

# TPS25948xx 3.5-V–23-V, 13-mΩ, 8-A eFuse With True Reverse Current Blocking

## 1 Features

- Wide operating input voltage range: 3.5 V to 23 V
  - 28-V absolute maximum
  - Can be powered from either IN or OUT
- Integrated back-to-back FETs with low On-resistance:  $R_{ON} = 13\text{ m}\Omega$  (typ.)
- Ideal diode operation with true reverse current blocking (RCB)
  - External pin control (RCBCTRL) to disable RCB and allow bi-directional current flow in steady-state to support USB OTG operation
- Fast overvoltage protection
  - Adjustable overvoltage lockout (OVLO) with 1- $\mu\text{s}$  (typ.) response time
- Overcurrent protection with load current monitor output (ILM)
  - Active current limit response
  - Adjustable threshold ( $I_{LIM}$ ) 1 A–9 A
    - $\pm 10\%$  accuracy for  $I_{LIM} > 2\text{ A}$
  - Adjustable transient blanking timer (ITIMER) to allow peak currents  $> I_{LIM}$
  - Output load current monitor accuracy:  $\pm 6\%$  ( $I_{OUT} \geq 3\text{ A}$ )
- Fast-trip response for short-circuit protection
  - $< 1\text{-}\mu\text{s}$  (typ.) response time
  - Adjustable and fixed thresholds
- Active high enable input with adjustable undervoltage lockout threshold (UVLO)
- Adjustable output slew rate control (dVdt)
- Overtemperature protection
- Digital outputs: Supply Good (SPLYGD/SPLYGD) and fault indication (FLT)
- UL 2367 recognition (planned)
- IEC 62368-1 CB certification (planned)
- Small footprint: PowerWCSP 2.4 mm  $\times$  1.7 mm, 0.5-mm pitch

## 2 Applications

- Adapter and charger input protection
- USB PD protection: [smartphone](#), [tablet](#), [PC](#), [notebook](#), [monitor](#), [dock](#)
- [Server motherboard](#), [add-on cards](#)
- Enterprise storage: [HBA](#), [SAN](#), and [eSSD](#)
- Power MUXing and ORing

## 3 Description

The TPS25948xx family of eFuses is a highly integrated, circuit-protection and power-management solution in a small package. The devices provide multiple protection modes that use few external

components and are a robust defense against overloads, short-circuits, voltage surges, reverse polarity, and excessive inrush current. With integrated back-to-back FETs, reverse current flow from output to input is blocked at all times, making the devices well suited for power MUX and ORing applications, as well as systems that need load side energy hold up storage if input power supply fails. The devices use a linear ORing based scheme to ensure almost zero DC reverse current and emulate ideal diode behavior with minimum forward voltage drop and power dissipation. The devices also provide an external pin control option to disable the reverse current blocking and allow bi-directional current flow in steady-state.

Output slew rate and inrush current can be adjusted using a single external capacitor. Loads are protected from input overvoltage conditions by cutting off the output if input exceeds an adjustable overvoltage threshold. The devices respond to output overload by actively limiting the current. The output current limit threshold as well as the transient overcurrent blanking timer are user adjustable. The current limit control pin also functions as an analog load current monitor.

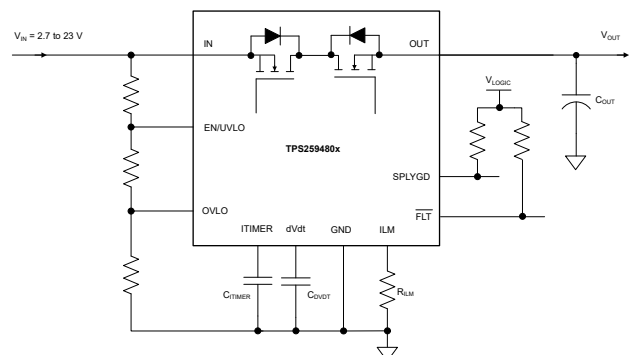
The devices are available in a 2.4-mm  $\times$  1.7-mm, 12-ball power wafer chip scale package (PowerWCSP) for improved thermal performance and reduced system footprint.

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

### Package Information

PART NUMBER	PACKAGE <sup>(1)</sup>	BODY SIZE (NOM)
TPS25948xxYWP	PWCSP (12)	2.40 mm $\times$ 1.70 mm

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



Simplified Schematic



## Table of Contents

<b>1 Features</b> .....	1	9.1 Application Information.....	29
<b>2 Applications</b> .....	1	9.2 Single Device, Self-Controlled.....	29
<b>3 Description</b> .....	1	9.3 Typical Application.....	30
<b>4 Revision History</b> .....	2	9.4 Active ORing.....	34
<b>5 Device Comparison Table</b> .....	3	9.5 Priority Power MUXing.....	36
<b>6 Pin Configuration and Functions</b> .....	4	9.6 Parallel Operation.....	41
<b>7 Specifications</b> .....	5	9.7 USB PD Port Protection.....	43
7.1 Absolute Maximum Ratings.....	5	9.8 Power Supply Recommendations.....	44
7.2 ESD Ratings.....	5	9.9 Layout.....	46
7.3 Recommended Operating Conditions.....	5	<b>10 Device and Documentation Support</b> .....	48
7.4 Electrical Characteristics.....	6	10.1 Documentation Support.....	48
7.5 Timing Requirements.....	8	10.2 Receiving Notification of Documentation Updates.....	48
7.6 Switching Characteristics.....	9	10.3 Support Resources.....	48
7.7 Typical Characteristics.....	10	10.4 Trademarks.....	48
<b>8 Detailed Description</b> .....	13	10.5 Electrostatic Discharge Caution.....	48
8.1 Overview.....	13	10.6 Glossary.....	48
8.2 Functional Block Diagram.....	14	<b>11 Mechanical, Packaging, and Orderable Information</b> .....	49
8.3 Feature Description.....	17	11.1 Tape and Reel Information.....	49
8.4 Device Functional Modes.....	28		
<b>9 Application and Implementation</b> .....	29		

## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
February 2023	*	Initial Release

## 5 Device Comparison Table

Part Number	Steady-state fast-trip threshold	SPLYGD polarity	FLT or RCBCTRL	Response to Fault
TPS259480AYWP	Adjustable ( $2 \times I_{LIM}$ )	Active High	FLT	Auto-Retry
TPS259480LYWP				Latch-Off
TPS259482AYWP			RCBCTRL	Auto-Retry
TPS259482LYWP				Latch-Off
TPS259481AYWP	Fixed	Active Low	RCBCTRL	Auto-Retry
TPS259481LYWP				Latch-Off

## 6 Pin Configuration and Functions

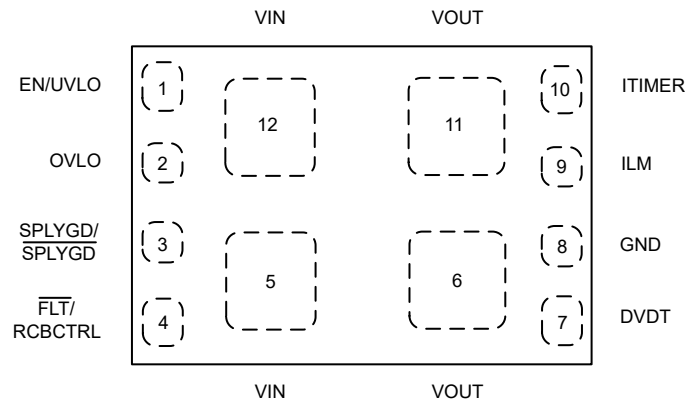


Figure 6-1. YWP Package, 12-Ball PWCSOP (Top View)

Table 6-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
EN/UVLO	1	Analog input	Active high enable for the device. A resistor divider on this pin from input supply to GND can be used to adjust the undervoltage lockout threshold. <i>Do not leave floating.</i> Refer to <a href="#">Section 8.3.1</a> for details.
OVLO	2	Analog input	A resistor divider on this pin from supply to GND can be used to adjust the overvoltage lockout threshold. This pin can also be used as an Active low enable for the device. <i>Do not leave floating.</i> Refer to <a href="#">Section 8.3.2</a> for details.
SPLYGD	3	Digital output	<i>TPS259480x/2x:</i> Active high Supply Good indication. This is an open drain signal which is asserted high when the input supply is valid and channel has completed inrush sequence. This can be used to enable/disable the auxiliary supply eFuse to facilitate smooth switchover in a priority power MUXing configuration. Refer to <a href="#">Section 8.3.8</a> for more details.
$\overline{\text{SPLYGD}}$		Digital output	<i>TPS259481x:</i> Active low Supply Good indication. This is an open drain signal which is asserted Low when the input supply is valid and channel has completed inrush sequence. This can be used to enable/disable the auxiliary supply eFuse to facilitate smooth switchover in a priority power MUXing configuration. Refer to <a href="#">Section 8.3.8</a> for more details.
FLT	4	Digital output	<i>TPS259480x:</i> Active low fault event indicator. This is an open drain signal which will be pulled low when a fault is detected. Refer to <a href="#">Section 8.3.7</a> for more details.
RCBCTRL		Digital input	<i>TPS259481x/2x:</i> Active high reverse current blocking enable input. Leave the pin floating or pull it high to enable reverse current blocking at all times. Pull the pin low to disable reverse current blocking in steady-state to enable bi-directional current flow.
IN	5, 12	Power	Power input.
OUT	6, 11	Power	Power output.
DVDT	7	Analog output	A capacitor from this pin to GND sets the output turn on slew rate. Leave this pin floating for the fastest turn on slew rate. Refer to <a href="#">Section 8.3.3.1</a> for details.
GND	8	Ground	This is the ground reference for all internal circuits and must be connected to system GND.
ILM	9	Analog output	This is a dual function pin used to limit and monitor the output current. An external resistor from this pin to GND sets the output current limit threshold during start-up as well as steady state. The pin voltage can also be used as analog output load current monitor signal. <i>Do not leave floating.</i> Refer to <a href="#">Section 8.3.3.2</a> for more details.
ITIMER	10	Analog output	A capacitor from this pin to GND sets the overcurrent blanking interval during which the output current can temporarily exceed set current limit (but lower than fast-trip threshold) before the device overcurrent response takes action. Leave this pin open for fastest response to overcurrent events. Refer to <a href="#">Section 8.3.3.2</a> for more details.

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

Parameter		Pin	MIN	MAX	UNIT
V <sub>IN</sub>	Maximum Input Voltage Range, $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$	IN	V <sub>OUT</sub> – 21	28	V
V <sub>IN</sub>	Maximum Input Voltage Range, $-10^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$	IN	V <sub>OUT</sub> – 22	28	V
V <sub>OUT</sub>	Maximum Output Voltage Range, $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$	OUT	–0.3	min (28, V <sub>IN</sub> + 21)	
V <sub>OUT</sub>	Maximum Output Voltage Range, $-10^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$	OUT	–0.3	min (28, V <sub>IN</sub> + 22)	
V <sub>OUT,PLS</sub>	Minimum Output Voltage Pulse (< 1 μs)	OUT	–0.8		
V <sub>EN/UVLO</sub>	Maximum Enable Pin Voltage Range	EN/UVLO	–0.3	6.5	V
V <sub>OV</sub>	Maximum OVLO Pin Voltage Range	OVLO	–0.3	6.5	V
V <sub>dVdt</sub>	Maximum dVdt Pin Voltage Range	dVdt	Internally Limited		V
V <sub>ITIMER</sub>	Maximum ITIMER Pin Voltage Range	ITIMER	Internally Limited		V
V <sub>RCBCTRL</sub>	Maximum RCBCTRL Pin Voltage Range	RCBCTRL	–0.3	6.5	V
V <sub>SPLYGD</sub>	Maximum SPLYGD/SPLYGD Pin Voltage Range	SPLYGD/SPLYGD	–0.3	6.5	V
V <sub>FLTB</sub>	Maximum FLT Pin Voltage Range	FLT	–0.3	6.5	V
V <sub>ILM</sub>	Maximum ILM Pin Voltage Range	ILM	Internally Limited		V
I <sub>MAX</sub>	Maximum Continuous Switch Current	IN to OUT	Internally Limited		A
T <sub>J</sub>	Junction Temperature		Internally Limited		°C
T <sub>LEAD</sub>	Maximum Lead Temperature			300	°C
T <sub>stg</sub>	Storage Temperature		–65	150	°C

- (1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

### 7.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±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)

Parameter		Pin	MIN	MAX	UNIT
V <sub>IN</sub>	Input Voltage Range	IN	2.7	23	V
V <sub>OUT</sub>	Output Voltage Range	OUT		min (23, V <sub>IN</sub> + 20)	V
V <sub>EN/UVLO</sub>	Enable Pin Voltage Range	EN/UVLO		5 <sup>(1)</sup>	V
V <sub>OV</sub>	OVLO Pin Voltage Range	OVLO	0.5	1.5	V
V <sub>dVdt</sub>	dVdt Capacitor Voltage Rating	dVdt	V <sub>IN</sub> + 5 V <sup>(2)</sup>		V
V <sub>RCBCTRL</sub>	RCBCTRL Pin Voltage Range	RCBCTRL		5	V
V <sub>FLTB</sub>	FLTB Pin Voltage Range	FLTB		5	V
V <sub>SPLYGD</sub>	SPLYGD/SPLYGD Pin Voltage Range	SPLYGD/SPLYGD		5	V

### 7.3 Recommended Operating Conditions (continued)

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

Parameter		Pin	MIN	MAX	UNIT
V <sub>ITIMER</sub>	ITIMER Pin Capacitor Voltage Rating	ITIMER	4		V
R <sub>ILM</sub>	ILM Pin Resistance	ILM	536	4834	Ω
I <sub>MAX</sub>	Continuous Switch Current, , T <sub>J</sub> ≤ 125°C	IN to OUT		8	A
T <sub>J</sub>	Junction temperature		-40	125	°C

- For supply voltages below 5 V, it is okay to pull up the EN pin to IN directly. For supply voltages greater than 5 V, it is recommended to use a resistor divider to step down the voltage.
- In a PowerMUX scenario with unequal supplies, the dVdt capacitor rating for each device should be chosen based on the highest of the 2 rails.

### 7.4 Electrical Characteristics

 (Test conditions unless otherwise noted) -40°C ≤ T<sub>J</sub> ≤ 125°C, V<sub>IN</sub> = 12 V, OUT = Open, V<sub>EN/UVLO</sub> = 2 V, V<sub>OVLO</sub> = 0 V, R<sub>ILM</sub> = 536 Ω, dVdt = Open, ITIMER = Open, SPLYGD/SPLYGD = Open, FLT = Open for TPS259480x, RCBCTRL = Open for TPS259481x/2x. All voltages referenced to GND.

Test Parameter	Description	MIN	TYP	MAX	UNITS
<b>INPUT SUPPLY (IN)</b>					
V <sub>UVP(R)</sub>	IN supply undervoltage protection rising threshold		3.026		V
V <sub>UVP(F)</sub>	IN supply undervoltage protection falling threshold		2.433		V
I <sub>Q(ON,IN)</sub>	IN supply ON state quiescent current when powered from IN, V <sub>EN</sub> > V <sub>UVLO(R)</sub>		448		μA
I <sub>SD(IN)</sub>	IN supply shutdown current when powered from IN, V <sub>EN</sub> < V <sub>SD(F)</sub>		7		μA
V <sub>UVP(R)</sub>	OUT supply undervoltage protection rising threshold		3.026		V
V <sub>UVP(F)</sub>	OUT supply undervoltage protection falling threshold		2.433		V
<b>OUTPUT SUPPLY (OUT)</b>					
I <sub>Q(ON,OUT)</sub>	OUT supply ON state quiescent current when powered from OUT, V <sub>EN</sub> > V <sub>UVLO(R)</sub>		440		μA
I <sub>SD(OUT)</sub>	OUT supply shutdown current when powered from OUT, V <sub>EN</sub> < V <sub>SD(F)</sub>		6.3		μA
<b>ON RESISTANCE (IN - OUT)</b>					
R <sub>ON</sub>	V <sub>IN</sub> = 12 V, I <sub>OUT</sub> = 3 A, T <sub>J</sub> = 25°C		13		mΩ
	3.5 ≤ V <sub>IN</sub> ≤ 23 V, I <sub>OUT</sub> = 3 A, -40°C ≤ T <sub>J</sub> ≤ 125°C			TBD	mΩ
<b>ENABLE/UNDERVOLTAGE LOCKOUT (EN/UVLO)</b>					
V <sub>UVLO(R)</sub>	EN/UVLO pin rising threshold to turn FET ON		1.20		V
V <sub>UVLO(F)</sub>	UVLO pin falling threshold to turn FET OFF		1.09		V
V <sub>SD(F)</sub>	EN/UVLO falling threshold for lowest shutdown current		0.76		V
I <sub>ENLKG</sub>	EN/UVLO pin leakage current	-0.1		0.1	μA
<b>OVERVOLTAGE LOCKOUT (OVLO)</b>					
V <sub>OV(R)</sub>	OVLO pin rising threshold		1.20		V
V <sub>OV(F)</sub>	OVLO pin falling threshold		1.09		V
I <sub>OVLKG</sub>	OVLO pin leakage current, 0.5 V < V <sub>OVLO</sub> < 1.5 V	-0.1		0.1	μA
<b>OUTPUT LOAD CURRENT MONITOR (IMON)</b>					
G <sub>IMON</sub>	Analog load current monitor gain (IMON : I <sub>OUT</sub> ), I <sub>OUT</sub> = 1 A to 8 A, I <sub>OUT</sub> < I <sub>LIM</sub>		135		μA/A
<b>OVERCURRENT PROTECTION (OUT)</b>					

## 7.4 Electrical Characteristics (continued)

(Test conditions unless otherwise noted)  $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ,  $V_{IN} = 12\text{ V}$ ,  $\text{OUT} = \text{Open}$ ,  $V_{EN/UVLO} = 2\text{ V}$ ,  $V_{OVLO} = 0\text{ V}$ ,  $R_{ILM} = 536\ \Omega$ ,  $dVdT = \text{Open}$ ,  $\text{ITIMER} = \text{Open}$ ,  $\text{SPLYGD}/\overline{\text{SPLYGD}} = \text{Open}$ ,  $\overline{\text{FLT}} = \text{Open}$  for TPS259480x,  $\text{RCBCTRL} = \text{Open}$  for TPS259481x/2x. All voltages referenced to GND.

Test Parameter	Description	MIN	TYP	MAX	UNITS
$I_{\text{ILM}}$	Overcurrent threshold, $R_{\text{ILM}} = 4.81\text{ k}\Omega$		1		A
	Overcurrent threshold, $R_{\text{ILM}} = 1.62\text{ k}\Omega$		3		A
	Overcurrent threshold, $R_{\text{ILM}} = 965\ \Omega$		5		A
	Overcurrent threshold, $R_{\text{ILM}} = 536\ \Omega$		9		A
$I_{\text{FLT}}$	Circuit-breaker threshold, ILM pin open (Single point failure)		0.1		A
	Circuit-breaker threshold, ILM pin shorted to GND (Single point failure)		1.5		A
$I_{\text{SCGain}}$	Scalable Fast Trip Threshold ( $I_{\text{SC}}$ ) : ILM Ratio, TPS259480x/2x variants only		200		%
$I_{\text{FFT}}$	Fixed Fast-trip current threshold, TPS259480x/2x variants only		23.5		A
	Fixed Fast-trip current threshold, TPS259481x variants only		21.6		A
$V_{\text{FB}}$	$V_{\text{OUT}}$ threshold to exit current limit foldback		1.89		V
<b>OVERCURRENT FAULT TIMER (ITIMER)</b>					
$V_{\text{INT}}$	ITIMER pin internal pull-up voltage		2.57		V
$R_{\text{ITIMER}}$	ITIMER pin internal pull-up resistance		15		k $\Omega$
$I_{\text{ITIMER}}$	ITIMER pin discharge current, $I_{\text{OUT}} > I_{\text{ILM}}$		1.95		$\mu\text{A}$
$\Delta V_{\text{ITIMER}}$	ITIMER discharge differential voltage threshold		1.5		V
<b>REVERSE CURRENT BLOCKING (IN - OUT)</b>					
$V_{\text{FWD}}$	$V_{\text{IN}} - V_{\text{OUT}}$ forward regulation voltage, $I_{\text{OUT}} = 10\text{ mA}$		10.2		mV
$V_{\text{REVTH}}$	$V_{\text{IN}} - V_{\text{OUT}}$ threshold for fast BFET turn off (enter reverse current blocking)		-28.7		mV
$V_{\text{FWDTH}}$	$V_{\text{IN}} - V_{\text{OUT}}$ threshold for fast BFET turn on (exit reverse current blocking)		106		mV
$I_{\text{REVLKG}}$	Reverse leakage current during reverse current blocking condition		0.13		$\mu\text{A}$
<b>SUPPLY GOOD INDICATION (SPLYGD/SPLYGD)</b>					
$V_{\text{SPLYGD}}$	SPLYGD pin low voltage $V_{\text{IN}} > 3.3\text{ V}$ , Strong pull-up		100		mV
$V_{\text{SPLYGD}}$	SPLYGD pin low voltage $V_{\text{IN}} < 3.3\text{ V}$ , $\text{EN} < V_{\text{SD(F)}}$ , weak pull-up		658		mV
$V_{\text{SPLYGD}}$	SPLYGD pin low voltage $V_{\text{IN}} < 3.3\text{ V}$ , $\text{EN} < V_{\text{SD(F)}}$ , strong pull-up		793		mV
$I_{\text{SPLYGDLKG}}$	SPLYGD High leakage current		1		$\mu\text{A}$
$I_{\text{SPLYGDBLKG}}$	$\overline{\text{SPLYGD}}$ High leakage current		0.2		$\mu\text{A}$
<b>FAULT INDICATION (FLT) or REVERSE BLOCKING CONTROL (RCBCTRL)</b>					
$I_{\text{FLTBLKG}}$	$\overline{\text{FLT}}$ leakage current	-1		1	$\mu\text{A}$
$R_{\text{FLTB}}$	$\overline{\text{FLT}}$ pin internal pull-down resistance, TPS259480x variants only		12.3		$\Omega$
$I_{\text{RCBCTRL}}$	RCBCTRL pin internal pull-up current, TPS259481x/2x variants only		5		$\mu\text{A}$
$V_{\text{IH,RCBCTRL}}$	RCBCTRL pin logic high detection threshold, TPS259481x/2x variants only		1.15		V
$V_{\text{IL,RCBCTRL}}$	RCBCTRL pin logic low detection threshold, TPS259481x/2x variants only		1.04		V

## 7.4 Electrical Characteristics (continued)

(Test conditions unless otherwise noted)  $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ,  $V_{IN} = 12\text{ V}$ ,  $\text{OUT} = \text{Open}$ ,  $V_{EN/UVLO} = 2\text{ V}$ ,  $V_{OVLO} = 0\text{ V}$ ,  $R_{ILM} = 536\ \Omega$ ,  $dVdt = \text{Open}$ ,  $\text{ITIMER} = \text{Open}$ ,  $\text{SPLYGD}/\text{SPLYGD} = \text{Open}$ ,  $\overline{\text{FLT}} = \text{Open}$  for TPS259480x,  $\text{RCBCTRL} = \text{Open}$  for TPS259481x/2x. All voltages referenced to GND.

Test Parameter	Description	MIN	TYP	MAX	UNITS
<b>OVERTEMPERATURE PROTECTION (OTP)</b>					
TSD	Thermal shutdown rising threshold, $T_J$ rising		154		$^{\circ}\text{C}$
TSD <sub>HYS</sub>	Thermal shutdown hysteresis, $T_J$ falling		10		$^{\circ}\text{C}$
<b>SLEW RATE CONTROL (DVDT)</b>					
I <sub>dvdT</sub>	dVdt pin charging current		5.4		$\mu\text{A}$

## 7.5 Timing Requirements

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>OVLO</sub>	Overvoltage lock-out response time	$V_{OVLO} > V_{OV(R)}$ to $V_{OUT}\downarrow$		1		$\mu\text{s}$
t <sub>LIM</sub>	Current limit response time	$I_{OUT} > 1.2 \times I_{LIM}$ & ITIMER expired to $I_{OUT}$ settling to within 5 % of $I_{LIM}$		250		$\mu\text{s}$
t <sub>SC</sub>	Scalable fast-trip response time (TPS259480x/2x only)	$I_{OUT} > 3 \times I_{LIM}$ to $I_{OUT}\downarrow$		900		ns
t <sub>FT</sub>	Fixed fast-trip response time	$I_{OUT} > I_{FFT}$ to $I_{OUT}\downarrow$		750		ns
t <sub>RST</sub>	Auto-Retry interval after fault (TPS25948xA only)			103		ms
t <sub>SWOV</sub>	OVLO fast recovery response time	$V_{OVLO} < V_{OV(F)}$ to $V_{OUT}\uparrow$		85		$\mu\text{s}$
t <sub>SWRCB</sub>	Reverse Current Blocking recovery time	$(V_{IN} - V_{OUT}) > V_{FWDTH}$ to $V_{OUT}\uparrow$		43		$\mu\text{s}$
t <sub>RCB</sub>	Reverse Current Blocking comparator response time	$(V_{OUT} - V_{IN}) > 1.3 \times V_{REVTH}$ to BFET OFF		1.1		$\mu\text{s}$
t <sub>SPLYGDA</sub>	Supply Good assertion de-glitch			14.7		$\mu\text{s}$
t <sub>SPLYGDD</sub>	Supply Good de-assertion de-glitch			14.3		$\mu\text{s}$



### 7.6 Switching Characteristics

The output rising slew rate is internally controlled and constant across the entire operating voltage range to ensure the turn on timing is not affected by the load conditions. The rising slew rate can be adjusted by adding capacitance from the dVdt pin to ground. As  $C_{dVdt}$  is increased it will slow the rising slew rate (SR). See Slew Rate and Inrush Current Control (dVdt) section for more details. The Turn-Off Delay and Fall Time, however, are dependent on the RC time constant of the load capacitance ( $C_{OUT}$ ) and Load Resistance ( $R_L$ ). The Switching Characteristics are only valid for the power-up sequence where the supply is available in steady state condition and the load voltage is completely discharged before the device is enabled. Typical values are taken at  $T_J = 25^\circ\text{C}$  unless specifically noted otherwise.  $R_{OUT} = 100 \Omega$ ,  $C_{OUT} = 1 \mu\text{F}$

PARAMETER	VIN	$C_{dVdt} = \text{Open}$	$C_{dVdt} = 3.3 \text{ nF}$	$C_{dVdt} = 6.8 \text{ nF}$	UNITS	
$t_{D,ON}$	Turn on delay	3.5	0.15	0.78	1.31	ms
		12	0.17	1.04	2.04	
		23	0.18	1.60	3.44	
$SR_{ON}$	Output rising slew rate	3.5	14.40	1.25	0.58	V/ms
		12	25.30	1.36	0.60	
		23	38.30	1.44	0.65	
$t_R$	Rise time	3.5	0.20	2.12	4.59	ms
		12	0.36	7.04	17.08	
		23	0.47	12.83	27.70	
$t_{ON}$	Turn on time	3.5	0.41	2.88	5.89	ms
		12	0.55	8.09	19.14	
		23	0.65	14.66	31.20	
$t_{D,OFF}$	Turn off delay	3.5	17.30	17.30	17.30	$\mu\text{s}$
		12	15.80	15.80	15.80	
		23	13.50	13.50	13.50	
$t_F$	Fall time	3.5	Depends on $R_{OUT}$ and $C_{OUT}$			$\mu\text{s}$
		12				
		23				

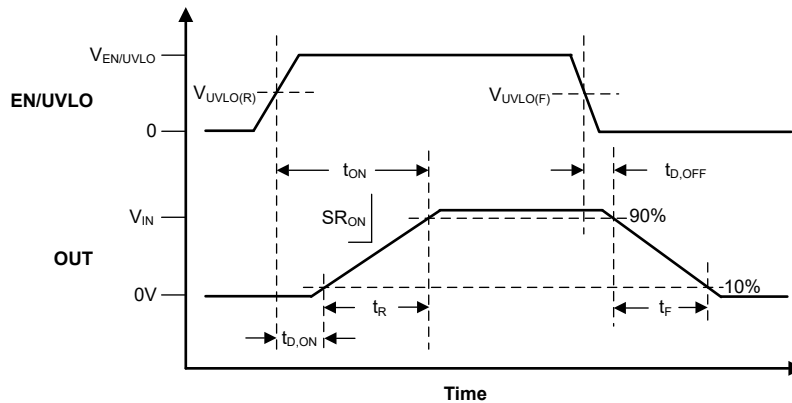
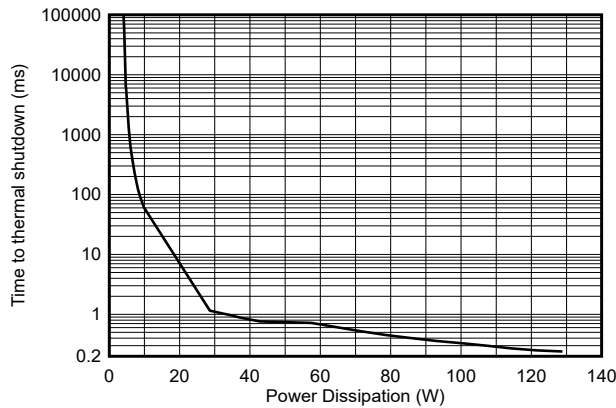


Figure 7-1. Timing Diagram: Switching Characteristics

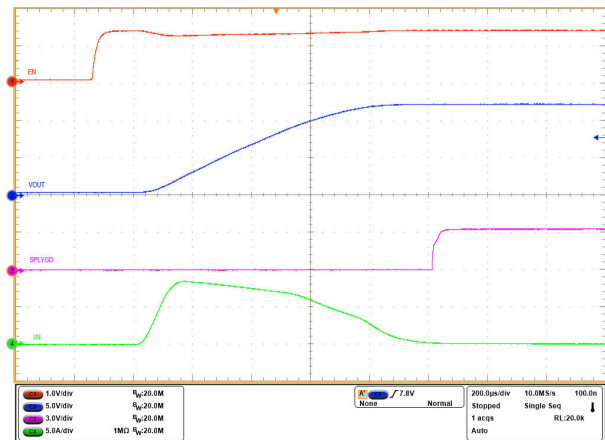
ADVANCE INFORMATION

### 7.7 Typical Characteristics

ADVANCE INFORMATION

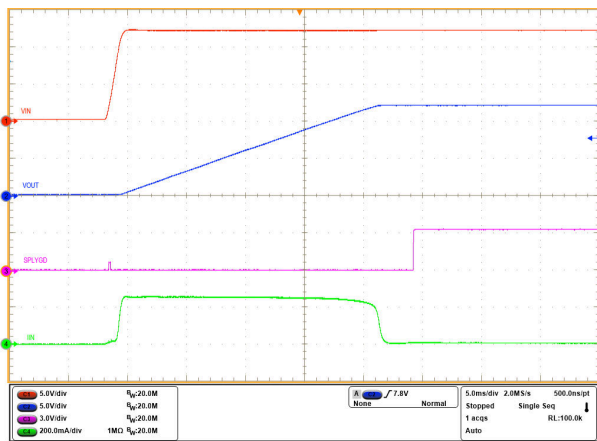


**Figure 7-2. Time to Thermal Shut-Down During Inrush State**



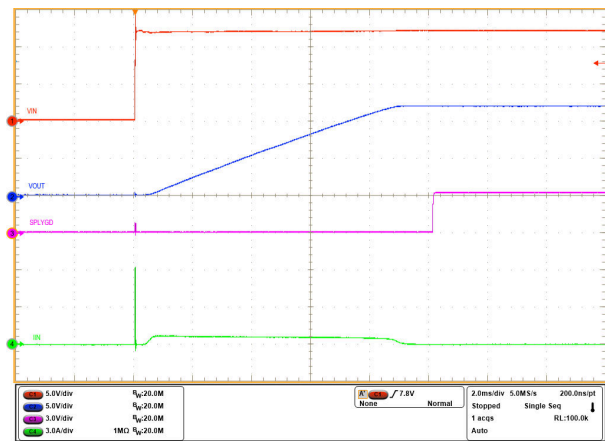
$V_{IN} = 12\text{ V}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $C_{dVdt} = \text{Open}$ ,  $V_{EN/UVLO}$  stepped up to 2 V

**Figure 7-3. Start Up With Enable**



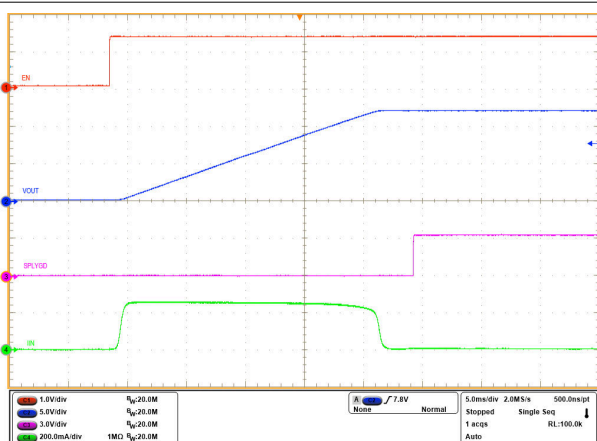
$V_{EN/UVLO} = 2\text{ V}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $C_{dVdt} = 10\ \text{nF}$ ,  $V_{IN}$  ramped up to 12 V

**Figure 7-4. Start Up With Supply**



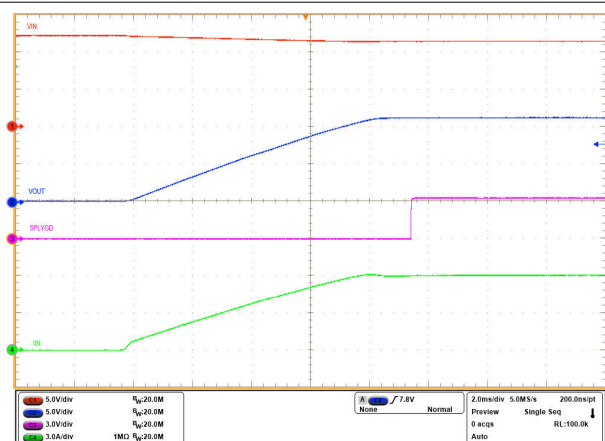
$C_{OUT} = 220\ \mu\text{F}$ ,  $C_{dVdt} = 10\ \text{nF}$ , EN/UVLO connected to IN through resistor ladder, 12 V hot-plugged to IN

**Figure 7-5. Input Hot-Plug**



$V_{IN} = 12\text{ V}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $C_{dVdt} = 10\ \text{nF}$ ,  $V_{EN/UVLO}$  stepped up to 2 V

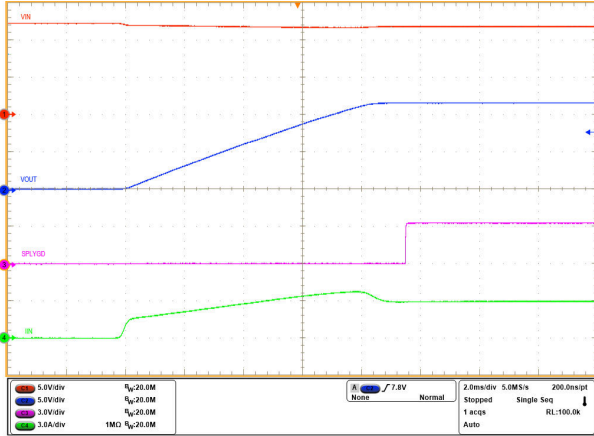
**Figure 7-6. Inrush Current With Capacitive Load**



$V_{IN} = 12\text{ V}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $R_{OUT} = 2\ \Omega$ ,  $C_{dVdt} = 3300\ \text{pF}$ ,  $V_{EN/UVLO}$  stepped up to 2 V

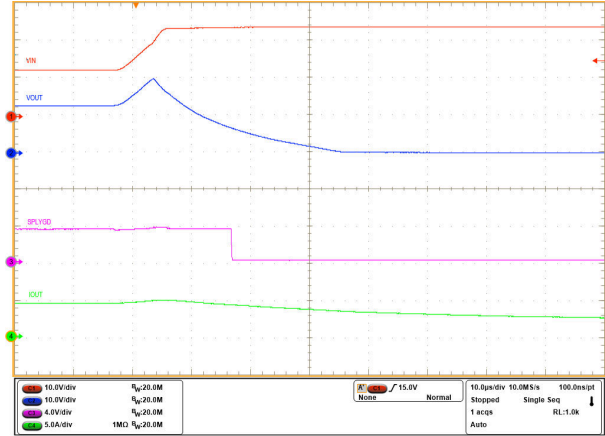
**Figure 7-7. Inrush Current With Resistive and Capacitive Load**

## 7.7 Typical Characteristics (continued)



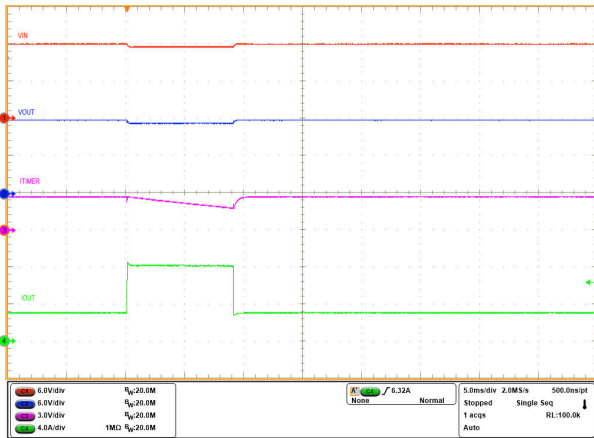
$V_{IN} = 12\text{ V}$ ,  $C_{OUT} = 690\ \mu\text{F}$ ,  $R_{OUT} = 4\ \Omega$ ,  $C_{dVdt} = 3300\ \text{pF}$ ,  
 $V_{EN/UVLO}$  stepped up to 2 V

**Figure 7-8. Inrush Current With Resistive and Capacitive Load**



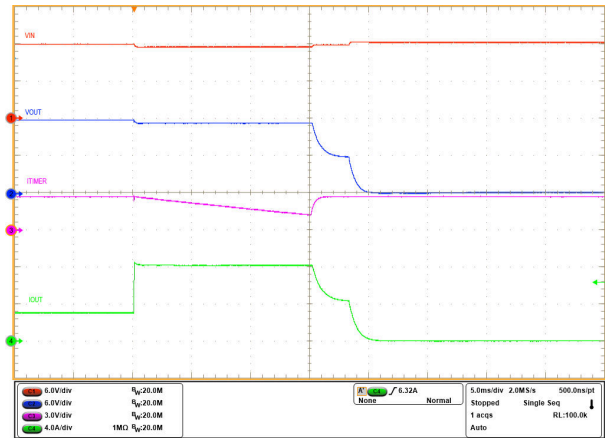
$V_{IN}$  Overvoltage threshold set to 16.5 V,  $V_{IN}$  ramped up from 12 V to 16 V

**Figure 7-9. Overvoltage Lockout Response**



$V_{IN} = 12\text{ V}$ ,  $C_{TIMER} = 22\ \text{nF}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $I_{LIM} = 4.5\ \text{A}$ ,  $I_{OUT}$   
 ramped from 3 A → 8 A → 3 A within 9 ms

**Figure 7-10. Transient Overcurrent Blanking Timer Response**

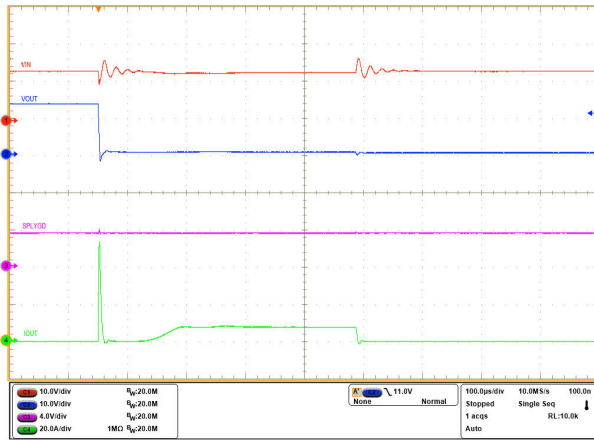


$V_{IN} = 12\text{ V}$ ,  $C_{TIMER} = 22\ \text{nF}$ ,  $C_{OUT} = 220\ \mu\text{F}$ ,  $I_{LIM} = 4.5\ \text{A}$ ,  $I_{OUT}$   
 stepped from 3 A → 9 A

**Figure 7-11. Active Current Limit Response Followed by TSD**

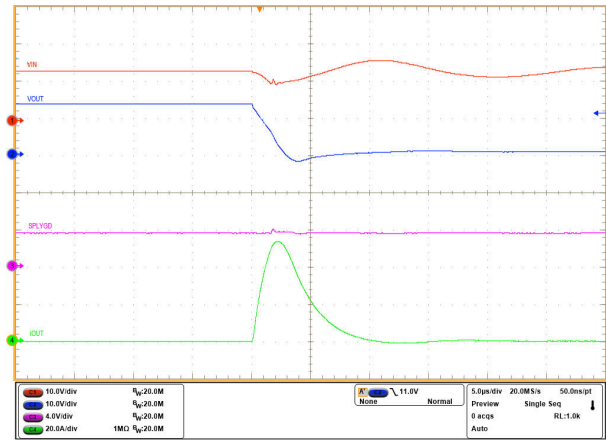
## 7.7 Typical Characteristics (continued)

ADVANCE INFORMATION



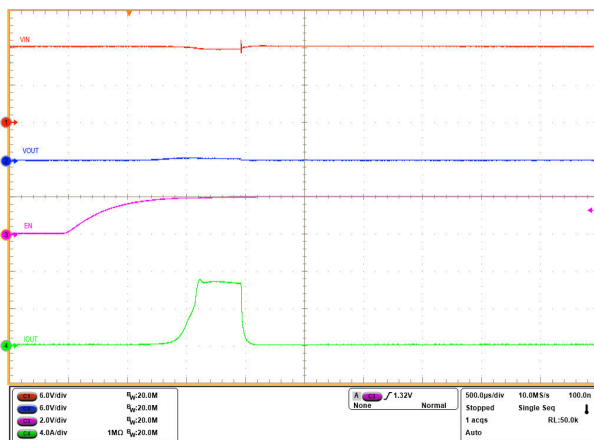
$V_{IN} = 12\text{ V}$ ,  $I_{LIM} = 9\text{ A}$ ,  $V_{EN/UVLO} = 2\text{ V}$ , OUT stepped from Open → Short-circuit to GND

**Figure 7-12. Output Short-Circuit During Steady State**



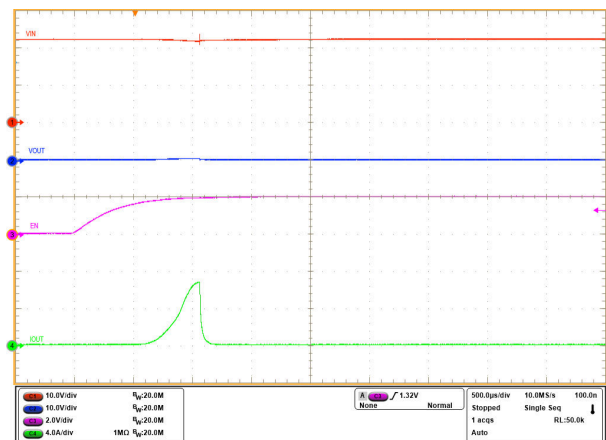
$V_{IN} = 12\text{ V}$ ,  $I_{LIM} = 9\text{ A}$ ,  $V_{EN/UVLO} = 2\text{ V}$ , OUT stepped from Open → Short-circuit to GND

**Figure 7-13. Output Short-Circuit During Steady State (Zoomed In)**



$V_{IN} = 12\text{ V}$ , OUT short-circuit to GND,  $I_{LIM} = 4.5\text{ A}$ ,  $V_{EN/UVLO}$  stepped from 0 V to 2 V

**Figure 7-14. Power Up Into Short-Circuit**



$V_{IN} = 22\text{ V}$ , OUT short-circuit to GND,  $I_{LIM} = 9\text{ A}$ ,  $V_{EN/UVLO}$  stepped from 0 V to 2 V

**Figure 7-15. Power Up Into Short-Circuit**

## 8 Detailed Description

### 8.1 Overview

The TPS25948xx is an eFuse with integrated power path that is used to ensure safe power delivery in a system. The device starts its operation by monitoring the IN and OUT bus voltage. When the supply voltage ( $V_{IN}$  or  $V_{OUT}$ ) exceeds the Undervoltage Protection threshold ( $V_{UVP}$ ), the device samples the EN/UVLO pin. A high level ( $> V_{UVLO}$ ) on this pin enables the internal power path (BFET+HFET) to start conducting and allow current to flow between IN and OUT. When EN/UVLO is held low ( $< V_{UVLO}$ ), the internal power path is turned off to block current flow between IN and OUT.

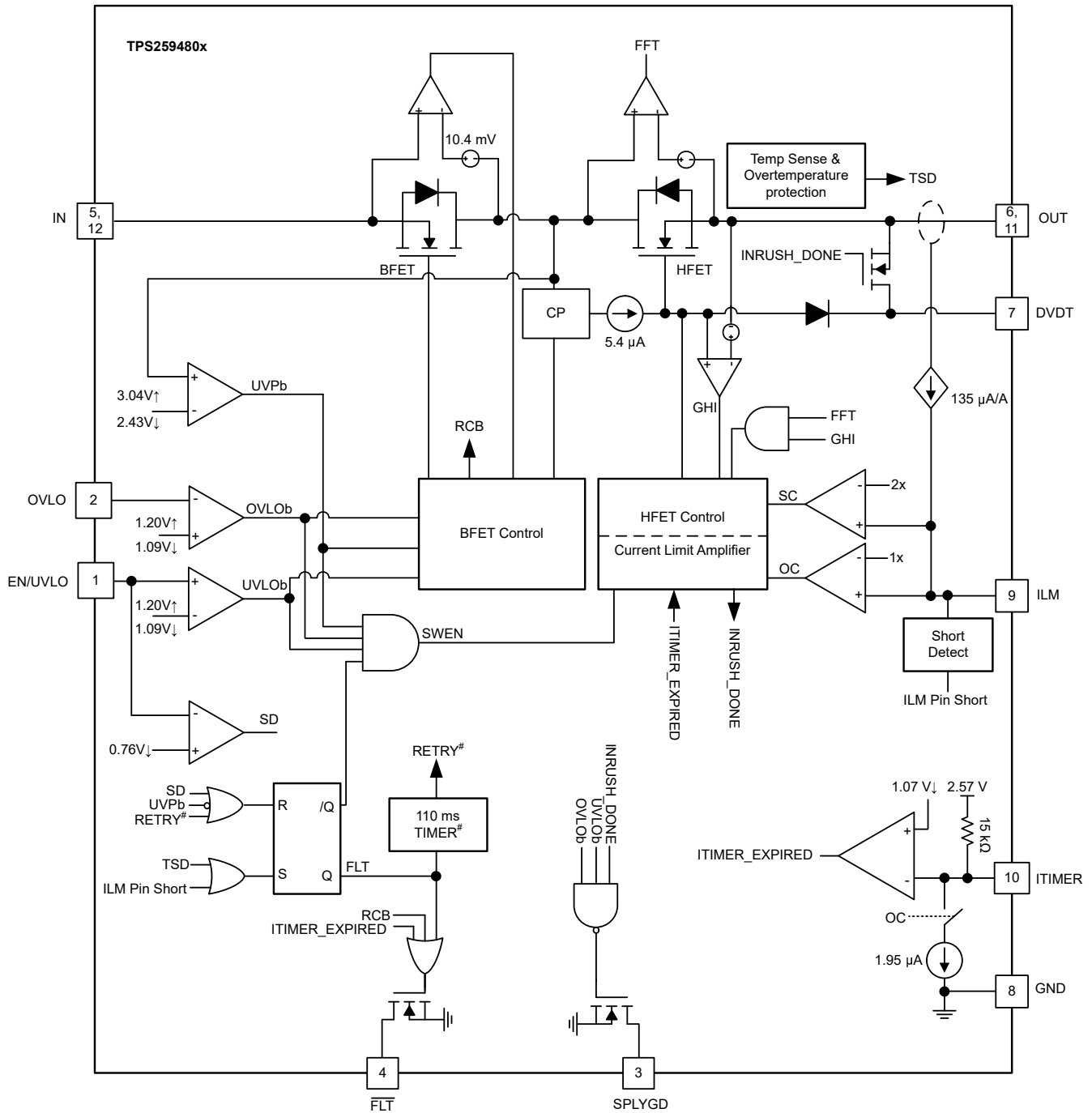
After a successful start-up sequence, the device now actively monitors its load current and bus voltage and controls the internal HFET to ensure that the user adjustable overcurrent limit threshold ( $I_{LIM}$ ) is not exceeded and overvoltage spikes are cut-off once they cross the user adjustable overvoltage lockout threshold ( $V_{OVLO}$ ). The device also provides fast protection against severe overcurrent during short-circuit events. This keeps the system safe from harmful levels of voltage and current. At the same time, a user adjustable overcurrent blanking timer allows the system to pass moderate transient peaks in the load current profile without tripping the eFuse. This ensures a robust protection solution against real faults which is also immune to transients, thereby ensuring maximum system uptime.

The device has integrated reverse current blocking FET (BFET) which operates like an ideal diode. The BFET is linearly regulated to maintain a small constant forward drop ( $V_{FWD}$ ) in forward conduction mode and turned off completely to block reverse current if output voltage exceeds the input voltage. In some device variants, the reverse current blocking can be disabled using an external pin control (RCBCTRL) to allow bi-directional current flow to support applications such as USB On-the-go or DRP (Dual Role Port).

The device also has a built-in thermal sensor based shutdown mechanism to protect itself in case the device temperature ( $T_J$ ) exceeds the recommended operating conditions.

## 8.2 Functional Block Diagram

ADVANCE INFORMATION

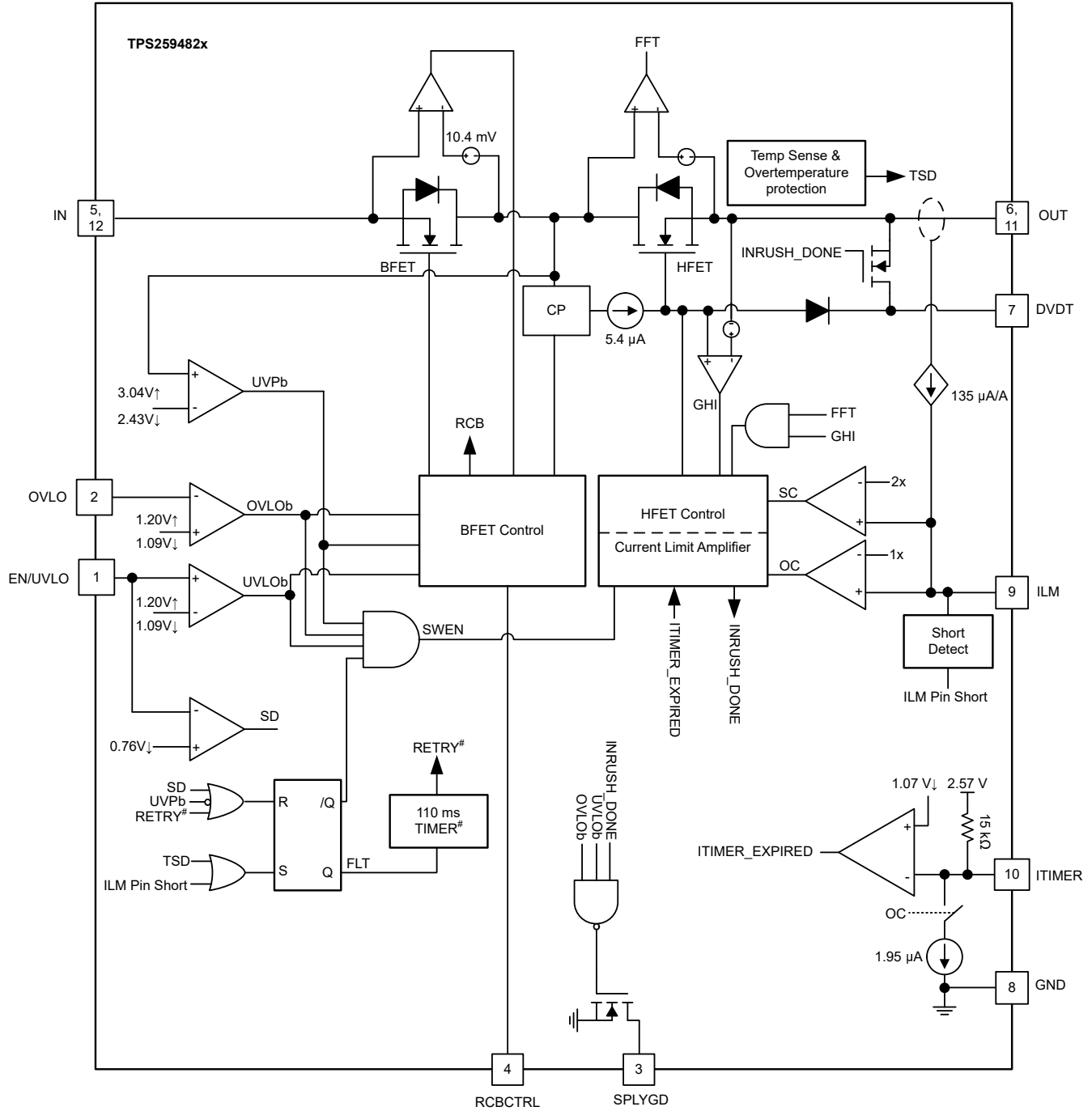


# Not applicable to Latch-off variant (TPS259480L)

Figure 8-1. TPS259480x Block Diagram



ADVANCE INFORMATION



# Not applicable to Latch-off variant (TPS259482L)

**Figure 8-3. TPS259482x Block Diagram**

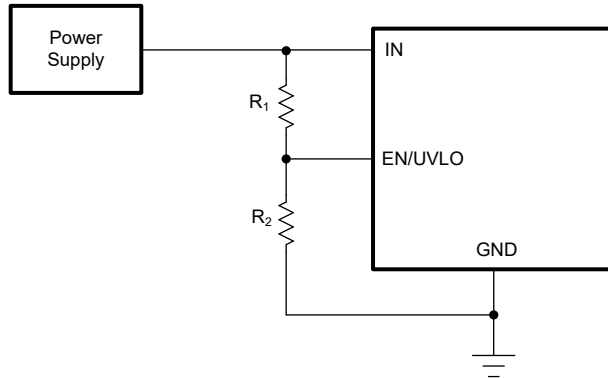


### 8.3 Feature Description

The TPS25948x eFuse is a compact, feature rich power management device that provides detection, protection and indication in the event of system faults.

#### 8.3.1 Undervoltage Lockout (UVLO & UVP)

The TPS25948xx implements Undervoltage Protection on IN and OUT in case the applied voltage becomes too low for the system or device to properly operate. The Undervoltage Protection has a default lockout threshold of  $V_{UVP}$  which is fixed internally. Also, the UVLO comparator on the EN/UVLO pin allows the Undervoltage Protection threshold to be externally adjusted to a user defined value. Figure 8-4 and Equation 1 show how a resistor divider can be used to set the UVLO set point for a given voltage supply.

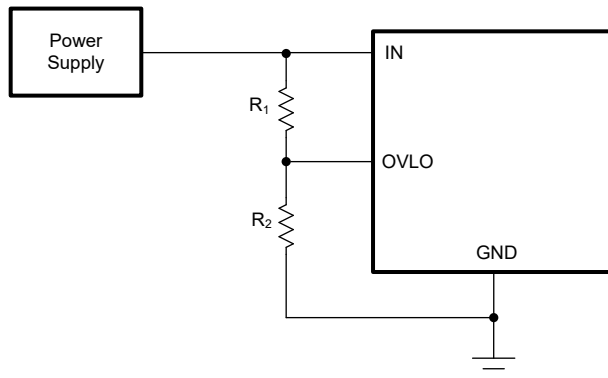


**Figure 8-4. Adjustable Undervoltage Protection**

$$V_{IN(UV)} = V_{UVLO(F)} \times \frac{R_1 + R_2}{R_2} \quad (1)$$

#### 8.3.2 Overvoltage Lockout (OVLO)

The TPS25948xx allows the user to implement Overvoltage protection on the bus to shield the system against supply overvoltage conditions. The internal fast comparator on the OVLO pin allows the Overvoltage Lockout threshold to be adjusted to a user defined value. Once the voltage at the OVLO pin crosses the OVLO rising threshold  $V_{OV(R)}$ , the device turns off both the FETs to cut off the power path. Thereafter, the devices wait for the voltage at the OVLO pin to fall below the OVLO falling threshold  $V_{OV(F)}$  before the FETs are turned ON again. The rising and falling thresholds are slightly different to provide hysteresis. Figure 8-5 and Equation 2 show how a resistor divider can be used to set the OVLO set point for a given voltage supply.



**Figure 8-5. Adjustable Overvoltage Protection**

$$V_{IN(OV)} = V_{OV(F)} \times \frac{R1 + R2}{R2} \quad (2)$$

While recovering from a OVLO event, the TPS25948xx bypasses the inrush control (dVdt) and starts up in a current limited manner to provide faster turn ON and minimize power supply droop during supply transient conditions.

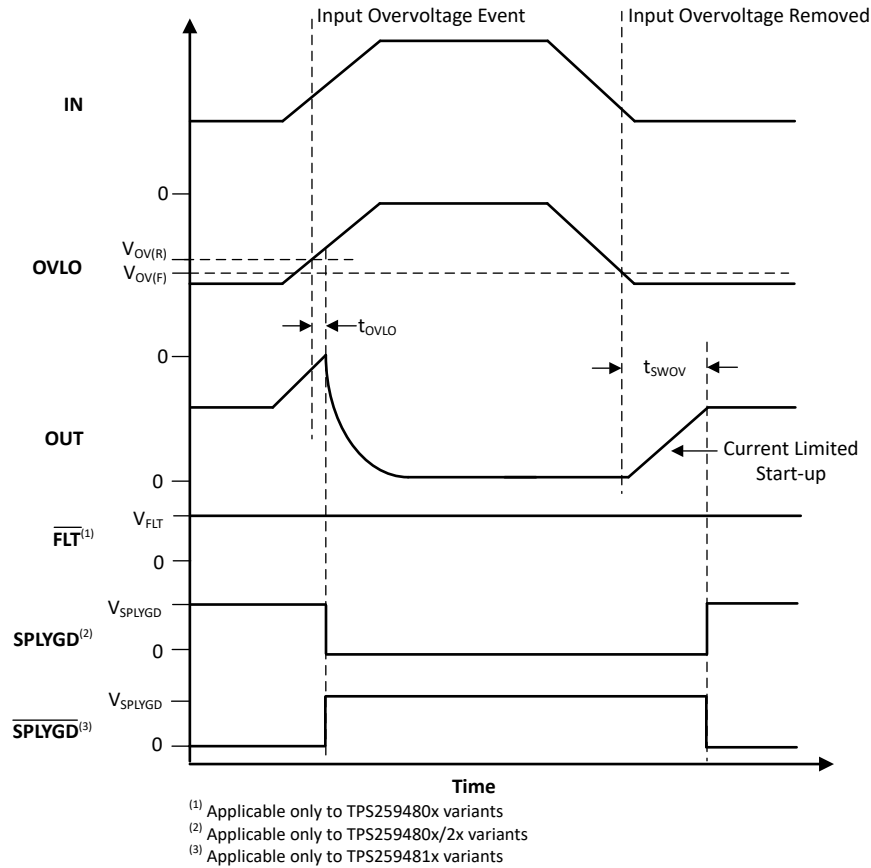


Figure 8-6. TPS25948xx Overvoltage Lockout and Recovery

### 8.3.3 Inrush Current, Overcurrent, and Short Circuit Protection

TPS25948xx incorporates four levels of protection against overcurrent:

1. Adjustable slew rate (dVdt) for inrush current control
2. Adjustable threshold ( $I_{LIM}$ ) for overcurrent protection during start-up or steady-state
3. Adjustable threshold ( $I_{SC}$ ) for fast-trip response to severe overcurrent during start-up or steady-state
4. Fixed threshold ( $I_{FT}$ ) for fast-trip response to quickly protect against hard output short-circuits during steady-state

#### 8.3.3.1 Slew Rate (dVdt) and Inrush Current Control

During hot-plug events or while trying to charge a large output capacitance at start-up, there can be a large inrush current. If the inrush current is not managed properly, it can damage the input connectors and/or cause the system power supply to droop leading to unexpected restarts elsewhere in the system. The inrush current during turn on is directly proportional to the load capacitance and rising slew rate.

Equation 3 can be used to find the slew rate (SR) required to limit the inrush current ( $I_{INRUSH}$ ) for a given load capacitance ( $C_{OUT}$ ):

$$I_{INRUSH} \text{ (mA)} = C_{OUT} \text{ (}\mu\text{F)} \times SR_{ON} \text{ (V/ms)} \quad (3)$$

A capacitor can be connected to the dVdt pin to control the rising slew rate and lower the inrush current during turn on. The required  $C_{dVdt}$  capacitance to produce a given slew rate can be calculated using the equation:

$$CDVDT \text{ (pF)} = \frac{5000}{SRON \text{ (V/ms)}} \quad (4)$$

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

**Note**

1. Slew rate control during start-up is provided only on the HFET which enables inrush current control from IN to OUT.
2. For  $C_{dVdt} > 10 \text{ nF}$ , it's recommended to add a  $100\text{-}\Omega$  resistor in series with the capacitor on the dVdt pin.

**8.3.3.2 Active Current Limiting**

The TPS25948xx responds to output overcurrent conditions by actively limiting the current after a user adjustable transient fault blanking interval. When the load current exceeds the set overcurrent threshold ( $I_{LIM}$ ) set by the ILM pin resistor ( $R_{ILM}$ ), but stays lower than the short-circuit threshold ( $2 \times I_{LIM}$  or  $I_{FFT}$  depending on the variant), the device starts discharging the ITIMER pin capacitor using an internal  $1.95\text{-}\mu\text{A}$  pull-down current. If the load current drops below the overcurrent threshold before the ITIMER capacitor ( $C_{ITIMER}$ ) discharges by  $\Delta V_{ITIMER}$ , the ITIMER is reset by pulling it up to  $V_{INT}$  internally and the current limit action is not engaged. This allows short load transient pulses to pass through the device without getting current limited. If the overcurrent condition persists, the  $C_{ITIMER}$  continues to discharge and once it discharges by  $\Delta V_{ITIMER}$ , the current limit starts regulating the HFET to actively limit the current to the set overcurrent threshold ( $I_{LIM}$ ). At the same time, the  $C_{ITIMER}$  is charged up to  $V_{INT}$  again so that it is at its default state before the next overcurrent event. This ensures the full blanking timer interval is provided for every overcurrent event. Equation 5 can be used to calculate the  $R_{ILM}$  value for a desired overcurrent threshold.

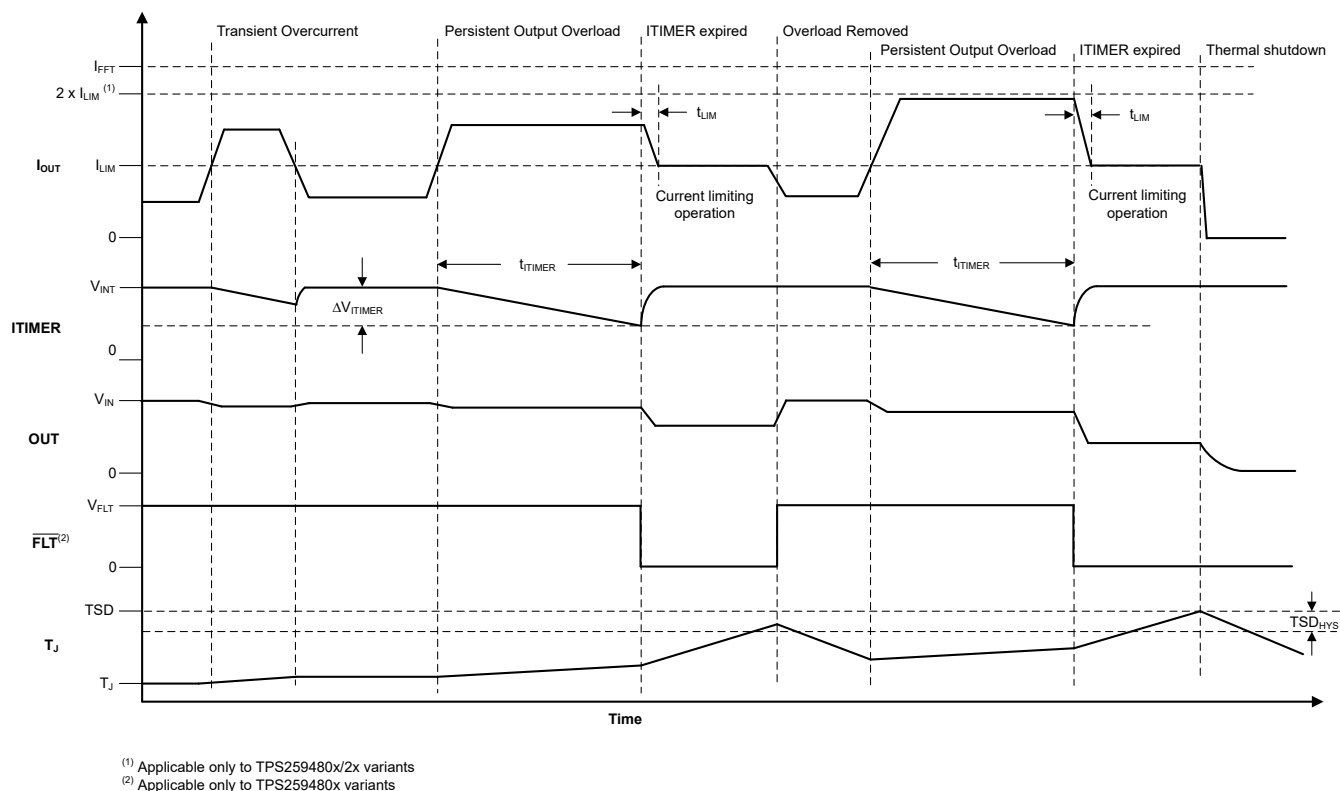
$$RILM \text{ (}\Omega\text{)} = \frac{4834}{ILIM \text{ (A)}} \quad (5)$$

**Note**

1. The TPS259480x/2x variants allow a maximum transient load current up to  $2 \times I_{LIM}$  for the ITIMER duration. The TPS259481x variants allow a maximum transient load current up to  $I_{FFT}$  for the ITIMER duration.
2. Leaving the ILM pin Open sets the current limit to nearly zero and results in the part entering current limit with the slightest amount of loading at the output.
3. The current limit circuit employs a foldback mechanism. The current limit threshold in the foldback region ( $0 \text{ V} < V_{OUT} < V_{FB}$ ) is lower than the steady state current limit threshold ( $I_{LIM}$ ).
4. Shorting the ILM pin to ground at any point during normal operation is detected as a fault and the part shuts down. There's a minimum current ( $I_{FLT}$ ) which the part allows in this condition before the pin short condition is detected.

The duration for which transients are allowed can be adjusted using an appropriate capacitor value from ITIMER pin to ground. The  $C_{ITIMER}$  value needed to set the desired transient overcurrent blanking interval can be calculated using Equation 6 below.

$$CITIMER \text{ (nF)} = \frac{tITIMER \text{ (ms)} \times IITIMER \text{ (}\mu\text{A)}}{\Delta VITIMER \text{ (V)}} \quad (6)$$


**Figure 8-7. TPS25948xx Active Current Limit Response**
**Note**

1. Leave the ITIMER pin open to allow the part to limit the current with the minimum possible delay.
2. Shorting the ITIMER pin to ground results in minimum overcurrent response delay (similar to ITIMER pin open condition), but increases the device current consumption. This is not a recommended mode of operation.
3. Active current limiting based on  $R_{ILIM}$  is active during startup. In case the startup current exceeds  $I_{LIM}$ , the device regulates the current to the set limit. However, during startup the current limit is engaged without waiting for the ITIMER delay.
4. Increasing the  $C_{ITIMER}$  value extends the overcurrent blanking interval, but it also extends the time needed for the  $C_{ITIMER}$  to recharge up to  $V_{INT}$ . If the next overcurrent event occurs before the  $C_{ITIMER}$  is recharged fully, it will take lesser time to discharge to the ITIMER expiry threshold, thereby providing a shorter blanking interval than intended.

During active current limit, the output voltage will drop resulting in increased device power dissipation across the HFET. If the device internal temperature ( $T_J$ ) exceeds the thermal shutdown threshold (TSD), the HFET is turned off. Once the part shuts down due to TSD fault, it would either stay latched off (TPS25948xL variants) or restart automatically after a fixed delay (TPS25948xA variants). See [Overtemperature Protection \(OTP\)](#) for more details on device response to overtemperature.

**8.3.3.3 Short-Circuit Protection**

During an output short-circuit event, the current through the device increases very rapidly. When a severe overcurrent condition is detected, the device triggers a fast-trip response to limit the current to a safe level. For the TPS259480x/2x variants, the internal fast-trip comparator employs a scalable threshold ( $I_{SC} = 2 \times I_{LIM}$ ). This enables the user to adjust the fast-trip threshold rather than using a fixed threshold which can be too high for some low current systems. The device also employs a fixed fast-trip threshold ( $I_{FFT}$ ) to protect fast protection against hard short-circuits during steady state. The fixed fast-trip threshold is higher than the maximum recommended user adjustable scalable fast-trip threshold. The TPS259481x variants employ only

the fixed fast-trip threshold. Once the current exceeds  $I_{SC}$  or  $I_{FFT}$ , the HFET is turned off completely within  $t_{FT}$ . Thereafter, the device tries to turn the HFET back on after a short de-glitch interval (30  $\mu$ s) in a current limited manner instead of a  $dV/dt$  limited manner. This ensures that the HFET has a faster recovery after a transient overcurrent event and minimizes the output voltage droop. However, if the fault is persistent, the device will stay in current limit causing the junction temperature to rise and eventually enter thermal shutdown. See [Overtemperature Protection \(OTP\)](#) section for details on the device response to overtemperature.

Figure 8-8. TPS259480x/2x Short-Circuit Response

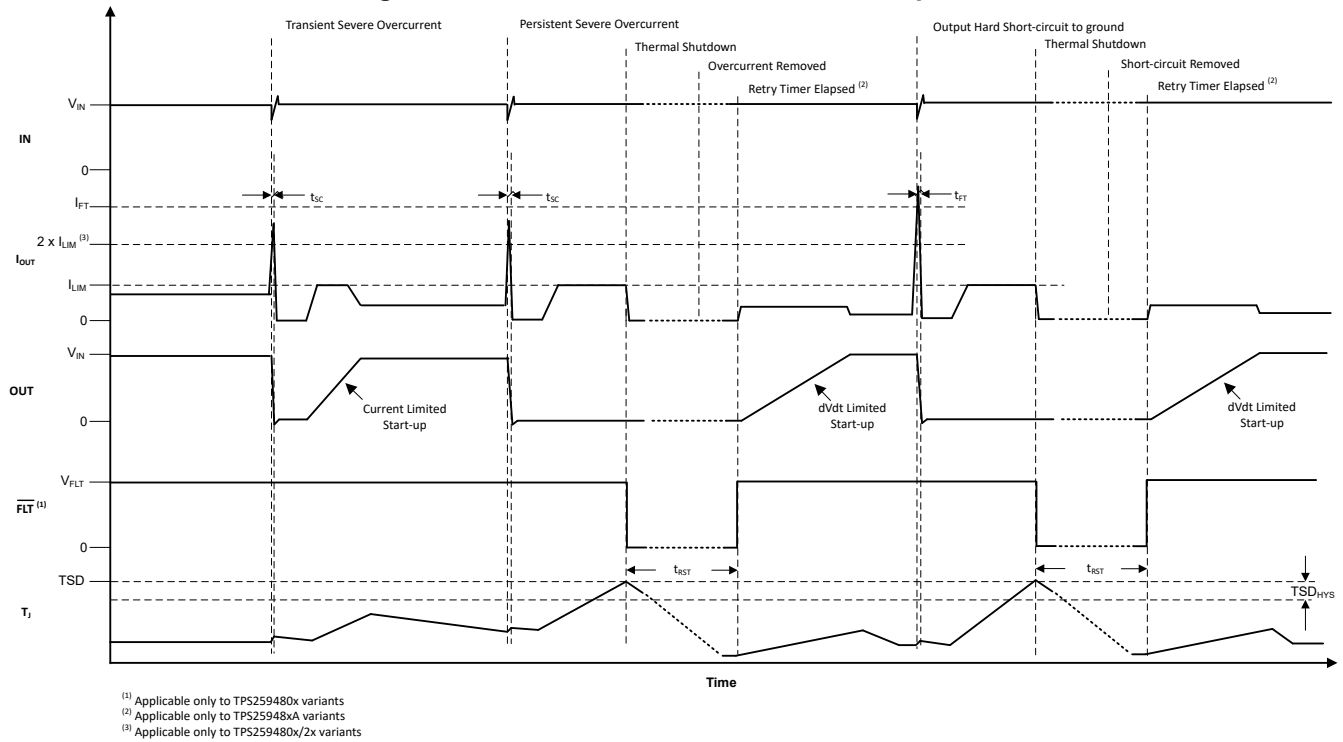
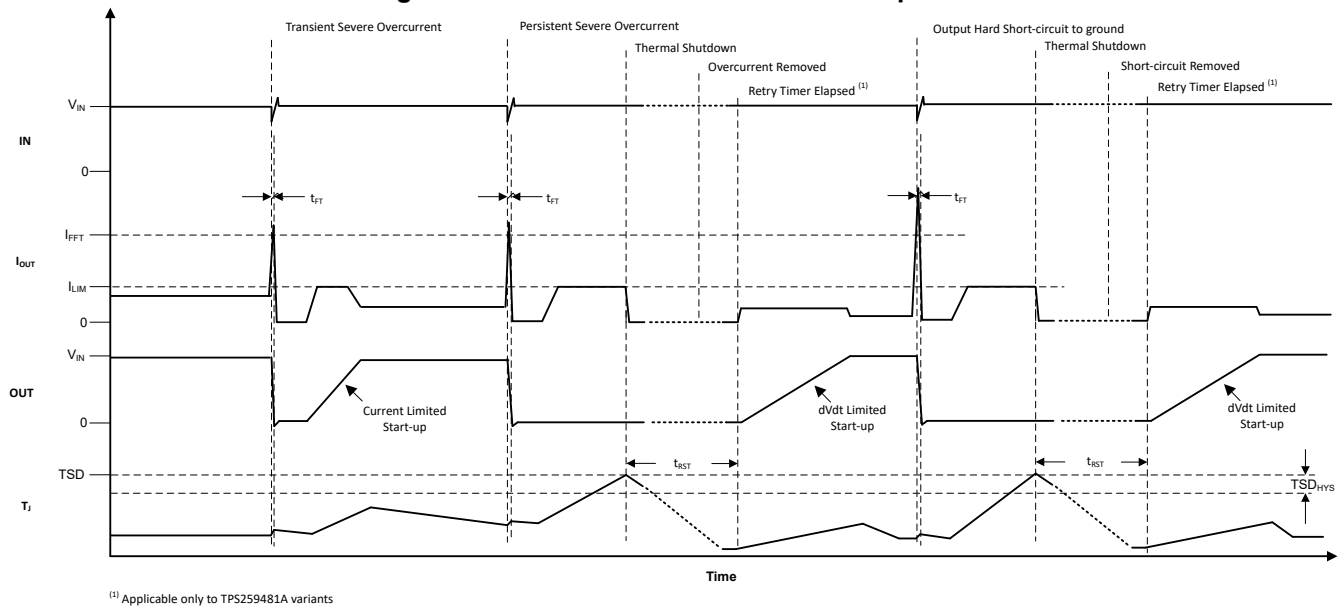


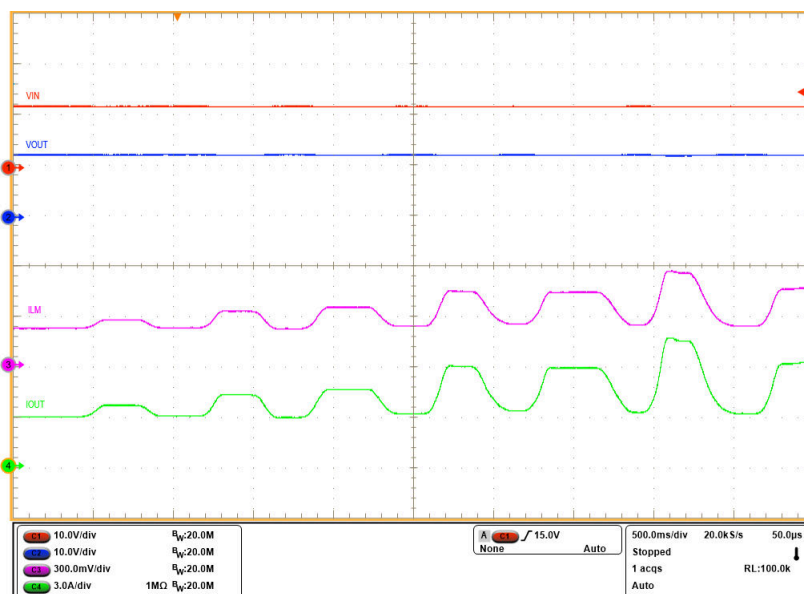
Figure 8-9. TPS259481x Short-Circuit Response



### 8.3.4 Analog Load Current Monitor

The TPS25948xx allows the system to accurately monitor the output load current by providing an analog current sense output on the ILM pin which is proportional to the current through the FET. The user can sense the voltage ( $V_{ILM}$ ) across the  $R_{ILM}$  to get a measure of the output load current.

$$I_{LOAD} (A) = \frac{V_{IMON} (\mu V)}{R_{ILM} (\Omega) \times G_{IMON} (\mu A/A)} \quad (7)$$



$V_{IN} = 12V$ ,  $C_{OUT} = 220\mu F$ ,  $R_{ILM} = 536\Omega$ ,  $I_{OUT}$  varied dynamically between 3A and 8A

**Figure 8-10. Analog Load Current Monitor Response**

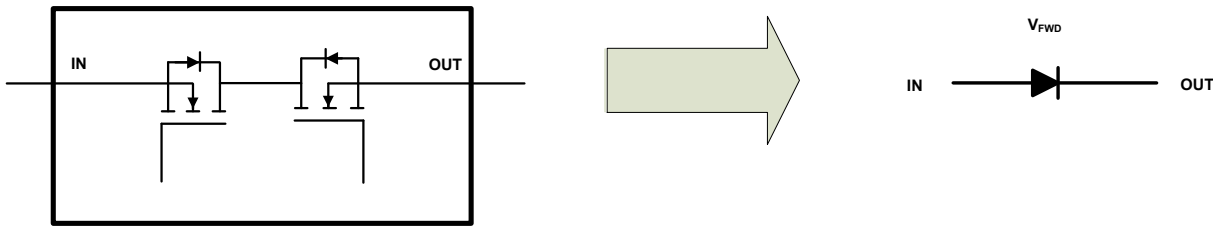
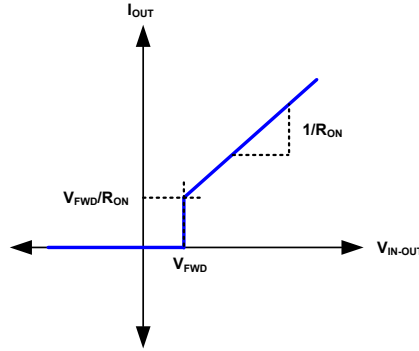
#### Note

The ILM pin is sensitive to capacitive loading. Careful design and layout is needed to ensure the parasitic capacitive loading on the ILM pin is  $< 50\text{ pF}$  for stable operation.

### 8.3.5 Reverse Current Protection

The device functions like an ideal diode and blocks reverse current flow from OUT to IN under all conditions. The device has integrated back-to-back MOSFETs connected in a common drain configuration. The voltage drop between the IN and OUT pins is constantly monitored and the gate drive of the blocking FET (BFET) is adjusted as needed to regulate the forward voltage drop at  $V_{FWD}$ . This closed loop regulation scheme (linear ORing control) enables graceful turn off of the MOSFET during a reverse current event and ensures there's almost no DC reverse current flow.

The device also uses a conventional comparator ( $V_{REVTH}$ ) based reverse blocking mechanism to provide fast response ( $t_{RCB}$ ) to transient reverse currents. Once the device enters reverse current blocking condition, it waits for the  $(V_{IN} - V_{OUT})$  forward drop to exceed the  $V_{FWDTH}$  before it performs a fast recovery to reach full forward conduction state. This provides sufficient hysteresis to prevent supply noise or ripple from affecting the reverse current blocking response. The recovery from reverse current blocking is very fast ( $t_{SWRCB}$ ). This ensures minimum supply droop which is helpful in applications such as supply MUXing/ORing and USB Fast Role Swap (FRS).



BFET operating state

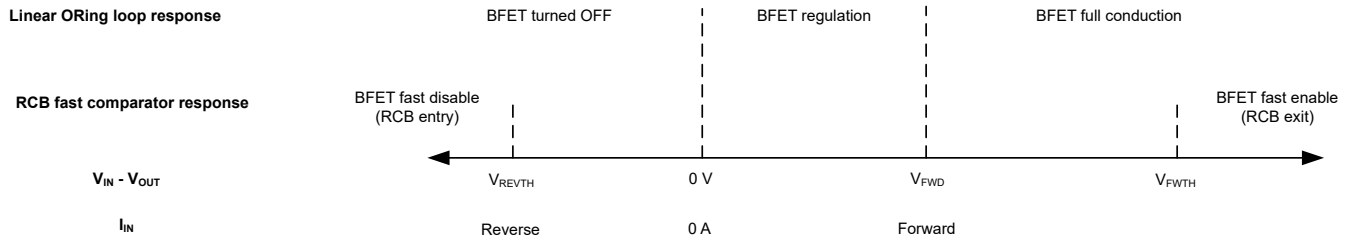
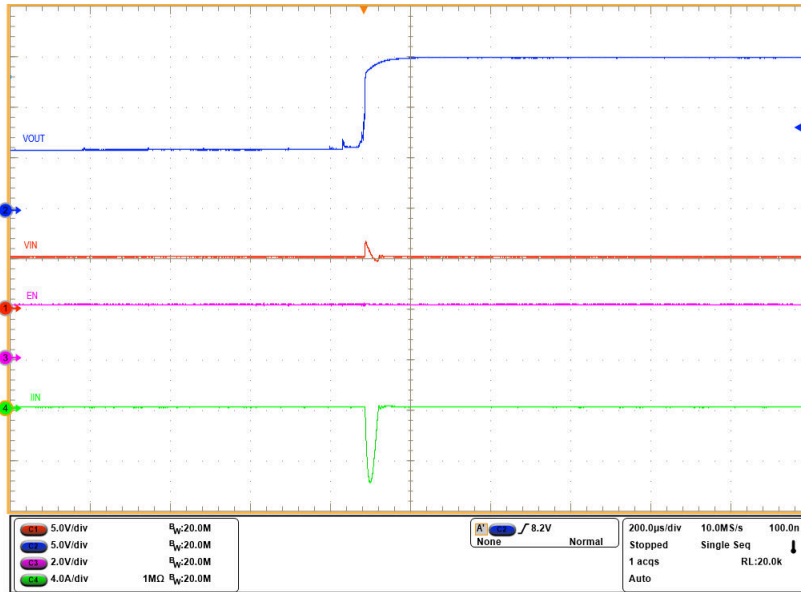


Figure 8-11. Reverse Current Blocking Response

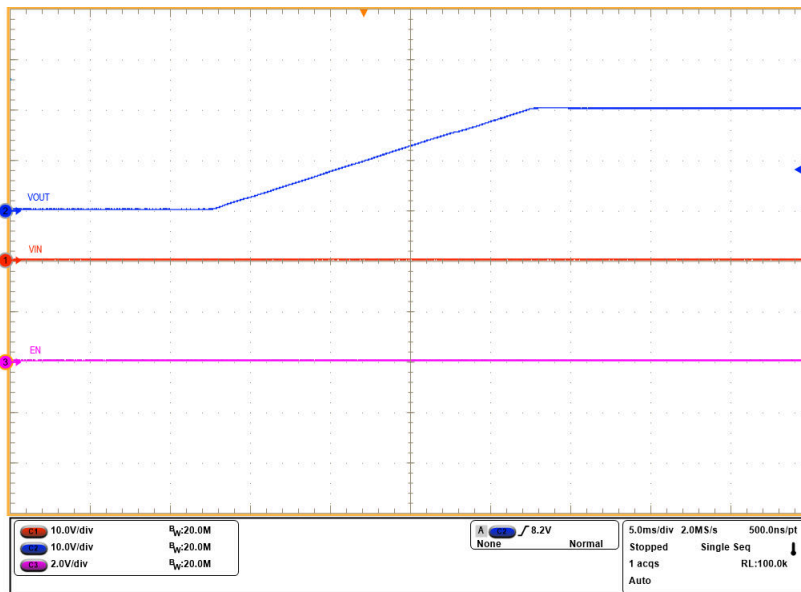
The waveforms below illustrate the reverse current blocking performance in various scenarios.

During fast voltage step at output (e.g. hot-plug), the fast comparator based reverse blocking mechanism ensures minimum jump/glitch on the input rail.



**Figure 8-12. Reverse Current Blocking Performance During Fast Voltage Step at Output**

During slow voltage ramp at output, the linear ORing based reverse blocking mechanism ensures there's almost no DC current flow from OUT to IN, thereby avoiding input rail from getting slowly charged up to output voltage.

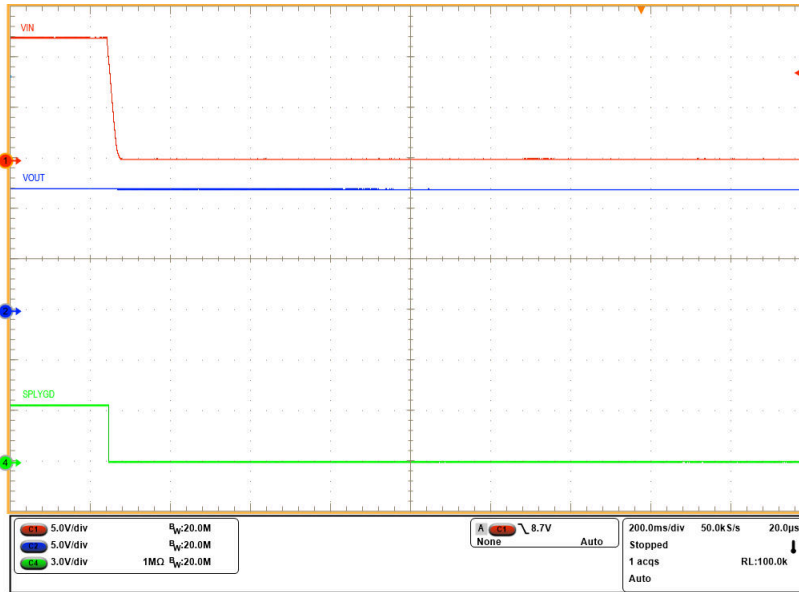


**Figure 8-13. Reverse Current Blocking Performance During Slow Voltage Ramp at Output**

When the input supply droops or gets disconnected while the output storage element (bulk capacitor or super capacitor) is charged to the full voltage, the linear ORing scheme minimizes the self-discharge from OUT to IN. This ensures maximum hold-up time for the output storage element in critical power back-up applications.

It also prevents incorrect supply presence indication in applications which sense the input voltage to detect if the supply is connected.





**Figure 8-14. Reverse Current Blocking Performance During Input Supply Failure**

The TPS259481x/2x variants provide the option of disabling the reverse current blocking scheme using the RCBCTRL pin. Leaving the RCBCTRL pin floating or pulling it high enables the reverse current blocking during steady-state, while pulling the pin low disables it.

**Note**

RCBCTRL pin controls the reverse current blocking mechanism only during steady-state. It has no effect during disabled or fault state where the reverse current blocking is always active.

**8.3.6 Overtemperature Protection (OTP)**

The device monitors the internal die temperature ( $T_J$ ) at all times and shuts down the part as soon as the temperature exceeds a safe operating level (TSD) thereby protecting the device from damage. The device will not turn back on until the junction cools down sufficiently, that is the die temperature falls below ( $TSD - TSD_{HYS}$ ).

When the TPS25948xL (latch-off variant) detects thermal overload, it will be shut down and remain latched-off until the device is power cycled or re-enabled. When the TPS25948xA (auto-retry variant) detects thermal overload, it will remain off until it has cooled down by  $TSD_{HYS}$ . Thereafter, it will remain off for an additional delay of  $t_{RST}$  after which it will automatically retry to turn on if it is still enabled.

**Table 8-1. Thermal Shutdown**

Device	Enter TSD	Exit TSD
TPS25948xL (Latch-Off)	$T_J \geq TSD$	$T_J < TSD - TSD_{HYS}$ $V_{IN}$ cycled to 0 V and then above $V_{UVP(R)}$ OR EN/UVLO toggled below $V_{SD(F)}$
TPS25948xA (Auto-Retry)	$T_J \geq TSD$	$T_J < TSD - TSD_{HYS}$ $V_{IN}$ cycled to 0 V and then above $V_{UVP(R)}$ OR EN/UVLO toggled below $V_{SD(F)}$ OR $t_{RST}$ timer expired

**8.3.7 Fault Response and Indication (FLT)**

The following table summarizes the device response to various fault conditions. Additionally, an active low external fault indication (FLT) pin is available on the TPS259480x variants.

**Table 8-2. Fault Summary**

Event	Protection Response	Fault Latched Internally	FLT Pin status <sup>(1)</sup>	FLT Assertion Delay <sup>(1)</sup>
Overtemperature	Shutdown	Y	L	
Undervoltage (UVP or UVLO)	Shutdown	N	H	
Input Overvoltage	Shutdown	N	H	
Transient Overcurrent ( $I_{LIM} < I_{OUT} < 2 \times I_{LIM}$ or $I_{FFT}$ )	None	N	L	
Persistent Overcurrent	Current Limit	N	L	$t_{TIMER}$
Output Short-Circuit to GND	Circuit Breaker followed by Current Limit	N	H	
ILM Pin Open (During Steady State)	Shutdown	N	L	$t_{TIMER}$
ILM Pin Shorted to GND	Shutdown	Y	L	
Reverse Current ( $(V_{OUT} - V_{IN}) > V_{REVTH}$ )	Reverse Current Blocking	N	H	

(1) Applicable to TPS259480x variants only

Faults which are latched internally can be cleared either by power cycling the part (pulling  $V_{IN}$  to 0 V) or by pulling the EN/UVLO pin voltage below  $V_{SD}$ . This also releases the  $\overline{FLT}$  pin pull-down for the TPS259480x variants and resets the  $t_{RST}$  timer for the TPS25948xA (auto-retry) variants.

During a latched fault, pulling the EN/UVLO just below the UVLO threshold has no impact on the device. This is true for both TPS25948xL (latch-off) & TPS25948xA (auto-retry) variants.

For TPS25948xA (auto-retry) variants, on expiry of the  $t_{RST}$  timer after a fault, the device restarts automatically and the  $\overline{FLT}$  pin is de-asserted (TPS259480A variant).

### 8.3.8 Supply Good Indication ( $\overline{SPLYGD}/\overline{SPLYGD}$ )

The TPS25948xx provides a digital output ( $\overline{SPLYGD}/\overline{SPLYGD}$ ) which is asserted to indicate when the priority input supply is in a valid range (above UVP/UVLO and below OVLO thresholds) and the device has successfully completed its inrush sequence. The  $\overline{SPLYGD}/\overline{SPLYGD}$  pin is an open-drain signal which needs to be pulled up to an external supply. For the TPS259480x/2x variants,  $\overline{SPLYGD}$  is an active high output. For the TPS259481x variant,  $\overline{SPLYGD}$  is an active low output.

After power up,  $\overline{SPLYGD}/\overline{SPLYGD}$  pin is de-asserted initially. The device initiates a inrush sequence in which the HFET is turned on in a controlled manner. When the FET gate voltage has reached the full overdrive indicating that the inrush sequence is complete and device is capable of delivering full power, the  $\overline{SPLYGD}/\overline{SPLYGD}$  pin is asserted. Thereafter, the  $\overline{SPLYGD}/\overline{SPLYGD}$  pin is de-asserted only if the input supply becomes invalid (below UVP/UVLO or above OVLO thresholds). No load side events/faults have any control over the  $\overline{SPLYGD}/\overline{SPLYGD}$  de-assertion.

This pin is used to control the auxiliary channel when 2 TPS25948xx devices are connected in a priority power MUX configuration. It can also be used as a supply valid status indication to the downstream load or system supervisor.

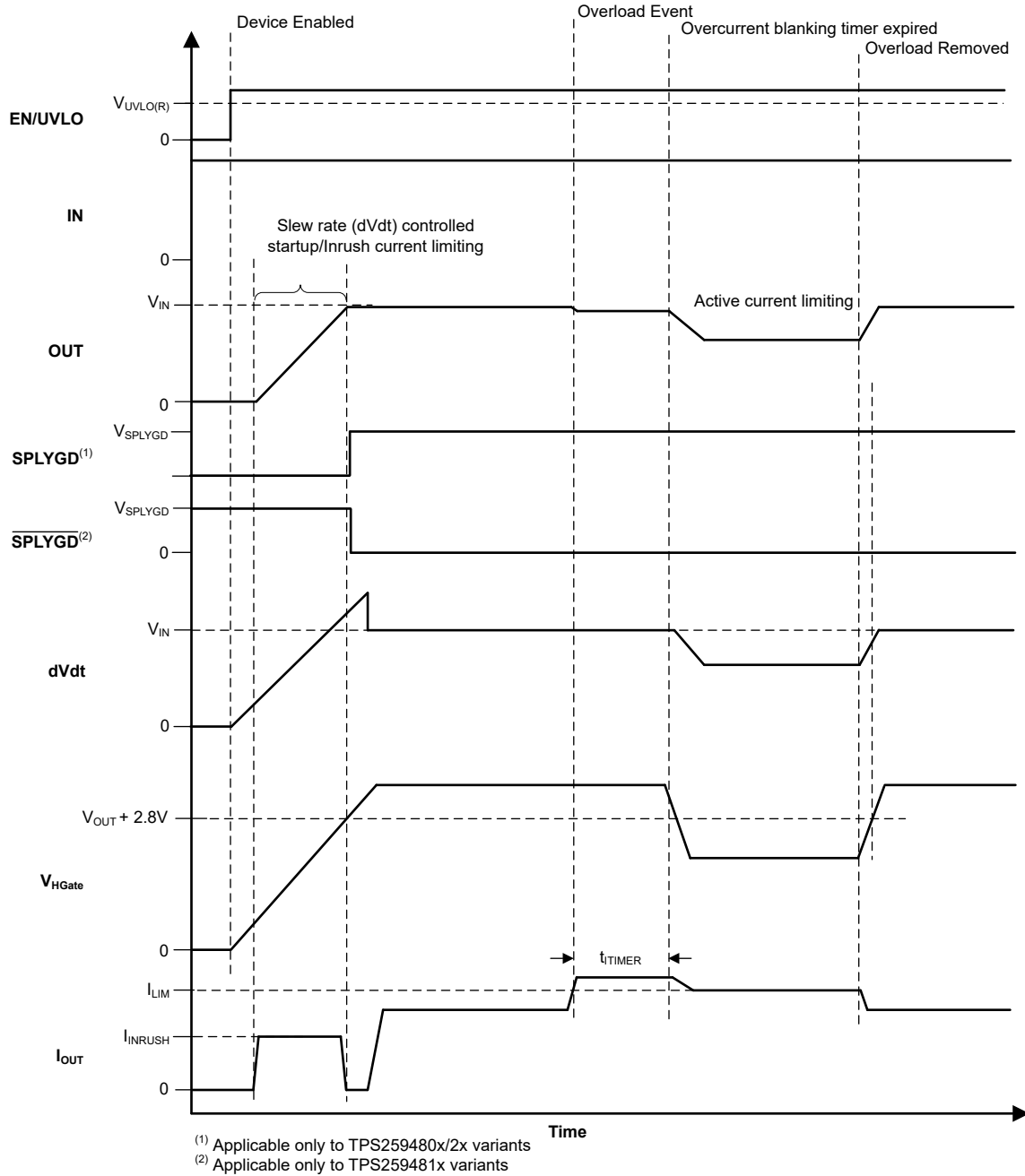


Figure 8-15. TPS25948xx SPLYGD behavior

Table 8-3. TPS25948xx SPLYGD/SPLYGD Indication Summary

Event/Condition	SPLYGD Pin <sup>(1)</sup>	SPLYGD Pin <sup>(2)</sup>
Supply Brownout (UVP)	L	L
Shutdown (EN < V <sub>SD</sub> )	L	L
Undervoltage (UVLO)	L	H
Overvoltage (OVLO)	L	H
Inrush	L	H
Steady State	H	L
Overcurrent	H	L

**Table 8-3. TPS25948xx SPLYGD/SPLYGD Indication Summary (continued)**

Event/Condition	SPLYGD Pin <sup>(1)</sup>	SPLYGD Pin <sup>(2)</sup>
Short-Circuit	H	L
ILM Pin Open	H	L
ILM Pin Shorted to GND	H	L
Reverse current ( $(V_{OUT} - V_{IN}) > V_{REVTH}$ )	H	L
Overtemperature	H	L

(1) Applicable only to TPS259480x/2x variants.

(2) Applicable only to TPS259481x variants.

When there is no supply to the device, the SPLYGD pin is expected to stay low. However, there is no active pull-down in this condition to drive this pin all the way down to 0 V. If the SPLYGD pin is pulled up to an independent supply which is present even if the device is unpowered, there can be a small voltage seen on this pin depending on the pin sink current, which is a function of the pull-up supply voltage and resistor. Minimize the sink current to keep this pin voltage low enough not to be detected as a logic HIGH by associated external circuits in this condition. This also ensures that the auxiliary channel is not turned off inadvertently in a priority power MUX configuration.

#### 8.4 Device Functional Modes

**Table 8-4. TPS259481x/2x Reverse Current Blocking Operation**

RCBCTRL Pin Connection	Reverse Current Blocking in Steady-State
Low	Disabled
Open or High	Enabled

## 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, as well as validating and testing their design implementation to confirm system functionality.

### 9.1 Application Information

The TPS25948x is a 3.5 V to 23 V, 8-A eFuse that is typically used for power rail protection applications. It operates from 3.5 V to 23 V with adjustable overvoltage and undervoltage protection. It provides ability to control inrush current and protection against reverse current conditions. It can be used in a variety of systems such as Adapter/Charger input protection, USB PD protection in Smartphone/Tablets/PC/notebook/monitors/docks, Server/PC motherboard/add-on cards, Enterprise storage – RAID/HBA/SAN/eSSD, Power MUXing/ORing. The design procedure explained in the subsequent sections can be used to select the supporting component values based on the application requirement. Additionally, a spreadsheet design tool [TPS25948x Design Calculator](#) is available in the web product folder.

### 9.2 Single Device, Self-Controlled

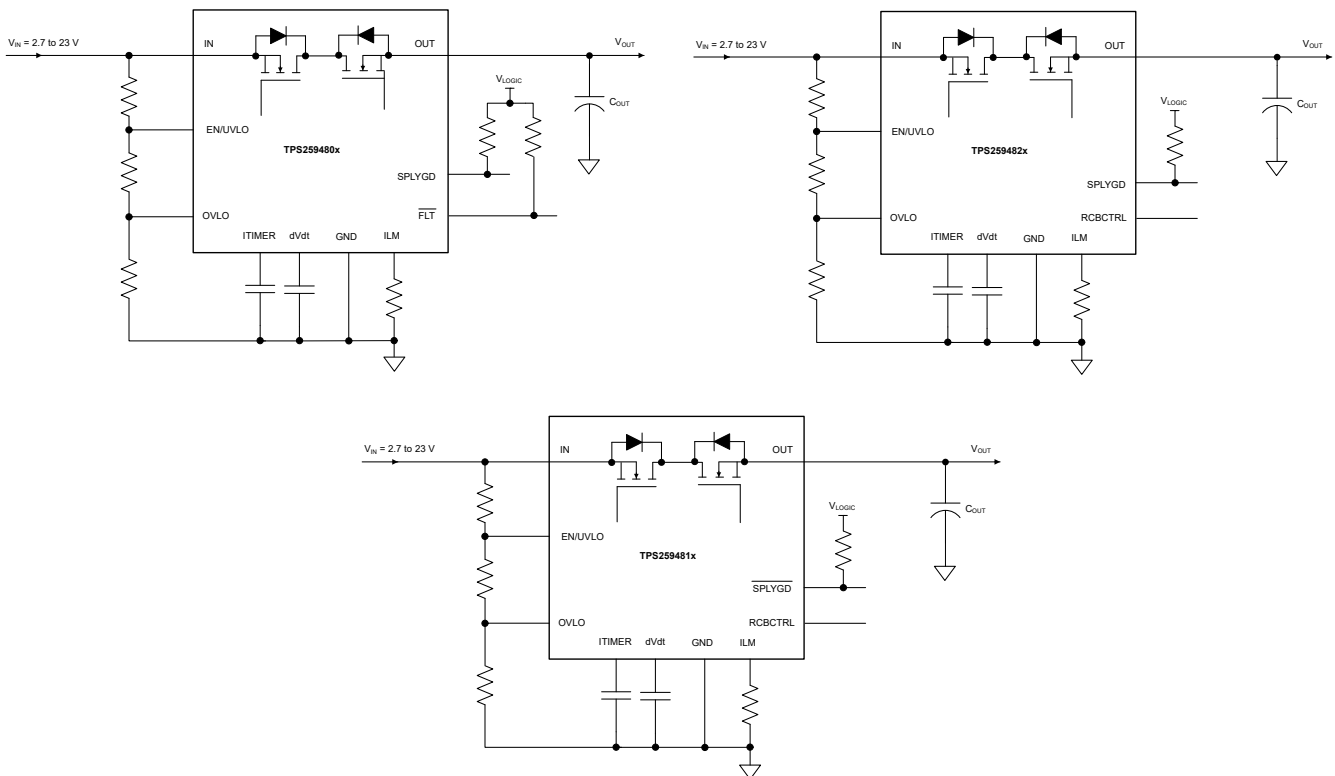


Figure 9-1. Single Device, Self-Controlled

#### Other variations:

In a Host MCU controlled system, EN/UVLO or OVLO can also be driven from the host GPIO to control the device.

ILM pin can be connected to the MCU ADC input for current monitoring purpose.

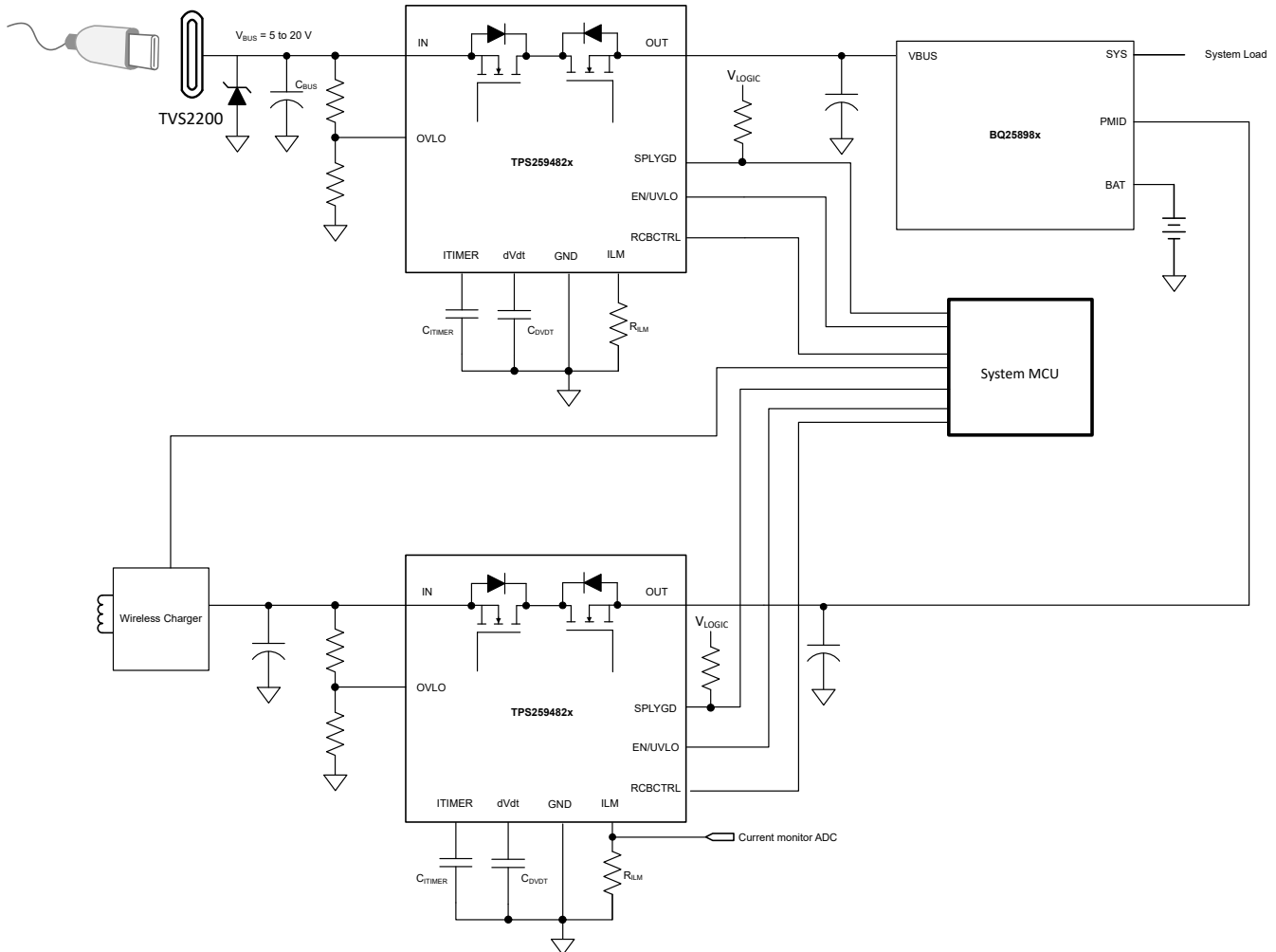
**Note**

It's recommended to keep parasitic capacitance on ILM pin below 50 pF to ensure stable operation.

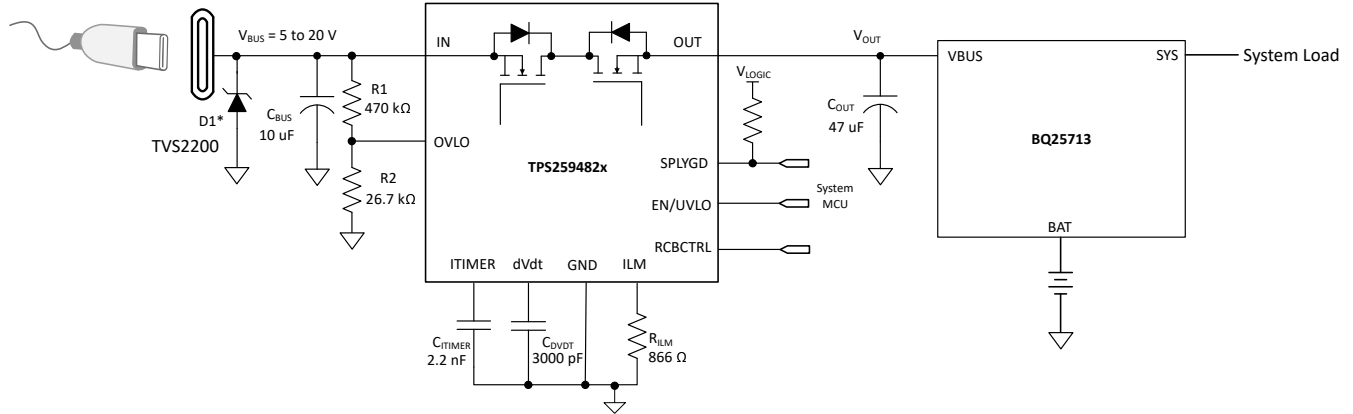
**9.3 Typical Application**

Smartphones come equipped with USB OTG functionality that allows their USB port to be used not only for charging the phone battery but also allow the smartphone to act as a USB host and deliver power to external accessories such as headphones, pen drives, and so forth. Some smartphones also support a wireless charging path which can also be used to wirelessly share power to other devices. TPS259482 can be used as a bi-directional power switch in such applications as shown in Figure 9-3. For the USB power path, when an external charger is connected at the port, TPS259482 provides a conduction path from IN pin to OUT pin and the battery charger IC is configured to charge the battery and also power the internal circuits. TPS259482 also provides overvoltage and overcurrent protection in this case. In another use case scenario where an accessory such as headphone is connected to the USB port, the phone MCU detects this and the battery charger is configured in OTG boost mode to provide power from battery to the USB port. MCU will also pull down RCBCTRL pin to allow current flow from OUT pin to IN pin of TPS259482 and enables the TPS259482 and establishes a low impedance power path capable of delivering high power to the accessory. Similarly, the TPS259482 also provides controlled bi-directional power flow in the wireless charging and power share sub-system.

ADVANCE INFORMATION



**Figure 9-2. Smartphone Power Path Example**



\* Optional circuit components needed for transient protection depending on input and output inductance. Please refer to [Section 9.8.1](#) section for details.

**Figure 9-3. USB On-The-Go Port Protection Design Example**

### 9.3.1 Design Requirements

**Table 9-1. Design Parameters**

PARAMETER	VALUE
Bus voltage during charging ( $V_{IN}$ )	20 V
Overvoltage protection threshold during charging ( $V_{IN(OV)}$ )	22 V
Max continuous charging current	5 A
Load transient blanking interval during charging ( $t_{ITIMER}$ )	2 ms
Output capacitance ( $C_{OUT}$ )	47 $\mu$ F
Output rise time ( $t_R$ )	12 ms
Overcurrent threshold ( $I_{ILIM}$ ) during charging	5.5 A

### 9.3.2 Detailed Design Procedure

#### 9.3.2.1 Setting Overvoltage Threshold

The supply overvoltage threshold is set using the resistors, R1 and R2, whose values can be calculated as:

$$V_{IN(OV)} = \frac{V_{OV(R)} \times (R1 + R2)}{R2} \quad (8)$$

Where  $V_{OV(R)}$  is the OVLO rising threshold. Because R1, R2 leak the current from input supply  $V_{IN}$ , these resistors must be selected based on the acceptable leakage current from input power supply  $V_{IN}$ . The current drawn by R1, R2 from the power supply is  $I_{R12} = V_{IN} / (R1 + R2)$ . 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 20 times greater than the leakage current expected on the OVLO pin.

From the device electrical specifications, OVLO leakage current is 0.1  $\mu$ A (maximum),  $V_{OV(R)} = 1.2$  V. From design requirements,  $V_{IN(OV)} = 22$  V. To solve the equation, first choose the value of  $R1 = 470$  k $\Omega$  and use the above equation to solve for  $R2 = 27.11$  k $\Omega$ .

Using the closest standard 1% resistor values, we get  $R1 = 470$  k $\Omega$ ,  $R2 = 26.7$  k $\Omega$ .

#### 9.3.2.2 Setting Output Voltage Rise Time ( $t_R$ )

For a successful design, the junction temperature of device must 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 inrush current limit required with system capacitance to avoid thermal shutdown during start-up.

The slew rate (SR) needed to achieve the desired output rise time can be calculated as:

$$SR (V/ms) = \frac{VIN (V)}{tR (ms)} = \frac{20 V}{12 ms} = 1.67 V/ms \quad (9)$$

The  $C_{dVdt}$  needed to achieve this slew rate can be calculated as:

$$CdVdt (pF) = \frac{5000}{SR (V/ms)} = \frac{5000}{1.67} = 2994 pF \quad (10)$$

Choose the nearest standard capacitor value as 3000 pF.

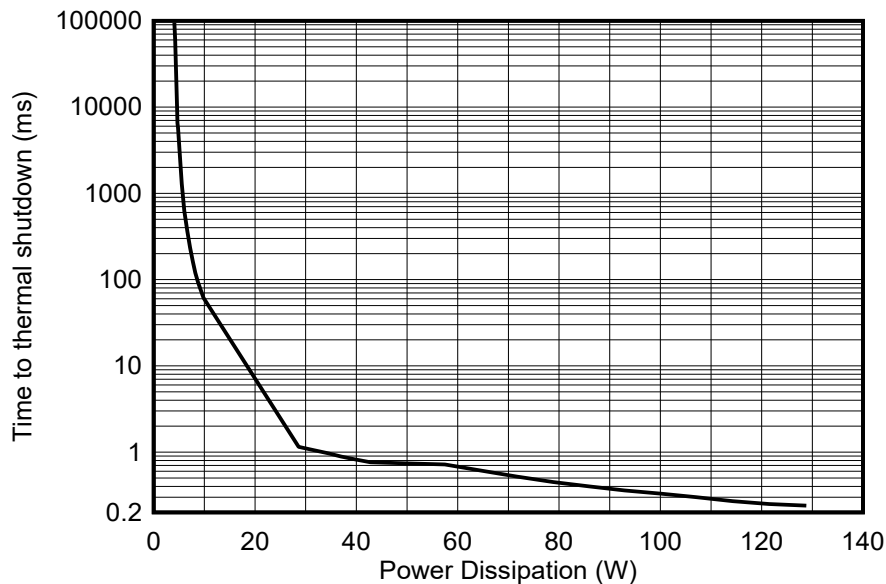
For this slew rate, the inrush current can be calculated as:

$$IINRUSH (mA) = SR (V/ms) \times COUT (\mu F) = 1.67 \times 47 = 79 mA \quad (11)$$

The average power dissipation inside the part during inrush can be calculated as:

$$PDINRUSH (W) = \frac{IINRUSH (A) \times VIN (V)}{2} = \frac{0.079 \times 20}{2} = 0.8 W \quad (12)$$

For the given power dissipation, the thermal shutdown time of the device must be greater than the ramp-up time  $t_R$  to avoid start-up failure. Figure 9-4 shows the thermal shutdown limit, for 0.8 W of power, the shutdown time is more than 10 s which is very large as compared to  $t_R = 12 ms$ . Therefore, it is safe to use 12 ms as the startup time for this application.



**Figure 9-4. Thermal Shut-Down Plot During Inrush**

### 9.3.2.3 Setting Overcurrent Threshold ( $I_{LIM}$ )

The overcurrent protection threshold can be set using the  $R_{ILM}$  resistor whose value can be calculated as:

$$RILM (\Omega) = \frac{4834}{ILIM (A)} = \frac{4834}{5.5 A} = 879 \Omega \quad (13)$$

Choose nearest 1% standard resistor value as 866  $\Omega$ .

### 9.3.2.4 Setting Overcurrent Blanking Interval ( $t_{TIMER}$ )

The overcurrent blanking timer interval can be set using the  $C_{TIMER}$  capacitor whose value can be calculated as:



$$CITIMER \text{ (nF)} = \frac{tITIMER \text{ (ms)} \times IITIMER \text{ (\mu A)}}{\Delta VITIMER \text{ (V)}} = \frac{2 \times 1.95}{1.51} = 2.6 \text{ nF} \quad (14)$$

Choose nearest standard capacitor value as 2.2 nF.

### 9.3.3 Application Curves

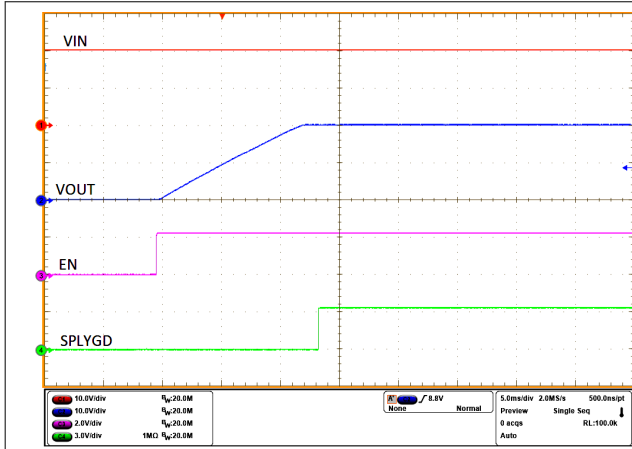


Figure 9-5. Power Up

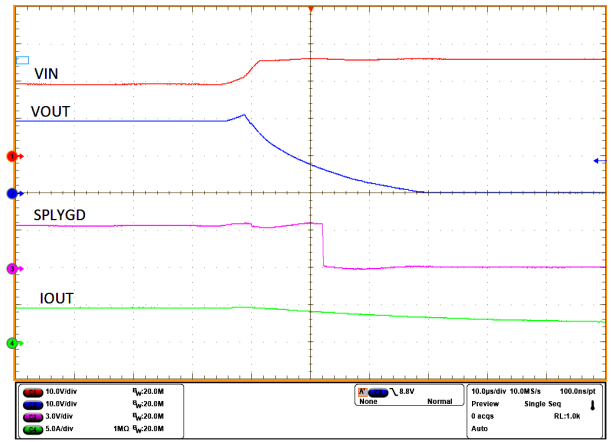


Figure 9-6. Overvoltage Protection

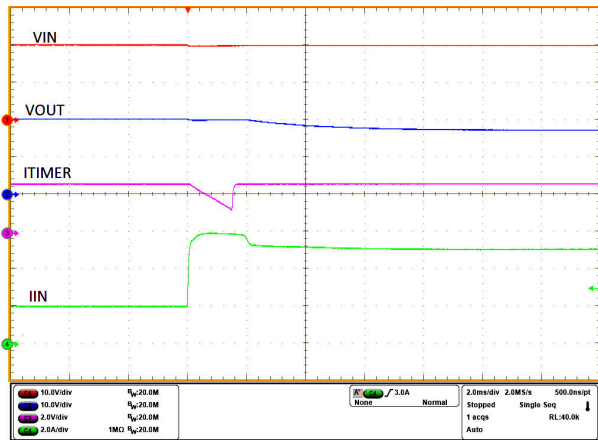


Figure 9-7. Overcurrent Protection

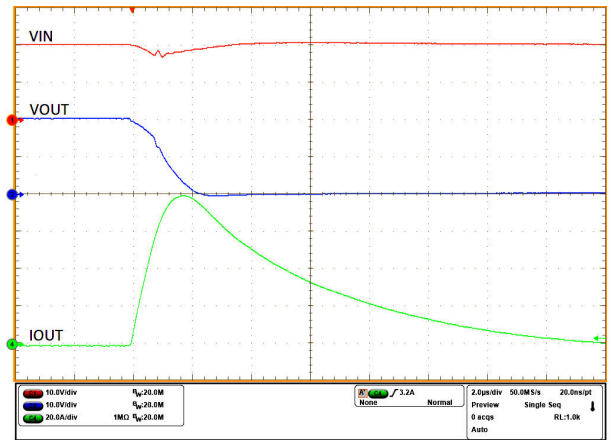


Figure 9-8. Short at Output Protection

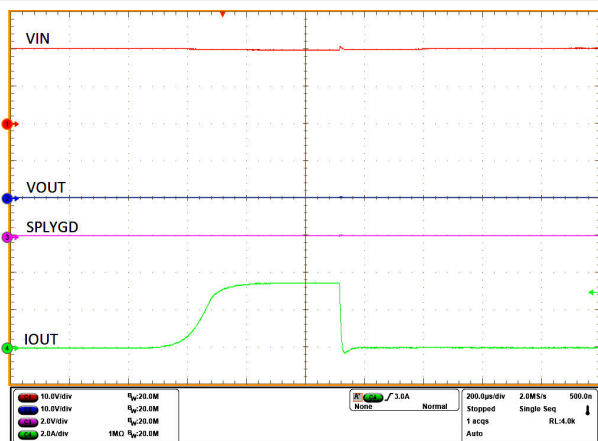


Figure 9-9. Wake up into Short Protection

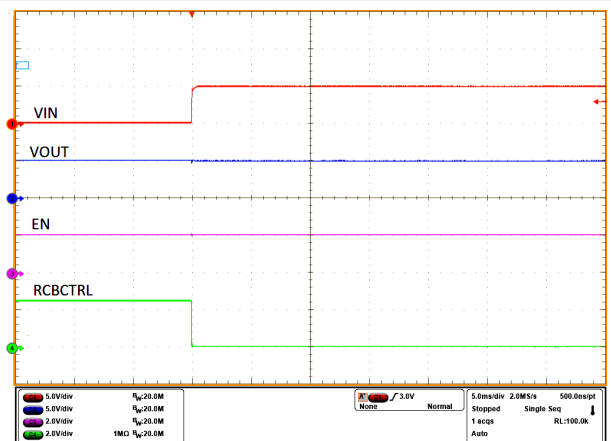
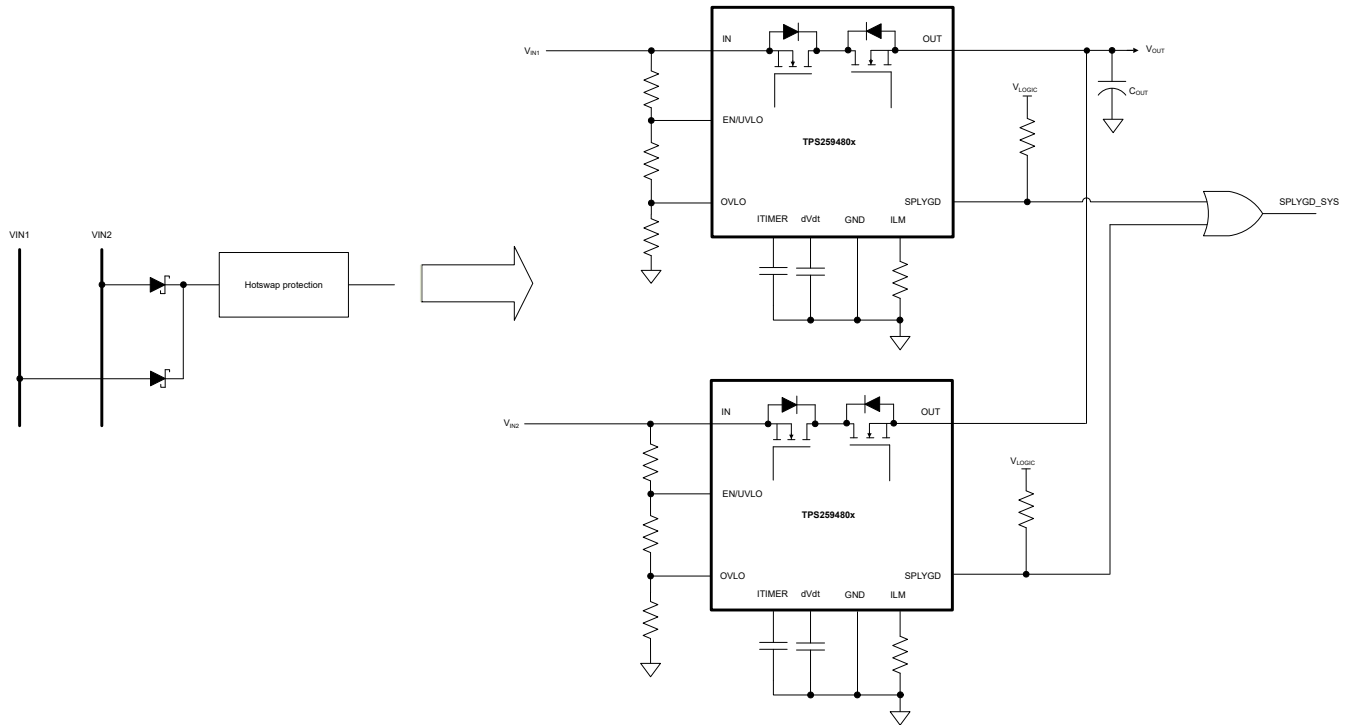


Figure 9-10. Power Up in OTG Mode

ADVANCE INFORMATION

## 9.4 Active ORing

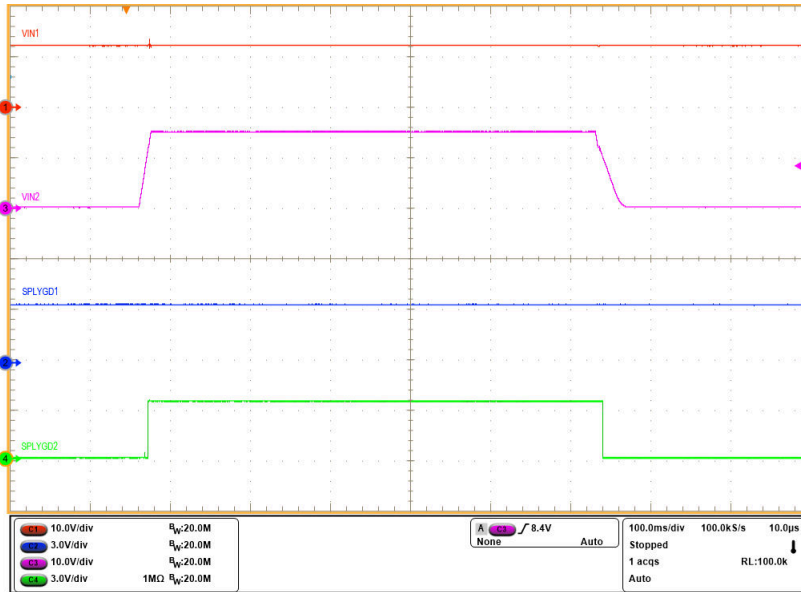
A typical redundant power supply configuration is shown in Figure 9-11 below. Schottky ORing diodes have been popular for connecting parallel power supplies, such as parallel operation of wall adapter with a battery or a hold-up storage capacitor. The disadvantage of using ORing diodes is high voltage drop and associated power loss. The TPS25948xx with integrated, low-ohmic, back-to-back FETs provide a simple and efficient solution. Figure 9-11 below shows the Active ORing implementation using TPS249480x devices.



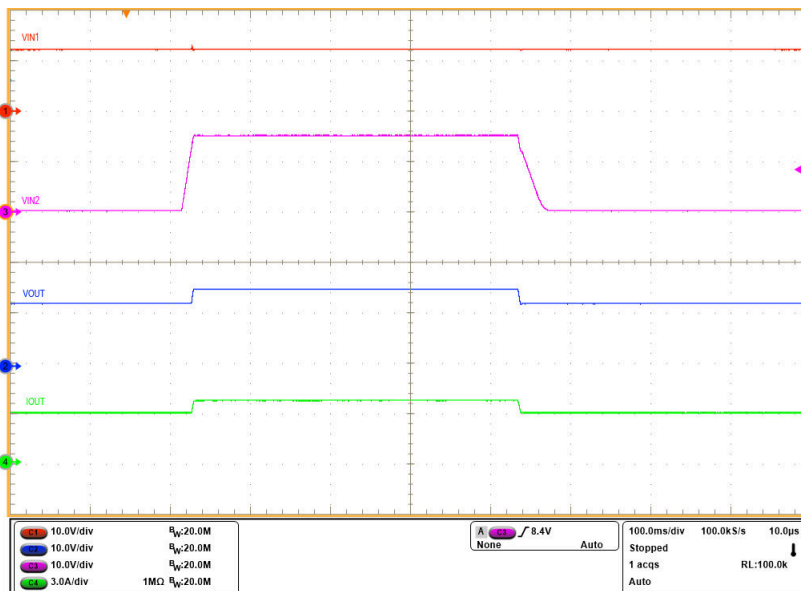
**Figure 9-11. Two Devices, Active ORing Configuration**

The linear ORing mechanism in TPS25948xx ensures that there's no reverse current flowing from one power source to the other during fast or slow ramp of either supply.

The following waveform illustrates the active ORing behavior when the supply rails are being ramped up sequentially.



**Figure 9-12. Active ORing Response**



**Figure 9-13. Active ORing Response**

When the bus voltages (IN1 and IN2) are matched, device in each path sees a forward voltage drop and is ON delivering the load current. During this period, current is shared between the rails in the ratio of differential voltage drop across each device.

In addition to supply ORing, the devices protect the system from overvoltage, excessive inrush current, overload and short-circuit faults at all times.

**Note**

ORing can be done either between two similar rails or between dissimilar rails. For ORing cases with skewed voltage combinations, the dVdt pin capacitor rating should be chosen based on the highest of the 2 supplies. Refer to Recommended Operating Conditions table for more details.

## 9.5 Priority Power MUXing

Applications having two energy sources such as PCIe cards, Tablets and Portable battery powered equipment require preference of one source to another. For example, mains power (wall-adaptor) has the priority over the internal battery back-up power. These applications demand for switchover from mains power to backup power only when main input voltage falls below a user defined threshold. The TPS25948xx devices provide a simple solution for priority power multiplexing needs.

Figure 9-14 below shows a typical priority power multiplexing implementation using TPS259480x devices. When primary (priority) power source (IN1) is present and within the valid range (not in UV/OV condition), the primary path device powers the OUT bus irrespective of whether auxiliary supply voltage ( $V_{IN2}$ ) is greater than, equal to or less than primary supply voltage ( $V_{IN1}$ ). The device in auxiliary path is held in off condition by forcing its OVLO pin to high using the SPLYGD signal from the primary path device.

Once the primary supply voltage falls outside the user-defined valid operating range (UV/OV condition), the primary path device de-asserts the SPLYGD which signals the auxiliary path device to turn on and the system starts operating from the auxiliary supply. During this transition, the auxiliary path device bypasses its dVdt limited startup and performs a fast recovery to start delivering power within  $t_{SWOV}$ .

When the primary supply is restored, the primary path device turns on fully at a defined slew rate and then asserts its SPLYGD pin high to turn the auxiliary path device off, allowing a seamless transition from auxiliary to the primary supply with minimal output voltage droop and with no shoot-through current.

A key consideration in power MUXing applications is the minimum voltage the output bus droops to during the switchover from one supply to another. This in turn depends on multiple factors including the output load current ( $I_{LOAD}$ ), output bus hold-up capacitance ( $C_{OUT}$ ) and switchover time ( $t_{SW}$ ).

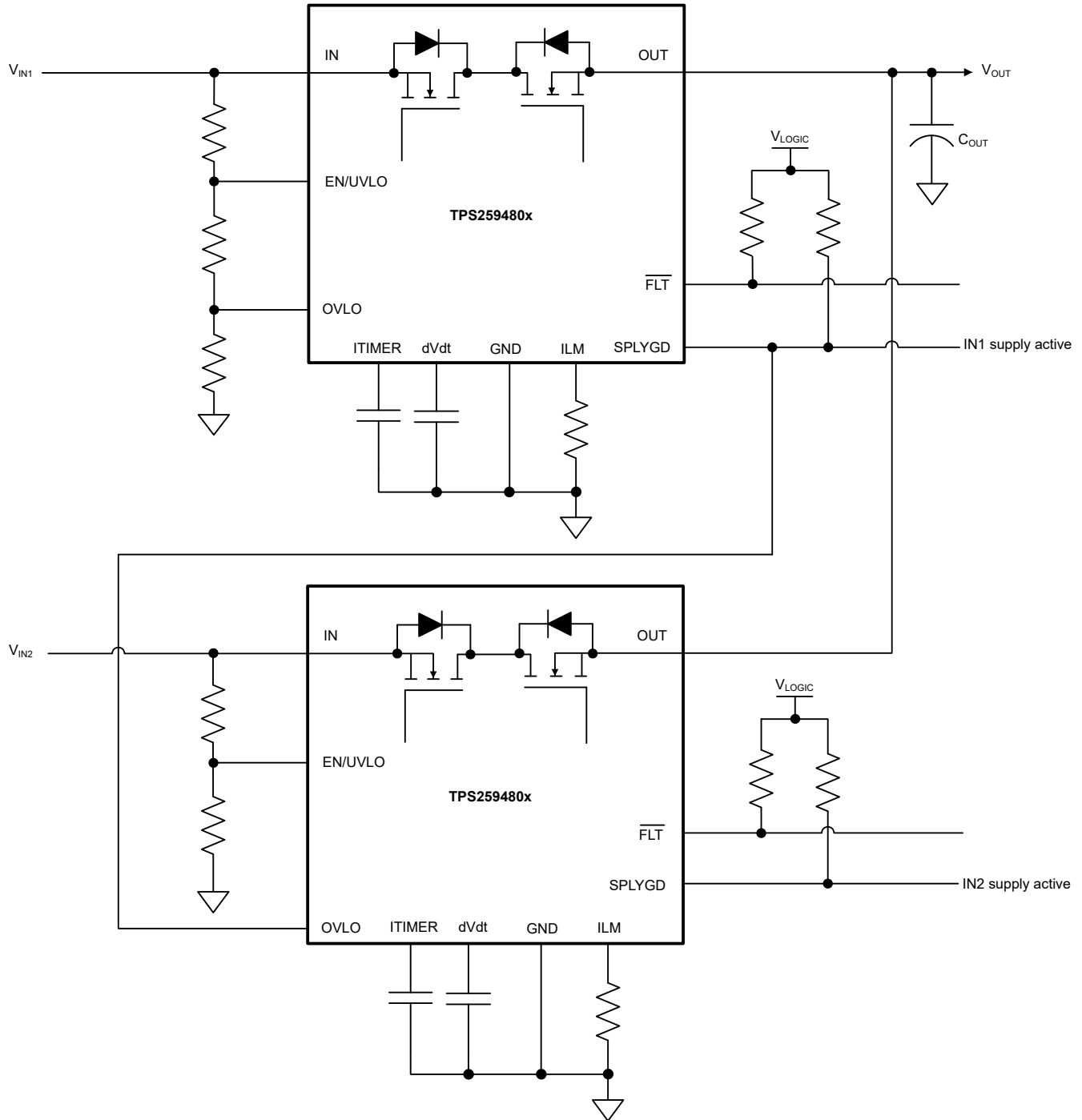
While switching from primary supply ( $V_{IN1}$ ) to auxiliary supply ( $V_{IN2}$ ), the minimum bus voltage can be calculated using Equation 15. Here, the switchover time ( $t_{SW}$ ) is equal to the fast OVLO recovery time ( $t_{SWOV}$ ) taken by the TPS259480x variants to turn on fully and start delivering current to the load.

$$V_{OUT,min} (V) = \min (V_{IN1}, V_{IN2}) - \frac{t_{SW} (\mu s) \times I_{LOAD} (A)}{C_{OUT} (\mu F)} \quad (15)$$

While switching from auxiliary supply ( $V_{IN2}$ ) to primary supply ( $V_{IN1}$ ), the minimum bus voltage can be calculated using Equation 16. Here the maximum switchover time is equal to the RCB recovery time ( $t_{SWRCB}$ ), depending on whether  $V_{IN1}$  is equal to or lower than  $V_{IN2}$  to start with.

$$V_{OUT,min} (V) = \min (V_{IN1}, V_{IN2}) - V_{FWDTH} (V) - \frac{t_{SWRCB} (\mu s) \times I_{LOAD} (A)}{C_{OUT} (\mu F)} \quad (16)$$

The SPLYGD pins of the devices can be used as a digital indication to identify which of the 2 supplies is active and delivering power to the load.



ADVANCE INFORMATION

**Figure 9-14. Priority Power MUXing with 2 × TPS259480x - Option 1**

This configuration provides the most compact priority power MUXing solution with multiple benefits, including active current limit protection on both channels as well as overvoltage protection on primary channel. It also provides the fastest switchover time from primary to auxiliary, but at the cost of a slightly increased quiescent current on the auxiliary path while primary path is active. Also, it uses the fewest external components, but at the cost of bypassing overvoltage protection on auxiliary channel.

The following waveforms illustrate the TPS259480x performance in a priority power MUXing configuration.

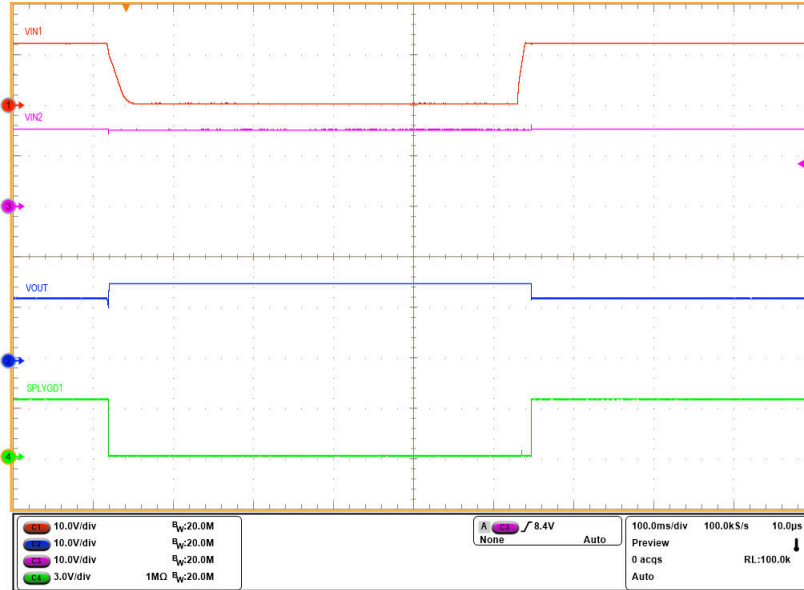


Figure 9-15. TPS259480x Power MUX - Switchover between Primary and Auxiliary Supplies

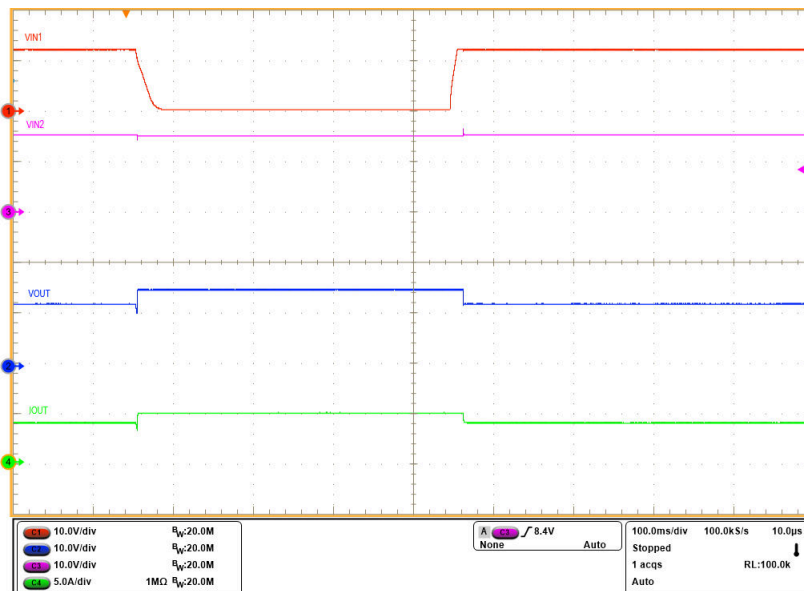
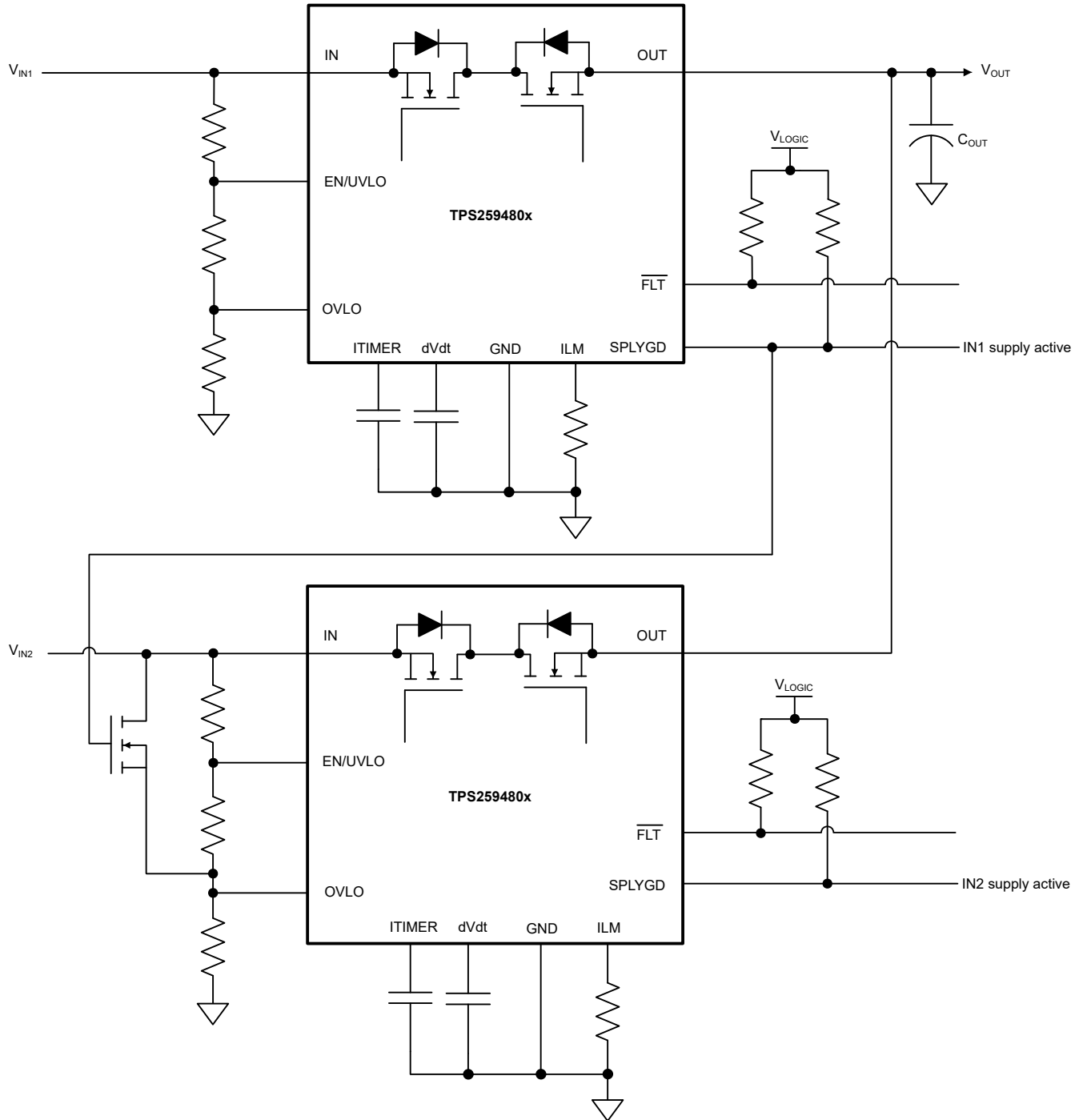


Figure 9-16. TPS259480x Power MUX - Switchover between Primary and Auxiliary Supplies

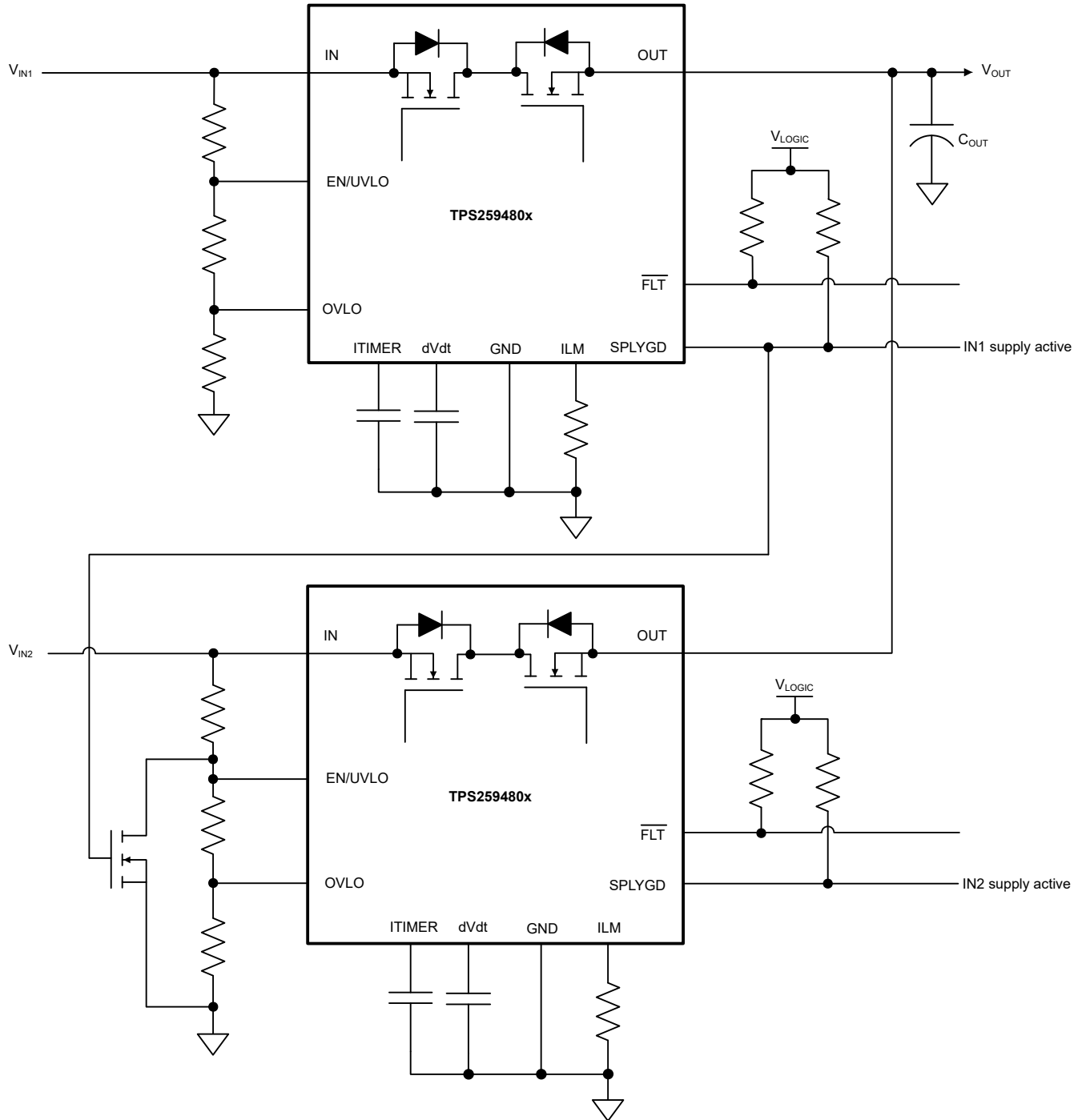
There's a possible variation to the above configuration in case overvoltage protection is needed on both channels. This needs an additional signal N-FET to drive the OVLO pin of the auxiliary path device as shown in [Figure 9-17](#) below. The switchover times are similar to the previous configuration.



ADVANCE INFORMATION

Figure 9-17. Priority Power MUXing with 2 × TPS259480x - Option 2

Another variation of the previous configuration ensures minimum quiescent current on the auxiliary channel while primary channel is active, but at the cost of additional N-FET to drive the EN/UVLO pin of auxiliary path device as shown in Figure 9-18 below. At the same time, it has a higher switchover delay from primary to auxiliary supply as compared to the previous configuration.



**Figure 9-18. Priority Power MUXing with 2 × TPS259480x - Option 3**

While switching from a higher supply rail to lower supply rail, the minimum bus voltage can be calculated using [Equation 17](#). Here, the switchover time is equal to the time taken by the device to come out of reverse current blocking state ( $t_{SWRCB}$ ).

$$V_{OUT,min} (V) = \min (V_{IN1}, V_{IN2}) - V_{FWDTH} (V) - \frac{t_{SWRCB} (\mu s) \times I_{LOAD} (A)}{C_{OUT} (\mu F)} \quad (17)$$

While switching from a lower supply rail to higher supply rail, the minimum bus voltage can be calculated using [Equation 18](#). Here, the switchover time ( $t_{SW}$ ) is the time taken by the device to turn on fully and start delivering



current to the load, which is equal to the device turn-on time ( $t_{ON}$ ), which in turn includes the turn-on delay ( $t_{D,ON}$ ) and rise time ( $t_R$ ) determined by the dVdt capacitor ( $C_{dVdt}$ ) and bus voltage.

$$V_{OUT,min} (V) = \min (VIN1, VIN2) - \frac{t_{SW} (\mu s) \times I_{LOAD} (A)}{C_{OUT} (\mu F)} \quad (18)$$

---

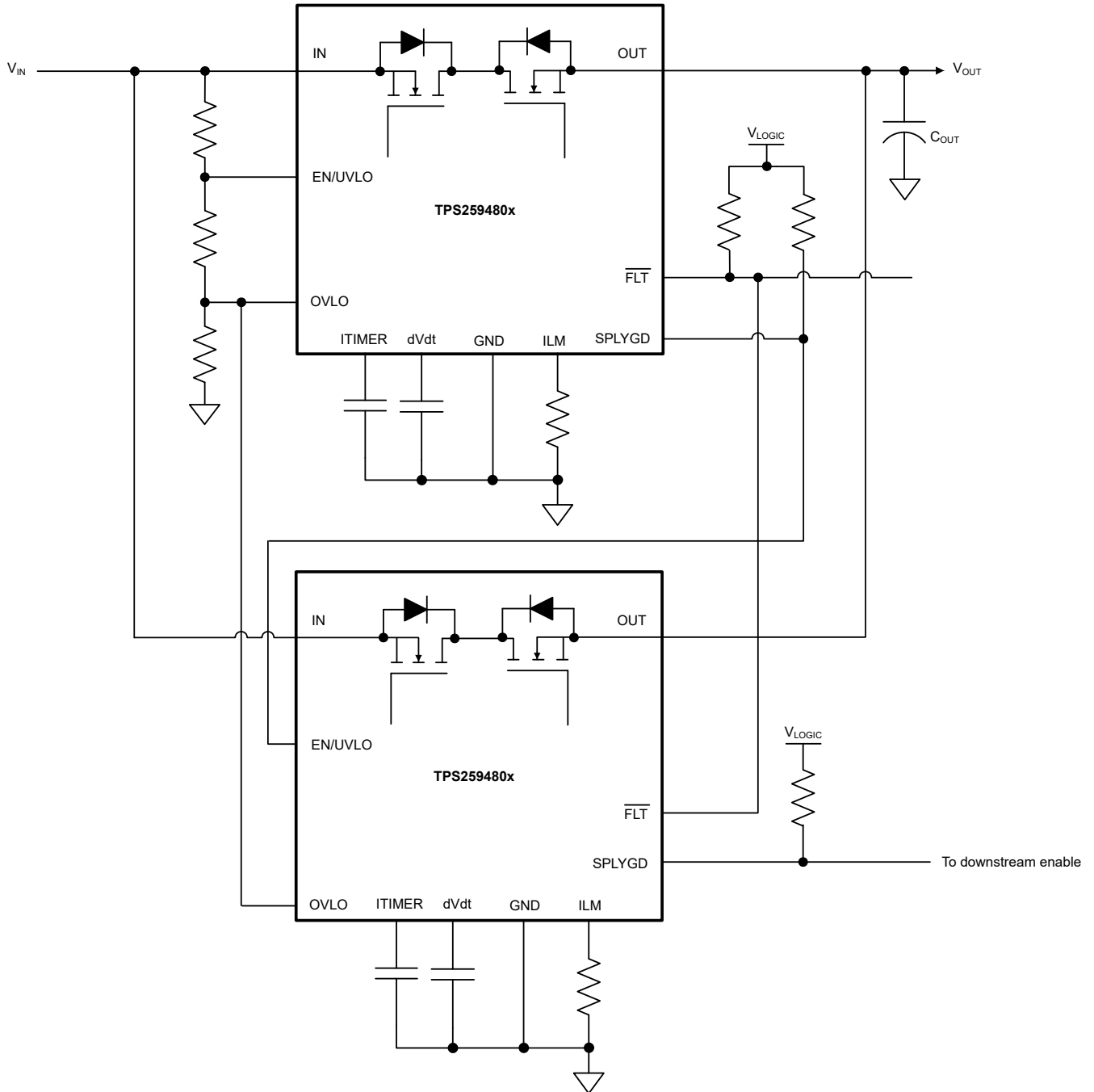
**Note**

1. Power MUXing can be done either between two similar rails (such as 12-V Primary & 12-V Aux, 3.3-V Primary & 3.3-V Aux) or between dissimilar rails (such as 12-V Primary & 5-V Aux or vice versa).
  2. For power MUXing cases with skewed voltage combinations, care must be taken to design circuit components on EN/OVLO pins for the lower voltage channel devices such that the Absolute maximum ratings on those pins are not exceeded when higher voltage is present on the other channel. Also, the dVdt pin capacitor rating should be chosen based on the highest of the 2 supplies. Refer to Recommended Operating Conditions table for more details.
- 

## 9.6 Parallel Operation

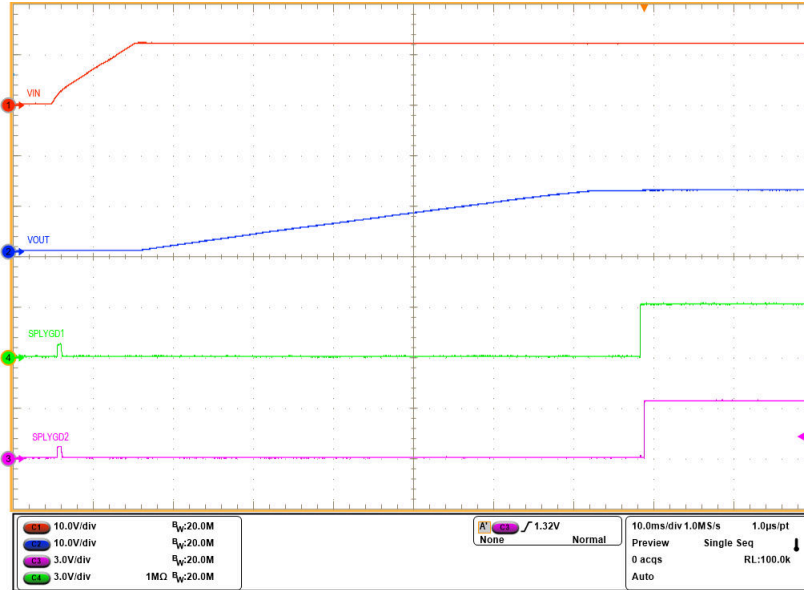
Applications which need higher steady current can use 2 TPS25948x devices connected in parallel as shown in [Figure 9-19](#) below. In this configuration, the first device turns on initially to provide the inrush current limiting. The second device is held in an OFF state by driving its EN/UVLO pin low using the SPLYGD signal of the first device. Once the inrush sequence is complete, the first device asserts its SPLYGD pin high and turns on the second device. The second device asserts its SPLYGD signal to indicate when it has turned on fully, thereby indicating to the system that the parallel combination is ready to deliver the full steady state current.

Once in steady state, both devices share current nearly equally. There could be a slight skew in the currents depending on the part-to-part variation in the  $R_{ON}$  as well as the PCB trace resistance mismatch.

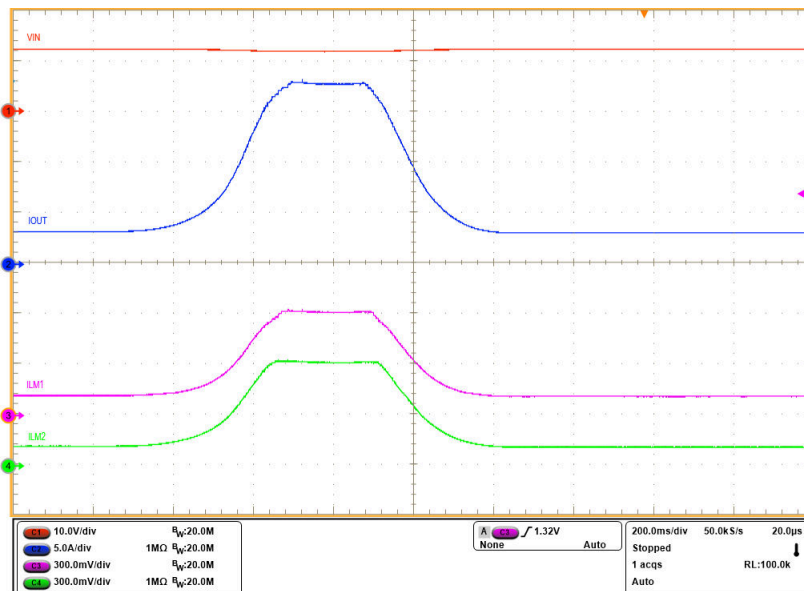


**Figure 9-19. Two Devices Connected in Parallel for Higher Steady State Current Capability**

The waveforms below illustrate the behavior of the parallel configuration during start-up as well as during steady state.



**Figure 9-20. Parallel Devices Sequencing During Start-Up**

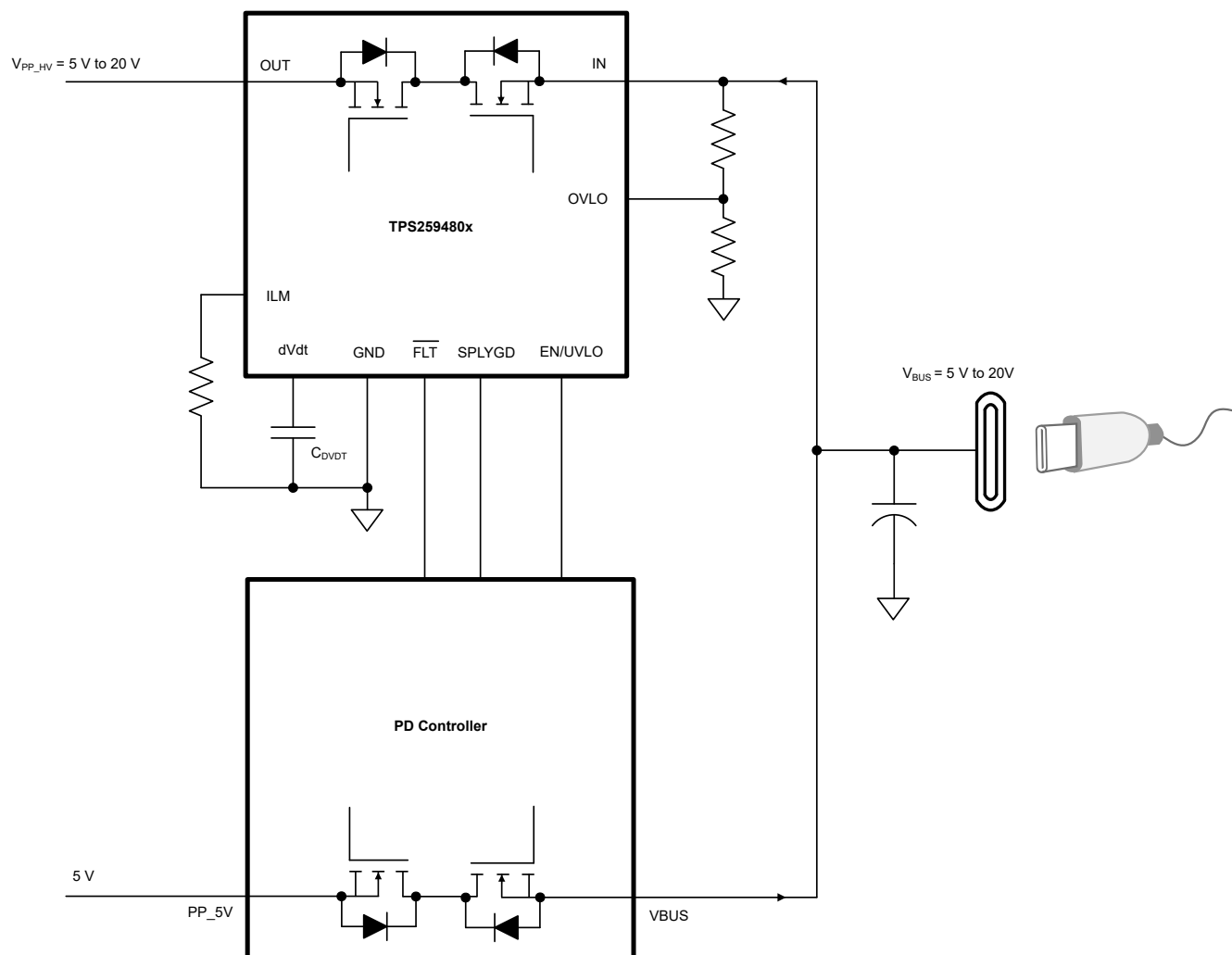


**Figure 9-21. Parallel Devices Load Current During Steady State**

## 9.7 USB PD Port Protection

End equipments like PC, Notebooks, Docking Stations, Monitors etc.. have USB PD ports which can be configured as DFP (Source), UFP (Sink) or DRP (Source+Sink). TPS25948xx can be used to as a fully integrated power path solution for USB PD ports as shown in [Figure 9-22](#) below.

TPS25948xx provides all the basic protection functions needed on the USB power path e.g. overvoltage, overcurrent and short-circuit protection along with monitoring and control. The linear ORing mechanism in TPS25948xx ensures that there's no reverse current flowing from one power source to the other during fast or slow ramp of either supply.


**Figure 9-22. USB PD Port Protection**

## 9.8 Power Supply Recommendations

The TPS25948x devices are designed for a supply voltage range of  $3.5\text{ V} \leq V_{\text{IN}}$  or  $V_{\text{OUT}} \leq 23\text{ V}$ . An input ceramic bypass capacitor higher than  $0.1\text{ }\mu\text{F}$  is recommended if the input supply is located more than a few inches from the device. The power supply must be rated higher than the set current limit to avoid voltage droops during overcurrent and short-circuit conditions.

### 9.8.1 Transient Protection

In the case of a short-circuit and overload current limit when the device interrupts current flow, the input inductance generates a positive voltage spike on the input, and the output inductance generates a negative voltage spike on the output. The peak amplitude of voltage spikes (transients) is dependent on the 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:

- Minimize lead length and inductance into and out of the device.
- Use a large PCB GND plane.
- Connect a Schottky diode from the OUT pin ground to absorb negative spikes.
- Connect a low ESR capacitor larger than  $1\text{ }\mu\text{F}$  at the OUT pin very close to the device.

- Use a low-value ceramic capacitor  $C_{IN} = 1 \mu\text{F}$  to absorb the energy and dampen the transients. The capacitor voltage rating should be atleast twice the input supply voltage to be able to withstand the positive voltage excursion during inductive ringing.

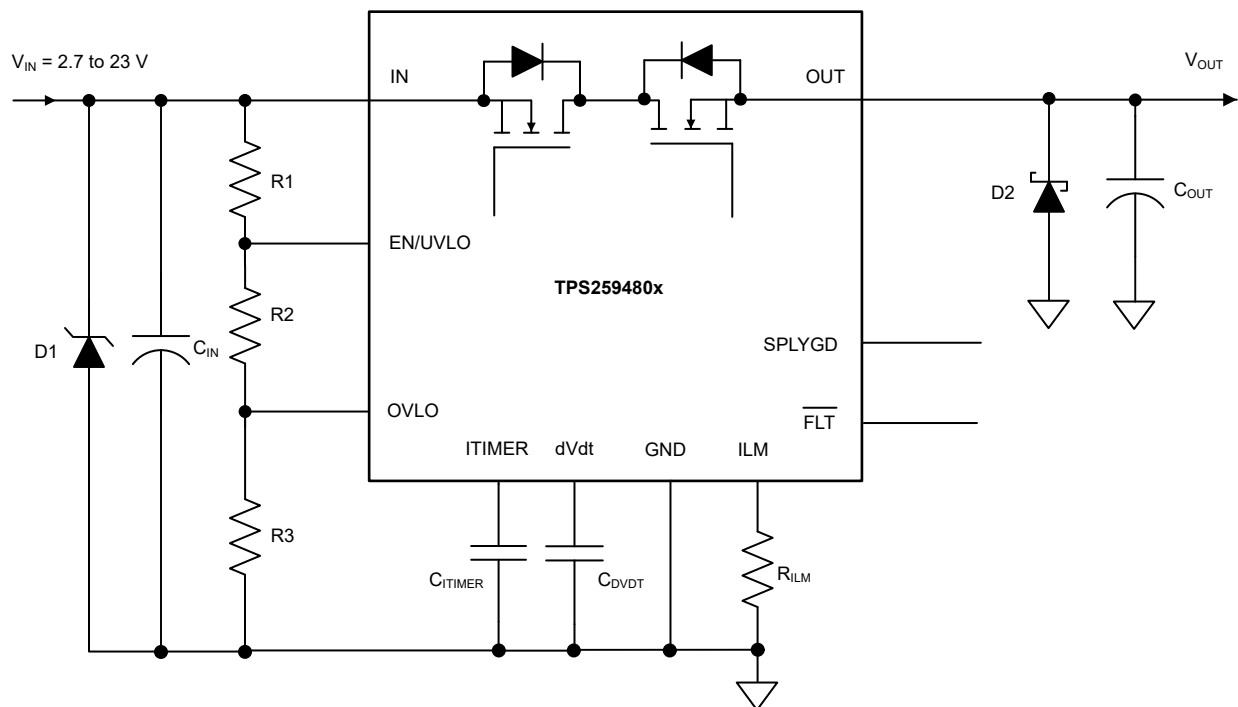
The approximate value of input capacitance can be estimated with the equation:

$$V_{SPIKE(ABSOLUTE)} = V_{IN} + I_{LOAD} \times \sqrt{\frac{L_{IN}}{C_{IN}}} \quad (19)$$

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. In some cases, even if the maximum amplitude of the transients is below the absolute maximum rating of the device, a TVS can help to absorb the excessive energy dump and prevent it from creating very fast transient voltages on the input supply pin of the IC, which can couple to the internal control circuits and cause unexpected behavior.
- For applications such as USB-C ports where a powered cable can be plugged to the output of the device, there could be excess voltage stress from OUT to IN which exceeds the absolute maximum rating of the device. It's recommended to add a TVS diode from OUT to IN to clamp the voltage to a safe level.

The circuit implementation with optional protection components is shown in [Figure 9-23](#).



**Figure 9-23. Circuit Implementation with Optional Protection Components**

### 9.8.2 Output Short-Circuit Measurements

It is difficult to obtain repeatable and similar short-circuit testing results. The following contribute to variation in results:

- Source bypassing
- Input leads

- Circuit layout
- Component selection
- Output shorting method
- Relative location of the short
- Instrumentation

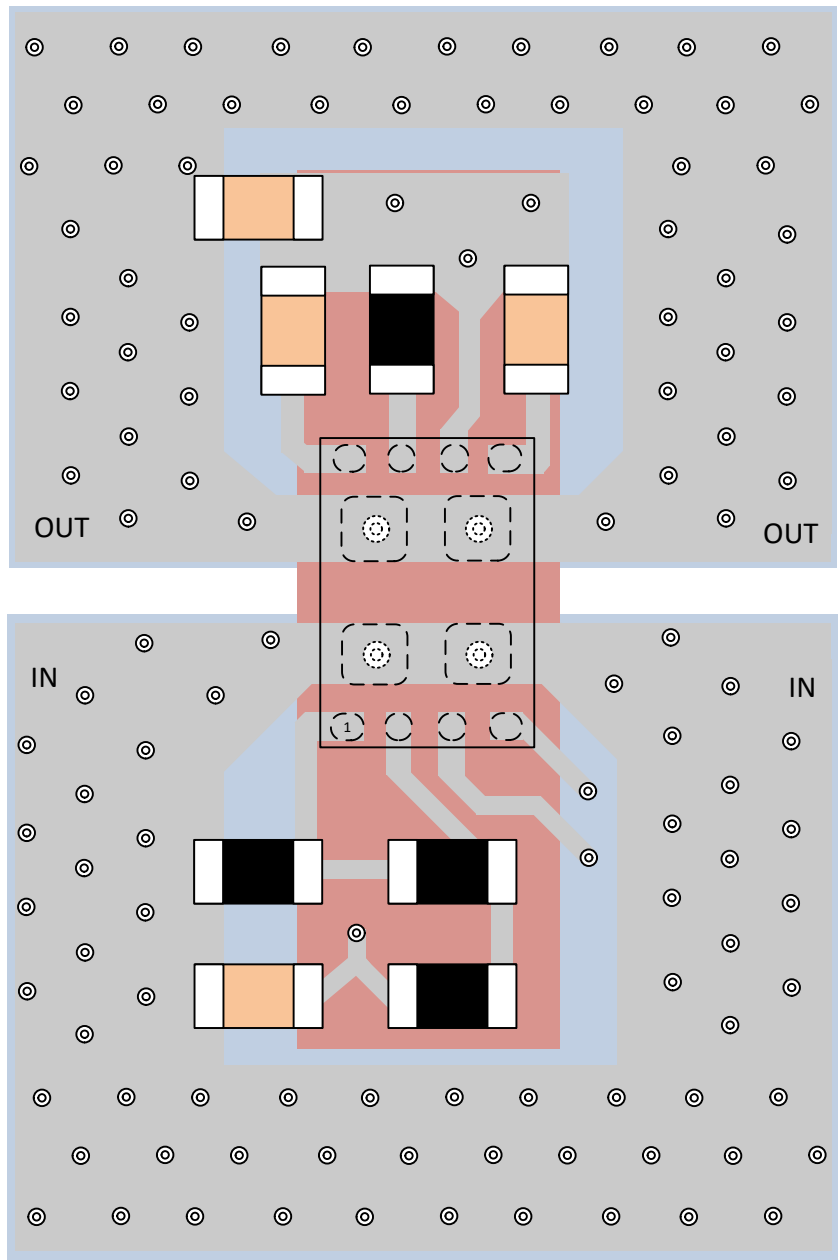
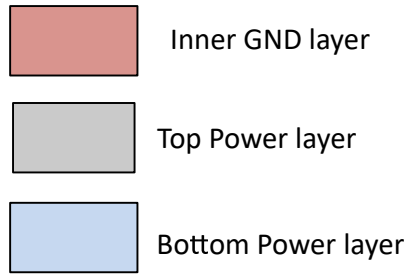
The actual short exhibits a certain degree of randomness because it microscopically bounces and arcs. Ensure that configuration and methods are used to obtain realistic results. Do not expect to see waveforms exactly like those in this data sheet because every setup is different.

## 9.9 Layout

### 9.9.1 Layout Guidelines

- For all applications, a ceramic decoupling capacitor of 0.1  $\mu\text{F}$  or greater is recommended between the IN terminal and GND terminal.
- The optimal placement of the 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.
- High current-carrying power-path connections must be as short as possible and must 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 with the shortest possible trace. The PCB ground must be a copper plane or island on the board. It's recommended to have a separate ground plane island for the eFuse. This plane doesn't carry any high currents and serves as a quiet ground reference for all the critical analog signals of the eFuse. The device ground plane should be connected to the system power ground plane using a star connection.
- The IN and OUT pads are used for heat dissipation. Connect to as much copper area on top and bottom PCB layers using as possible with thermal vias. The vias under the device also help to minimize the voltage gradient across the IN and OUT pads and distribute current uniformly through the device, which is essential to achieve the best on-resistance and current sense accuracy.
- Locate the following support components close to their connection pins:
  - $R_{\text{ILM}}$
  - $C_{\text{dVdt}}$
  - $C_{\text{TIMER}}$
  - Resistors for the EN/UVLO and OVLO pins
- Connect the other end of the component to the GND pin of the device with shortest trace length. The trace routing for the  $R_{\text{ILM}}$ ,  $C_{\text{TIMER}}$  and  $C_{\text{dVdt}}$  components to the device must be as short as possible to reduce parasitic effects on the current limit, overcurrent blanking interval and soft start timing. It's recommended to keep parasitic capacitance on ILM pin below 50 pF to ensure stable operation. These traces must not have any coupling to switching signals on the board.
- Since the bias current on ILM pin directly controls the overcurrent protection behavior of the device, the PCB routing of this node must be kept away from any noisy (switching) signals.
- Protection devices such as TVS, snubbers, capacitors, or diodes must be placed physically close to the device they are intended to protect. These protection devices must be 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. It's also recommended to add a ceramic decoupling capacitor of 1  $\mu\text{F}$  or greater between OUT and GND. These components must be physically close to the OUT pins. Care must be taken to minimize the loop area formed by the Schottky diode/bypass-capacitor connection, the OUT pin and the GND terminal of the IC.

### 9.9.2 Layout Example



**ADVANCE INFORMATION**

**Figure 9-24. Layout Example**

## 10 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

### 10.1 Documentation Support

#### 10.1.1 Related Documentation

For related documentation see the following:

- [TPS25948EVM eFuse Evaluation Board](#)
- [TPS25948x Design Calculator](#)
- [Application brief - eFuses for USB Type-C protection](#)

### 10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](#). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 10.3 Support Resources

TI E2E™ [support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is 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](#).

### 10.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 10.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 10.6 Glossary

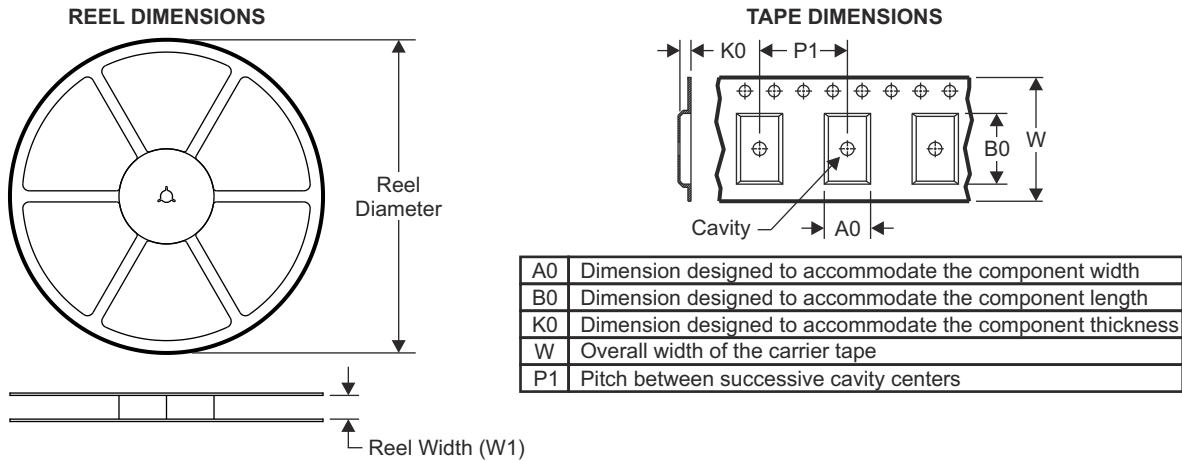
[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.



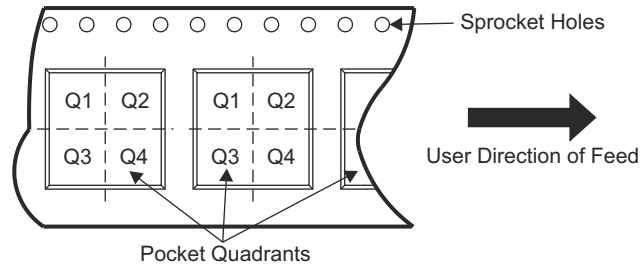
## 11 Mechanical, Packaging, and Orderable Information

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.

### 11.1 Tape and Reel Information

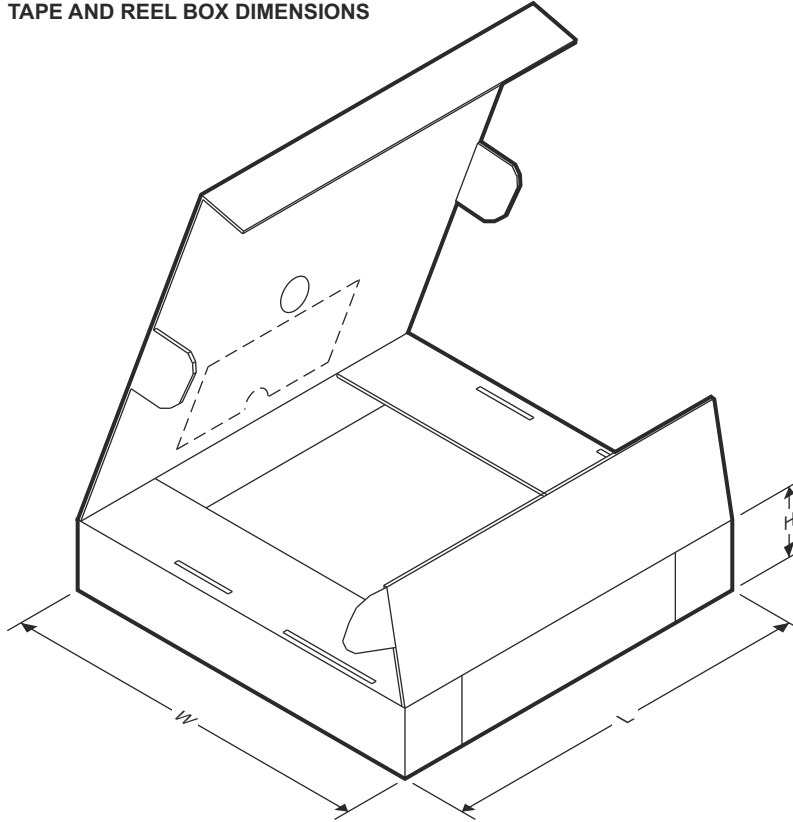


#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
PTPS259840AYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
PTPS259842LYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259840AYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259840LYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259841AYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259841LYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259842AYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1
TPS259842LYWPR	DSBGA	YWP	12	3000	180	8.4	1.88	2.59	0.53	4	8	Q1

TAPE AND REEL BOX DIMENSIONS



ADVANCE INFORMATION

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PTPS259840AYWPR	DSBGA	YWP	12	3000	182	182	20
PTPS259842LYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259840AYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259840LYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259841AYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259841LYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259842AYWPR	DSBGA	YWP	12	3000	182	182	20
TPS259842LYWPR	DSBGA	YWP	12	3000	182	182	20

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTPS259480AYWPR	ACTIVE	DSBGA	YWP	12	3000	TBD	Call TI	Call TI	-40 to 125		Samples
PTPS259482LYWPR	ACTIVE	DSBGA	YWP	12	3000	TBD	Call TI	Call TI	-40 to 125		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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2023, Texas Instruments Incorporated