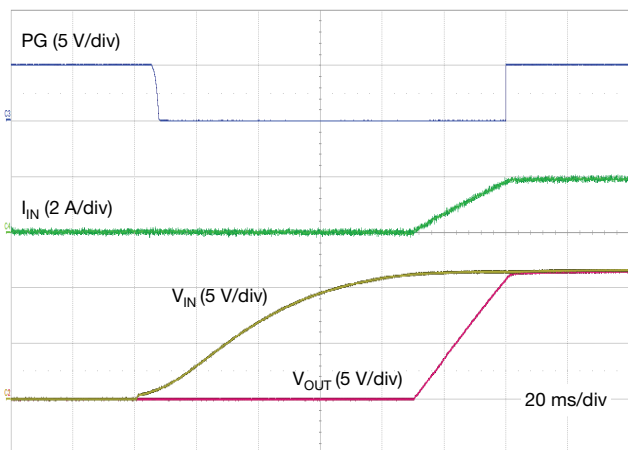
**Fig. 23 - Turn On by Hot-Plug of  $V_{IN}$**   
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$   
 EN Voltage Divider Resistors,  $1\ \text{M}\Omega$  and  $133\ \text{k}\Omega$



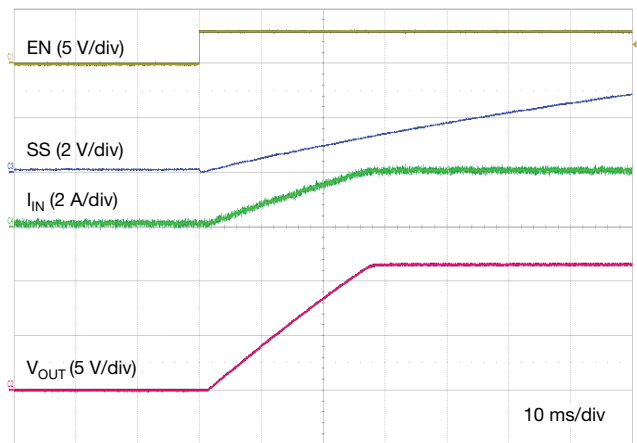
**Fig. 21 - Turn Off by EN**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$



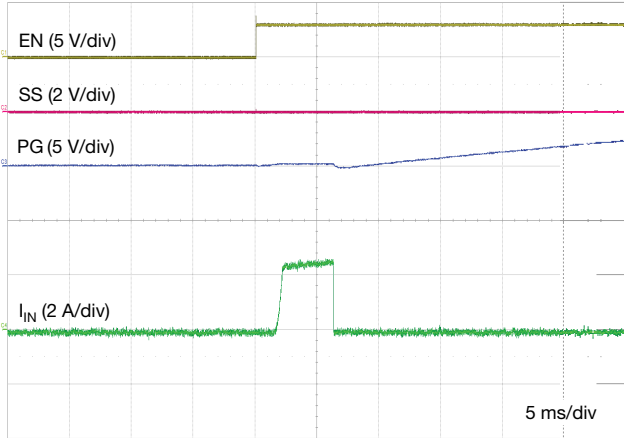
**Fig. 24 - Turn On by  $V_{IN}$  When EN is 3 V**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$



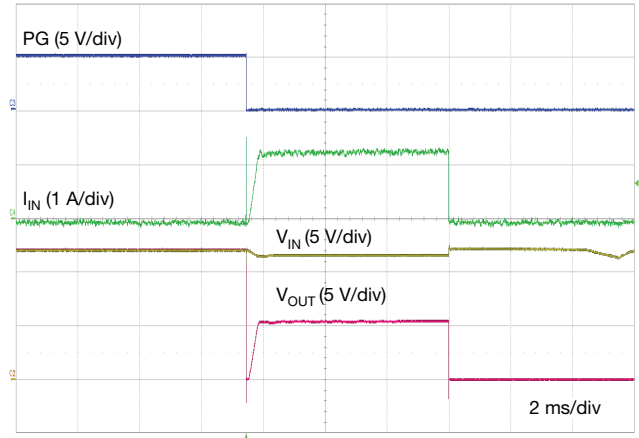
**Fig. 22 - Turn On by  $V_{IN}$**   
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$   
 EN Voltage Divider Resistors,  $1\ \text{M}\Omega$  and  $133\ \text{k}\Omega$



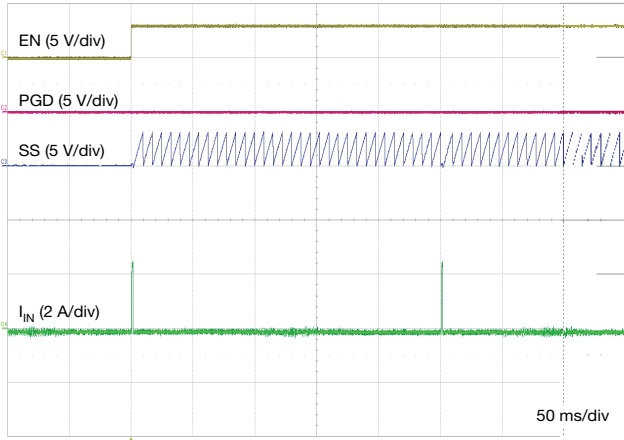
**Fig. 25 - Turn On by EN Into Resistive Load**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 6\ \Omega$ ,  $C_{SS} = 133\ \text{nF}$ ,  $R_{LIM} = 2.49\ \text{k}\Omega$



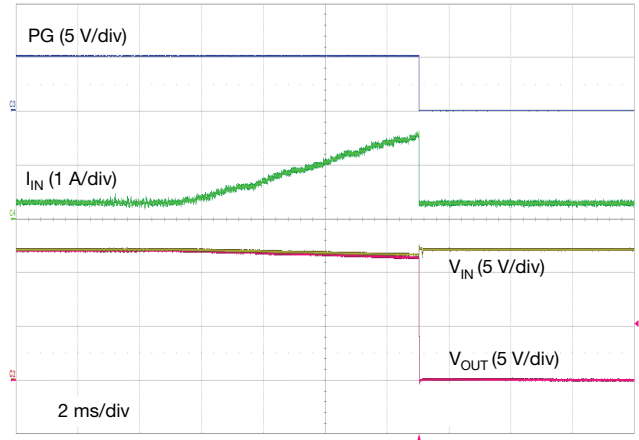
**Fig. 26 - Turn On Into Output Short**  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 133\text{ nF}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$



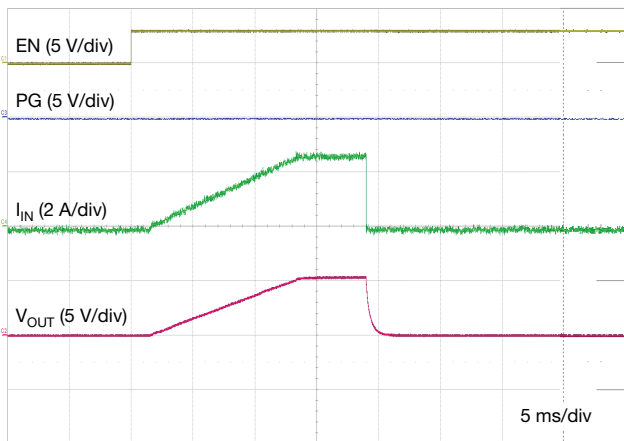
**Fig. 29 -  $V_{OUT}$  Short With a  $2\ \Omega$  Load**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 2\ \Omega$ ,  $C_L = 0\ \mu\text{F}$ ,  $C_{SS} = 133\text{ nF}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$



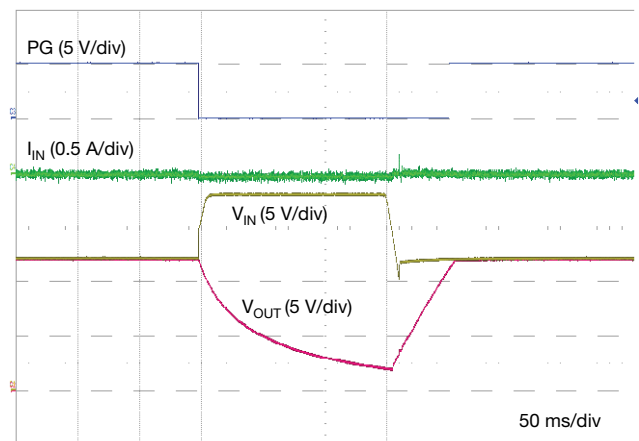
**Fig. 27 - Turn On Into Output Short, Auto-Retry**  
 $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 133\text{ nF}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$



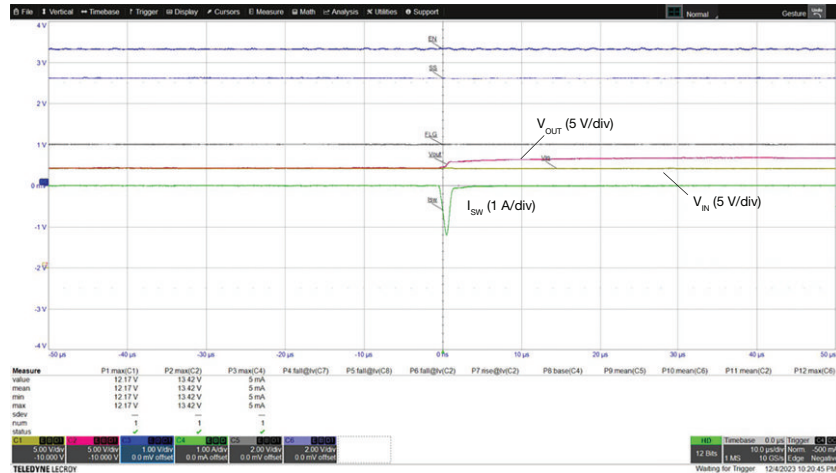
**Fig. 30 - Output Current Protection Increase Load Current Slowly**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 2\ \Omega$ ,  $C_L = 47\text{ nF}$ ,  $C_{SS} = 133\text{ nF}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$



**Fig. 28 - Turn On by EN Into OCP Load**  
 $V_{IN} = 12\text{ V}$ ,  $R_L = 2\ \Omega$ ,  $C_L = 47\ \mu\text{F} \times 3$ ,  $C_{SS} = 133\ \mu\text{F}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$



**Fig. 31 - Over Voltage Protection**  
 $R_L = 1\text{ k}\Omega$ ,  $C_L = 100\ \mu\text{F}$ ,  $C_{SS} = 133\text{ nF}$ ,  $R_{LIM} = 2.49\text{ k}\Omega$ ,  
 OVP Set to 18 V



**Fig. 32 - Active Reverse Current Blocking**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT}$  Raised Up to  $13.5\text{ V}$

**OPERATION**

The SIPQ32433A and SIPQ32433B are 78 mΩ switches designed to operate in the 2.8 V to 22 V range. The  $V_{IN}$  maximum DC tolerance is 28 V.

The devices start their operation by checking the  $V_{IN}$ ,  $V_{OUT}$ , OVP, and EN / UVLO pins. When the voltages are within the operation ranges, the PGD open drain switch is off. The PGD is high through an external pull high resistor. A high level on the EN / UVLO pin turns on the soft start current source charging CSS and enables internal MOSFET gate driver control the  $V_{OUT}$  to follow SS voltage at 9 times ratio. In case of OCP during soft start, the switch current will be regulated to the set current limit level.

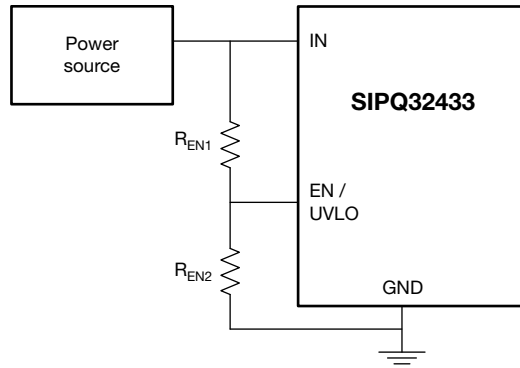
After a successful turn-on sequence, the device now actively monitors its load current, input voltage, and protects the load from harmful over-current, and over-voltage conditions. A built-in thermal sense circuit will detect junction over temperature and shut down the switch for safety.

**SWITCH ON / OFF, AND UNDER-VOLTAGE LOCKOUT PROTECTION - UVLO**

EN / UVLO pin controls the on / off of the power switch. When EN / UVLO is at a logic high the switch is on. When EN / UVLO is at a logic low, the switch is off.

The SIPQ32433A and SIPQ32433B implement under-voltage protection on the EN / UVLO to turn off the output. It is a user-defined under-voltage protection setting to flexibly select the proper minimum applied voltage for the downstream load or the device’s proper operation.

The diagram shows how a resistor divider from supply to GND can be used to set the UVLO set point for a given voltage supply level.

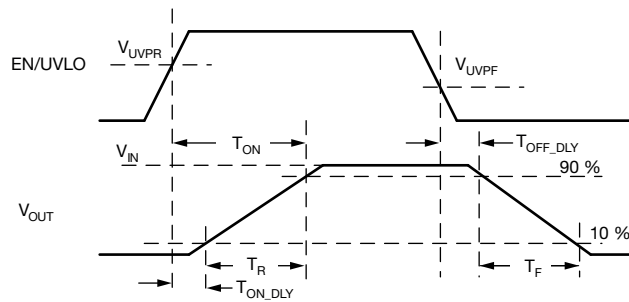

**Fig. 33**

The resistors must be sized large enough to minimize the constant leakage from supply to ground through the resistor divider network. At the same time, keep the current through the resistor network sufficiently larger than the leakage current on the EN / UVLO pin to minimize the error in the resistor divider ratio.

$$R_{EN1} = \frac{R_{EN2}(V_{IN} - V_{UVPR})}{V_{UVPR}}$$

Where  $V_{UVPR}$  is 1.25 V.

UVLO turn off delay ( $T_{OFF\_DLY}$ ) is typically 550  $\mu$ s and turn on delay  $T_{ON\_DLY}$  is typically 500  $\mu$ s.


**Fig. 34 - Switching Times**

### INRUSH CURRENT, AND OVER-CURRENT PROTECTION

The SIPQ32433A and SIPQ32433B incorporate two protections against over-current:

- Adjustable slew rate (SR) for inrush current control
- Adjustable over-current protection / active current limit to protect against overload conditions

The over-current protection (OCP) is active also during soft start. The over-current protection circuit controls the switch impedance to limit the current to the level programmed by the  $R_{SET}$  resistor.

If the over-current condition persists for more than 6 ms (typ.), the switch shuts off and alert the drain FLG is asserted, pulling the pin to GND.

### SLEW RATE CONTROL

An inrush current happens when the switch turns on into a large output capacitance. If the inrush current is not controlled, it can damage the input connectors and / or cause the system power supply to droop, leading to unexpected restarts elsewhere in the system.

The SIPQ32433A and SIPQ32433B provide integrated output slew rate control to manage the inrush current during start-up. This is achieved by forcing the  $V_{OUT}$  to follow the voltage on a soft start capacitor. A constant current source of  $5 \mu\text{A}$  charges the  $C_{SS}$ , generating a linear ramp up voltage on  $C_{SS}$ .

$$V_{OUT} = 9 \times V_{SS}$$

The inrush current is proportional to the load capacitance and rising slew rate. The following equations can be used to calculate the  $C_{SS}$  and slew rate required to limit the inrush current ( $I_{INRUSH}$ ) for a given load capacitance ( $C_{OUT}$ ):

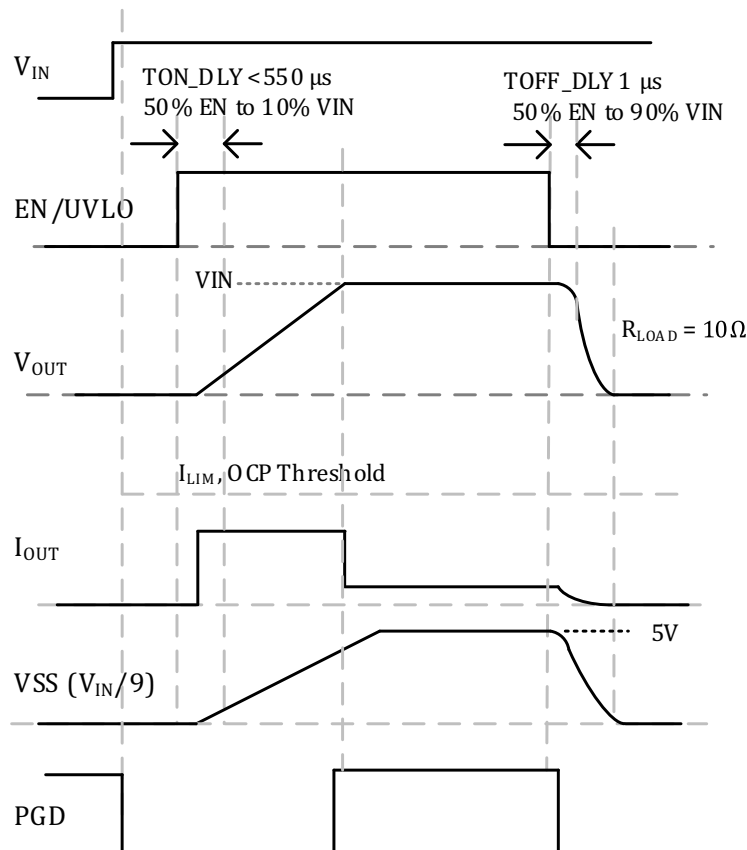
$$SR \text{ (V/ms)} = \frac{I_{INRUSH} \text{ (mA)}}{C_{OUT} \text{ (}\mu\text{F)}}$$

$$SR = \frac{I_{SS}}{C_{SS}} \times 9$$

$$T_{SS} = \frac{V_{IN}}{SR} = V_{IN} \times \frac{C_{OUT} \text{ (}\mu\text{F)}}{I_{INRUSH} \text{ (mA)}}$$

Inrush current should be controlled well below 20 % of set current limit, and within the device SOA.

The fastest output slew rate is achieved by leaving the soft start pin open.



*PGD is pulled through a resistor to an external voltage source*

**Fig. 35**

**CURRENT LIMIT SETTING**

The SIPQ32433A and SIPQ32433B actively monitor the current flow through the switch and provide a quick response to over-current conditions by actively regulating the current to a set limit. The current limit is set by connecting a resistor between the I<sub>LIM</sub> pin and GND. R<sub>SET</sub> can be calculated by the following formula for a desired current limit:

$$I_{LIM} = \frac{V_{OCP}}{R_{SET}} \times 10\ 300$$

V<sub>OCP</sub> is 0.6 V.

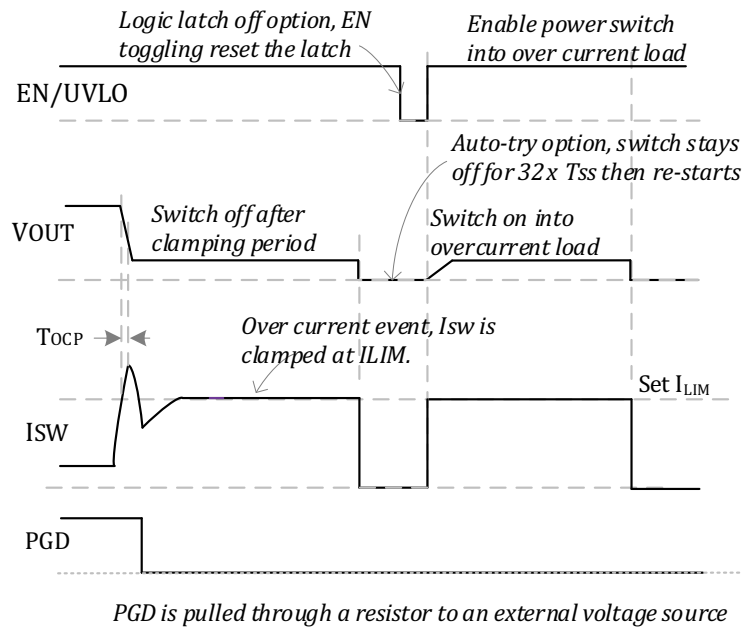
When the load current exceeds the threshold (I<sub>LIM</sub>), the parts respond within 1 μs (typ.) to turn off the switch and then regulate the switch gate voltage to limit the output current to the set I<sub>LIM</sub> level. During this brief period before the over-current protection circuit is engaged, 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 over-current 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.

If the over-current condition persists for more than 6 ms / typ., the switch shuts off. When V<sub>OUT</sub> falls below 95 % of V<sub>IN</sub>, the PGD is pulled low. The device will exit current limiting when the load current falls below I<sub>LIM</sub> before the end of the current limit period. The control circuit will increase the gate drive in the same manner as the soft start when the switch exits from the current limit mode.

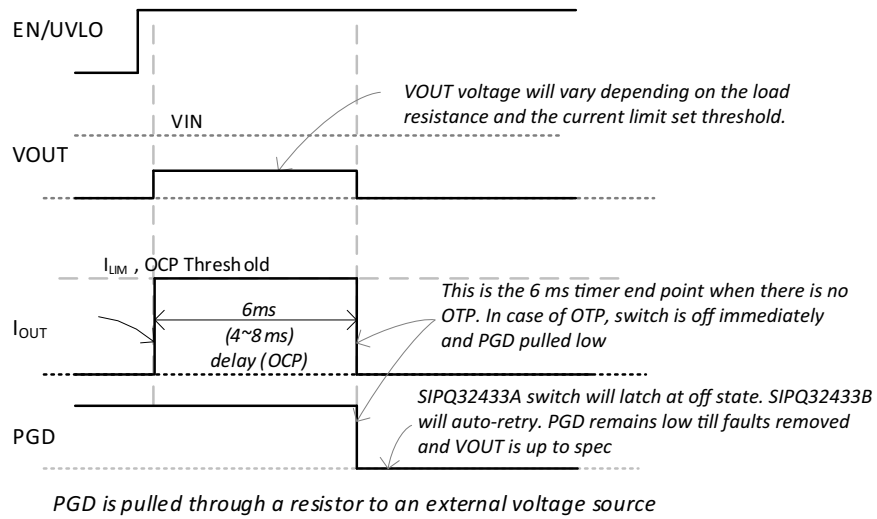
The I<sub>LIMIT</sub> / I<sub>MON</sub> pin can also be used for current reporting. The output path should be of high impedance to prevent any disruption to the current limit circuitry.

The current limit mode could result in excessive power on the switch, which increases the T<sub>J</sub> quickly. The SIPQ32433A and SIPQ32433B have OTP, providing an enhanced level of protection.

Once the device is off due to OCP or OTP faults, the SIPQ32433A stays in the latch-off state and the SIPQ32433B auto-retries after 32 times of the programmed soft start time. They can be reset by toggling V<sub>IN</sub> or EN / UVLO.



**Fig. 36 - Over-Current Protection**

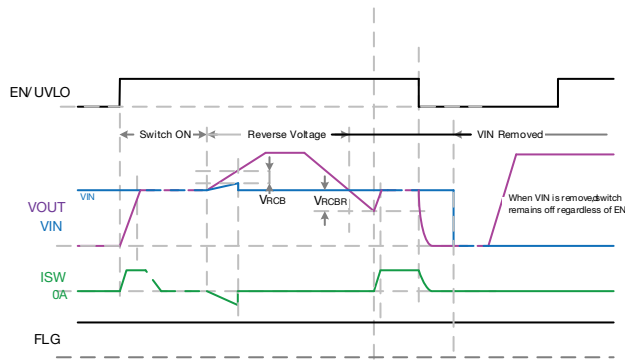


**Fig. 37 - Turn On Into Over-Current Load**

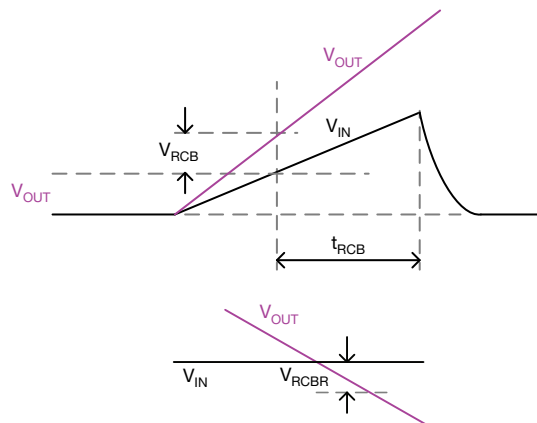


**Active Reverse Current Blocking**

The SIPQ32433A and SIPQ32433B feature ARCB (active reverse current blocking) ideal diode operation. When  $V_{OUT}$  is detected higher than  $V_{IN}$  by  $V_{RCB}$  (20 mV typ.) the switch is turned off. The TRCB response time  $t_{RCB}$  is 300 ns ( $V_{OUT} - V_{IN} = 100$  mV) and 3  $\mu$ s ( $V_{OUT} - V_{IN} = 3$  mV). TRCB is a non-latchable fault. Once  $V_{OUT}$  falls below the TRCB recovery threshold ( $V_{RCBR}$  20 mV typically), the switch will turn on without soft start procedure. The SIP32419B also blocks the current from  $V_{OUT}$  to  $V_{IN}$  when  $V_{IN}$  is short to GND. When the switch is disabled, current flow is blocked in both directions.



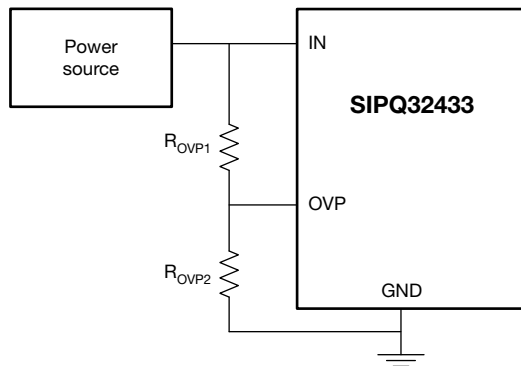
FLG remains high on this event  
**Fig. 38 - Active Reverse Current Blocking**



**Fig. 39 - Active Reverse Current Blocking**

**OVER-VOLTAGE PROTECTION (OVP)**

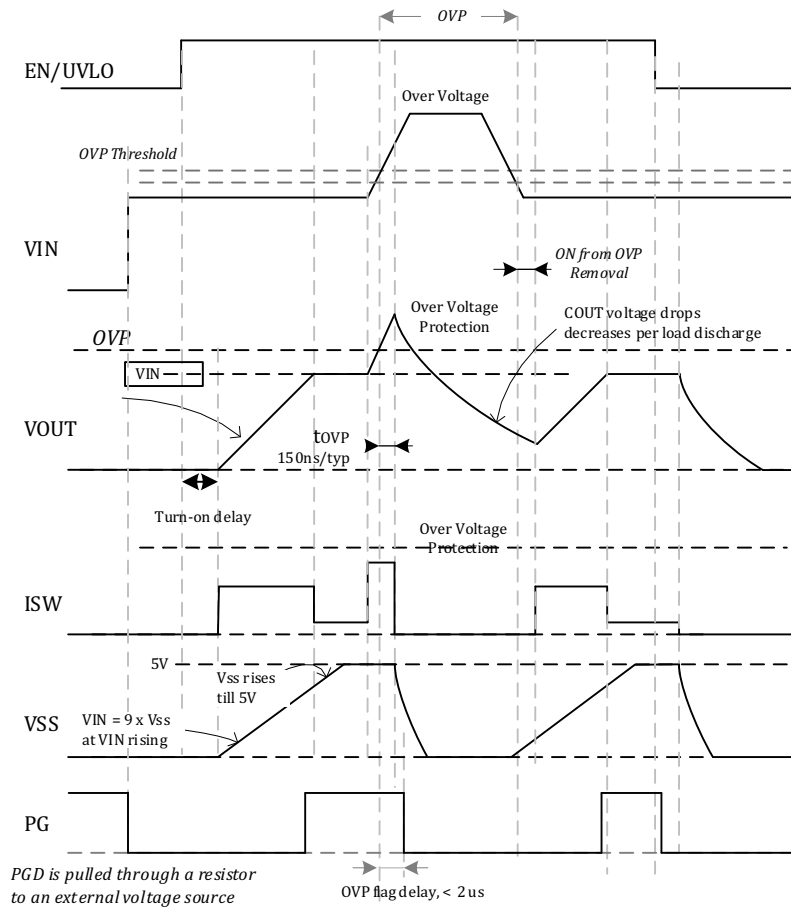
The SIPQ32433A and SIPQ32433B implement overvoltage protection (OVP) on both the  $V_{IN}$  and OVP pins to protect the output load in the event of an input over-voltage. When the input exceeds the over-voltage protection thresholds  $V_{OVP(R)}$  or the  $I_{NOVP}$ , which is typically 24 V, the device turns off the output within  $t_{OVP}$ , while the open drain PGD asserts in the meantime. As long as an over-voltage condition is present on the input, the device stays disabled with the output turned off. Over-voltage is a non-latchable fault. Once the input voltage returns to the normal operating range, the device attempts to start up normally.



**Fig. 40**

$$\frac{R_{OVP1}}{R_{OVP2}} = \frac{V_{IN(OVP)} - 1.2 V}{1.2 V}$$

OVP voltage divider resistors total resistance should not be over 2.5 M $\Omega$ .



**Fig. 41 - Over-Voltage Protection**

### OTP, OVER-TEMPERATURE PROTECTION

Over-temperature protection turns off the power switch when the die temperature reaches the OTP threshold of 165 °C. The hysteresis is 45 °C. When the die temperature drops below 120 °C, it is allowed to turn on again.

### PGD, POWER GOOD REPORTING

PGD is an open drain output. Connect an external pull-up resistor to 3.3 V or 5 V.. It is asserted low when  $V_{OUT}$  is below 95 % of  $V_{IN}$ , an over-current, over-voltage, or over-temperature fault condition occurs.

### INPUT CAPACITOR

A 2.2  $\mu F$  or larger  $C_{IN}$  is recommended. It should be placed as physically close to the device's input pins and ground 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. For hot-plug applications, where input path inductance is negligible, this input capacitor can be minimized or eliminated.

### OUTPUT CAPACITOR

The SIP32433A and SIP32433B do not require an output capacitor for proper operation. Still, a proper value  $C_{OUT}$  is recommended to accommodate load transient per circuit design requirements. There are no ESR or capacitor type requirements.

Protection

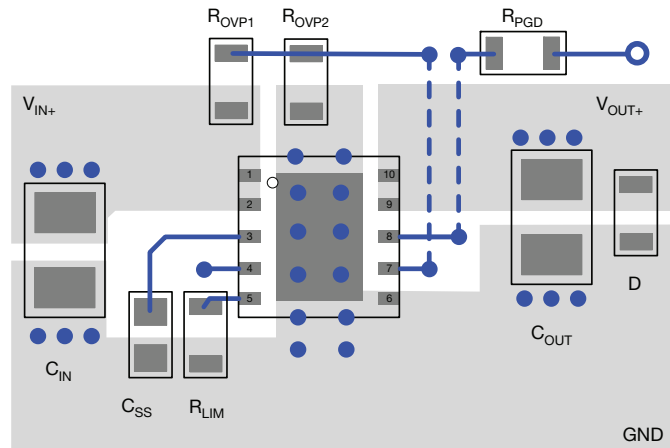
**LAYOUT GUIDELINES**

The SIPQ32433A and SIPQ32433B are protection switches designed to maintain a constant output load current upon over-current fault. Optimized layout with efficient heat sinking is critical. It is recommended to put as much copper as possible to the devices' central exposed pad which is connected to ground. Connect all ground planes with all possible thermal VIAs.

The circuit setting components should be laid close to their connection pins. The components include current limit setting resistor, soft start setting capacitor, and resistors connected to EN / UVLO and OVP pins.

Protection devices such as input TVS or output Schottky diodes must be located close the pins to be protected and routed with short traces to reduce inductance.

Below is a layout example.


**Fig. 42**



PRODUCT SUMMARY		
Part number	SiPQ32433A	SiPQ32433B
Description	3.5 A, 78 mΩ, 2.8 V to 22 V eFuse with accurate current limit, OVP, and active reverse current blocking	3.5 A, 78 mΩ, 2.8 V to 22 V eFuse with accurate current limit, OVP, and active reverse current blocking
Configuration	Single	Single
Slew rate time (μs)	Adjustable	Adjustable
On delay time (μs)	190	190
Input voltage min. (V)	2.8	2.8
Input voltage max. (V)	28	28
On-resistance at input voltage min. (mΩ)	78	78
On-resistance at input voltage max. (mΩ)	78	78
Quiescent current at input voltage min. (μA)	180	180
Quiescent current at input voltage max. (μA)	250	250
Output discharge (yes / no)	N	N
Reverse blocking (yes / no)	Active Reverse Current Blocking	Active Reverse Current Blocking
Continuous current (A)	3.5	3.5
Package type	DFN33 10L wettable flank	DFN33 10L wettable flank
Package size (W, L, H) (mm)	3.0 x 3.0 x 0.9	3.0 x 3.0 x 0.9
Status code	1	1
Product type	Slew rate, current limit	Slew rate, current limit
Applications	Automotive infotainment, ADAS and auto pilot, cameras and sensors, USB hubs, holdup power switching, power muxing	Automotive infotainment, ADAS and auto pilot, cameras and sensors, USB hubs, holdup power switching, power muxing

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