TPS25927x 4.5-V to 18-V eFuse with Blocking FET Control

1 Features

- 4.5-V to 18-V Protection
- Integrated 28-mΩ Pass MOSFET
- Absolute Maximum Voltage of 20 V
- 1-A to 5-A Adjustable I_{LIMIT}
- ±8% I_{LIMIT} Accuracy at 3.7A
- Reverse Current Blocking Support
- Programmable OUT Slew Rate, UVLO
- Built-in Thermal Shutdown
- UL 2367 Recognition Pending
- Safe During Single Point Failure Test (UL60950)
- Small Foot Print – 10L (3 mm x 3 mm) VSON

2 Applications

- HDD and SSD Drives
- Set Top Boxes
- Servers / AUX Supplies
- Fan Control
- PCI/PCIe Cards
- Adapter Powered Devices

3 Description

The TPS25927x family of eFuses is a highly integrated circuit protection and power management solution in a tiny package. The devices use few external components and provide multiple protection modes. They are a robust defense against overloads, shorts circuits, excessive inrush current, and reverse current.

Current limit level can be set with a single external resistor. Applications with particular voltage ramp requirements can set dV/dT pin with a single capacitor to ensure proper output ramp rates.

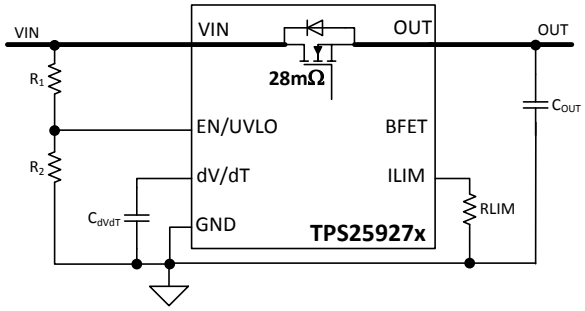
Many systems, such as SSDs, must not allow holdup capacitance energy to dump back through the FET body diode onto a drooping or shorted input bus. The BFET pin is for such systems. An external NFET can be connected “Back to Back (B2B)” with the TPS25927x output and the gate driven by BFET to prevent current flow from load to source.

Device Information[1]

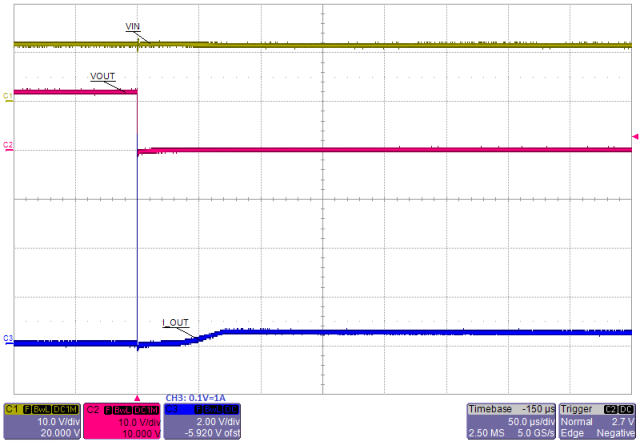
PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS259270	VSON (10)	3.00 mm × 3.00 mm
TPS259271		

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Application Schematic



Transient: Output Short Circuit



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Revision History

Changes from Original (August 2015) to Revision A **Page**

- Changed from Product Preview to Production Data ... 1

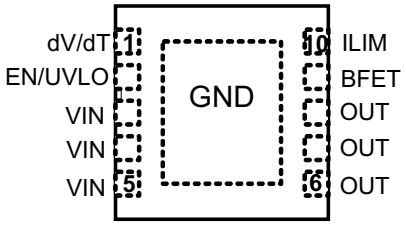
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5 Device Comparison Table

PART NUMBER	UV	OV CLAMP	FAULT RESPONSE	STATUS
TPS259271	4.3 V	—	Auto-retry	Active
TPS259270	4.3 V	—	Latched	Preview

6 Pin Configuration and Functions

DRC Package
10-Pin VSON
Top View



Pin Functions

PIN		DESCRIPTION
NAME	NUMBER	
BFET	9	Connect this pin to the gate of a blocking NFET. See the *Feature Description*. This pin can be left floating if it is not used.
dV/dT	1	Connect a capacitor from this pin to GND to control the ramp rate of OUT at device turn-on.
EN/UVLO	2	This is a dual function control pin. When used as an ENABLE pin and pulled down, it shuts off the internal pass MOSFET and pulls BFET to GND. When pulled high, it enables the device and BFET. As an UVLO pin, it can be used to program different UVLO trip point via external resistor divider.
GND	Thermal Pad	GND
ILIM	10	A resistor from this pin to GND will set the overload and short circuit limit.
OUT	6-8	Output of the device
VIN	3-5	Input supply voltage

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7 Specifications

7.1 Absolute Maximum Ratings

over operating temperature range (unless otherwise noted) (1) (2)

		MIN	MAX	UNIT
Supply voltage(1)	VIN	–0.3	20	V
	VIN (10 ms Transient)		22	
Output voltage	OUT	–0.3	VIN + 0.3	V
	OUT (Transient < 1 µs)		-1.2	V
Voltage	ILIM	–0.3	7	V
	EN/UVLO	–0.3	7	
	dV/dT	–0.3	7	
	BFET	–0.3	30	
Storage temperature range, T_{stg}		-65	150	°C

(1) 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 conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values, except differential voltages, are with respect to network ground terminal.

7.2 ESD Ratings

			MAX	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101(2)	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	TYP	MAX	UNIT
Input voltage	VIN	4.5		18(1)	V
	BFET	0		VIN + 6	
	dV/dT, EN/UVLO	0		6	
	ILIM	0		3	
Continuous output current	I_{OUT}	0		5	A
Resistance	ILIM	10	100	162	kΩ
External capacitance	OUT	0.1	1	1000	µF
	dV/dT		1	1000	nF
Operating junction temperature range, T_J		–40	25	125	°C
Operating Ambient temperature range, T_A		–40	25	85	°C

(1) Maximum voltage (including input transients) at VIN pin should not exceed absolute maximum rating as specified in *Absolute Maximum Ratings*.

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7.4 Thermal Information(1)

over operating free-air temperature range (unless otherwise noted)

THERMAL METRIC		TPS25927x DRC (VSON) 10 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	45.9	°C/W
$R_{\theta JCtop}$	Junction-to-case (top) thermal resistance	53	
$R_{\theta JB}$	Junction-to-board thermal resistance	21.2	
ψ_{JT}	Junction-to-top characterization parameter	1.2	
ψ_{JB}	Junction-to-board characterization parameter	21.4	
$R_{\theta JCbot}$	Junction-to-case (bottom) thermal resistance	5.9	

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

7.5 Electrical Characteristics

–40°C ≤ T_J ≤ 125°C, VIN = 12 V, $V_{EN\ /UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{dVdT} = OPEN. All voltages referenced to GND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
VIN (INPUT SUPPLY)						
V_{UVR}	UVLO threshold, rising		4.15	4.3	4.45	V
V_{UVhyst}	UVLO hysteresis(1)			5%		
IQ_{ON}	Supply current	Enabled: EN/UVLO = 2 V	0.3	0.42	0.55	mA
IQ_{OFF}		EN/UVLO = 0 V		0.13	0.225	mA
EN/UVLO (ENABLE/UVLO INPUT)						
V_{ENR}	EN Threshold voltage, rising		1.37	1.4	1.44	V
V_{ENF}	EN Threshold voltage, falling		1.32	1.35	1.39	V
I_{EN}	EN Input leakage current	0 V ≤ V_{EN} ≤ 5 V	–100	0	100	nA
dV/dT (OUTPUT RAMP CONTROL)						
I_{dVdT}	dV/dT Charging current(1)	V_{dVdT} = 0 V		220		nA
R_{dVdT_disch}	dV/dT Discharging resistance	EN/UVLO = 0 V, I_{dVdT} = 10 mA sinking	50	73	100	Ω
$V_{dVdTmax}$	dV/dT Max capacitor voltage(1)			5.5		V
$GAIN_{dVdT}$	dV/dT to OUT gain(1)	ΔV_{dVdT}		4.85		V/V
ILIM (CURRENT LIMIT PROGRAMMING)						
I_{ILIM}	ILIM Bias current(1)			10		µA
I_{OL}	Overload current limit(2)	R_{ILIM} = 10 kΩ, $V_{VIN-OUT}$ = 1 V		1.02		A
		R_{ILIM} = 45.3 kΩ, $V_{VIN-OUT}$ = 1 V	1.79	2.10	2.42	
		R_{ILIM} = 100 kΩ, $V_{VIN-OUT}$ = 1 V	3.46	3.75	4.03	
		R_{ILIM} = 150 kΩ, $V_{VIN-OUT}$ = 1 V	4.5	5.1	5.7	
$I_{OL-R-Short}$		R_{ILIM} = 0 Ω, Shorted Resistor Current Limit (Single Point Failure Test: UL60950)(1)		0.84		A
$I_{OL-R-Open}$		R_{ILIM} = OPEN, Open Resistor Current Limit (Single Point Failure Test: UL60950)(1)		0.73		A
I_{SCL}	Short-circuit current limit(2)	R_{ILIM} = 10 kΩ, $V_{VIN-OUT}$ = 12 V		1		A
		R_{ILIM} = 45.3 kΩ, $V_{VIN-OUT}$ = 12 V	1.66	1.98	2.37	
		R_{ILIM} = 100 kΩ, $V_{VIN-OUT}$ = 12 V	2.90	3.32	3.85	
		R_{ILIM} = 150 kΩ, $V_{VIN-OUT}$ = 12 V	3.7	4.5	5.5	
$RATIO_{FASTRIP}$	Fast-Trip comparator level w.r.t. overload current limit(1)	$I_{FASTRIP}$: I_{OL}		160%		
$V_{OpenILIM}$	ILIM Open resistor detect threshold(1)	V_{ILIM} Rising, R_{ILIM} = OPEN		3.1		V

(1) These parameters are provided for reference only and do not constitute part of TI's published device specifications for purposes of TI's product warranty.
(2) Pulsed testing techniques used during this test maintain junction temperature approximately equal to ambient temperature.

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Electrical Characteristics (continued)

–40°C ≤ T_J ≤ 125°C, VIN = 12 V, $V_{EN\ /UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{dVdT} = OPEN. All voltages referenced to GND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUT (PASS FET OUTPUT)						
$R_{DS(on)}$	FET ON resistance	T_J = 25°C	21	28	37	mΩ
		T_J = 125°C		39	48	
$I_{OUT-OFF-LKG}$	OUT Bias current in off state	$V_{EN/UVLO}$ = 0 V, V_{OUT} = 0 V (Sourcing)	–5	0	1.2	µA
$I_{OUT-OFF-SINK}$		$V_{EN/UVLO}$ = 0 V, V_{OUT} = 300 mV (Sinking)	10	15	20	
BFET (BLOCKING FET GATE DRIVER)						
I_{BFET}	BFET Charging current(1)	V_{BFET} = V_{OUT}		2		µA
$V_{BFETmax}$	BFET Clamp voltage(1)			V_{VIN} + 6.4		V
$R_{BFETdisch}$	BFET Discharging resistance to GND	$V_{EN/UVLO}$ = 0 V, I_{BFET} = 100 mA	15	26	36	Ω
TSD (THERMAL SHUT DOWN)						
T_{SHDN}	TSD Threshold, rising(1)			150		°C
$T_{SHDNhyst}$	TSD Hysteresis(1)			10		°C
	Thermal fault: latched or autoretry	TPS259270		LATCHED		
		TPS259271		AUTO-RETRY		

7.6 Timing Requirements

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T_{ON}	Turn-on delay(1)	EN/UVLO → H to I_{VIN} = 100 mA, 1-A resistive load at OUT		220		µs
t_{OFFdly}	Turn Off delay(1)	EN↓ to BFET↓, C_{BFET} = 0		0.4		µs
dV/dT (OUTPUT RAMP CONTROL)						
t_{dVdT}	Output ramp time	EN/UVLO → H to OUT = 11.7 V, C_{dVdT} = 0	0.7	1	1.3	ms
		EN/UVLO → H to OUT = 11.7 V, C_{dVdT} = 1 nF(1)		12		
ILIM (CURRENT LIMIT PROGRAMMING)						
$t_{FastOffDly}$	Fast-Trip comparator delay(1)	I_{OUT} > $I_{FASTRIP}$ to I_{OUT}= 0 (Switch Off)		300		ns
BFET (BLOCKING FET GATE DRIVER)						
$t_{BFET-ON}$	BFET Turn-On duration(1)	EN/UVLO → H to V_{BFET} = 12 V, C_{BFET} = 1 nF		4.2		ms
		EN/UVLO → H to VB_{FET} = 12 V, C_{BFET} = 10 nF		42		
$t_{BFET-OFF}$	BFET Turn-off duration(1)	EN/UVLO → L to $_{VBFET}$ = 1 V, C_{BFET} = 1 nF		0.4		µs
		EN/UVLO → L to V_{BFET} = 1 V, C_{BFET} = 10 nF		1.4		
Thermal Shutdown (TSD)						
t_{TSDdly}	Retry delay after TSD recovery, T_J < [T_{SHDN} - 10°C](1)	TPS259271 only		100		µs

(1) These parameters are provided for reference only and do not constitute part of TI's published device specifications for purposes of TI's product warranty.

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7.7 Typical Characteristics

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)

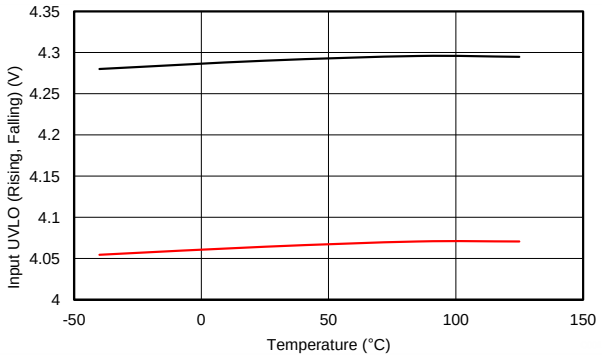


Figure 1. Input UVLO vs Temperature

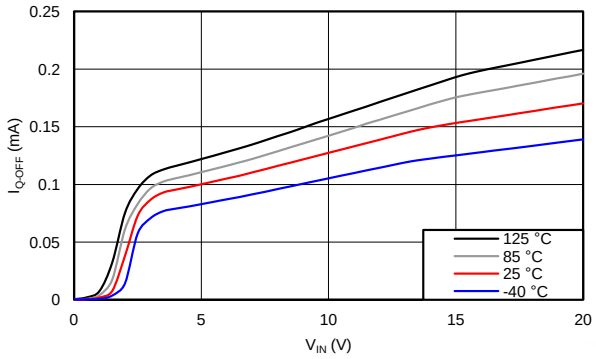


Figure 2. I_{Q-OFF} vs V_{IN}

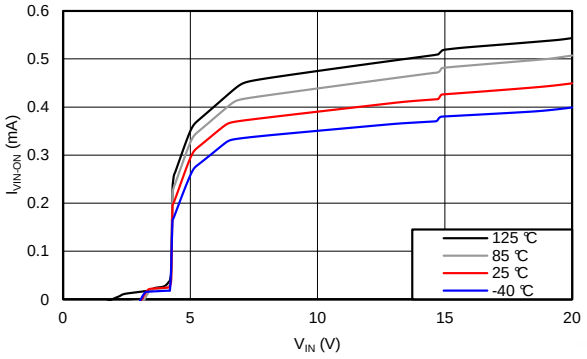


Figure 3. I_{VIN-ON} vs V_{IN}

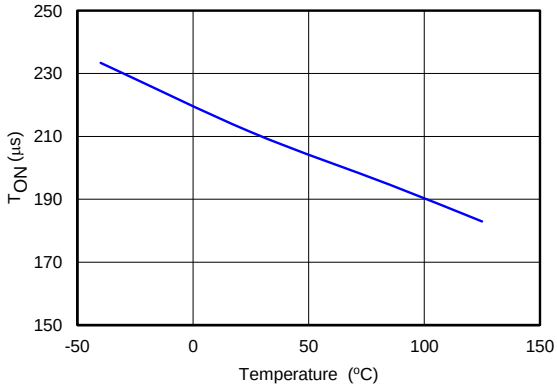


Figure 4. T_{ON} vs Temperature

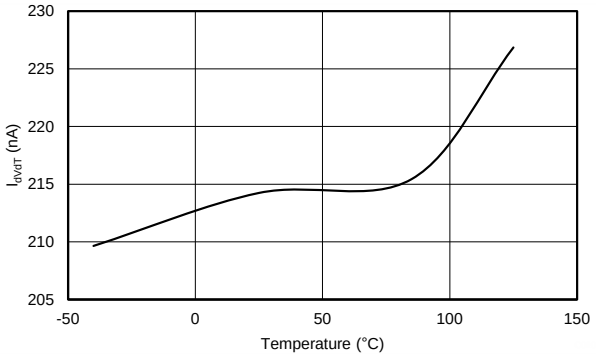


Figure 5. I_{dVdT} vs Temperature

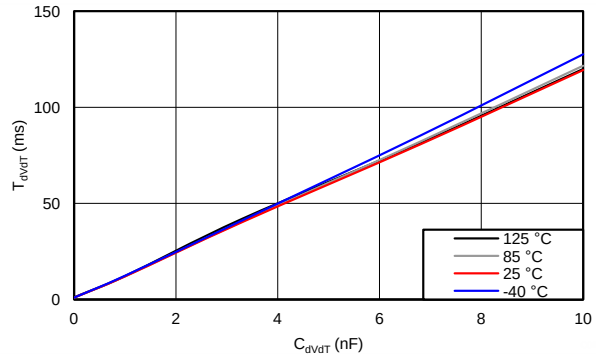


Figure 6. T_{dVdT} vs C_{dVdT}

Typical Characteristics (continued)

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)

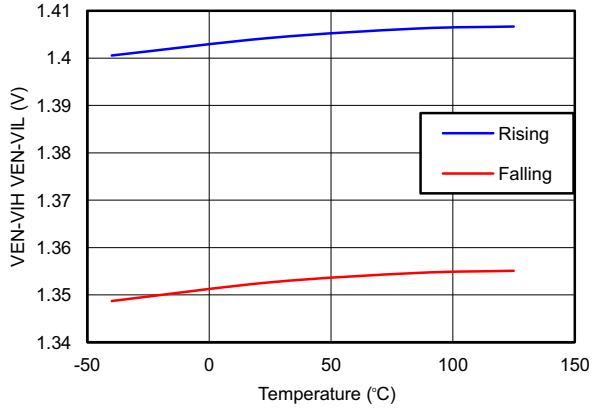


Figure 7. V_{EN-VIH}, V_{EN-VIL} vs Temperature

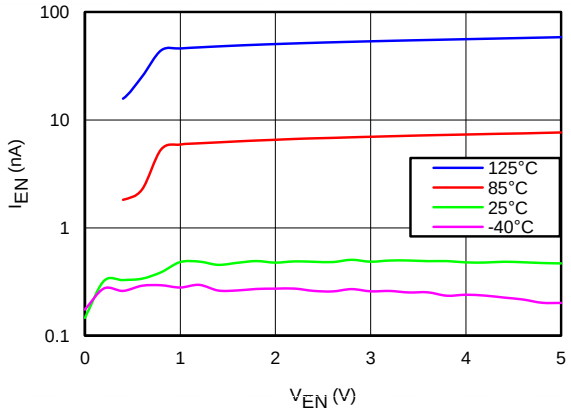


Figure 8. I_{EN} (Leakage Current) vs V_{EN}

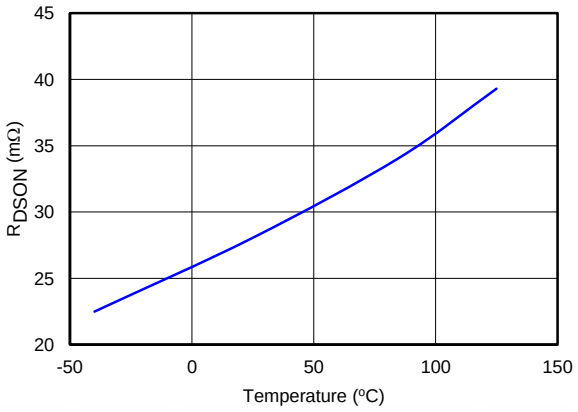
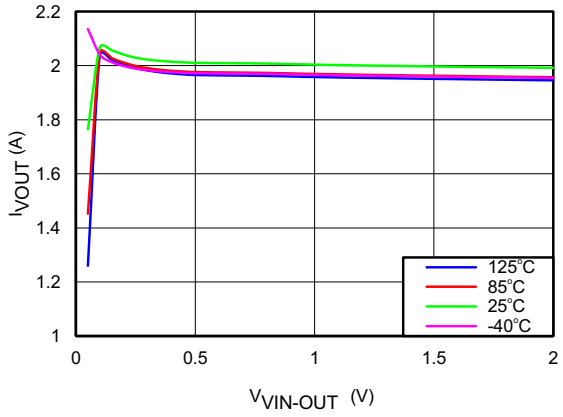
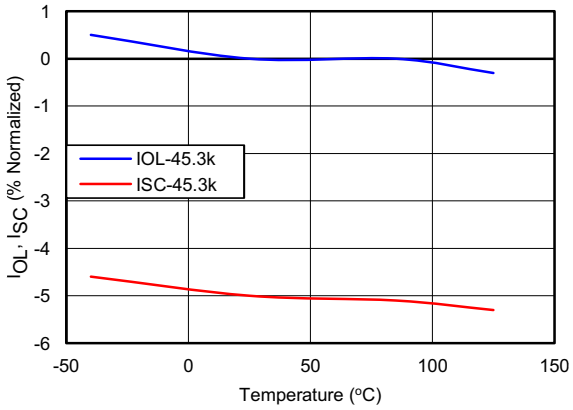


Figure 9. R_{DSON} vs Temperature



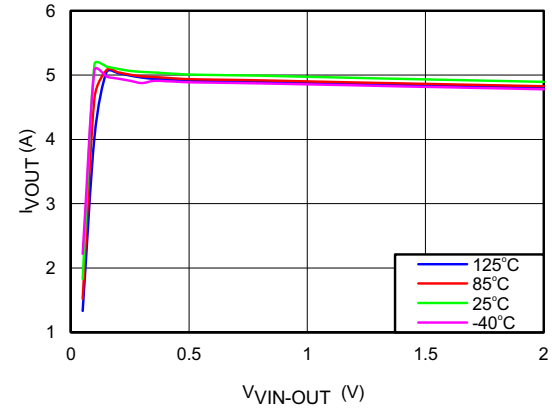
R_{ILIM} = 45.3 kΩ

Figure 10. I_{VOUT} vs $V_{VIN-OUT}$



R_{ILIM} = 45.3 kΩ

Figure 11. I_{OL}, I_{SC} vs Temperature



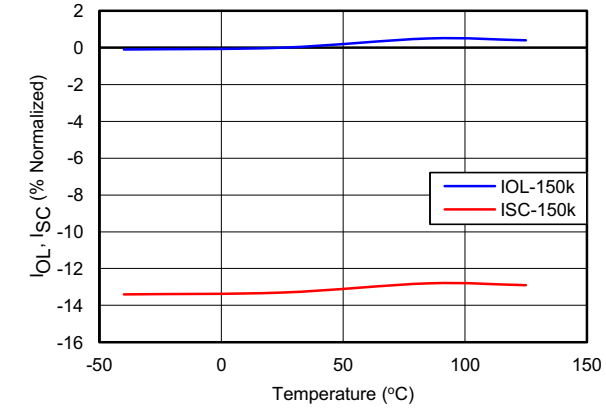
R_{ILIM} = 150 kΩ

Figure 12. I_{VOUT} vs $V_{VIN-OUT}$

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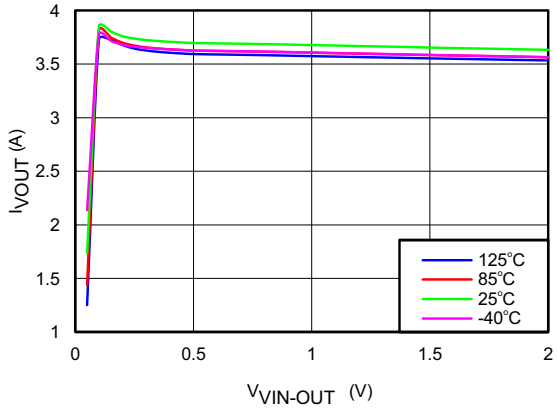
Typical Characteristics (continued)

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)



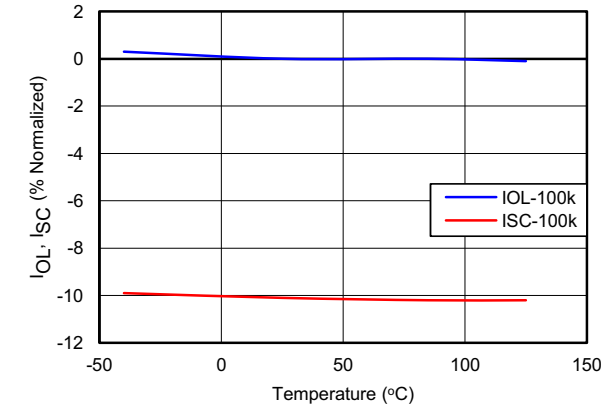
R_{ILIM} = 150 kΩ

Figure 13. I_{OL}, I_{SC} vs Temperature



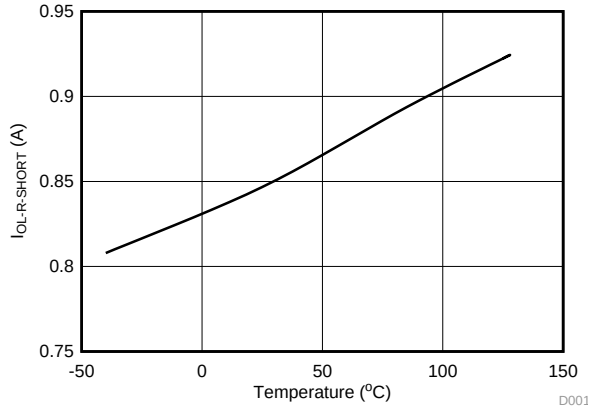
R_{ILIM} = 100 kΩ

Figure 14. I_{VOUT} vs $V_{VIN-OUT}$



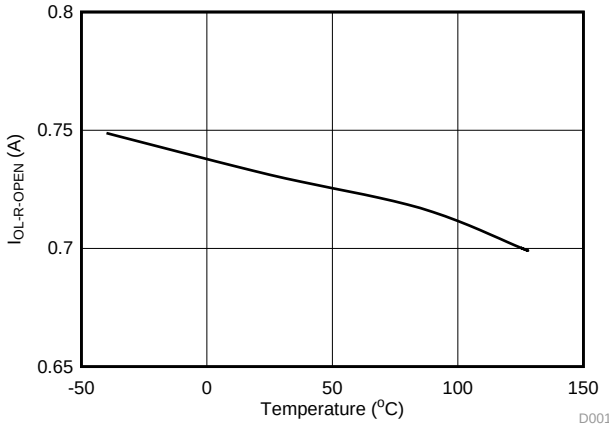
R_{ILIM} = 100 kΩ

Figure 15. I_{OL}, I_{SC} vs Temperature



R_{ILIM} = 0 Ω

Figure 16. $I_{OL-R-Short}$ vs Temperature



R_{ILIM} = OPEN

Figure 17. $I_{OL-R-Open}$ vs Temperature

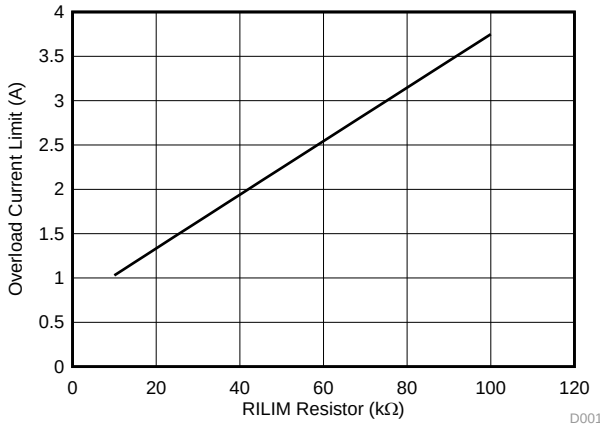


Figure 18. Overload Current Limit vs RILIM Resistor

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Typical Characteristics (continued)

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)

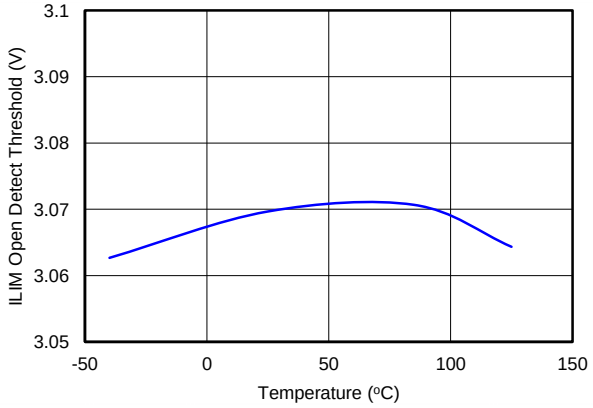


Figure 19. $V_{OpenILIM}$ vs Temperature

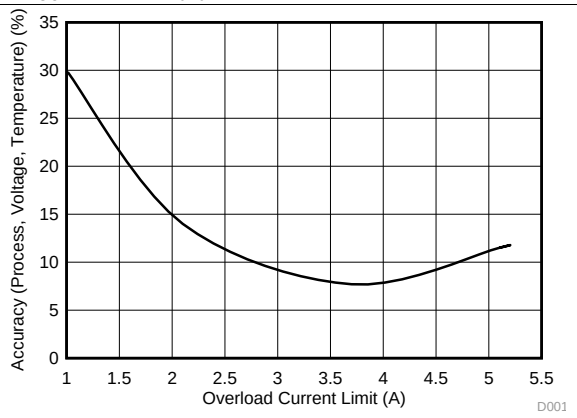


Figure 20. Accuracy vs Overload Current Limit

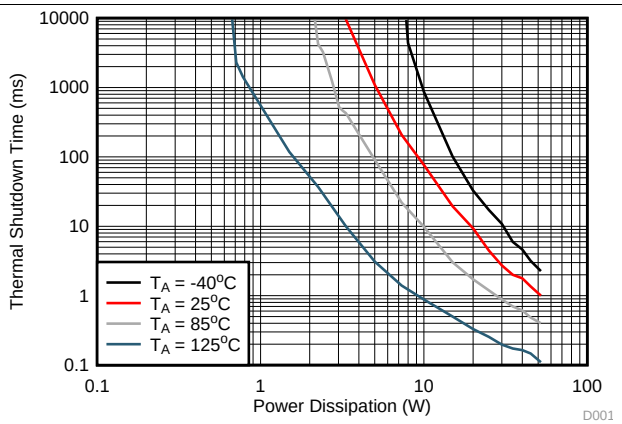
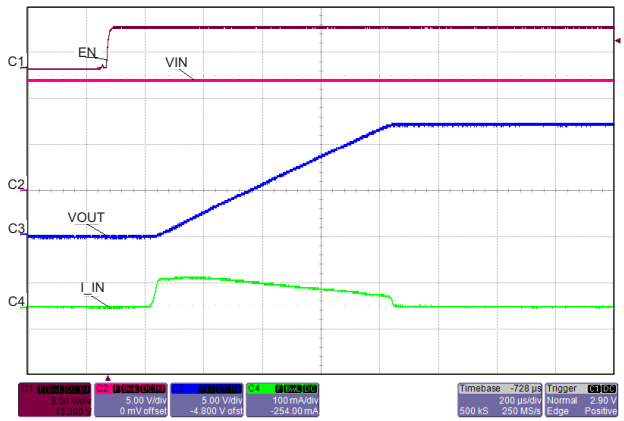
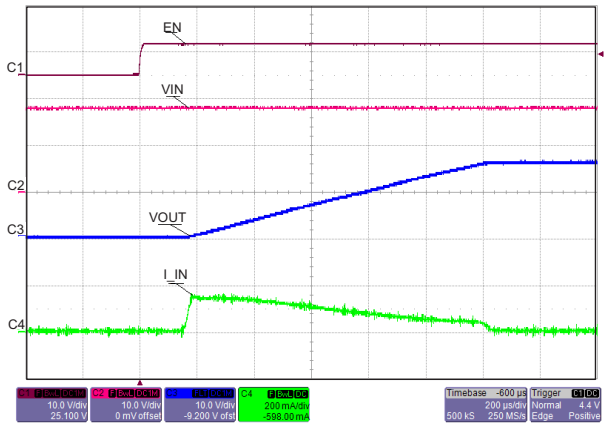


Figure 21. Thermal Shutdown Time vs Power Dissipation



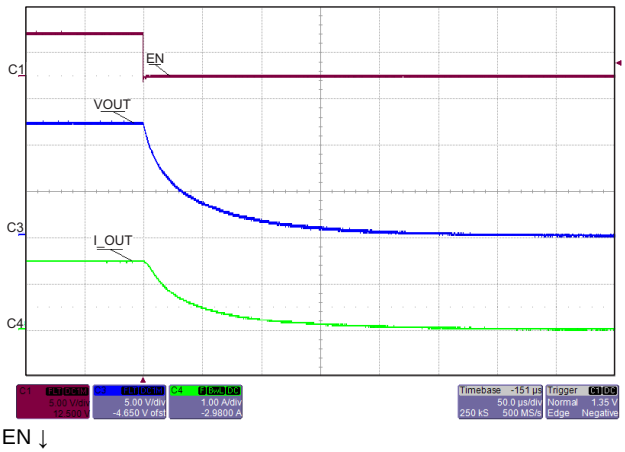
TPS25927x, C_{dVdT} = OPEN, C_{OUT} = 4.7 µF

Figure 22. Transient: Output Ramp



TPS25927x, VIN = 18 V, C_{dVdT} = OPEN, C_{OUT} = 10 µF

Figure 23. Transient: Output Ramp



EN ↓

Figure 24. Transient: Turn Off Delay

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Typical Characteristics (continued)

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)

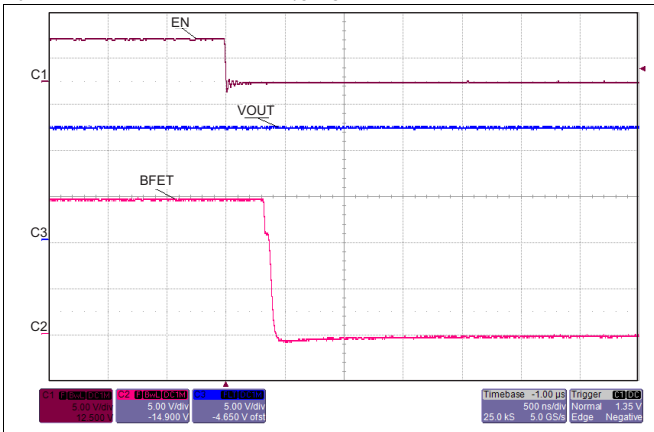


Figure 25. Turn Off Delay to BFET

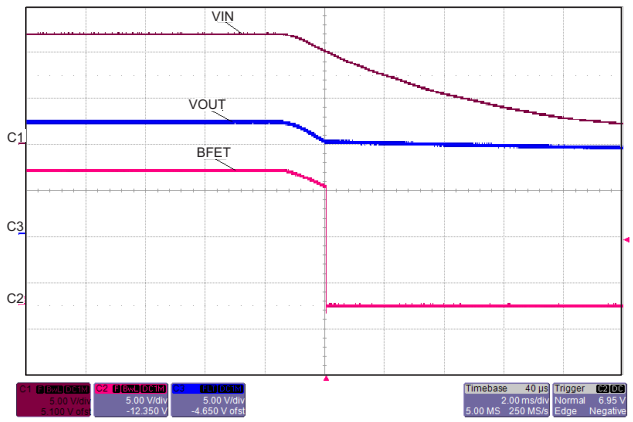


Figure 26. Turn Off Delay to BFET

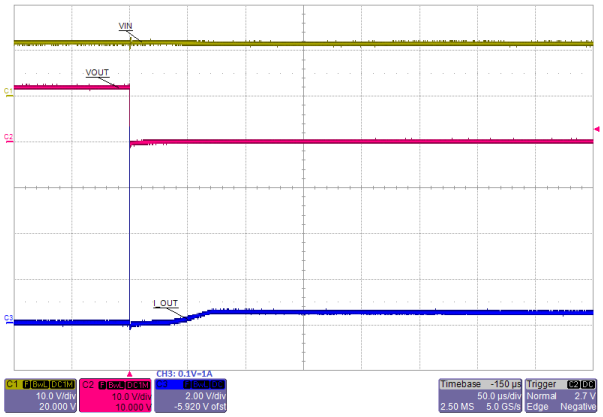


Figure 27. Transient: Output Short Circuit

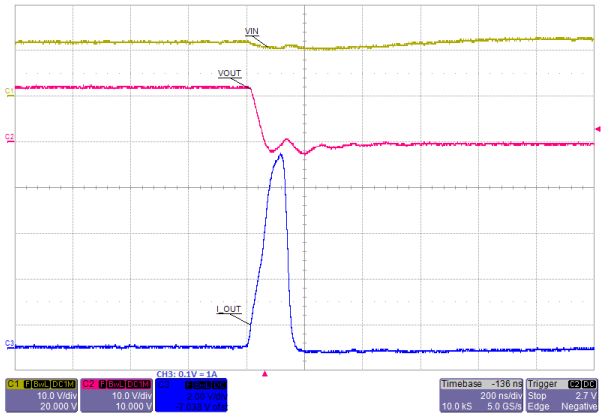


Figure 28. Short Circuit (Zoom): Fast-Trip Comparator

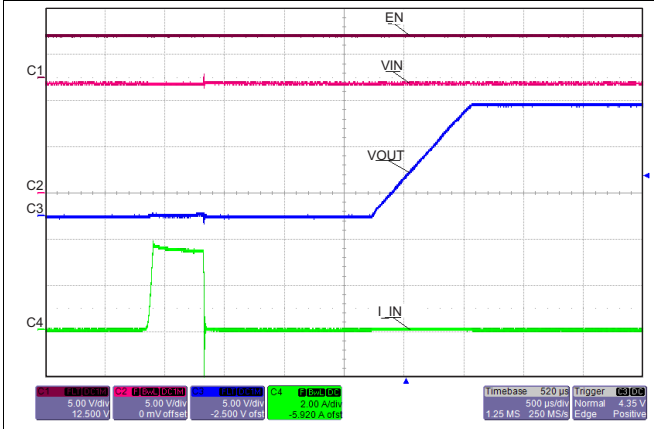


Figure 29. Transient: Recovery from Short Circuit / Over Current

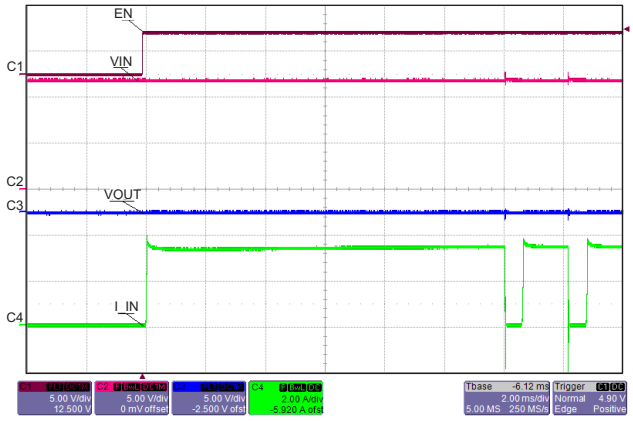
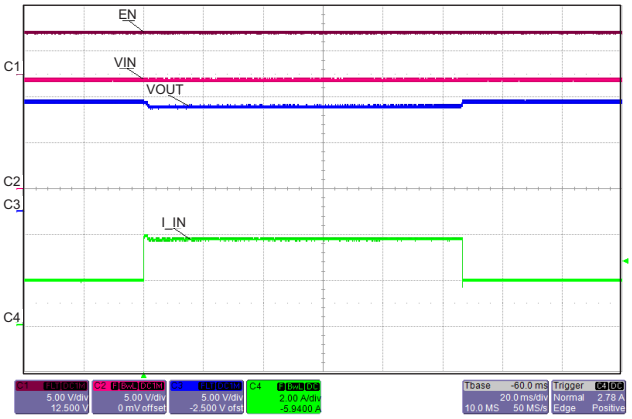


Figure 30. Transient: Wake Up to Short Circuit

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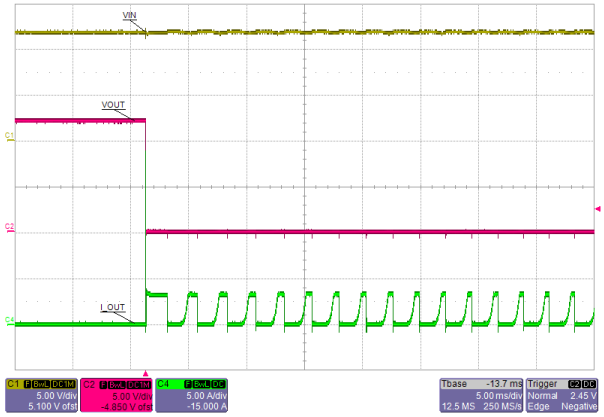
Typical Characteristics (continued)

T_J = 25°C, V_{VIN} = 12 V, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN} = 0.1 µF, C_{OUT} = 1 µF, C_{dVdT} = OPEN (unless stated otherwise)



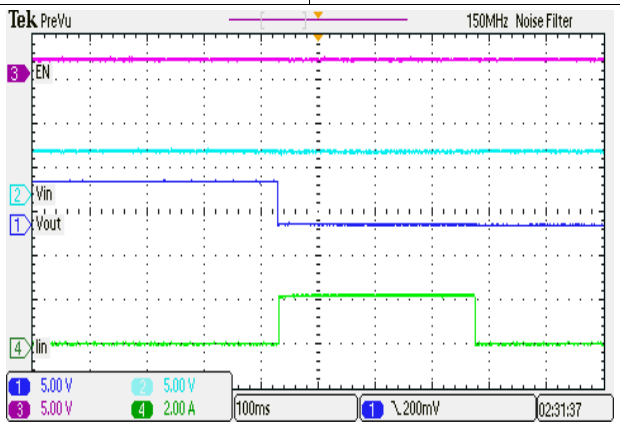
I_{LOAD} Stepped from 50% to 120%, Back to 50%

Figure 31. Transient: Overload Current Limit



TPS259271

Figure 32. Transient: Thermal Fault Auto-Retry



TPS259270, VIN = 5 V

Figure 33. Transient: Thermal Fault Latched

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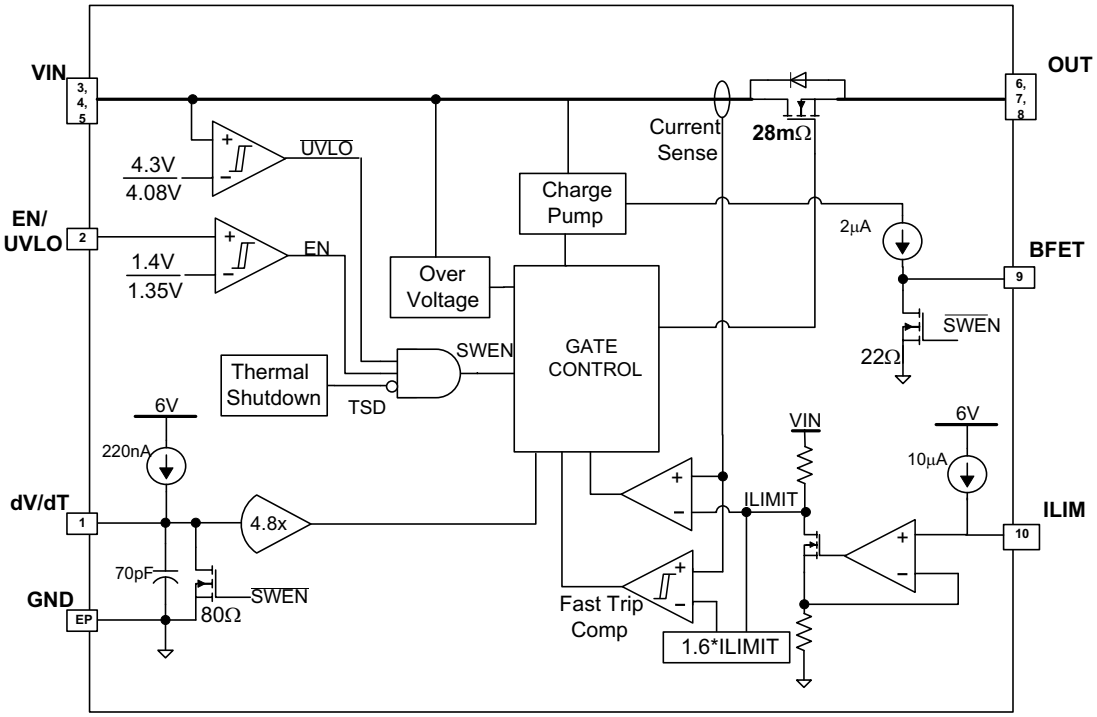
8 Detailed Description

8.1 Overview

The TPS25927x is an e-fuse with integrated power switch that is used to manage current/voltage/start-up voltage ramp to a connected load. The device starts its operation by monitoring the VIN bus. When VIN exceeds the undervoltage-lockout threshold (V_{UVR}), the device samples the EN/UVLO pin. A high level on this pin enables the internal MOSFET. As VIN rises, the internal MOSFET of the device will start conducting and allow current to flow from VIN to OUT. When EN/UVLO is held low (below V_{ENF}), internal MOSFET is turned off. User also has the ability to modify the output voltage ramp time by connecting a capacitor between dV/dT pin and GND.

After a successful start-up sequence, the device now actively monitors its load current, ensuring that the adjustable overload current limit I_{OL} is not exceeded. The device also has built-in thermal sensor. In the event device temperature (T_J) exceeds T_{SHDN}, typically 150°C, the thermal shutdown circuitry will shut down the internal MOSFET thereby disconnecting the load from the supply. In TPS259270, the output will remain disconnected (MOSFET open) until power to device is recycled or EN/UVLO is toggled (pulled low and then high). The TPS259271 device will remain off during a cooling period until device temperature falls below T_{SHDN} – 10°C, after which it will attempt to restart. This ON and OFF cycle will continue until fault is cleared.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 GND

This is the most negative voltage in the circuit and is used as a reference for all voltage measurements unless otherwise specified.

8.3.2 VIN

Input voltage to the TPS25927x. A ceramic bypass capacitor close to the device from VIN to GND is recommended to alleviate bus transients. The recommended operating voltage range is 4.5 V to 18 V for TPS25927x. The device can continuously sustain a voltage of 20 V on VIN pin. However, above the recommended maximum bus voltage, the device will be in over-voltage protection (OVP) mode, limiting the output voltage to V_{OVC}. The power dissipation in OVP mode is $P_{D_OVP} = (V_{VIN} - V_{OVC}) \times I_{OUT}$, which can potentially heat up the device and cause thermal shutdown.

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Feature Description (continued)

8.3.3 dV/dT

Connect a capacitor from this pin to GND to control the slew rate of the output voltage at power-on. This pin can be left floating to obtain a predetermined slew rate (minimum T_{dVdT}) on the output. Equation governing slew rate at start-up is shown below:

$$\frac{dV_{OUT}}{dt} = \frac{I_{dVdT} \times GAIN_{dVdT}}{C_{dVdT} + C_{INT}} \quad (1)$$

Where:

I_{dVdT} = 220 nA (TYP)
C_{INT} = 70 pF (TYP)
$GAIN_{dVdT}$ = 4.85
$\frac{dV_{OUT}}{dT}$ = Desired output slew rate

The total ramp time (T_{dVdT}) for 0 to VIN can be calculated using the following equation:

$$T_{dVdT} = 10^6 \times V_{IN} \times (C_{dVdT} + 70\ pF) \quad (2)$$

For details on how to select an appropriate charging time/rate, refer to the applications section *Setting Output Voltage Ramp Time (T_{dVdT})*.

8.3.4 BFET

Connect this pin to an external NFET that can be used to disconnect input supply from rest of the system in the event of power failure at VIN. The BFET pin is controlled by either input UVLO (V_{UVR}) event or EN/UVLO (see Table 1). BFET can source charging current of 2 µA (TYP) and sink (discharge) current from the gate of the external FET via a 26-Ω internal discharge resistor to initiate fast turn-off, typically <1 µs. Due to 2-µA charging current, it is recommended to use >10 MΩ impedance when probing the BFET node.

Table 1. BFET

EN/UVLO > V_{ENR}	VIN>V_{UVR}	BFET MODE
H	H	Charge
X	L	Discharge
L	X	Discharge

8.3.5 EN/UVLO

As an input pin, it controls both the ON/OFF state of the internal MOSFET and that of the external blocking FET. In its high state, the internal MOSFET is enabled and charging begins for the gate of external FET. A low on this pin will turn off the internal MOSFET and pull the gate of the external FET to GND via the built-in discharge resistor. High and Low levels are specified in the parametric table of the datasheet. The EN/UVLO pin is also used to clear a thermal shutdown latch in the TPS259270 by toggling this pin (H→L).

The internal de-glitch delay on EN/UVLO falling edge is intentionally kept low (1 us typical) for quick detection of power failure. When used with a resistor divider from supply to EN/UVLO to GND, power-fail detection on EN/UVLO helps in quick turn-off of the BFET driver, thereby stopping the flow of reverse current. For applications where a higher de-glitch delay on EN/UVLO is desired, or when the supply is particularly noisy, it is recommended to use an external bypass capacitor from EN/UVLO to GND.

8.3.6 ILIM

The device continuously monitors the load current and keeps it limited to the value programmed by R_{ILIM}. After start-up event and during normal operation, current limit is set to I_{OL} (over-load current limit).

$$I_{OL} = \left(0.7 + 3 \times 10^{-5} \times R_{ILIM}\right) \quad (3)$$

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When power dissipation in the internal MOSFET [$P_D = (V_{VIN} - V_{OUT}) \times I_{OUT}$] exceeds 10 W, there is a 2% – 12% thermal foldback in the current limit value so that I_{OL} drops to I_{SC}. In each of the two modes, MOSFET gate voltage is regulated to throttle short-circuit and overload current flowing to the load. Eventually, the device shuts down due to over temperature.

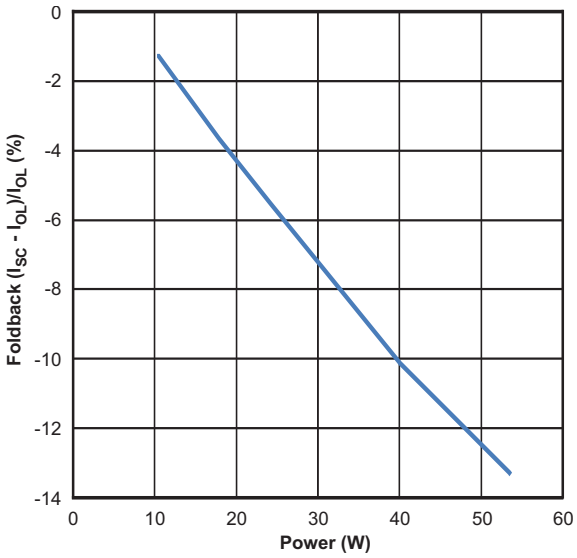


Figure 34. Thermal Foldback in Current Limit

During a transient short circuit event, the current through the device increases very rapidly. The current-limit amplifier cannot respond very quickly to this event due to its limited bandwidth. Therefore, the TPS25927x incorporates a fast-trip comparator, which shuts down the pass device very quickly when $I_{OUT} > I_{FASTRIP}$, and terminates the rapid short-circuit peak current. The trip threshold is set to 60% higher than the programmed over-load current limit ($I_{FASTRIP} = 1.6 \times I_{OL}$). After the transient short-circuit peak current has been terminated by the fast-trip comparator, the current limit amplifier smoothly regulates the output current to I_{OL} (see figure below).

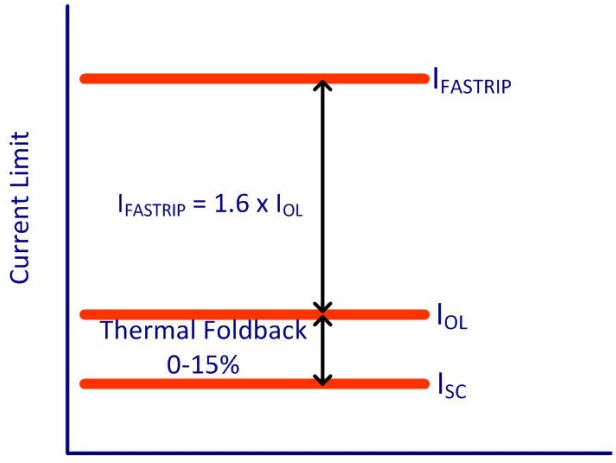


Figure 35. Fast-Trip Current

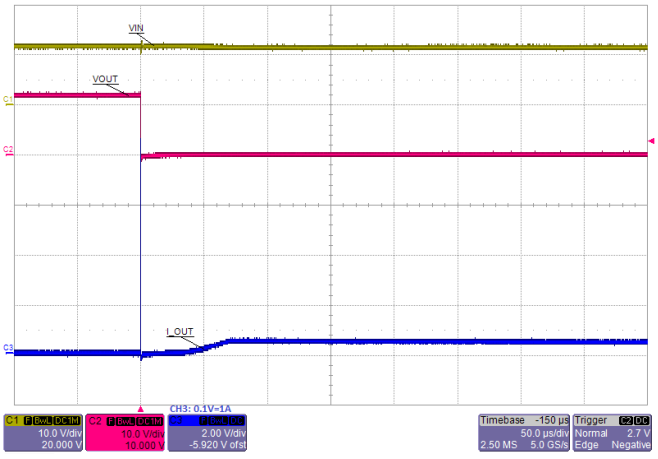


Figure 36. Fast-Trip and Current Limit Amplifier Response for Short Circuit

8.4 Device Functional Modes

The TPS25927x is a hot-swap controller with integrated power switch that is used to manage current/voltage/start-up voltage ramp to a connected load. The device starts its operation by monitoring the VIN bus. When V_{VIN} exceeds the undervoltage-lockout threshold (V_{UVR}), the device samples the EN/UVLO pin. A high level on this pin enables the internal MOSFET and also start charging the gate of external blocking FET (if connected) via the BFET pin. As VIN rises, the internal MOSFET of the device and external FET (if connected) will start conducting and allow current to flow from VIN to OUT. When EN/UVLO is held low (that is, below V_{ENF}), the internal MOSFET is turned off and BFET pin is discharged, thereby, blocking the flow of current from VIN to OUT. User also has the ability to modify the output voltage ramp time by connecting a capacitor between dV/dT pin and GND.

Having successfully completed its start-up sequence, the device now actively monitors its load current, ensuring that the adjustable overload current limit I_{OL} is not exceeded. This keeps the output device safe from harmful current transients. The device also has built-in thermal sensor. In the event device temperature (T_J) exceeds T_{SHDN} , typically 150°C, the thermal shutdown circuitry will shut down the internal MOSFET thereby disconnecting the load from the supply. In the TPS259270, the output will remain disconnected (MOSFET open) until power to device is recycled or EN/UVLO is toggled (pulled low and then high). The TPS259271 device will remain off during a cooling period until device temperature falls below T_{SHDN} – 10°C, after which it will attempt to restart. This ON and OFF cycle will continue until fault is cleared.

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9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

The TPA25927x is a smart eFuse. It is typically used for Hot-Swap and Power rail protection applications. It operates from 4.5 V to 18 V with programmable current limit and undervoltage protection. The device aids in controlling the in-rush current and provides precise current limiting during overload conditions for systems such as Set-Top-Box, DTVs, Gaming Consoles, SSDs/HDDs and Smart Meters. The device also provides robust protection for multiple faults on the sub-system rail.

The following design procedure can be used to select component values for the device. Alternatively, the WEBENCH® software may be used to generate a complete design. The WEBENCH® software uses an iterative design procedure and accesses a comprehensive database of components when generating a design. Additionally, a spreadsheet design tool *TPS2592xx Design Calculator* (SLUC570) is available on web folder. This section presents a simplified discussion of the design process.

9.2 Typical Application

9.2.1 Simple 2.1-A eFuse Protection for Set Top Boxes

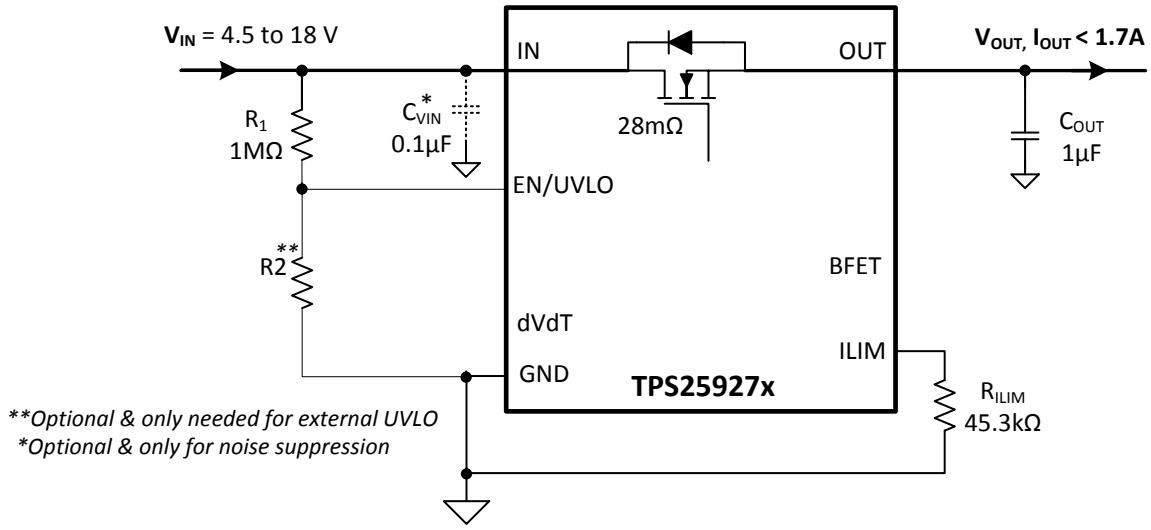


Figure 37. Typical Application Schematic: Simple e-Fuse for STBs

9.2.1.1 Design Requirements

Table 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input voltage range, V_{IN}	12 V
Undervoltage lockout set point, $V_{(UV)}$	Default: V_{UVR} = 4.3 V
Load at start-up, $R_{L(SU)}$	8 Ω
Current limit, $I_{OL} = I_{ILIM}$	2.1 A
Load capacitance, C_{OUT}	1 µF
Maximum ambient temperature, T_A	85°C

9.2.1.2 Detailed Design Procedure

The following design procedure can be used to select component values for the TPS25927x.

9.2.1.2.1 Step by Step Design Procedure

This design procedure below seeks to control the junction temperature of device under both static and transient conditions by proper selection of output ramp-up time and associated support components. The designer can adjust this procedure to fit the application and design criteria.

9.2.1.2.2 Programming the Current-Limit Threshold: R_{ILIM} Selection

The R_{ILIM} resistor at the ILIM pin sets the over load current limit, this can be set using Equation 4.

$$R_{ILIM} = \frac{I_{ILIM} - 0.7}{3 \times 10^{-5}} \quad (4)$$

For $I_{OL} = I_{ILIM} = 2.1$ A, from Equation 4, $R_{ILIM} = 45.3$ kΩ, choose closest standard value resistor with 1% tolerance.

9.2.1.2.3 Undervoltage Lockout Set Point

The undervoltage lockout (UVLO) trip point is adjusted using the external voltage divider network of R_1 and R_2 as connected between IN, EN/UVLO and GND pins of the device. The values required for setting the undervoltage are calculated solving Equation 5.

$$V_{(UV)} = \frac{R_1 + R_2}{R_2} \times V_{ENR} \quad (5)$$

Where $V_{ENR} = 1.4$ V is enable voltage rising threshold.

Since R_1 and R_2 will leak the current from input supply (VIN), these resistors should be selected based on the acceptable leakage current from input power supply (VIN). The current drawn by R_1 and R_2 from the power supply {$I_{R12} = V_{IN}/(R_1 + R_2)$}.

However, leakage currents due to external active components connected to the resistor string can add error to these calculations. So, the resistor string current, I_{R12} must be chosen to be 20x greater than the leakage current expected.

For default UVLO of $V_{UVR} = 4.3$ V, select R_2 = OPEN, and $R_1 = 1$ MΩ. Since EN/UVLO pin is rated only to 7 V, it cannot be connected directly to VIN = 12 V. It has to be connected through $R_1 = 1$ MΩ only, so that the pull-up current for EN/UVLO pin is limited to < 20 µA.

The power failure threshold is detected on the falling edge of supply. This threshold voltage is 4% lower than the rising threshold, V_{UVR}. This is calculated using Equation 6.

$$V_{(PFAIL)} = 0.96 \times V_{UVR} \quad (6)$$

Where V_{UVR} is 4.3 V, Power fail threshold set is : 4.1 V.

9.2.1.2.4 Setting Output Voltage Ramp Time (T_{dVdT})

For a successful design, the junction temperature of device should be kept below the absolute-maximum rating during both dynamic (start-up) and steady state conditions. Dynamic power stresses often are an order of magnitude greater than the static stresses, so it is important to determine the right start-up time and in-rush current limit required with system capacitance to avoid thermal shutdown during start-up with and without load.

The ramp-up capacitor C_{dVdT} needed is calculated considering the two possible cases:

9.2.1.2.4.1 Case 1: Start-Up without Load: Only Output Capacitance C_{OUT} Draws Current During Start-Up

During start-up, as the output capacitor charges, the voltage difference as well as the power dissipated across the internal FET decreases. The average power dissipated in the device during start-up is calculated using Equation 8.

For TPS25927x, the inrush current is determined as:

$$I_{(INRUSH)} = C_{(OUT)} \times \frac{V_{(IN)}}{T_{dVdT}} \quad (7)$$

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Power dissipation during start-up is:

$$P_{D(INRUSH)} = 0.5 \times V_{(IN)} \times I_{(INRUSH)} \quad (8)$$

Equation 8 assumes that load does not draw any current until the output voltage has reached its final value.

9.2.1.2.4.2 Case 2: Start-Up with Load: Output Capacitance C_{OUT} and Load Draws Current During Start-Up

When load draws current during the turn-on sequence, there will be additional power dissipated. Considering a resistive load during start-up ($R_{L(SU)}$), load current ramps up proportionally with increase in output voltage during T_{dVdT} time. The average power dissipation in the internal FET during charging time due to resistive load is given by:

$$P_{D(LOAD)} = \left(\frac{1}{6}\right) \times \frac{V^2_{(IN)}}{R_{L(SU)}} \quad (9)$$

Total power dissipated in the device during startup is:

$$P_{D(STARTUP)} = P_{D(INRUSH)} + P_{D(LOAD)} \quad (10)$$

Total current during startup is given by:

$$I_{(STARTUP)} = I_{(INRUSH)} + I_L(t) \quad (11)$$

If $I_{(STARTUP)} > I_{OL}$, the device limits the current to I_{OL} and the current limited charging time is determined by:

$$T_{dVdT(Current\text{-}Limited)} = C_{OUT} \times R_{L(SU)} \times \left[\frac{I_{OL}}{I_{(INRUSH)}} - 1 + LN\left(\frac{I_{(INRUSH)}}{I_{OL} - \frac{V_{(IN)}}{R_{L(SU)}}}\right)\right] \quad (12)$$

The power dissipation, with and without load, for selected start-up time should not exceed the shutdown limits as shown in Figure 38.

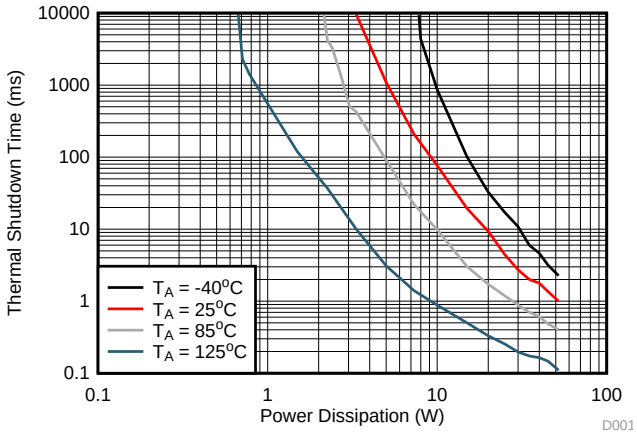


Figure 38. Thermal Shutdown Limit Plot

For the design example under discussion, select ramp-up capacitor C_{dVdT} = OPEN. Then, using Equation 2:

$$T_{dVdT} = 10^6 \times 12 \times (0 + 70\ pF) = 840\ \mu s \quad (13)$$

The inrush current drawn by the load capacitance (C_{OUT}) during ramp-up using Equation 7:

$$I_{(INRUSH)} = 1\ \mu F \times \frac{12}{840\ \mu s} = 15\ mA \quad (14)$$

The inrush power dissipation is calculated, using Equation 8:

$$P_{D(INRUSH)} = 0.5 \times 12 \times 15\ m = 90\ mW \quad (15)$$

For 90 mW of power loss, the thermal shut down time of the device should not be less than the ramp-up time T_{dVdT} to avoid the false trip at maximum operating temperature. From thermal shutdown limit graph Figure 38 at T_A = 85°C, for 90 mW of power, the shutdown time is infinite. So it is safe to use 0.79 ms as start-up time without any load on output.

Considering the start-up with load 8 Ω, the additional power dissipation, when load is present during start up is calculated, using Equation 9:

$$P_{D(LOAD)} = \frac{12 \times 12}{6 \times 8} = 3 \text{ W} \quad (16)$$

The total device power dissipation during start up is:

$$P_{D(STARTUP)} = 3 + 90 \text{ m} = 3.09 \text{ W} \quad (17)$$

From thermal shutdown limit graph at T_A = 85°C, the thermal shutdown time for 3.09 W is more than 100 ms. So it is well within acceptable limits to use no external capacitor ($C_{dV/dT}$) with start-up load of 8 Ω.

If, due to large C_{OUT}, there is a need to decrease the power loss during start-up, it can be done with increase of C_{dVdT} capacitor.

9.2.1.2.5 Support Component Selection - C_{VIN}

C_{VIN} is a bypass capacitor to help control transient voltages, unit emissions, and local supply noise. Where acceptable, a value in the range of 0.001 µF to 0.1 µF is recommended for C_{VIN}.

9.2.1.3 Application Curves

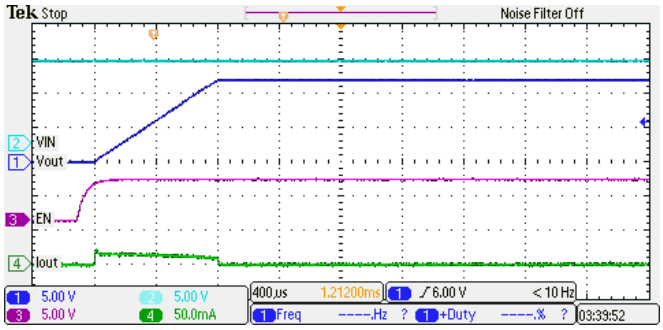


Figure 39. Output Ramp without Load on Output

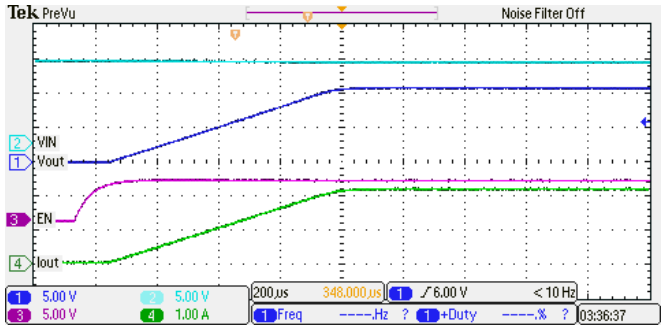


Figure 40. Output Ramp with 4-Ω Load at Start Up

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10 Power Supply Recommendations

The device is designed for supply voltage range of 4.5 V ≤ V_{IN} ≤ 18 V. If the input supply is located more than a few inches from the device an input ceramic bypass capacitor higher than 0.1 µF is recommended. Power supply should be rated higher than the current limit set to avoid voltage droops during over current and short-circuit conditions.

10.1 Transient Protection

In case of short circuit and over load current limit, when the device interrupts current flow, input inductance generates a positive voltage spike on the input and output inductance generates a negative voltage spike on the output. The peak amplitude of voltage spikes (transients) is dependent on value of inductance in series to the input or output of the device. Such transients can exceed the *Absolute Maximum Ratings* of the device if steps are not taken to address the issue.

Typical methods for addressing transients include:

- Minimizing lead length and inductance into and out of the device
- Using large PCB GND plane
- Schottky diode across the output to absorb negative spikes
- A low value ceramic capacitor ($C_{(IN)}$ = 0.001 µF to 0.1 µF) to absorb the energy and dampen the transients. The approximate value of input capacitance can be estimated with Equation 18:

$$V_{SPIKE(Absolute)} = V_{(IN)} + I_{(LOAD)} \times \sqrt{\frac{L_{(IN)}}{C_{(IN)}}} \quad (18)$$

Where:

- $V_{(IN)}$ is the nominal supply voltage
- $I_{(LOAD)}$ is the load current
- $L_{(IN)}$ equals the effective inductance seen looking into the source
- $C_{(IN)}$ is the capacitance present at the input

Some applications may require the addition of a Transient Voltage Suppressor (TVS) to prevent transients from exceeding the *Absolute Maximum Ratings* of the device.

The circuit implementation with optional protection components (a ceramic capacitor, TVS and schottky diode) is shown in Figure 41.

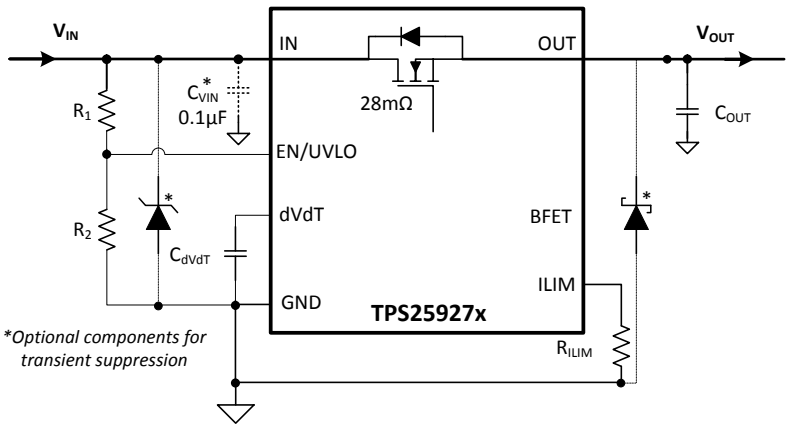


Figure 41. Circuit Implementation with Optional Protection Components

10.2 Output Short-Circuit Measurements

It is difficult to obtain repeatable and similar short-circuit testing results. Source bypassing, input leads, circuit layout and component selection, output shorting method, relative location of the short, and instrumentation all contribute to variation in results. The actual short itself exhibits a certain degree of randomness as it microscopically bounces and arcs. Care in configuration and methods must be used to obtain realistic results. Do not expect to see waveforms exactly like those in the data sheet; every setup differs.

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11 Layout

11.1 Layout Guidelines

- For all applications, a 0.01-uF or greater ceramic decoupling capacitor is recommended between IN terminal and GND. For hot-plug applications, where input power path inductance is negligible, this capacitor can be eliminated/minimized.
- The optimum placement of decoupling capacitor is closest to the IN and GND terminals of the device. Care must be taken to minimize the loop area formed by the bypass-capacitor connection, the IN terminal, and the GND terminal of the IC. See Figure 42 for a PCB layout example.
- High current carrying power path connections should be as short as possible and should be sized to carry at least twice the full-load current.
- The GND terminal must be tied to the PCB ground plane at the terminal of the IC. The PCB ground should be a copper plane or island on the board.
- Locate all support components: R_{ILIM}, C_{dVdT} and resistors for EN/UVLO, close to their connection pin. Connect the other end of the component to the GND pin of the device with shortest trace length. The trace routing for the R_{ILIM} and C_{dVdT} components to the device should be as short as possible to reduce parasitic effects on the current limit and soft start timing. These traces should not have any coupling to switching signals on the board.
- Protection devices such as TVS, snubbers, capacitors, or diodes should be placed physically close to the device they are intended to protect, and routed with short traces to reduce inductance. For example, a protection Schottky diode is recommended to address negative transients due to switching of inductive loads, and it should be physically close to the OUT pins.
- Obtaining acceptable performance with alternate layout schemes is possible; however this layout has been shown to produce good results and is intended as a guideline.

11.2 Layout Example

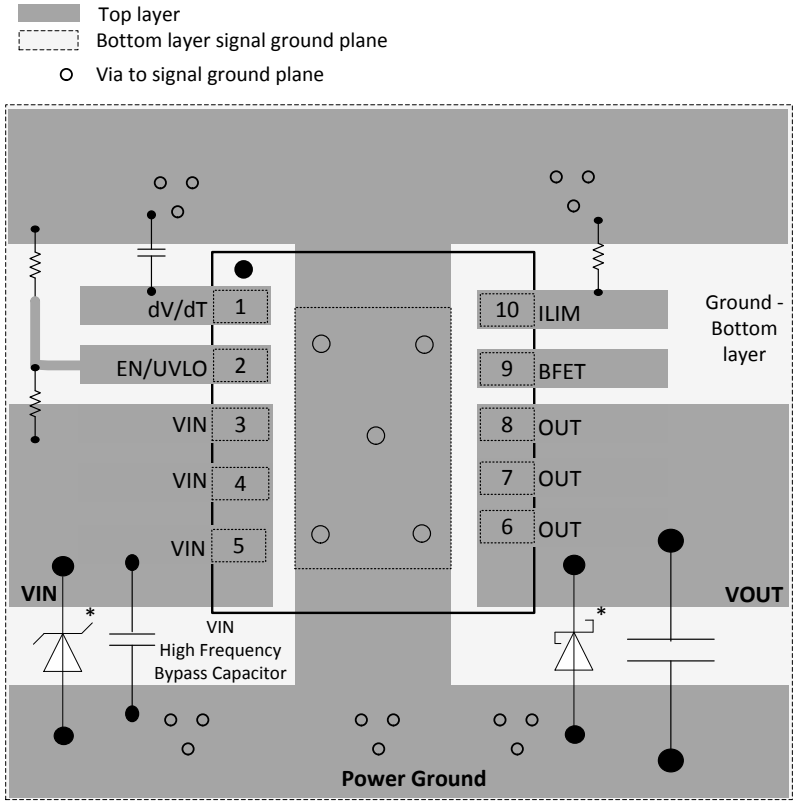


Figure 42. Layout Example

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12 Device and Documentation Support

12.1 Device Support

12.1.1 Third-Party Products Disclaimer

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12.2 Documentation Support

12.2.1 Related Documentation

TPS2592xx Design Calculator (SLUC570)

12.3 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 3. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TPS259270	Click here	Click here	Click here	Click here	Click here
TPS259271	Click here	Click here	Click here	Click here	Click here

12.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.5 Trademarks

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WEBENCH is a registered trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.6 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS259270DRCR	ACTIVE	VSON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	259270	Samples
TPS259270DRCT	ACTIVE	VSON	DRC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	259270	Samples
TPS259271DRCR	ACTIVE	VSON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	259271	Samples
TPS259271DRCT	ACTIVE	VSON	DRC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	259271	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

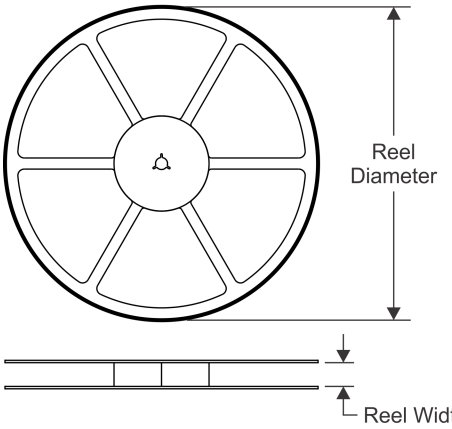
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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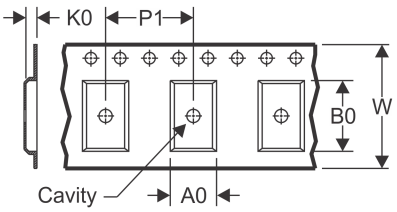
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

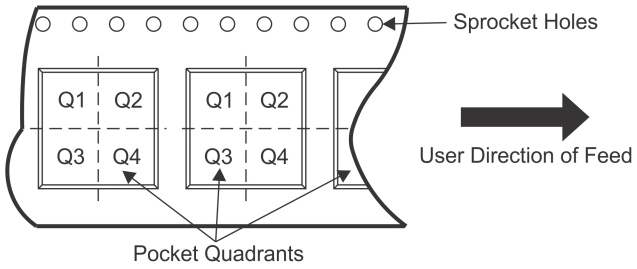


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

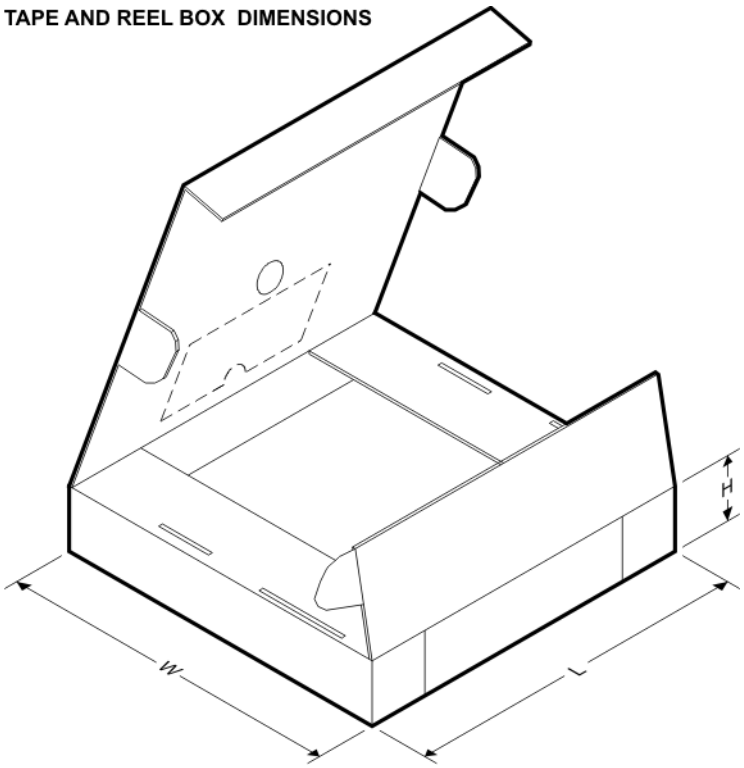
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS259270DRCR	VSON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS259270DRCT	VSON	DRC	10	250	180.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS259271DRCR	VSON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS259271DRCT	VSON	DRC	10	250	180.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

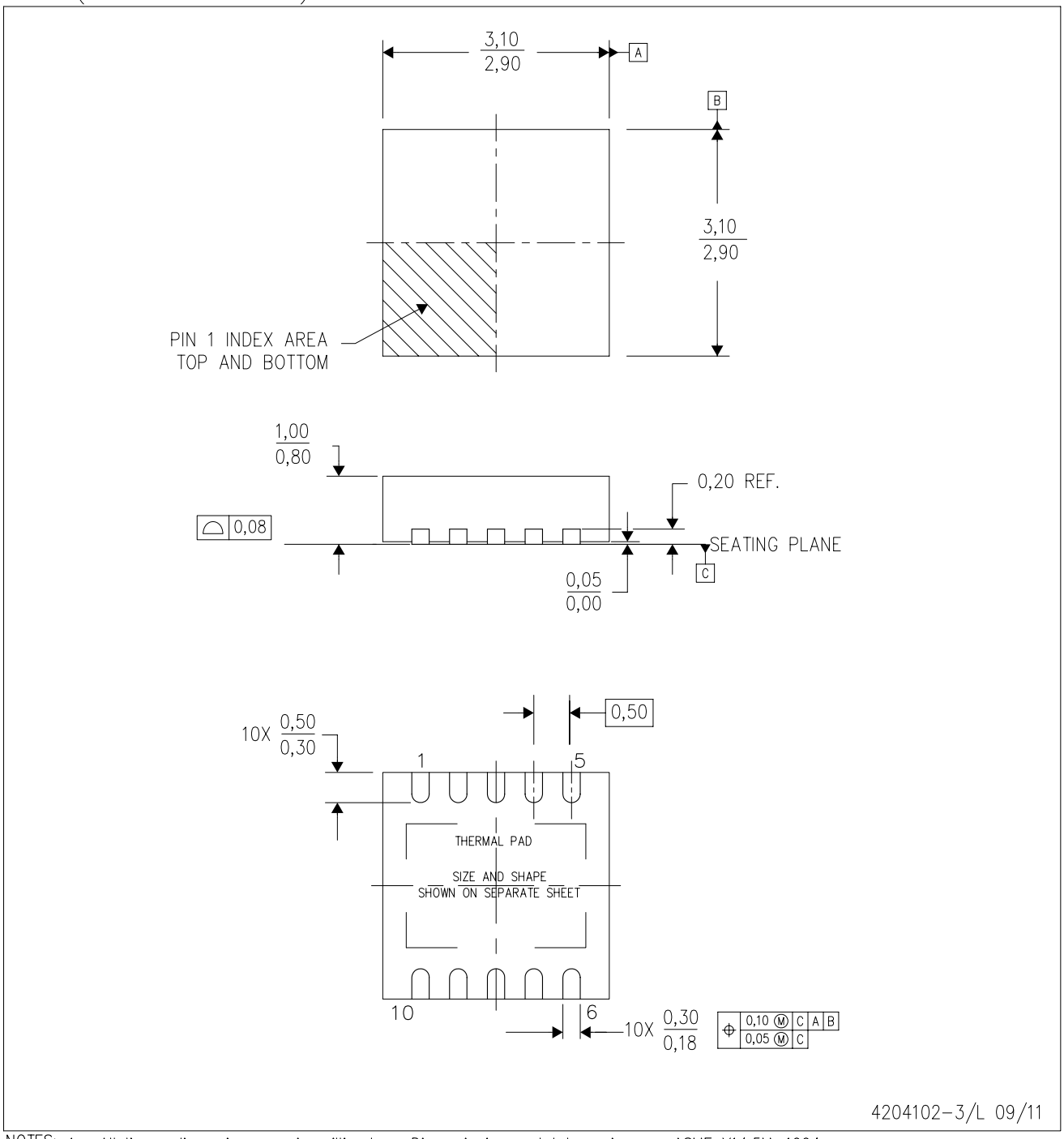
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS259270DRCR	VSON	DRC	10	3000	367.0	367.0	35.0
TPS259270DRCT	VSON	DRC	10	250	210.0	185.0	35.0
TPS259271DRCR	VSON	DRC	10	3000	367.0	367.0	35.0
TPS259271DRCT	VSON	DRC	10	250	210.0	185.0	35.0

DRC (S–PVSON–N10) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Small Outline No–Lead (SON) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance, if present.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions, if present

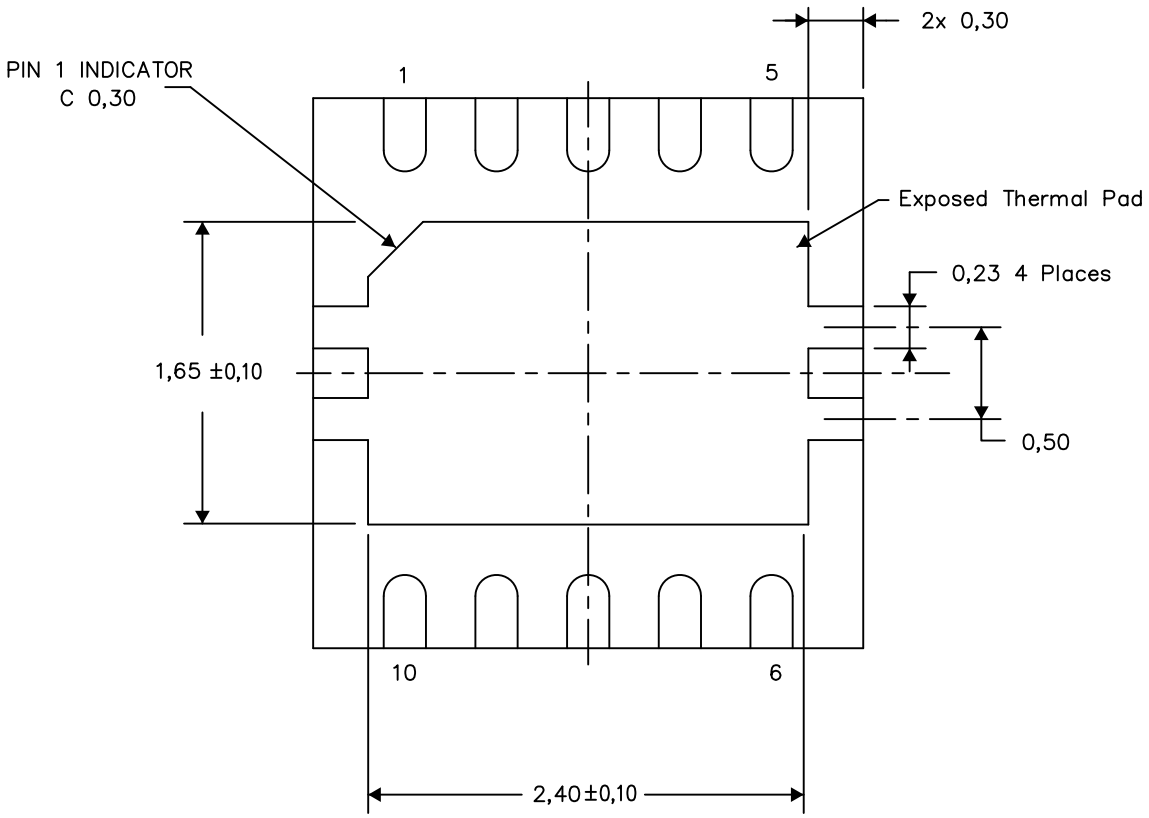
DRC (S–PVSON–N10) PLASTIC SMALL OUTLINE NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



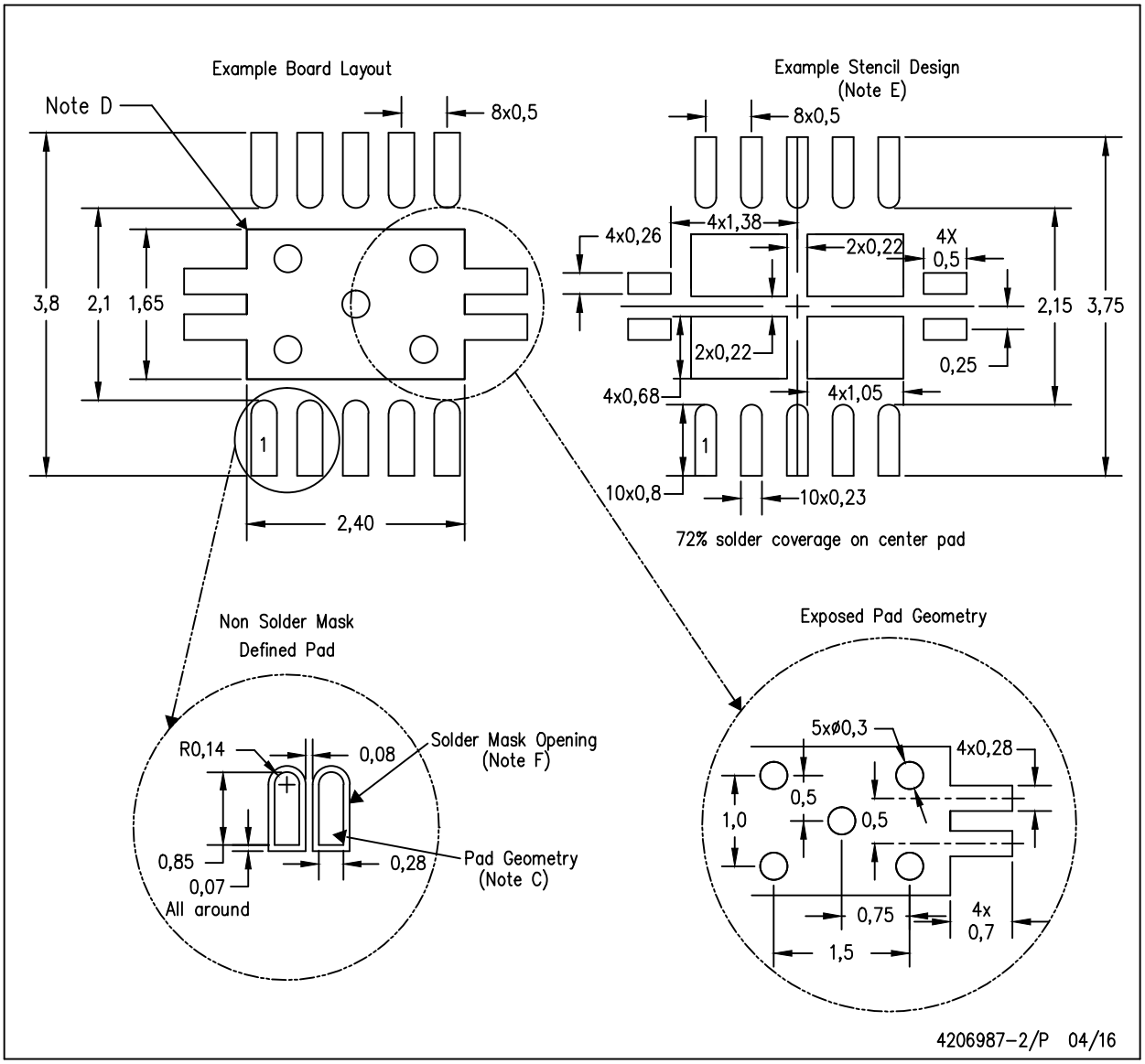
Bottom View

Exposed Thermal Pad Dimensions

4206565–3/Y 08/15

NOTE: A. All linear dimensions are in millimeters

DRC (S–PVSON–N10) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

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DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
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