

## 18 V, 30 A, 1.2 mΩ R<sub>DS(on)</sub> Hot-Swap eFuse Switch

### DESCRIPTION

This SiC32305 and SiC32306 are a programmable hot swap e-fuses for high current applications such as servers, data storage, and communication products. It contains a high-side MOSFET and other control circuitry that enables it to work as stand-alone device, or to be controlled by a hot-swap controller. SiC32305, SiC32306 drive up to 30 A of continuous current per device.

The SiC32305, SiC32306 limit the inrush current to the load when a circuit card is inserted into a live backplane power source, thereby limiting the backplane's voltage drop.

The device offers many features to simplify system designs. It provides an integrated solution for monitoring output current and die temperature, eliminating the need for an external current sensing shunt resistor, power MOSFET, and thermal sensing device.

The SiC32305, SiC32306 detect the power FET gate, source, and drain short conditions, in addition to feedback to the controller through PGD pin. The parts are available in a PowerPAK MLP28S-44

### FEATURES

- 4.5 V to 18 V operating input range
- 25 V guaranteed maximum input tolerance
- 2.3 ms moderate OCP blanking time
- Maximum 30 A continuous output current
- Integrated switch with lower R<sub>DS(on)</sub> of 1.2 mΩ
- Built-in MOSFET driver
- Integrated current sensing with sense output
- Separate current sensing output used to program over-current value
- Built-in soft start and insertion delay
- Output short-circuit protection
- Over-temperature protection
- Built-in fuse health diagnostics
- Fault status report
- Analog temperature report
- Available in a PowerPAK MLP28S-44 package
- Auto-retry, 1s after fault is removed (SiC32306).

### APPLICATIONS

- Hot swap
- PC cards
- Disk drives
- Servers
- Networking

### TYPICAL APPLICATION CIRCUIT

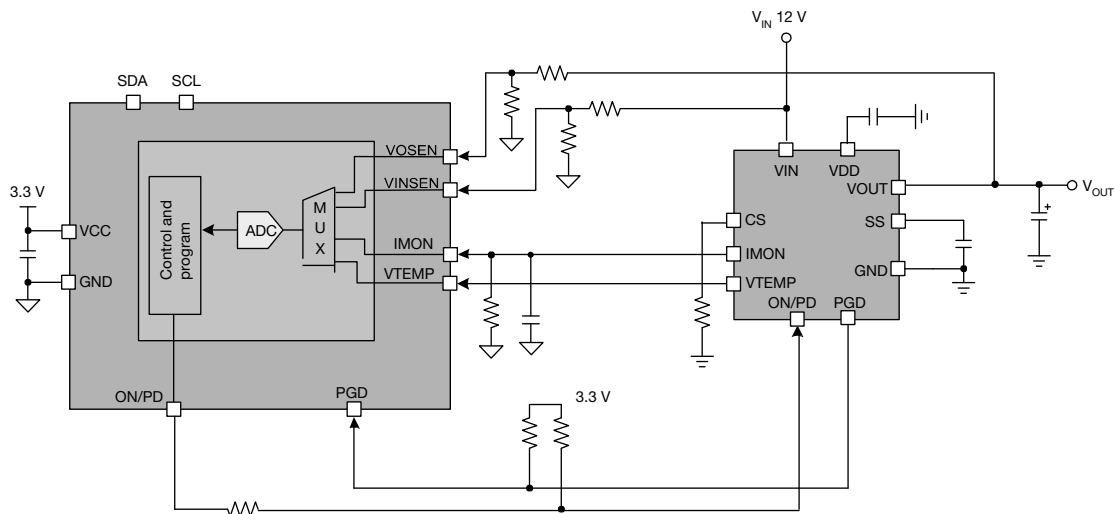
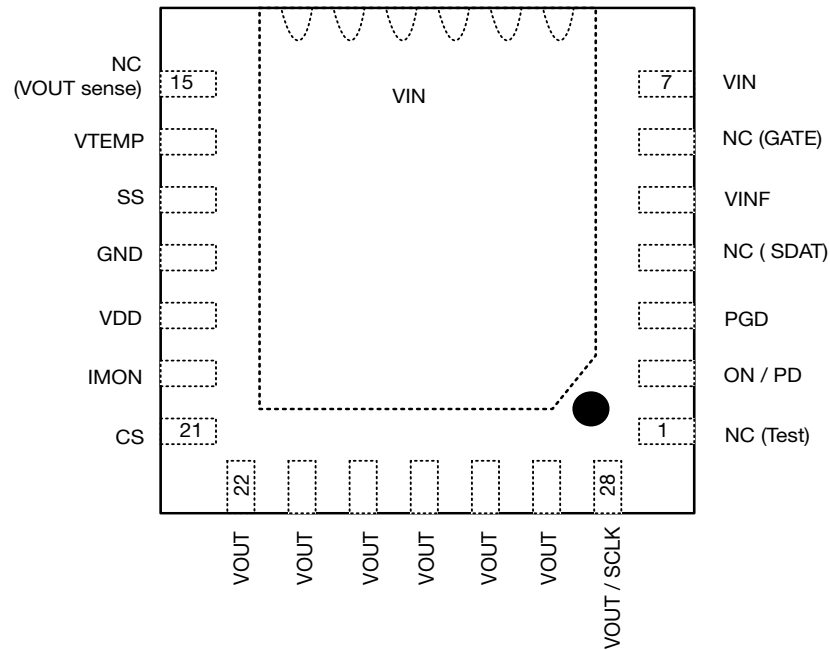
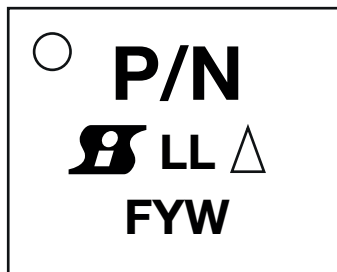


Fig. 1 - Typical Application Circuit

**PINOUT CONFIGURATION**

**Fig. 2 - Pins Out Configuration (Top View)**

<b>ORDERING INFORMATION</b>				
<b>PART NUMBER</b>	<b>PACKAGE</b>	<b>FAULT RESPONSE</b>	<b>ALERT PINS</b>	<b>MARKING CODE</b>
SiC32305CD-T5E3	PowerPAK MLP28S-44	Switch off, and latch upon fault event	PGD	32305
SiC32306CD-T5E3	PowerPAK MLP28S-44	Switch off, and auto retry after latch for 1 s upon fault event	PGD	32306
SiC32305EVB	Reference board			
SiC32306EVB	Reference board			

PIN DESCRIPTION		
PIN	NAME	FUNCTION
1	NC	Can be connected to VOUT, GND, or leave floating (internal test SDAT)
2	ON/PD	Switch on / off control and VOUT pull-down mode control during switch off state. Drive ON / PD high to turn on and low to off the power FET. Setting ON / PD to 1.1 V, the device will be off, and 2ms later, a 500 Ω discharge path to GND is on.
3	PGD	Digital output of Power Good indication. At the initial stage, PGD is set to low by an open Drain output. When VOUT reaches 95 % of VIN, PGD pin will turn high. There is a 5% hysteresis. PGD is hold low at soft start stage. If a fault is detected. PGD is pulled low. This pin has an internal 2 iA pull-up current to artificially pull the signal high in case the external pull-up resistor is missing. The faults include TJ over temperature, switch health check fault, severe over current, measured current greater than the CS programmed limit for 2.3 ms, and 200 ms soft-start timer expires/soft start failure
4	NC	Connect to GND or leave floating (internal SDAT)
5	VINF	This pin is the power source of the control circuit. It must be connected to VIN. Optionally an appropriate RC filter can be added to the input of this pin to filter noise from the power rail.
6	NC	Leaves floating. Power FET Gate pin.
7	VIN	Input power
8 - 14	VIN	Input power
15	NC (VOUT Sense)	VOUT sense voltage
16	VTEMP	Junction temperature sense output. The output temperature equals $200 \text{ mV} + 10 \text{ mV/C}^\circ \times T_J^\circ$
17	SS	The SS pin is the ramping control for soft-start ramping rate. An internal fixed current source charges an external capacitor in linear fashion. The VOUT voltage soft-starts at a rate that tracks the soft-start capacitor. If soft-start has not completed within 200ms, a fault is declared. In the event that the soft-start ramp is too fast and causes in-rush current to charge VOUT with too much current, the internal soft start current limit reference will override (slow down) the soft-start ramp rate. The ramping voltage on the SS pin will equal 10 % of the VOUT voltage during ramping.
18	GND	Signal ground.
19	VDD	Internal 5 V LDO output. Place a 4.7 μF (minimum 2.2 μF) decoupling capacitor close to VDD and GND.
20	IMON	Current monitor output. The output current is proportional to the current flowing through the power device. The IMON/IOUT gain is 20uA/A.
21	CS	Current sense output. CS requires an external resistor. The VCS voltage is compared with an internal current limit reference voltage to determine the current limit.
22 - 27	VOUT	Output voltage controlled by the IC. OUT is connected to the source of the integrated MOSFET
28	NC	Can be connected to VOUT, GND, or leave floating (internal test SCLK)

**MARKING CODE**


Format:

- Line 1: part number
- Line 2: Siliconix logo, lot code, and ESD logo
- Line 3: factory code, year code, work week code



ABSOLUTE MAXIMUM RATINGS				
PARAMETER	SYMBOL	MIN.	MAX.	UNIT
Input voltage	$V_{IN}, V_{INF}$	-0.3	+25	V
Output voltage (DC)	$V_{OUT}$	-0.3	+25	V
Output negative voltage (10 $\mu$ s)		-3	-	V
Output negative voltage (500 $\mu$ s)		-1	-	V
Internal 5 V LDO output	$V_{DD}$	-0.3	-0.3 to +6	V
All other pins		-0.3	-0.3 to $V_{DD} + 0.3$	V
Operating junction temperature range	$T_J$	-40	+150	$^{\circ}$ C
Lead temperature	$T_{SLD}$	-	260	$^{\circ}$ C
Storage temperature	$T_{STG}$	-65	+150	$^{\circ}$ C
Pin 8 "V <sub>OUT</sub> Sense" voltage range		Internally limited		
Pin 4, gate voltage range ( $V_{GATE} - V_{OUT}$ )		-20	20	V
Maximum continuous switch current		-	30	A
Electrostatic discharge, human body model (per EIA/JESD22-A114)	$ESD_{HBM}$	-	2	kV
Electrostatic discharge, charge device model (per EIA/JESD22-A115)	$ESD_{CDM}$	-	1.5	kV
Maximum latch-up current limit (per JESD78 class II)	$I_{LU}$	-	100	mA
Moisture sensitivity level	$MSL$	Level 1		
Storage	$T_{STG}$	-55	+125	$^{\circ}$ 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	MIN.	TYP.	MAX.	UNIT
Input voltage ( $V_{IN}$ )	4.5	-	18	V
Maximum continuous output current	-	-	30	A
$V_{DD}$ output capacitance range	2.2	-	10	$\mu$ F
Operation junction temperature	-40	-	+125	$^{\circ}$ C

THERMAL CHARACTERISTICS			
THERMAL PARAMETER	SYMBOL	VALUE	UNIT
Thermal resistance, junction to ambient	$R_{\theta JA}$	17	$^{\circ}$ C/W
Thermal resistance, junction to case, $V_{OUT}$ lead	$R_{\theta JCL}$	1.9	$^{\circ}$ C/W
Thermal resistance, junction to case, center of exposed pad	$R_{\theta JCB}$	1	$^{\circ}$ C/W

**Note**

- Thermal resistances are obtained by measurement with part mounted on evaluation board



<b>SPECIFICATIONS</b>						
PARAMETER	SYMBOL	TEST CONDITIONS $V_{IN} = V_{INF} = 12\text{ V}$ , ON / PD = 3.3 V, CVINF = 0.1 $\mu\text{F}$ , CVDSS = 4 $\mu\text{F}$ , CVTEMP = 0.1 $\mu\text{F}$ , RVTEMP = 1 k $\Omega$ , CSS = 100 nF, MIN. / MAX. LIMITS ARE OVER THE JUNCTION TEMPERATURE RANGE OF -40 °C TO +125 °C UNLESS SPECIFIED OTHERWISE, TYP. VALUES AT $T_A = 25\text{ °C}$	LIMITS			UNIT
			MIN.	TYP.	MAX.	
<b>Supplies Current</b>						
Quiescent current	$I_Q$	$V_{ONPD} = 3\text{ V}$ , no load	-	3	-	mA
		Fault latch off	-	6.3	-	mA
		$V_{ONPD} = 0\text{ V}$	-	6	-	mA
<b>V<sub>DD</sub> Regulator and UVLO</b>						
Regulator output voltage	$V_{VDD}$	$I_{VDD} = 0\text{ mA}$ , $V_{INF} = 6\text{ V}$	-5%	5	5%	V
V <sub>DD</sub> current limit			-	70	-	mA
V <sub>DD</sub> drop out voltage		$V_{INF} = V_{IN} = 4.5\text{ V}$ , $I = 20\text{ mA}$	-	200	-	mV
UVLO threshold, rising			-	4.2	-	V
UVLO threshold hysteresis			-	73	-	mV
<b>V<sub>IN</sub> Under Voltage</b>						
V <sub>IN</sub> under voltage lockout threshold rising	$V_{VIN\_THR}$		-	4.2	-	V
V <sub>IN</sub> under-voltage lockout hysteresis	$V_{VIN\_THF}$		-	105	-	mV
<b>ON / PD</b>						
Internal current source	$I_{ON\_PD}$		3	4.2	5	$\mu\text{A}$
FET on insertion delay time	$t_{ON\_DLY}$	<b>Note:</b> 1 ms timer begins after ON_PD pin transitions above 1.4 V	-	1	-	ms
FET on high-level input voltage	$V_{ON\_Hi}$		1.7	-	-	V
FET on-state hysteresis	$V_{ON\_Hyst}$		-	350	-	mV
PD mode pull-down resistor	$R_{PL\_DN}$	Internal resistor from V <sub>OUT</sub> to ground through PD controlled functionality	-	650	-	$\Omega$
PD mode pull-down delay time	$t_{PL\_DN\_DLY}$	<b>Note:</b> This 2.08 ms is the summation of the 80 $\mu\text{s}$ recognition time and 2 ms delay time	-	2.05	-	ms
<b>Soft-Start</b>						
Pull-up current	$I_{SS}$	$T_J = 25\text{ °C}$	4.5	5	5.5	$\mu\text{A}$
Gain to V <sub>OUT</sub>	AVSS	-	8.3	10	12.4	V/V
SS pulldown voltage	$V_{OL\_SS}$	0.1 mA into pin during ON delay	-	5.9	-	mV
Auto-retry delay (SiC32306)	$t_{DLY\_RETRY}$	Auto elay from power-down to retry of startup	-	1	-	S
<b>PGD Output</b>						
Output low current capability	$I_{PGD\_ACTIVE}$	$V_{PGD} = 0.2\text{ V}$	18	32	-	mA
PGD off-state leakage current	$I_{PGD\_LKG}$	<b>Note:</b> There is an intentional internal 2 M $\Omega$ pull down resistor $V_{PGD} = 5\text{ V}$	-	2.7	-	$\mu\text{A}$



SPECIFICATIONS						
PARAMETER	SYMBOL	TEST CONDITIONS $V_{IN} = V_{INF} = 12\text{ V}$ , ON / PD = 3.3 V, CVINF = 0.1 $\mu\text{F}$ , CVDSS = 4.7 $\mu\text{F}$ , CVTEMP = 0.1 $\mu\text{F}$ , RVTEMP = 1 k $\Omega$ , CSS = 100 nF, $T_J = 25\text{ }^\circ\text{C}$	LIMITS			UNIT
			MIN.	TYP.	MAX.	
<b>I<sub>MON</sub></b>						
Sense gain			-	20	-	$\mu\text{A}/\text{A}$
I <sub>MON</sub> accuracy <sup>(1)</sup>	I <sub>MON_ACC</sub>	$0.25\text{ A} \leq I_{OUT} \leq 3\text{ A}$ , $T_J = 25\text{ }^\circ\text{C}$	I <sub>OUT</sub> - 0.5	-	I <sub>OUT</sub> + 0.5	A
		$I_{OUT} = 3\text{ A}$ , $T_J = 25\text{ }^\circ\text{C}$	-3	-	+3	%
		$I_{OUT} = 10\text{ A}$ , $T_J = 25\text{ }^\circ\text{C}$	-3	-	+3	%
		$I_{OUT} = 30\text{ A}$ , $T_J = 25\text{ }^\circ\text{C}$	-3	-	+3	%
		$3\text{ A} \leq I_{OUT} \leq 30\text{ A}$ , $T_J = 0\text{ to }85\text{ }^\circ\text{C}$	-5	-	+5	%
<b>Short - Circuit Protection</b>						
Short-circuit current trip point <sup>(1)</sup>	I <sub>SC</sub>		-	100	-	A
Response time <sup>(1)</sup>	t <sub>SC</sub>		-	200	-	ns
<b>Over Current Protection</b>						
Internal CLRef voltage			-	1.6	-	V
OCP blanking time			-	2.3	-	ms

**Notes**

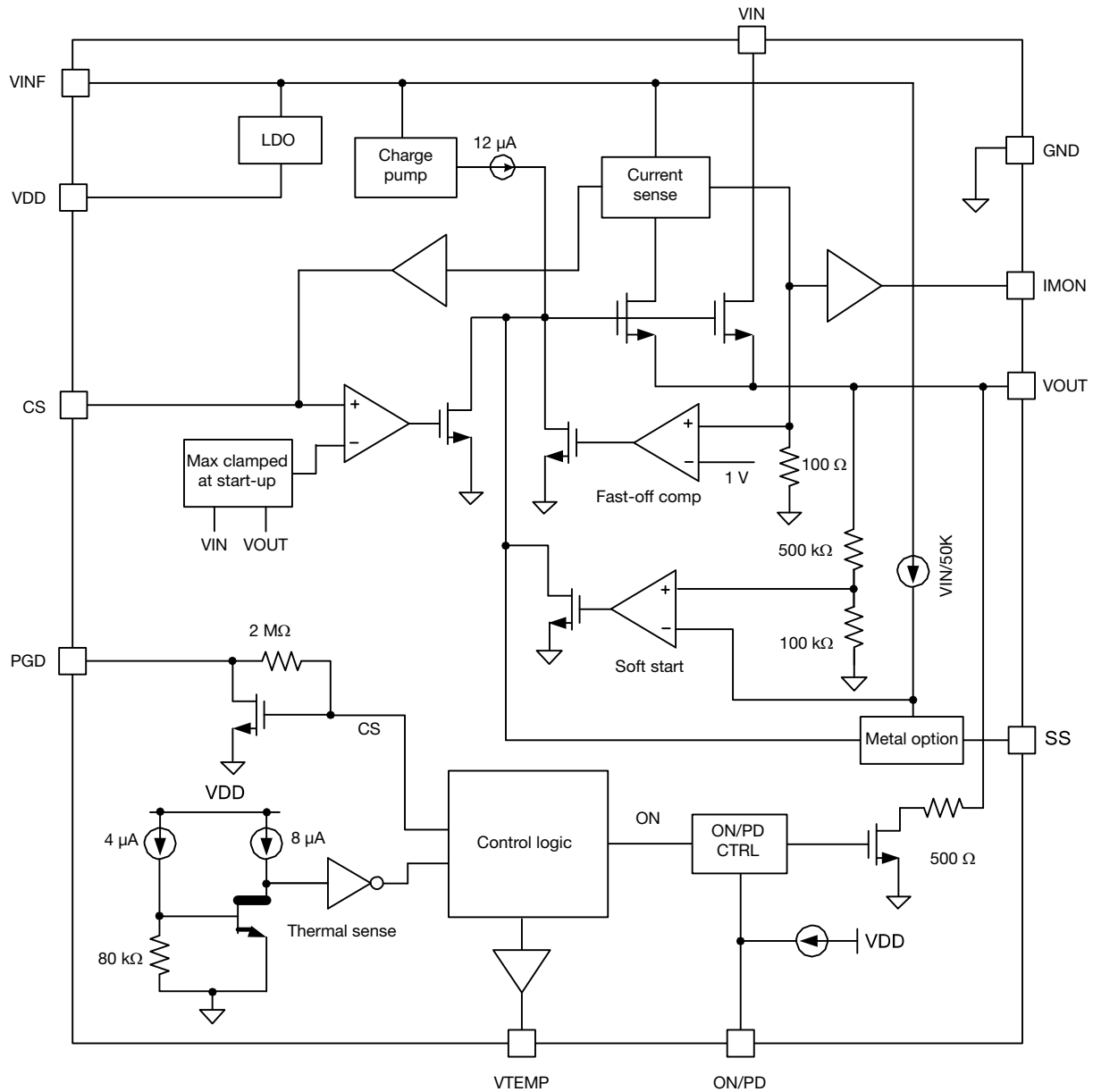
- (1) Guaranteed by design and characterization  
(2) Typical limits are established by characterization and are not production tested  
(3) Min. and Max. Parameters are not 100% production tested



SPECIFICATIONS						
PARAMETER	SYMBOL	TEST CONDITIONS $V_{IN} = 12\text{ V}$ , $V_{DD} = 5.0\text{ V}$ , $T_J = 25\text{ }^\circ\text{C}$ , unless otherwise noted	LIMITS			UNIT
			MIN. (3)	TYP. (2)	MAX. (3)	
<b>VTEMP</b>						
Sense Gain		Sense range $0\text{ }^\circ\text{C}$ to $140\text{ }^\circ\text{C}$	-	10	-	mV / $^\circ\text{C}$
Sense Offset		$T_J = 25\text{ }^\circ\text{C}$ ( $V_{TEMP} = 200\text{ mV} + T_J \times 10\text{ mV}/^\circ\text{C}$ )	-	450	-	mV
<b>Thermal Shutdown</b>						
Thermal shutdown temperature	$T_{THDN}$	PGD pulls low	-	142	-	$^\circ\text{C}$
<b>Power MOSFET</b>						
On resistance	$R_{DS(on)}$		-	1.08	1.6	m $\Omega$
		$T_J = 85\text{ }^\circ\text{C}$	-	1.25	-	m $\Omega$
<b>FET Health Diagnostic (Fault Detection)</b>						
FET VDS short threshold	$V_{SCTH\_DS}$	Startup postponed if $V_{OUT} > V_{SCTH\_DS}$ anytime after postponed <b>(Note: this is a non-latching fault)</b>	-	80	-	%
FET VDS short release threshold. (short flag removed threshold)	$V_{DS\_OK}$	Startup resumed if $V_{OUT} < V_{DS\_OK}$ anytime after postponed	-	70	-	%
FET gate to drain short threshold	$V_{SCTH\_DG}$	Startup postponed if $V_G$ is less than $V_{SCDG\_TH}$ at $V_{ON} > V_{ON\_HI}$ transition. It will resume once it is below $V_{DG\_OK}$ <b>(Note: this is a non-latching fault)</b>	-	2.7	-	V
FET gate to drain short OK threshold	$V_{DG\_OK}$	Startup resumed if $V_G < V_{DG\_OK}$ anytime after postponed	-	2.6	-	V
VG low threshold	$V_{G\_TH}$	Restart / latch if $V_{GD} < V_{G\_TH}$ after $t_{SS\_MAX}$ . During normal operation, it will be a flag and triggers restart / latch	-	7	-	V
$V_{OUT}$ low threshold	$V_{OUTL\_TH}$		-	90	-	%
FET maximum gate fault timer	$t_{gf\_max}$	After ON / PD goes high, if $V_{GS}$ remains low for longer than 200 ms <b>(Note: this fault causes PGD to latch)</b>	-	200	-	ms
Maximum soft-start time	$t_{SS\_MAX}$	After ON / PD goes high, if $V_{OUT} < 90\% V_{IN}$ within 200 ms, or if $V_{GS}$ remains less than 1.5 V below internal charge pump voltage (indication of fuse not fully on) within 200 ms <b>(Note: this fault causes PGD to latch)</b>	-	200	-	ms

**Notes**

- (1) Guaranteed by design and characterization
- (2) Typical limits are established by characterization and are not production tested
- (3) Min. and Max. Parameters are not 100% production tested

**FUNCTIONAL BLOCK DIAGRAM**

**Fig. 3 - Functional Block Diagram**



**TYPICAL CHARACTERISTICS** (Test conditions:  $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 220\text{ nF}$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{CLREF} = 120\text{ k}\Omega$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{IMON} = 2\text{ k}\Omega$ ,  $T_A = 25\text{ }^\circ\text{C}$ , unless otherwise specified)

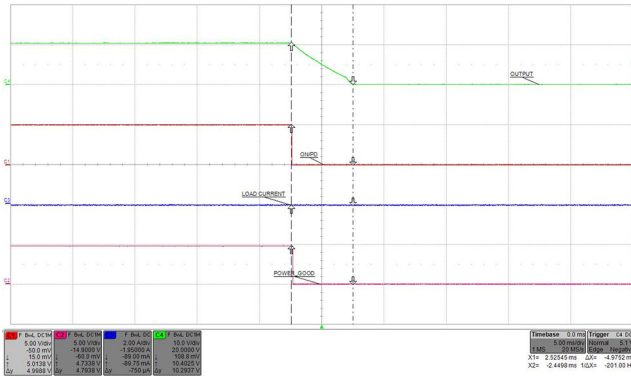


Fig. 4 - Shut down by EN ( $I_{OUT} = 0\text{ A}$ ), Time: 5 ms/Div

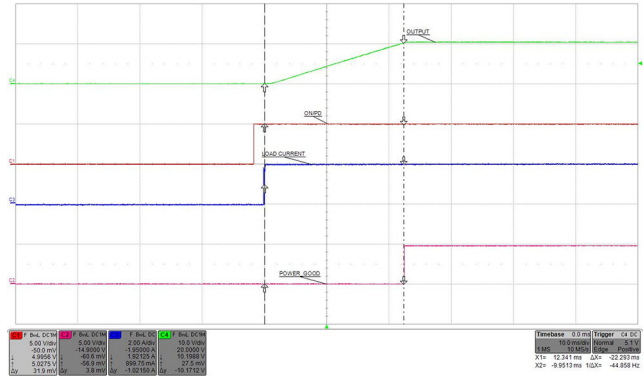


Fig. 7 - Start Up by EN ( $I_{OUT} = 0\text{ A}$ ), Time: 10 ms/Div

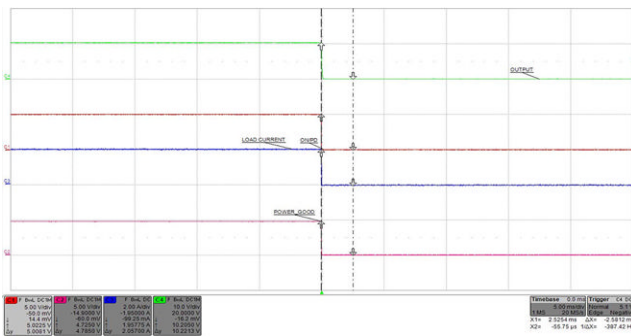


Fig. 5 - Shut down by EN ( $I_{OUT} = 2\text{ A}$ ), Time: 5 ms/Div

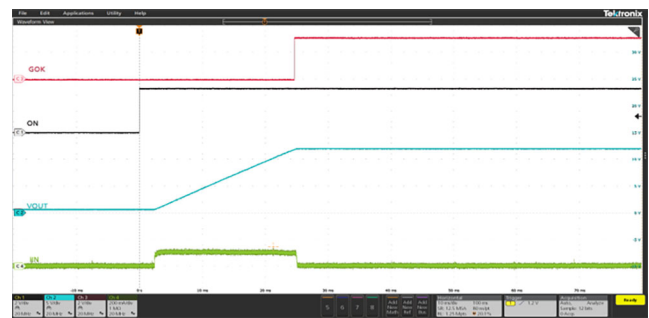


Fig. 8 - Power Up With ON-PD Control ( $C_{OUT} = 2 \times 220\text{ }\mu\text{F}$ ), Time: 10 ms/Div.

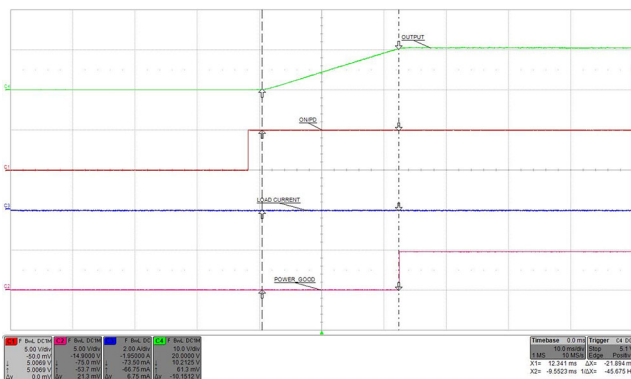


Fig. 6 - Start Up by EN ( $I_{OUT} = 0\text{ A}$ ), Time: 10 ms/Div

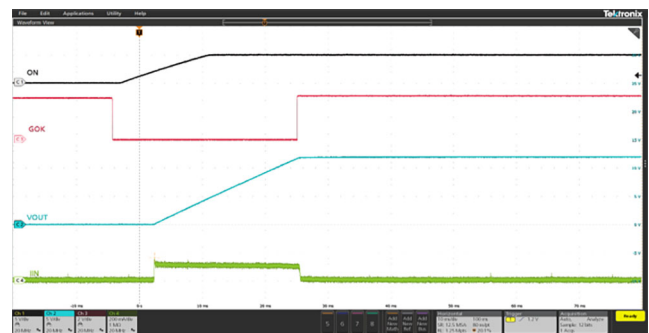


Fig. 9 - Power Up With  $V_{IN}$  ( $C_{OUT} = 2 \times 220\text{ }\mu\text{F}$ ), Time: 10 ms/Div.



**TYPICAL CHARACTERISTICS** (Test conditions:  $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 220\text{ nF}$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{CLREF} = 120\text{ k}\Omega$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{IMON} = 2\text{ k}\Omega$ ,  $T_A = 25\text{ }^\circ\text{C}$ , unless otherwise specified)

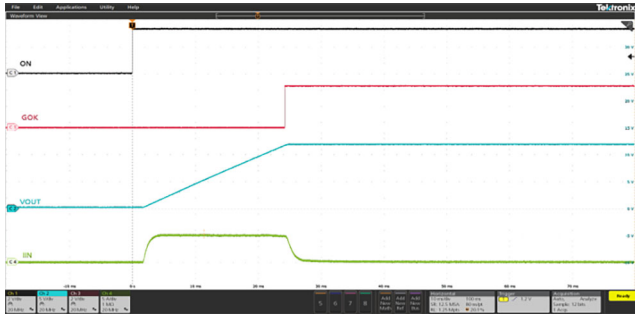


Fig. 10 - Power Up With ON/PD Control (COUT = 10 mF), Time: 10 ms/Div.

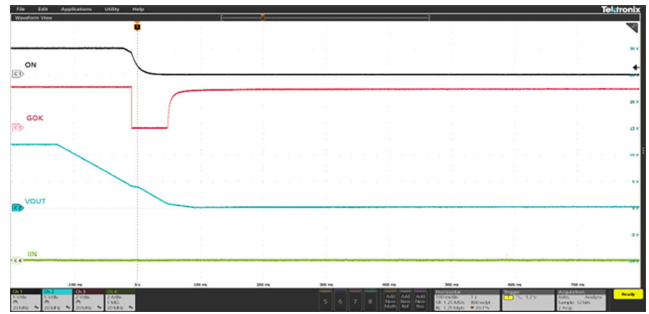


Fig. 13 - Power Down With  $V_{IN}$  (COUT = 2 x 220  $\mu\text{F}$ ), Time: 10 ms/Div.

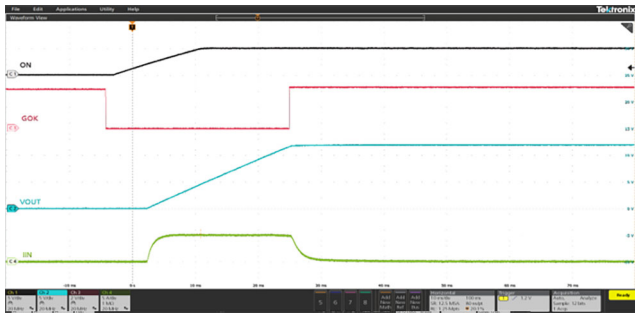


Fig. 11 - Power Up With  $V_{IN}$  (COUT = 10 mF), Time: 10 ms/Div.

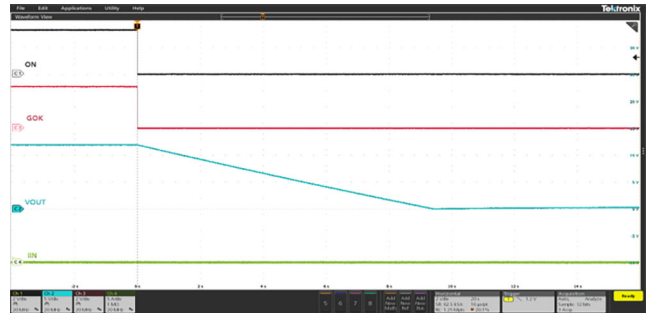


Fig. 14 - Power Down With ON/PD Control (COUT = 10 mF), Time: 2 ms/Div

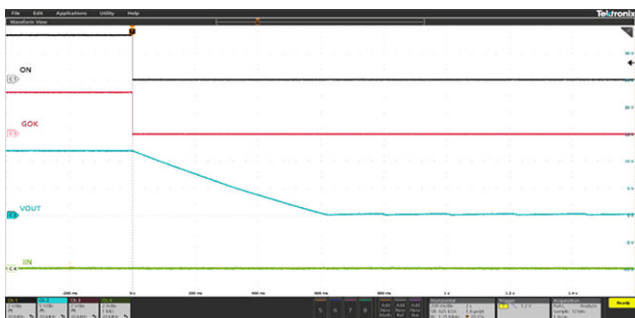


Fig. 12 - Power Down With ON/PD Control (COUT = 2 x 220  $\mu\text{F}$ ), Time: 10 ms/Div.

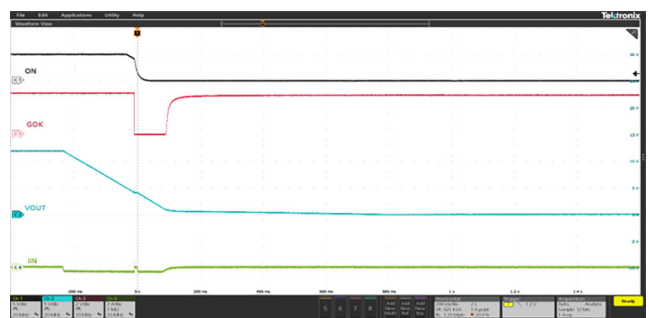
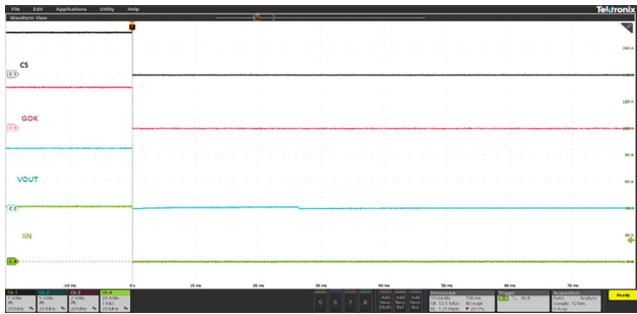


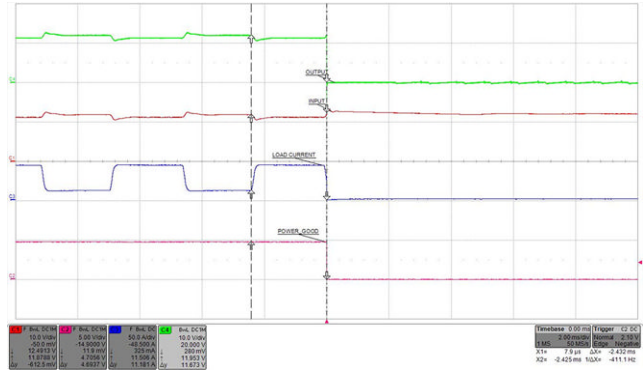
Fig. 15 - Power Down With  $V_{IN}$  (COUT = 10 mF), Time: 2 ms/Div



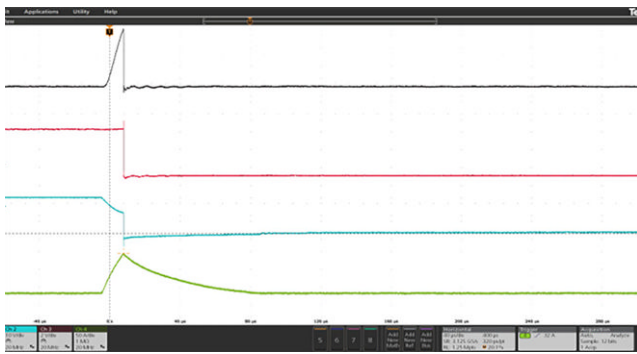
**TYPICAL CHARACTERISTICS** (Test conditions:  $V_{IN} = 12\text{ V}$ ,  $C_{SS} = 220\text{ nF}$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{CLREF} = 120\text{ k}\Omega$ ,  $R_{CS} = 2\text{ k}\Omega$ ,  $R_{IMON} = 2\text{ k}\Omega$ ,  $T_A = 25\text{ }^\circ\text{C}$ , unless otherwise specified)



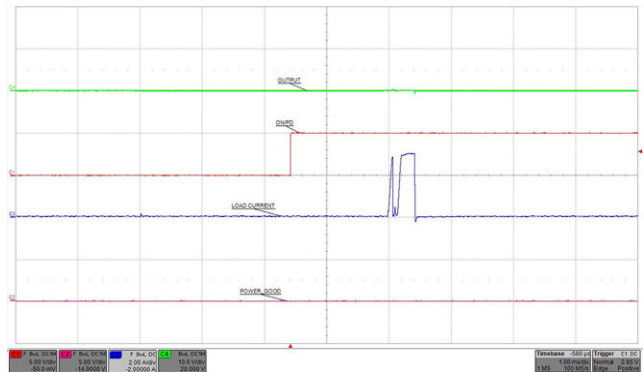
**Fig. 16 - Slow OCP During Normal Operation**  
( $C_{OUT} = 2 \times 220\text{ }\mu\text{F}$ ), Time: 10 ms/Div.



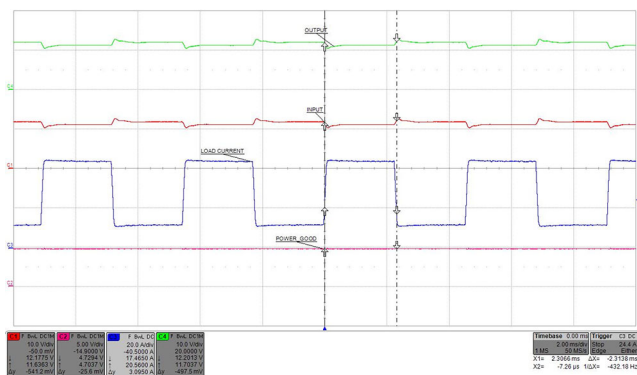
**Fig. 19 - Over Current Protection Switch Off after 2.3 ms**  
Blanking During Normal Operation, Time: 2.432 ms



**Fig. 17 - Output Short During Normal Operation**  
( $C_{OUT} = 2 \times 220\text{ }\mu\text{F}$ ), Time: 40  $\mu\text{s}$ /Div.



**Fig. 20 - Start Up by ON/PD with VOUT Short**  
( $I_{OUT}$  measured before  $C_{OUT}$ ), Time: 1 ms/Div.



**Fig. 18 - 2.3 ms Over Current Blanking During Normal**  
Operation, Time: 2 ms/Div.

## DETAILED OPERATIONAL DESCRIPTION

The SiC32305 and SiC32306 integrates a 30 A high-side MOSFET with  $R_{DS(on)}$  of 1.2 m $\Omega$ , which is suited for hot-swap applications.

The SiC32305 and SiC32306 limits the inrush current to the load when its circuit card is inserted into a live backplane power source, thereby limiting the backplane's voltage drop. It provides an integrated solution for monitoring the output current and the die temperature, eliminating the need for an external current-sensing power resistor, power MOSFET, and thermal sensing device. Also, it provides monitored current and temperature information feedback to the processor or controller. The SiC32305 and SiC32306 limits the internal MOSFET current by controlling the gate voltage through the current limit reference (internal VCLREF) and soft start ramp.

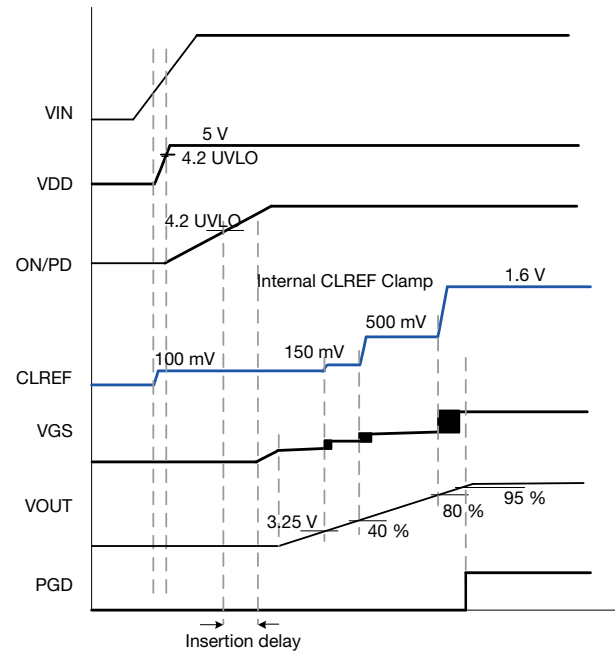
### Power-Up Sequence

For hot-swap applications, the input of the SiC32305 and SiC32306 can experience a voltage spike or transient during the hot-plug procedure. This is caused by the parasitic inductance of the input trace and the input capacitor. A fixed 1 ms insertion delay stabilizes the input voltage.

If the SiC32305 and SiC32306 is controlled by a front-end hot-swap controller, there will be a time-on delay before ON / PD can turn on the power FET.

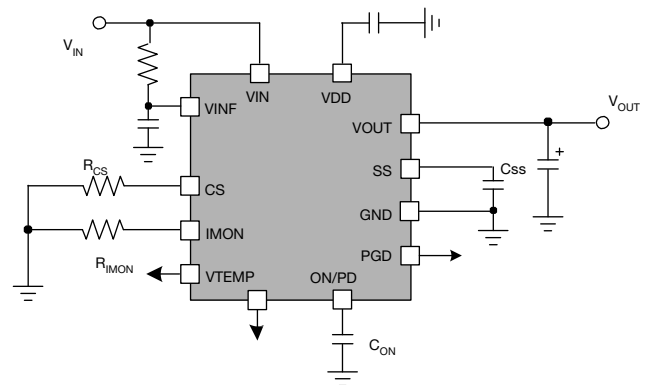
As shown in Fig. 25, the input voltage rises immediately. The power FET GATE voltage should always be pulled low during the  $V_{IN}$  plug-in with high  $dV/dt$ . The internal LDO output  $V_{DD}$  ramps up along with the input voltage. If the SiC32305 and SiC32306 co-operates with the hot-swap controller, the  $V_{DD}$  output can be used to power up the hot-swap controller.

The power FET remains off until the ON / PD signal is pulled high. When the ON / PD signal becomes high and the 1 ms insertion delay time ends, the power FET is charged up by the internal 12  $\mu$ A charge pump under the supervision of the soft-start control loop and the CLREF current limiting loop, which itself is a function of the  $V_{OUT}/V_{IN}$  voltage ratio, or alternately, the DAC output of a controller.



**Fig. 21 - Start-Up Sequences Between SiC32305/6 and Front-End Controller**

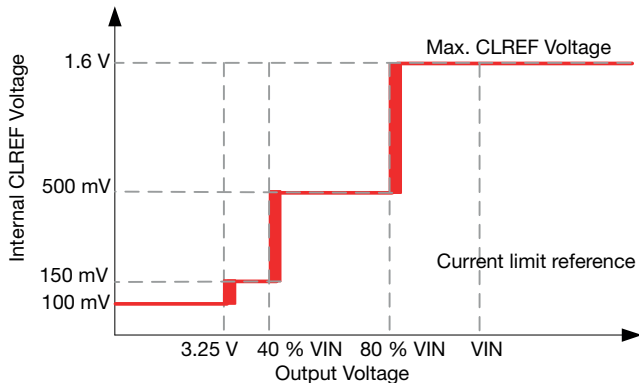
If the SiC32305/6 work as stand-alone devices (see Fig. 26), an external capacitor  $C_{ON}$  can be connected from ON / PD to ground for an automatic start-up. The internal 4.2  $\mu$ A current source charges the capacitor when  $V_{DD}$  is higher than UVLO. Also, ON / PD can be pulled up externally to the  $V_{DD}$  voltage. An internal current limit reference voltage (VCLREF) determines the current limit level.



**Fig. 22 - Standalone Operating Schematic**

### Current Limit at Start-Up

The SiC32305 and SiC32306 load current is limited by the VCLREF. The CS voltage is compared with the CLREF voltage through an OTA amplifier to regulate the power FET gate. This prevents the switch current from exceeding the CLREF defined current limit. The CLREF voltage is set per  $V_{OUT} / V_{IN}$  ratio during start-up to lower the current clamping level therefore lower power dissipation. Once  $V_{OUT}$  is ramped close to  $V_{IN}$ , the VCLREF can be raised to the full current limit, the power FET gate is fully enhanced, and the system is ready to draw power from the input.



**Fig. 23 - Internal Current Limit Reference Voltage (VCLREF) vs.  $V_{OUT}$**

As shown in Fig. 27, in order to protect the device from overheating during start-up, a maximum current limit is included during start-up. When  $V_{OUT}$  is less 3.25 V, the internal VCLREF is clamped at 100 mV. When  $V_{OUT}$  is between 3.25 V and 40 % of  $V_{IN}$ , the VCLREF is clamped at 150 mV. When  $V_{OUT}$  is between 40 % and 80 % of  $V_{IN}$ , CLREF is clamped at 500 mV. When  $V_{OUT}$  is > 80 %  $V_{IN}$ , CLREF is clamped to 1.6 V.

The desired start-up current limit is a function of the CS resistor  $R_{CS}$ . The CLREF voltage is calculated with equation (1):

$$I_{LIMIT\_SS} = \frac{V_{CLREF\_SS}}{CS_{gain} \times R_{CS}} \quad (1)$$

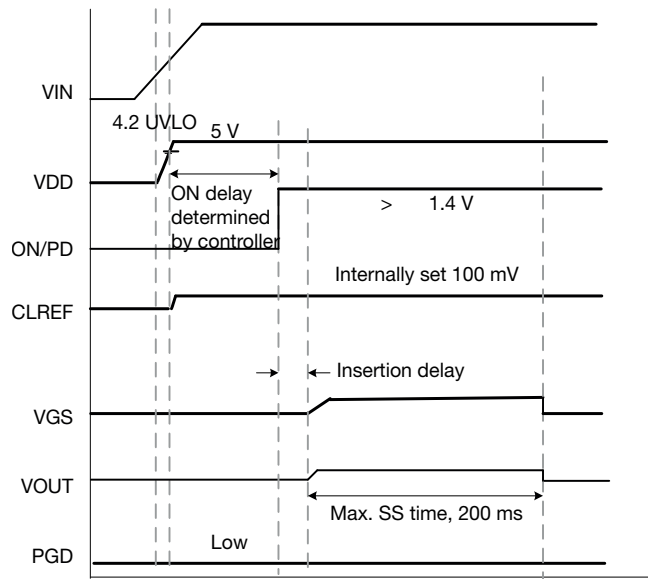
Where  $V_{CLREF\_SS}$  is the internal reference voltage at start-up. Then the  $V_{OUT}$  power-up ramp time can be approximately estimated with equation (2):

$$t_{RAMP} = \frac{V_{IN}}{I_{LOAD}} \times C_{OUT} \quad (2)$$

The  $V_{OUT}$  ramp time varies with the load condition and the output capacitor ( $C_{OUT}$ ) while adopting the VCLREF current limit during start-up. Please refer to design calculator for circuit setting.

A capacitor connected to SS determines the soft-start time. When ON / PD is pulled high, a constant-current source ramps up the voltage on SS. The output voltage rises at approximately ten times the SS slew rate. The SS capacitor can be set larger to increase the soft-start time.

During start-up, if the CS voltage reaches VCLREF, the power FET gate-to-source voltage is regulated to hold the FET current constant. If the over current clamp condition lasts for 250us, the switch is turned off. If the power FET remains on while the  $V_{OUT}$  remains lower than 90 %  $V_{IN}$  within the 200 ms maximum soft-start time, the power FET is shut down when the 200 ms time ends (see Fig. 28).



**Fig. 24 - Start-Up at Fault**

**Normal Operation**

When the output voltage has ramped up higher than 80 %  $V_{IN}$ , the  $V_{CLREF}$  voltage will be allowed to operate at full value, 1.6 V.

Once  $V_{OUT}$  has completed ramping, the charge pump will drive  $V_{GS}$  of the power FET to a fully enhanced phase. Fault supervision circuits will continue to monitor the need for corrective action.

**Current Limit at Normal Operation**

During normal operation, if the CS voltage exceeds  $V_{CLREF}$  voltage for more than 2.3 ms, the switch will be turned off, and the PGD flag will latch. During this 2.3 ms window, the  $V_{GS}$  of the power FET remains fully enhanced unless short circuit or over-temperature fault is detected. No current limiting occurs during this 2.3 ms interval. If the PGD pin latches, the power supply or ON / PD of SiC32305 will require cycling to clear the latch.

The desired OCP threshold at normal operation is a function of the CS resistor ( $R_{CS}$ ). The threshold should be higher than the normal maximum load current, allowing the tolerances in the current sense value. The current limit can be set using equation (5):

$$I_{LIMIT} = \frac{V_{CLREF}}{CS_{gain} \times R_{CS}}$$

Where  $V_{CLREF}$  is the voltage of CLREF in normal operation, which is 1.6 V.

$CS_{gain}$  is 20  $\mu A/A$ . For example, for  $V_{CLREF} = 1.6 V$ ,  $R_{CS} = 2.7 k\Omega$ ; the desired current limit is 30 A at normal operation.

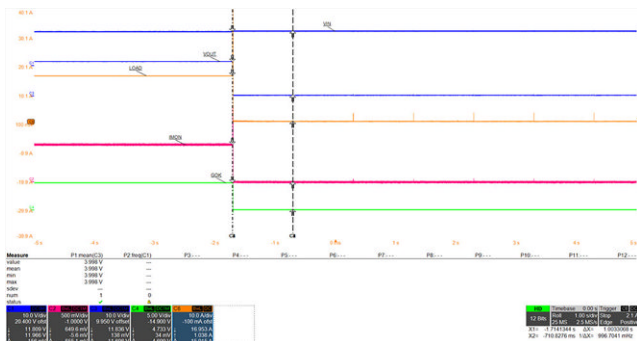
**Short-Circuit Protection**

Regardless of the programmed OCP setting level, if a current greater than 100 A is observed, the power FET  $V_{GS}$  is forced to turn off rapidly (typically within 200 ns) and the PGD fault will be latched.

SiC32305 will be latched off where as SiC32306 Auto retry 1s after fault is removed.

**Auto-Retry Restart (SiC32306):**

During short-circuit, overcurrent, or overtemperature faults, the FET turns off and auto-retries to restart after a 1-second delay.



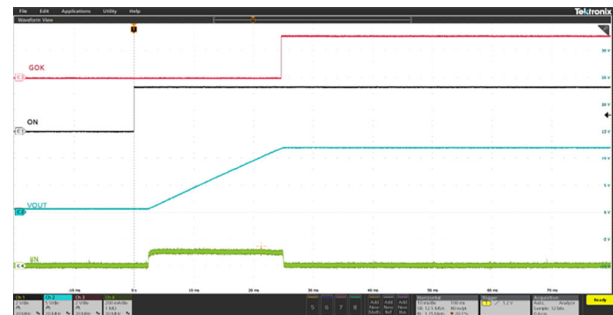
**Fig. 25 - SiC32306 Auto Retry after 1 s during short circuit at the outputs**

**ON / PD Control**

ON / PD is used to control both the on/off of the internal power FET and the pull-down mode of the output voltage. When ON / PD is used for power FET on / off control, the FET is turned on if the ON / PD voltage is higher than 1.4 V. If the ON / PD voltage is lower than 1.2 V, the FET is turned off. If ON / PD is used for  $V_{OUT}$  pull-down mode, the ON / PD voltage should be driven to approximately 1.1 V for more than 80  $\mu s$ . The device recognizes  $0.8 V < ON / PD < 1.2 V$  as a special state that requires pulling down  $V_{OUT}$ .

The ON / PD has a fixed 1 ms insertion delay after  $V_{DD}$  and  $V_{IN}$  have passed the UVLO threshold. All fault functionality is operative during the insertion delay, a fault is detected, PGD will remain low and device won't start up. If a non-latching fault self-clears, then a 1 ms timer will begin once the ON\_PD pin is above 1.4 V. When  $V_{IN}$  is below the UVLO threshold an internal 1 M $\Omega$  pull down resistor will attempt to discharge the ON\_PD pin. Once  $V_{IN}$  UVLO is cleared, the pull down resistor is disabled and the 4.2  $\mu A$  charge current is enabled.

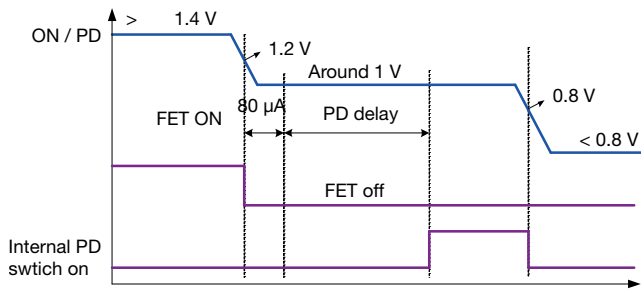
Once the ON / PD voltage is pulled higher than 1.4 V, and the 1 ms insertion delay ends, the internal charge pump charges the power FET's GATE. Once the GATE voltage reaches its threshold ( $V_{GSTH}$ ), the power FET turns on (Fig. 29). The output voltage rises following the soft-start control loop retarding the Gate voltage until  $V_{OUT}$  is sufficiently charged. This limits the power FET in-rush current.



**Fig. 26 - Power FET On / Off Control by ON / PD When no Fault Occurs**

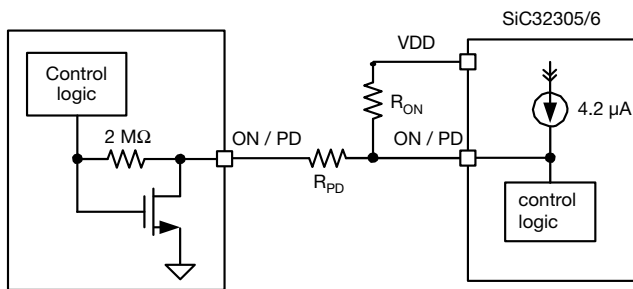
If the SiC32305 works in stand-alone mode, a capacitor on ON / PD can be used for automatic start-up by the internal 4.2  $\mu A$  pull-up current source. Once the ON / PD voltage reaches its turn-on threshold, the power FET Gate is charged by the internal charge pump.

When the ON / PD voltage is set to around 1.1 V for more than 80  $\mu s$ , devices enter in pull-down mode (see Fig. 31). In pull-down mode, an integrated 625  $\Omega$  pull-down resistor discharges the output after a fixed delay time (2 ms). If the ON / PD signal is pulled low directly, the pull-down mode is disabled, and the switch output voltage discharges through the external load.



**Fig. 27 - PD Mode Control by ON / PD**

The connection of ON / PD shown in Fig. 31. controls ON / PD through a resistor divider from the controller. For example, choose  $R_{ON} = 100\text{ k}\Omega$ . If ON / PD is only used for the power FET on / off control, the resistor  $R_{PD}$  can be set to  $0\ \Omega$ . Pull-down mode can be set by selecting a  $22\text{ k}\Omega$   $R_{PD}$  resistor. ON / PD is set to around 1 V by the external resistor divider and the ON / PD internal 4.2  $\mu\text{A}$  current source.



**Fig. 28 - ON / PD Connection**

**PGD Report**

PGD is an open-drain, active-low signal which reports the eFuse status. When a fault occurs, or  $V_{OUT}$  is below  $V_{TH\_PGD}$ , PGD is pulled low.

Pull up PGD to the  $V_{DD}$  voltage through a  $100\text{ k}\Omega$  resistor. During the  $V_{DD}$  power-up, the PGD output is driven low. Before the power FET is turned on, the PGD fault state is checked during the ON / PD 1 ms insertion delay. All fault functionality is operative during the insertion delay time.

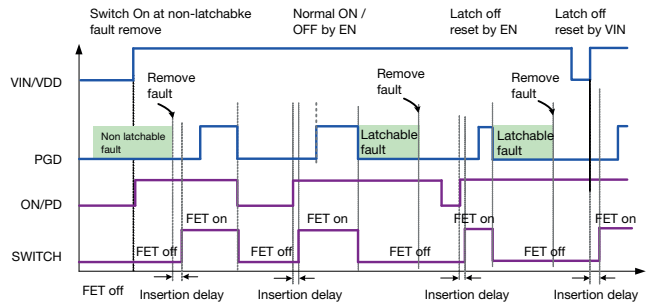
PGD flags the following fault events:

1. Over-current protection: when the CS voltage exceeds the CLREF threshold during normal operation, the PGD is pulled low and latches after a 2.3 ms moderate over-current blanking time
2. Short-circuit protection: when the load current reaches 100 A, short circuit current threshold rapidly, PGD is pulled low immediately and latches
3. The integrated power FET D-S, G-D, and G-S short detection: detailed performance characteristics can be reviewed in the “Damaged Integrated Power FET Detection” section. Although these faults cause PGD either to pull low immediately, or stays low, the PGD pin does not latch unless the 200 ms soft start timer expires.

4. Over-temperature protection at junction temperature  $T_J > 142\text{ }^\circ\text{C}$ : once a fault is detected PGD is pulled low and latches. Over-temperature protection hysteresis is  $20\text{ }^\circ\text{C}$ .

The release of the fault latch can be accomplished by recycling  $V_{IN}$  or by toggling ON / PD.

Fig. 32 shows the FET on / off control with the PGD timing diagram.



**Fig. 29 - FET On / Off Control With PGD Timing Diagram**

**Damaged Integrated Power FET Detection**

Damaged integrated power FET detection includes FET drain-source shorts, gate-drain shorts, and gate-source shorts.

1. D-S short detection during start-up

Once the  $V_{DD}$  is higher than the UVLO rising threshold, the controller detects a shorted pass FET during power-up by treating an output voltage that exceeds  $70\% \times V_{IN}$  during power up as a short on the MOSFET. Once the short is removed and the controller detects  $V_{OUT} < 70\% \times V_{IN}$ , and the hot-swap controller prepares for normal start-up.

2. G-D short detection during start-up

The G-D short is detected by monitoring the G-S voltage. During power-up, the controller detects the power FET G-D short by the condition of power FET drain-to-gate voltage ( $V_{GS} > 2\text{ V}$ ). The fault is removed, and the controller detects  $V_{GS} < 2\text{ V}$ .

3. G-S, G-D short detection during normal operation

When the part operates normally and  $V_{OUT}$  remains higher than  $90\%$  of  $V_{IN}$ , the controller determines the power FET G-S or G-D short by the  $V_{CP} - V_{GATE}$  voltage, where  $V_{CP}$  is the internal charge pump voltage. If  $V_{CP} - V_{GATE}$  voltage falls belows threshold, the switch is off and PGD pulls low. The fault latch can be cleared by recycling  $V_{IN}$  or by toggling ON / PD.



The power FET short faults are listed in Table 1

TABLE 1 - THE POWER FET SHORT FAULTS			
FET FAULT		DETECTION CONDITION	PGD FLAG
Start-up FET short	D - S	$V_{OUT} > 70 \% \times V_{IN}$	Keep low until $V_{OUT} < 70 \% \times V_{IN}$
	G - D	$V_{GS} > 2 \text{ V}$	Keep low until $V_{GS} < 2 \text{ V}$
Normal operation FET short	G - D / G - S	$(V_{CP} - V_{GATE}) > 2 \text{ V}$ after 200 ms	Pull low

### Input and Output Transient Protection

The hot-swap system experiences positive transients on the input during a hot plug or rapid turn-off with high current due to parasitic inductance in the input circuit.

For input transient protection, a TVS diode (transient voltage suppressor, a type of Zener diode) may be required on the input to limit transient voltages below the absolute maximum ratings.

The output may experience negative transients during rapid turn-off with high current due to inductance in the output circuit. The lowest voltage allowed on the device output is  $-0.3 V_{DC}$  and  $-1 \text{ V}$  for  $500 \mu\text{s}$  transient pulse. If a transient makes OUT more negative, the internal ESD Zener diode attached to the pin will become forward biased, and the current will be conducted across the substrate to the ground. The internal ESD diode may not be strong enough to sustain a large current, and the current may disrupt normal operation or, if large enough, damage the part.

An output voltage clamp diode may be required on the output to limit negative transients. Select a Schottky diode with a low forward voltage at the anticipated current during an output short. By doing this, the negative voltage spike at the output terminal can be clamped at less than  $-0.7 \text{ V}$ , thus the IC is protected during a short output.

### Current Sense (CS Output)

CS provides a current proportional to the output current (the current through the power device). The gain of the current sense is  $20 \mu\text{A/A}$ .

There is a resistor ( $R_{CS}$ ) connected from CS to form an external voltage. Use equation (6) and equation (7) to determine a proper reference voltage:

$$I_{CS} = I_{OUT} \times 20 \mu\text{A/A} \quad (6)$$

$$V_{CS} = I_{CS} \times R_{CS} \quad (7)$$

### Current Monitor ( $I_{MON}$ Output)

The gain of the current monitor is  $20 \mu\text{A/A}$ . There is a resistor ( $R_{IMON}$ ), connected from  $I_{MON}$  to ground. The  $I_{MON}$  voltage range of  $0 \text{ V}$  to  $1.6 \text{ V}$  is required to keep  $I_{MON}$ 's output current linearly proportional to the output current use equation (8) and equation (9) to determine a proper reference voltage:

$$I_{MON} = I_{OUT} \times 20 \mu\text{A/A} \quad (8)$$

$$V_{IMON} = I_{MON} \times R_{IMON} \quad (9)$$

The current monitor output can be used by the controller to accurately monitor the output current. Place a  $100 \text{ nF}$  capacitor from  $I_{MON}$  to GND to smooth the indicator voltage.

Generally, connect a  $2 \text{ k}\Omega$  resistor ( $R_{IMON}$ ) to ground to set the gain of the output, which is about  $20 \text{ mV}$  per ampere. For best accuracy, use resistors within 1 percent.

### Temperature Sense Output, $V_{TEMP}$

$V_{TEMP}$  reports the junction temperature. It is a voltage output proportional to the junction temperature. The  $V_{TEMP}$  output voltage is  $10 \text{ mV}/^\circ\text{C}$  with a  $200 \text{ mV}$  offset. See equation (10):

$$V_{TEMP} = T_{JUNCTION} \times 10 \text{ mV}/^\circ\text{C} + 200 \text{ mV} \quad (10)$$

For example, if the junction temperature is  $100^\circ\text{C}$ , the  $V_{TEMP}$  voltage is  $1.2 \text{ V}$ . If  $V_{TEMP} = 0 \text{ V}$ , the junction temperature is about  $-20^\circ\text{C}$ . The total temperature sense range is  $-20^\circ\text{C}$  to  $+140^\circ\text{C}$ . When the junction temperature is below  $-20^\circ\text{C}$ ,  $V_{TEMP}$  remains at  $0 \text{ V}$ .

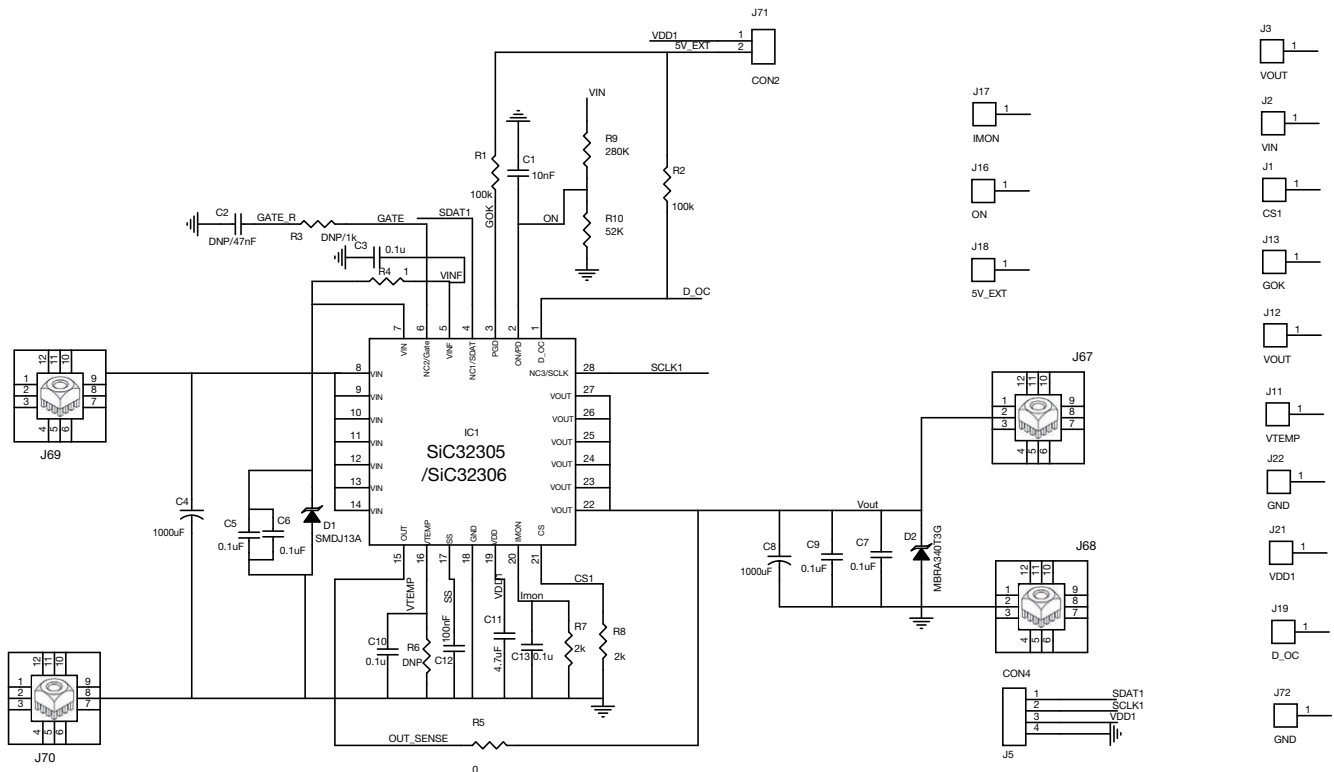
### Thermal Protection

The device temperature is sensed by monitoring the junction temperature of the IC. The temperature information can be read from  $V_{TEMP}$ .

The device itself has thermal protection. When the junction temperature exceeds the threshold ( $142^\circ\text{C}$ ), the power FET is turned off, and PGD is pulled low.

### UVLO Protection

The device has a under-voltage lockout protection feature on  $V_{DD}$  exceeds the UVLO threshold. The devices can start up only when  $V_{DD}$  exceeds the UVLO threshold. The UVLO protection is non-latching fault.

**APPLICATION SCHEMATICS**

**Fig. 30 - SiC32305, SiC3206 Proposed Circuit**

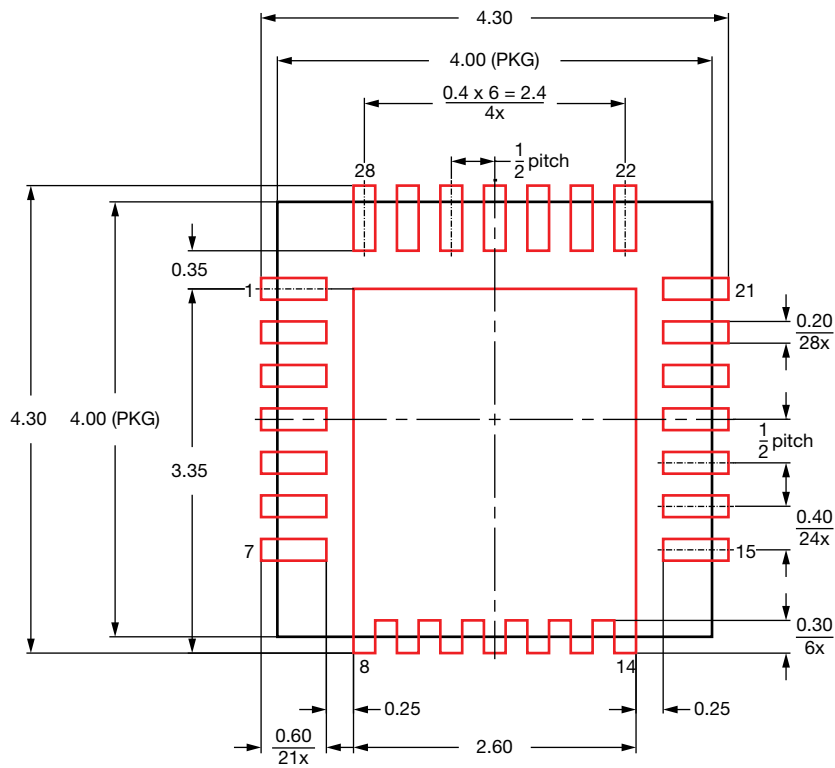
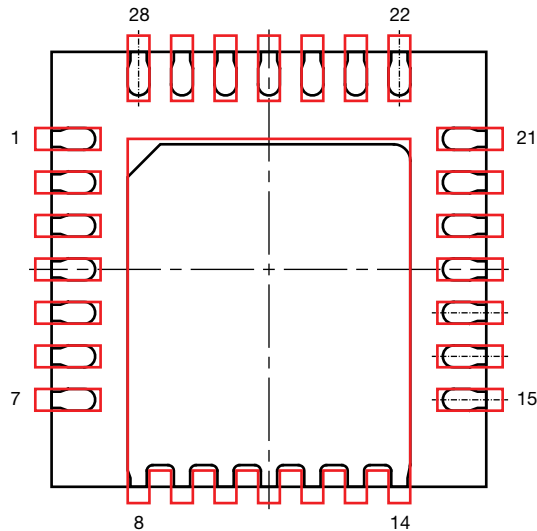
The ON pin can interface with micro-processor for on / off and discharge control. Toggling the ON pin will reset the fuse latch. The ON / PD can also be connected to a voltage divider from  $V_{IN}$  to set circuit UVLO level.



<b>PRODUCT SUMMARY</b>		
Part number	SiC32305	SiC32306
Description	1.2 mΩ, hot-swap eFuse, I <sub>MON</sub> , PGD report latch on fault	1.2 mΩ, hot-swap eFuse, I <sub>MON</sub> , PGD report auto-retry, 1 s after fault is removed
Configuration	Stand alone	Stand alone
Slew rate time (μs)	Adjustable	Adjustable
On delay time (μs)	1000	1000
Input voltage min. (V)	4.5	4.5
Input voltage max. (V)	25	25
On-resistance at input voltage min. (mΩ)	1.2	1.2
On-resistance at input voltage max. (mΩ)	1.2	1.2
Quiescent current at input voltage min. (μA)	2100	2100
Quiescent current at input voltage max. (μA)	2800	2800
Output discharge (yes / no)	Yes	Yes
Reverse blocking (yes / no)	No	No
Continuous current (A)	30	30
Package type	PowerPAK MLP28S-44	PowerPAK MLP28S-44
Package size (W, L, H) (mm)	4 x 4 x 1	4 x 4 x 1
Status code	-	-
Product type	Hot swap, eFuse, slew rate, current report	Hot swap, eFuse, slew rate, current report
Applications	Computers, telecom, industrial	Computers, telecom, industrial

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## Recommended Land Pattern MLP28S-44C MLP



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 DWG: 3036



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