5V/12V eFuse with Over Voltage Protection and Blocking FET Control

Check for Samples: TPS2592Ax, TPS2592Bx

FEATURES

- **12V Protection – TPS2592Ax**
- **5V Protection – TPS2592Bx**
- **Integrated 28mΩ Pass MOSFET**
- **Absolute Maximum Voltage of 20V**
- **Programmable Current Limit (±15% Accuracy)**
- **Blocking FET Driver**
- **Fixed Over Voltage Setting**
- **Programmable OUT Slew Rate, UVLO**
- **Built-in Thermal Shutdown**
- **UL Recognition Pending**
- **Safe during Single Point Failure Test (UL60950)**
- **Small Foot Print – 10L (3mm x 3mm) VSON**

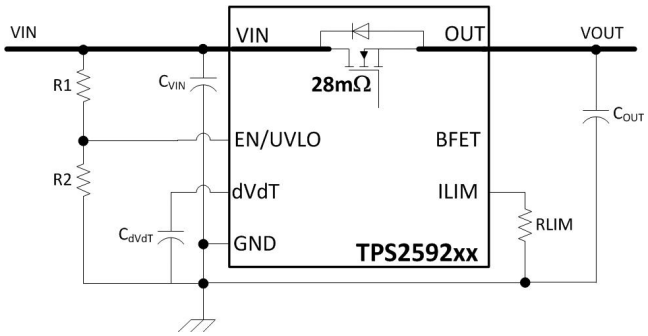
APPLICATIONS

- **HDD and SSD Drives**
- **Set Top Boxes**
- **Servers / AUX Supplies**
- **Fan Control**
- **PCI/PCIe Cards**
- **Switches/Routers**

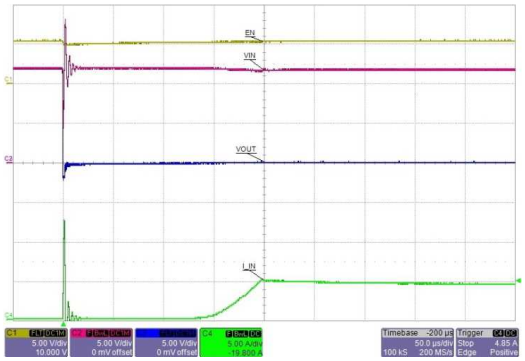
DESCRIPTION

The TPS2592xx family of eFuses are highly integrated circuit protection and power management solutions in a tiny package. With few external components and multiple protection modes, they are a robust defense against overloads, shorts circuits, voltage surges, excessive inrush current, and reverse current. Only one external resistor is required for setting the current limit level, which has a typical accuracy of ±15%. Over voltage events are limited by internal clamping circuits to a safe fixed maximum, with no external components required. TPS2592Ax devices provide over voltage protection (OVP) for 12V systems and TPS2592Bx devices for 5V systems. In cases with particular voltage ramp requirements, a dV/dT pin is provided that can be programmed with a single capacitor to ensure proper output ramp rates. Many systems, such as SSDs, must not allow holdup capacitance energy to dump back through the FET body diode onto a drooping or shorted bus. The BFET pin is for such systems. An external NFET can be connected “back to back” with the TPS2592xx output and the gate driven by BFET. When the TPS2592xx is disabled, then current flow is stopped in both directions. TPS2592xL parts will latch off after a fault and TPS2592xA parts will attempt to restart after the thermal shutoff resets.

Application Schematic



Transient: Output Short Circuit



PRODUCT INFORMATION

PART NUMBER	UVLO	OVERVOLTAGE CLAMP (TYP)	FAULT RESPONSE	STATUS
TPS2592AA	4.3 V	15.0 V	Auto Retry	Active
TPS2592BA	4.3 V	6.1 V	Auto Retry	Preview
TPS2592AL	4.3 V	15.0 V	Latched	Preview
TPS2592BL	4.3 V	6.1 V	Latched	Active

ORDERING INFORMATION(1)

PART NUMBER	PART MARKING	PACKAGE
TPS2592ALDRC	2592AL	10-pin DRC
TPS2592AADRC	2592AA	10-pin DRC
TPS2592BLDRC	2592BL	10-pin DRC
TPS2592BADRC	2592BA	10-pin DRC

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted) (1)

		VALUE(2)		UNIT
		MIN	MAX	
Supply voltage range(3)	VIN	–0.3	20	V
	VIN (10ms Transient)		22	
Output voltage	OUT	–0.3	VIN + 0.3	V
ILIM		–0.3	7	V
EN/UVLO		–0.3	7	V
dV/dT		–0.3	7	V
BFET		–0.3	30	V
Electrostatic discharge	Human body model(4)		±2000	V
	Charged-device model(5)		±500	V
Continuous power dissipation		See Thermal Characteristics		

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values, except differential voltages, are with respect to network ground terminal.
(3) Tested in accordance with JEDEC Standard 22, Test Method A114-B
(4) Tested in accordance with JEDEC Standard 22, Test Method C101-A
(5) Tested in accordance with JEDEC Standard 22, Test Method A115-A

THERMAL CHARACTERISTICS(1)

THERMAL METRIC		TPS2592xx	UNIT
		DRC (10) PINS	
θ_{JA}	Junction-to-ambient thermal resistance	45.9	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	53	
θ_{JB}	Junction-to-board thermal resistance	21.2	
ψ_{JT}	Junction-to-top characterization parameter	1.2	
ψ_{JB}	Junction-to-board characterization parameter	21.4	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	5.9	

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

RECOMMENDED OPERATING CONDITIONS

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

		MIN	TYP	MAX	UNIT
Input voltage range	VIN TPS2592Ax	4.5	12	13.8	V
	VIN TPS2592Bx	4.5	5	5.5	
	BFET	0		VIN+6	
	dV/dT, EN/UVLO	0		6	
	ILIM	0		3.3	
Resistance	ILIM	40.2	100	162	kΩ
External capacitance	OUT	0.1	1	1000	µF
	dV/dT		1	1000	nF
Operating junction temperature range, T_J		–40	25	125	°C
Operating Ambient temperature range, T_A		–40	25	85	°C

ELECTRICAL CHARACTERISTICS

–40°C ≤ T_J ≤ 125°C, VIN = 12V for TPS2592Ax, VIN = 5V for TPS2592Bx, $V_{EN/UVLO}$ = 2V, R_{ILIM} = 100kΩ, C_{dVdT} = OPEN. All voltages referenced to GND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
VIN (INPUT SUPPLY)						
V_{UVR}	UVLO threshold, rising		4.15	4.3	4.45	V
V_{UVhyst}	UVLO hysteresis			5.4%		
IQ_{ON}	Supply current	Enabled: EN/UVLO = 2V, TPS2592AX	0.2	0.42	0.65	mA
		Enabled: EN/UVLO = 2V, TPS2592Bx	0.4	0.62	0.80	mA
IQ_{OFF}		EN/UVLO = 0V		0.1	0.25	mA
V_{OVC}	Over-voltage clamp	VIN > 16.5V, I_{OUT} = 10mA, TPS2592Ax	13.8	15	16.5	V
		TPS2592Bx, VIN > 6.75V, I_{OUT} = 10 mA, –40℃ ≤ T_J ≤ 85℃	5.5	6.1	6.75	
		TPS2592Bx, VIN > 6.75V, I_{OUT} = 10 mA, –40℃ ≤ T_J ≤ 125℃	5.25	6.1	6.75	
EN/UVLO (ENABLE/UVLO INPUT)						
V_{ENR}	EN Threshold voltage, rising		1.37	1.4	1.44	V
V_{ENF}	EN Threshold voltage, falling		1.32	1.35	1.39	V
I_{EN}	EN Input leakage current	0 V ≤ V_{EN} ≤ 5V	–100	0	100	nA
T_{OFFdly}	Turn Off delay	EN↓ to BFET↓, C_{BFET} = 0		0.4		µs
dV/dT (OUTPUT RAMP CONTROL)						
T_{dVdT}	Output ramp time	TPS2592Ax, EN/UVLO → H to OUT = 11.7V, C_{dVdT} = 0	0.7	1	1.3	ms
		TPS2592Bx, EN/UVLO → H to OUT = 4.9V, C_{dVdT} = 0	0.28	0.4	0.52	
		TPS2592Ax, EN/UVLO → H to OUT = 11.7V, C_{dVdT} = 1 nF		12		
		TPS2592Bx, EN/UVLO → H to OUT = 4.9V, C_{dVdT} = 1 nF		5		
I_{dVdT}	dV/dT Charging current	V_{dVdT} = 0 V		220		nA
R_{dVdT_disch}	dV/dT Discharging resistance	EN/UVLO = 0 V, I_{dVdT} = 10 mA sinking	50	73	100	Ω
$V_{dVdTmax}$	dV/dT Max capacitor voltage			5.5		V
$GAIN_{dVdT}$	dV/dT to OUT gain	ΔV_{dVdT}		4.85		V/V

ELECTRICAL CHARACTERISTICS (continued)

–40°C ≤ T_J ≤ 125°C, VIN = 12V for TPS2592Ax, VIN = 5V for TPS2592Bx, $V_{EN/UVLO}$ = 2V, R_{ILIM} = 100kΩ, C_{dVdT} = OPEN. All voltages referenced to GND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ILIM (CURRENT LIMIT PROGRAMMING)						
I_{ILIM}	ILIM Bias current			10		µA
I_{OL}	Overload current limit	R_{ILIM} = 45.3 kΩ, $V_{VIN-OUT}$ = 1 V	1.79	2.10	2.42	A
		R_{ILIM} = 100 kΩ, $V_{VIN-OUT}$ = 1 V	3.46	3.75	4.03	
		R_{ILIM} = 150 kΩ, $V_{VIN-OUT}$ = 1 V	4.4	5.2	6	
$I_{OL-R-Short}$		R_{ILIM} = 0 Ω, Shorted Resistor Current Limit (Single Point Failure Test: UL60950)		0.7		A
$I_{OL-R-Open}$		R_{ILIM} = OPEN, Open Resistor Current Limit (Single Point Failure Test: UL60950)		0.55		A
I_{SCL}	Short-circuit current limit	R_{ILIM} = 45.3 kΩ, $V_{VIN-OUT}$ = 5 V, TPS2592Bx	1.72	2.05	2.38	A
		R_{ILIM} = 45.3 kΩ, $V_{VIN-OUT}$ = 12 V, TPS2592Ax	1.66	1.98	2.29	
		R_{ILIM} = 100 kΩ, $V_{VIN-OUT}$ = 5 V, TPS2592Bx	3.14	3.56	3.98	
		R_{ILIM} = 100 kΩ, $V_{VIN-OUT}$ = 12 V, TPS2592Ax	2.90	3.32	3.75	
		R_{ILIM} = 150 kΩ, $V_{VIN-OUT}$ = 5 V, TPS2592Bx	4.12	4.86	5.60	
		R_{ILIM} = 150 kΩ, $V_{VIN-OUT}$ = 12 V, TPS2592Ax	3.75	4.42	5.10	
$RATIO_{FASTRIP}$	Fast-Trip comparator level w.r.t. overload current limit	$I_{FASTRIP}$: I_{OL}		160%		
$T_{FastOffDly}$	Fast-Trip comparator delay	I_{OUT} > $I_{FASTRIP}$		3		µs
$V_{OpenILIM}$	ILIM Open resistor detect threshold	V_{ILIM} Rising, R_{ILIM} = OPEN		3.1		V
OUT (PASS FET OUTPUT)						
T_{ON}	Turn-on delay	EN/UVLO → H to I_{VIN} = 100mA, 1A resistive load at OUT		220		µs
R_{DSon}	FET ON resistance	T_J = 25°C	21	28	33	mΩ
		T_J = 125°C(1)		39	46	
$I_{OUT-OFF-LKG}$	OUT Bias current in off state	$V_{EN/UVLO}$ = 0 V, V_{OUT} = 0 V (Sourcing)	–5	0	1	µA
$I_{OUT-OFF-SINK}$		$V_{EN/UVLO}$ = 0V, V_{OUT} = 300 mV (Sinking)	10	15	20	
BFET (BLOCKING FET GATE DRIVER)						
I_{BFET}	BFET Charging current	V_{BFET} = V_{OUT}		2		µA
$V_{BFETmax}$	BFET Clamp voltage			$V_{VIN+6.4}$		V
$R_{BFETdisch}$	BFET Discharging resistance	$V_{EN/UVLO}$ = 0 V, I_{BFET} = 100 A	15	26	36	Ω
$T_{BFET-ON}$	BFET Turn-on duration	EN/UVLO → H to V_{BFET} = 12 V, C_{BFET} = 1 nF		4.2		ms
		EN/UVLO → H to VB_{FET} = 12 V, C_{BFET} = 10 nF		42		
$T_{BFET-OFF}$	BFET Turn-off duration	EN/UVLO → L to $_{VBFET}$ = 1 V, C_{BFET} = 1 nF		0.4		µs
		EN/UVLO → L to V_{BFET} = 1 V, C_{BFET} = 10 nF		1.4		
TSD (THERMAL SHUT DOWN)						
T_{SHDN}	TSD Threshold, rising(1)			160		°C
$T_{SHDNhyst}$	TSD Hysteresis(1)			10		°C
	Thermal fault: latched or autoretry	TPS2592xL		LATCHED		
		TPS2592xA		AUTO-RETRY		

(1) The limits for these parameters are specified based on characterization data, and are not tested during production.

TYPICAL CHARACTERISTICS

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

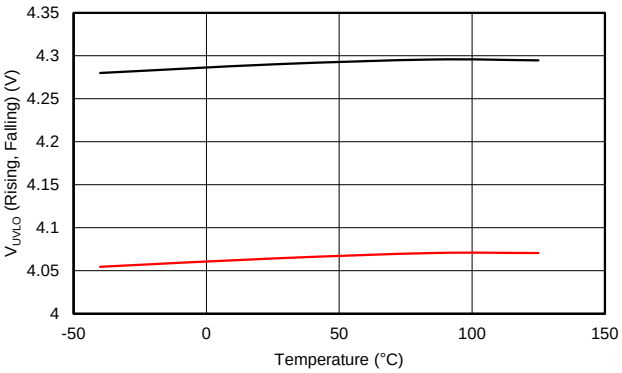


Figure 1. V_{UVLO} vs TEMPERATURE

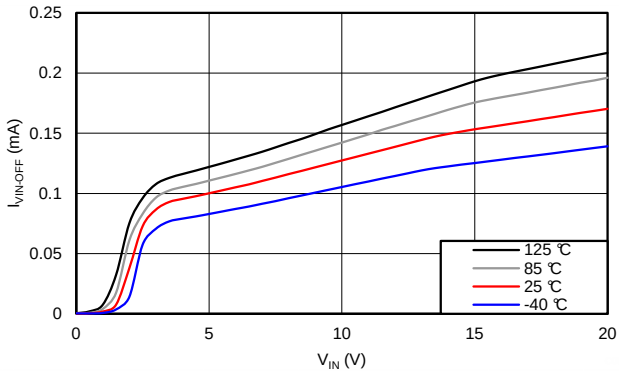


Figure 2. $I_{VIN-OFF}$ vs V_{IN} ACROSS TEMPERATURE

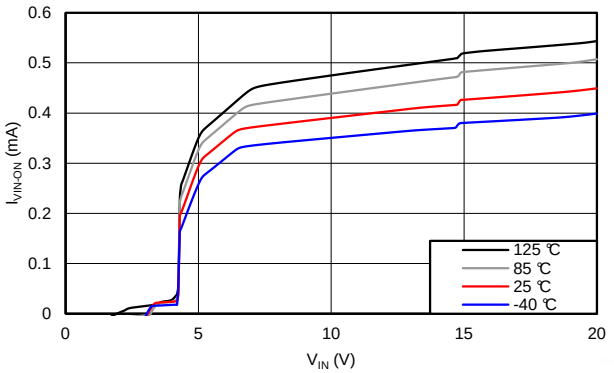


Figure 3. I_{VIN-ON} vs V_{IN} ACROSS TEMPERATURE (TPS2592Ax)

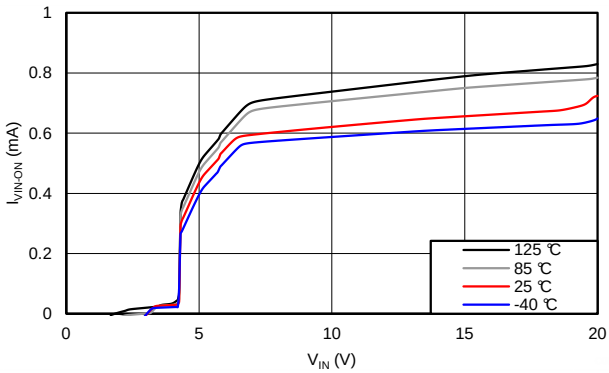


Figure 4. I_{VIN-ON} vs V_{IN} ACROSS TEMPERATURE (TPS2592Bx)

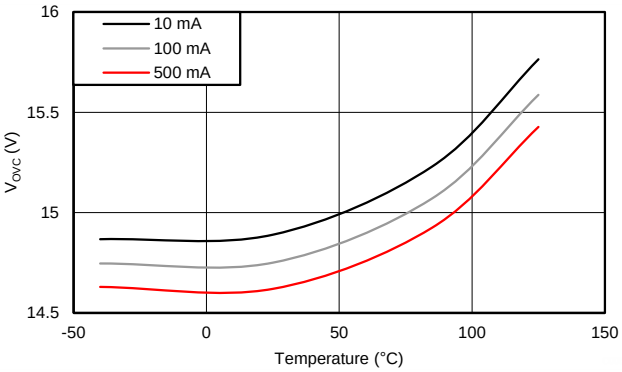


Figure 5. V_{OVC} vs TEMPERATURE ACROSS I_{OUT} (TPS2592Ax)

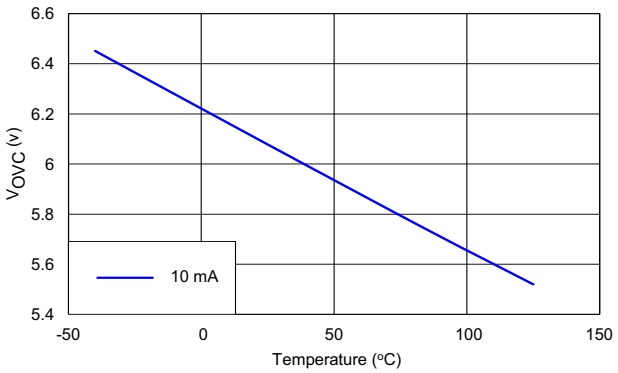


Figure 6. V_{OVC} vs TEMPERATURE (TPS2592Bx)

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

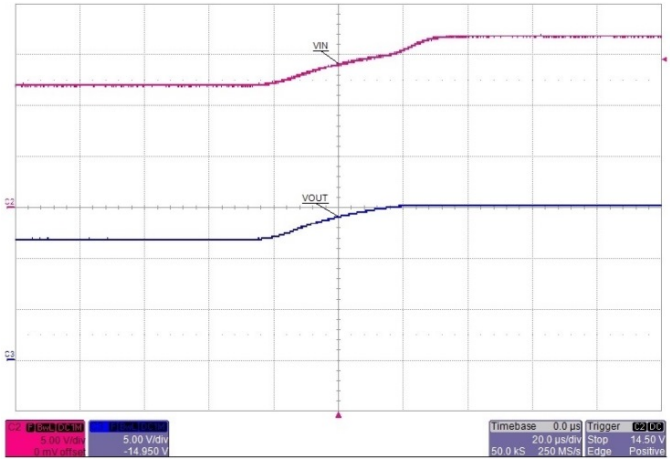


Figure 7. TRANSIENT: OVER-VOLTAGE CLAMP: TPS2592Ax

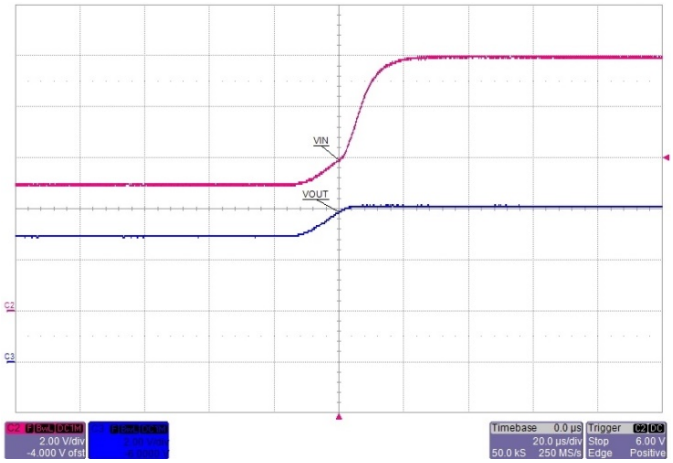


Figure 8. TRANSIENT: OVER-VOLTAGE CLAMP: TPS2592Bx

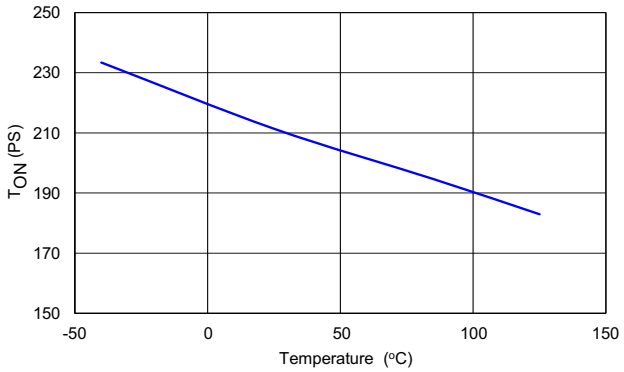


Figure 9. T_{ON} vs TEMPERATURE

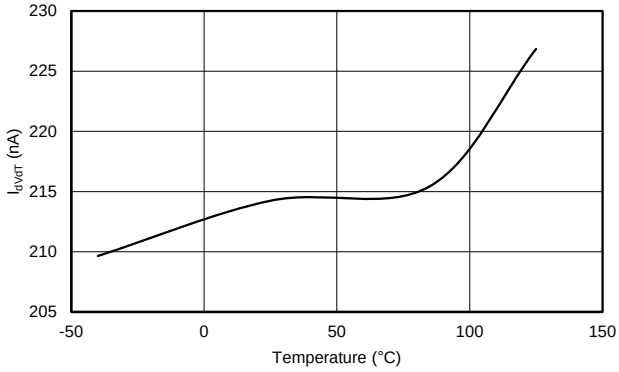


Figure 10. I_{dVdT} vs TEMPERATURE

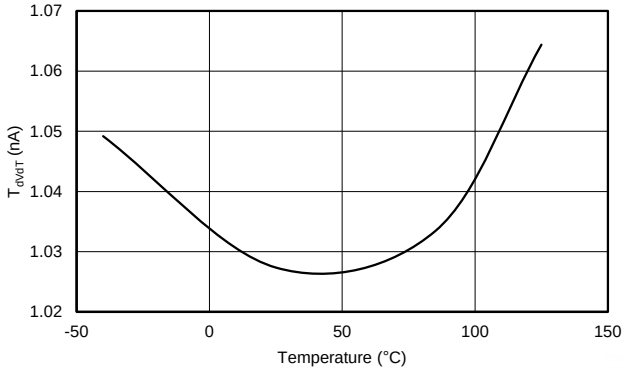


Figure 11. T_{dVdT} vs TEMPERATURE (TPS2592Ax)

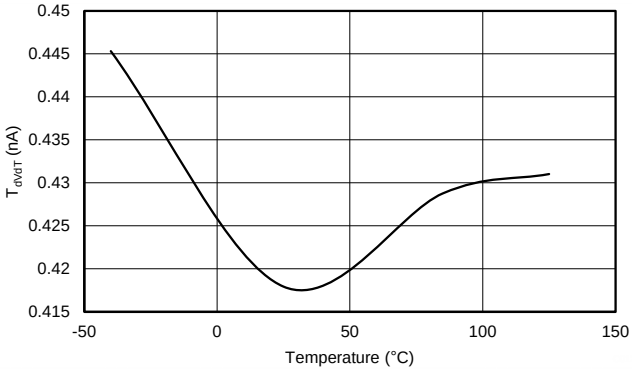


Figure 12. T_{dVdT} vs TEMPERATURE (TPS2592Bx)

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

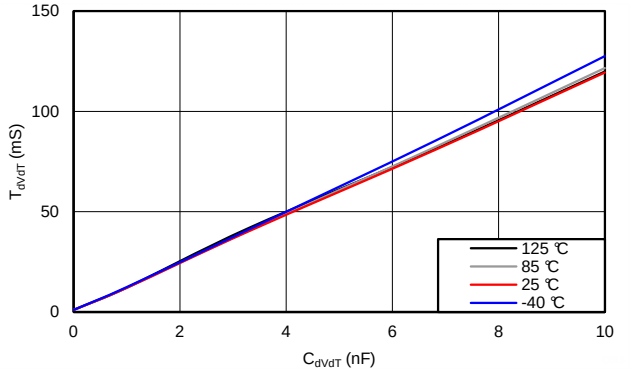


Figure 13. T_{dVdT} vs C_{dVdT} (TPS2592Ax)

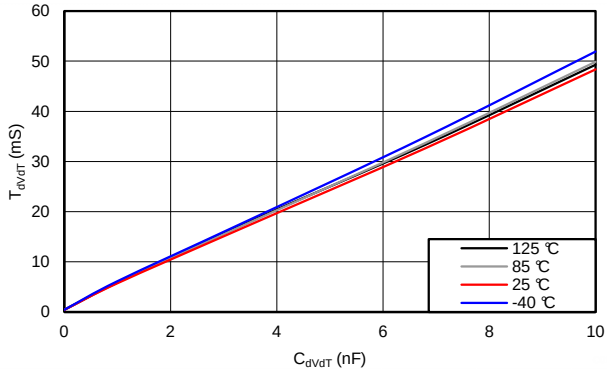


Figure 14. T_{dVdT} vs C_{dVdT} (TPS2592Bx)

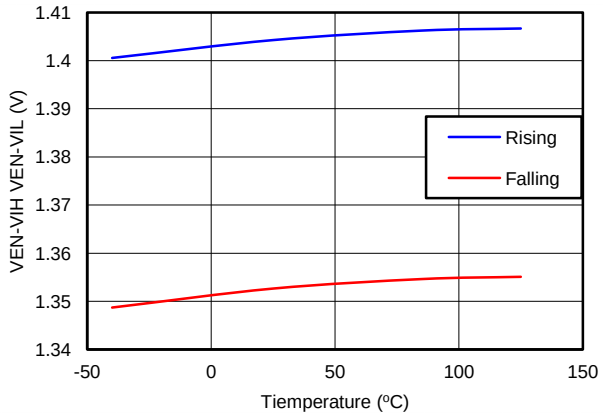


Figure 15. V_{EN_VIH}, V_{EN_VIL} vs TEMPERATURE

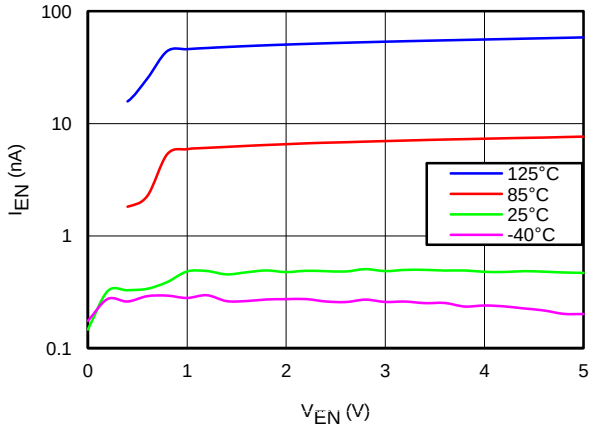


Figure 16. I_{EN} (Leakage Current) vs V_{EN}

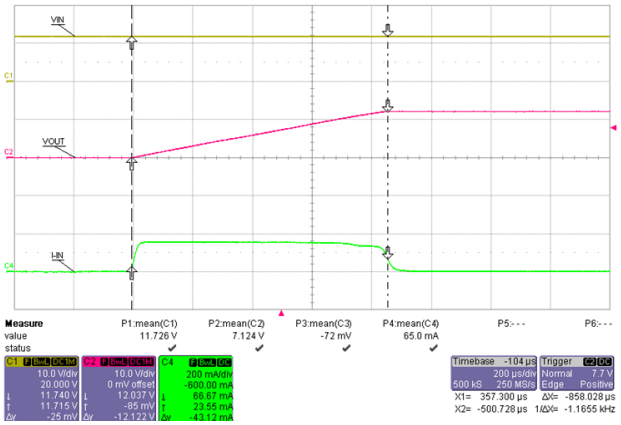


Figure 17. TRANSIENT: OUTPUT RAMP (C_{dVdT} = OPEN): TPS2592Ax

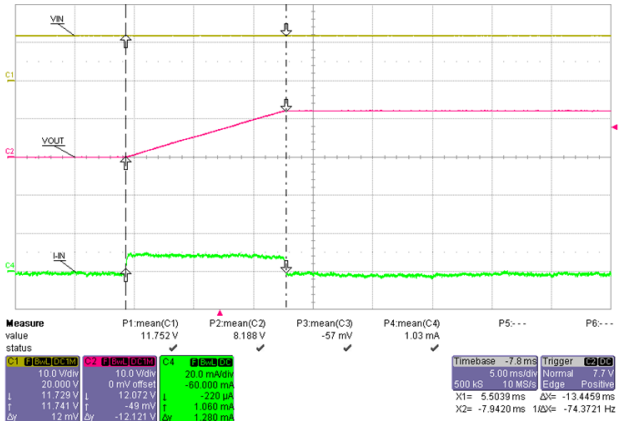


Figure 18. TRANSIENT: OUTPUT RAMP (C_{dVdT} = 1 nF): TPS2592Ax

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

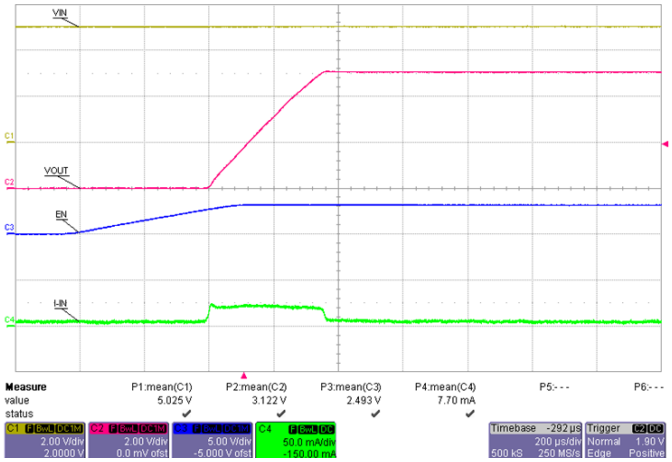


Figure 19. TRANSIENT: OUTPUT RAMP (C_{dVdT} = OPEN): TPS2592Bx

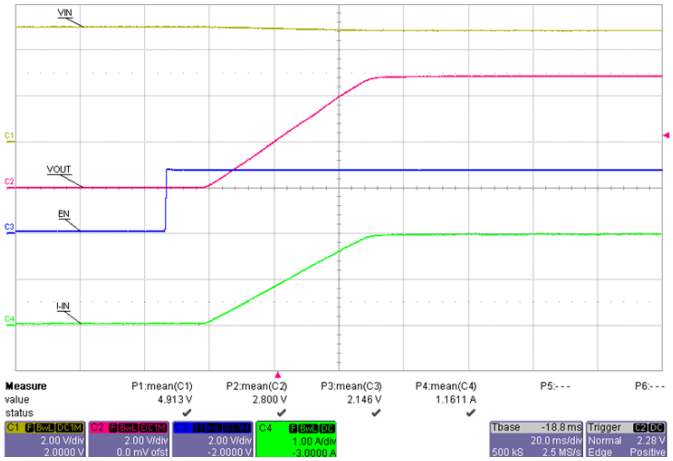


Figure 20. Transient Output Ramp (C_{dVdT} = 1 nF, C_{OUT}=10 µF, R_{OUT}= 2.5 Ω) : TPS2592Bx

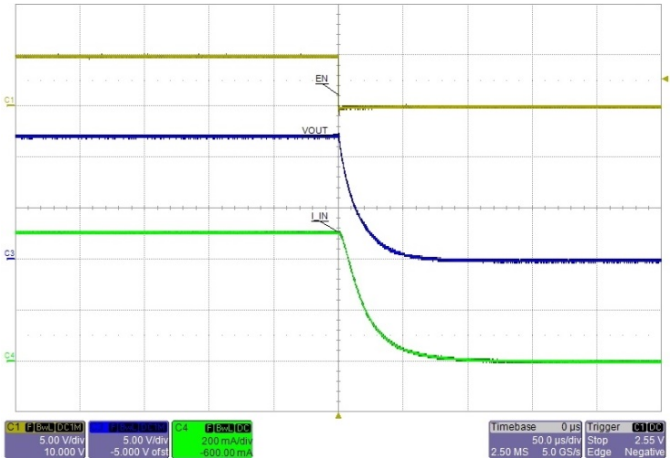


Figure 21. TRANSIENT: TURN OFF DELAY (EN ↓)

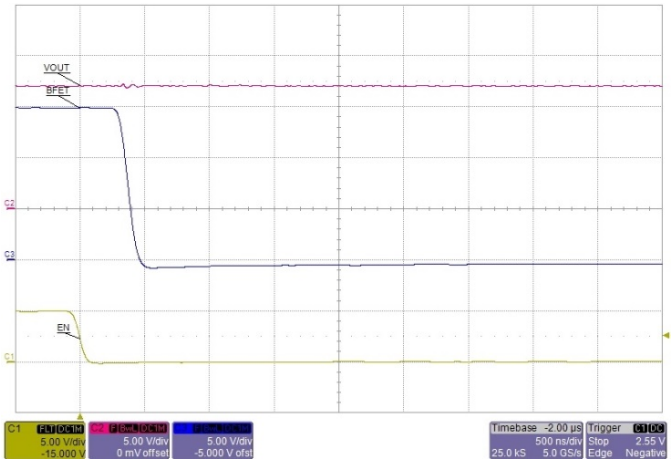


Figure 22. TURN OFF DELAY TO BFET (EN↓)

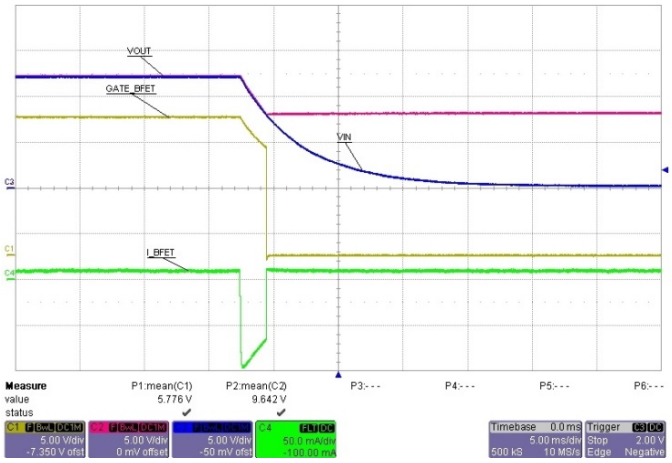


Figure 23. TURN OFF DELAY TO BFET (VIN↓)

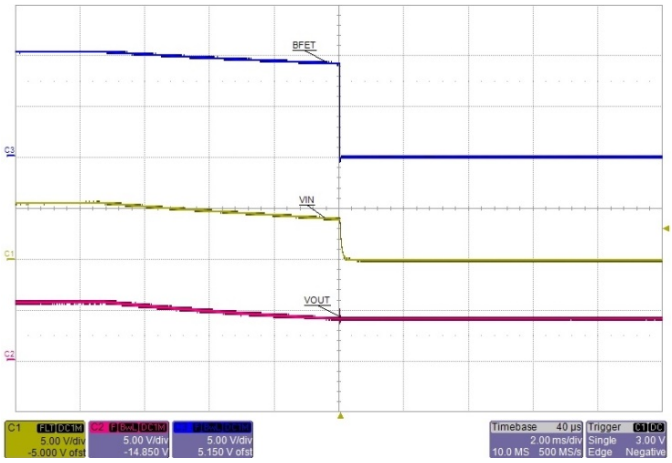


Figure 24. TRANSIENT: TURN OFF DELAY TO BFET (VIN↓)

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

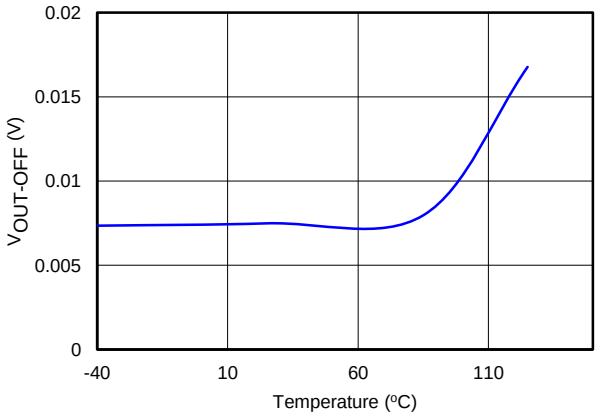


Figure 25. $V_{OUT-OFF}$ vs TEMPERATURE

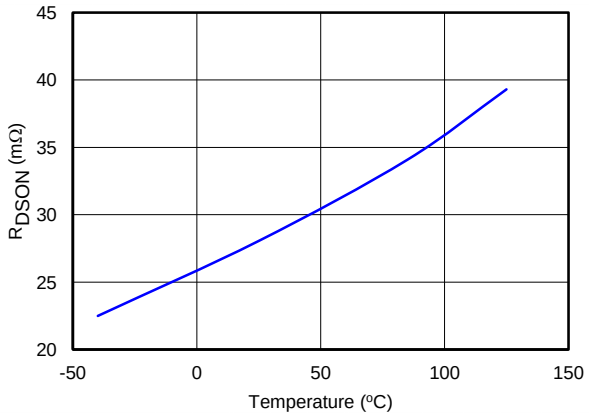


Figure 26. R_{DSON} vs TEMPERATURE

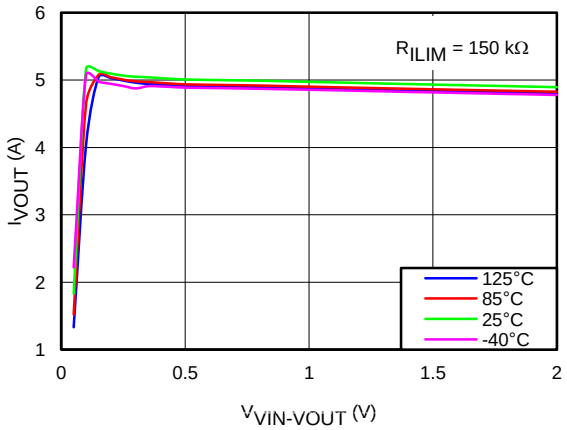


Figure 27. I_{OUT} vs $V_{VIN-OUT}$ ACROSS TEMPERATURE (150kΩ)

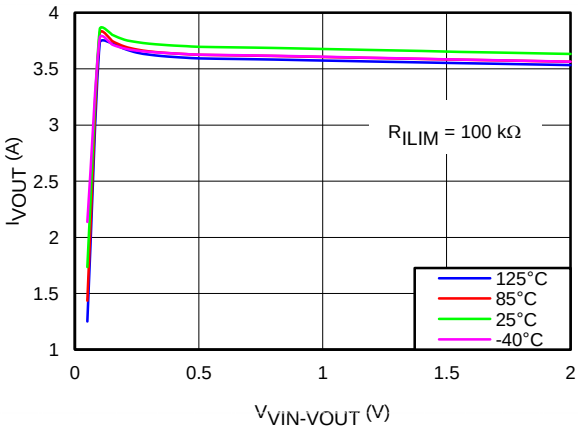


Figure 28. I_{OUT} vs $V_{VIN-OUT}$ ACROSS TEMPERATURE (100kΩ)

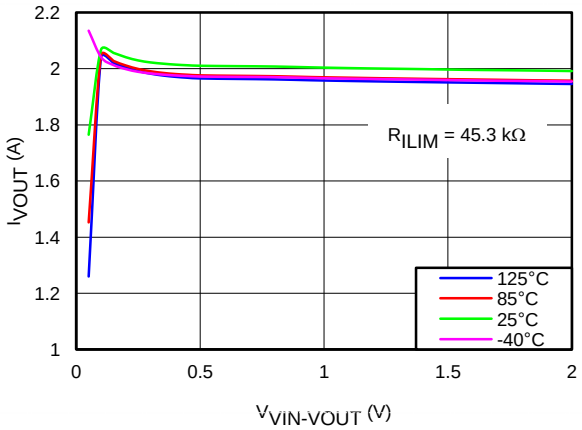


Figure 29. I_{OUT} vs $V_{VIN-OUT}$ ACROSS TEMPERATURE (45.3kΩ)

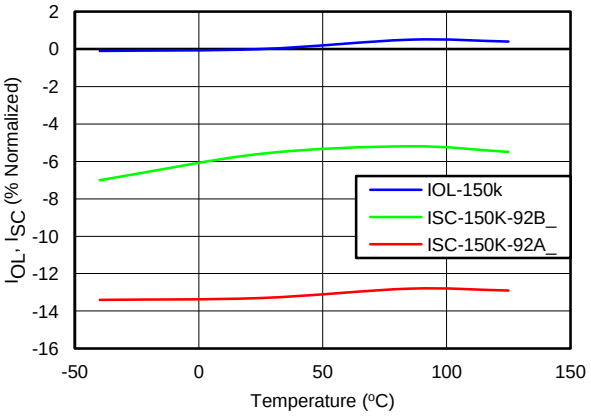


Figure 30. I_{OL}, I_{SC} vs TEMPERATURE (150kΩ)

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

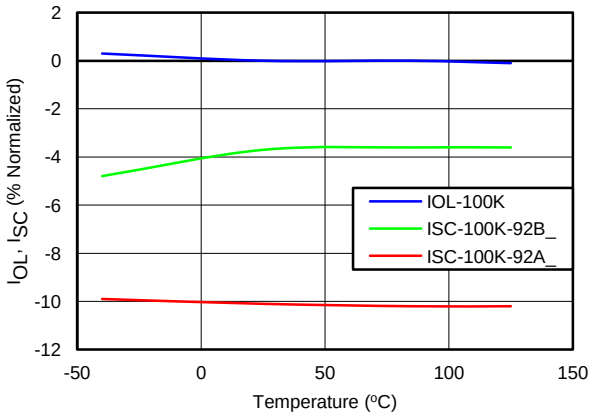


Figure 31. I_{OL}, I_{SC} vs TEMPERATURE (100kΩ)

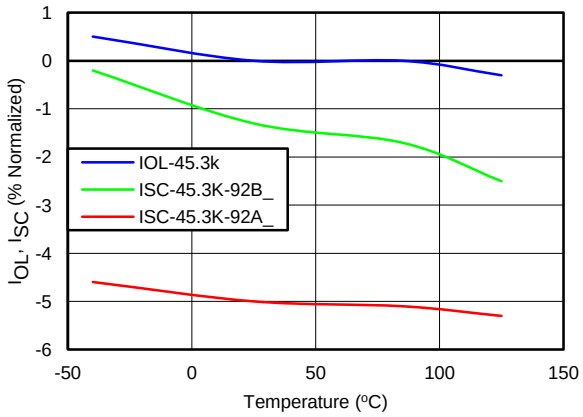


Figure 32. I_{OL}, I_{SC} vs TEMPERATURE (45.3kΩ)

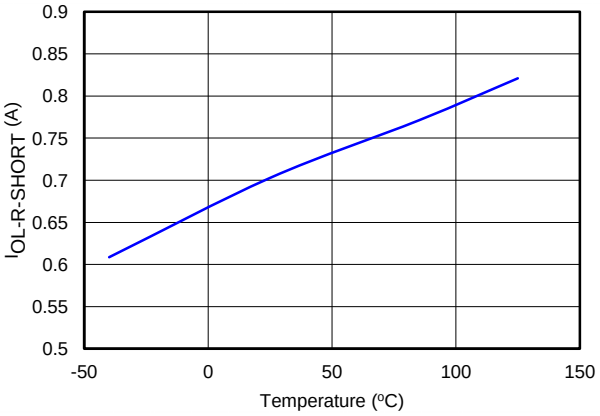


Figure 33. $I_{OL\text{-}R\text{-}Short}$ vs TEMPERATURE (R_{ILIM} = 0)

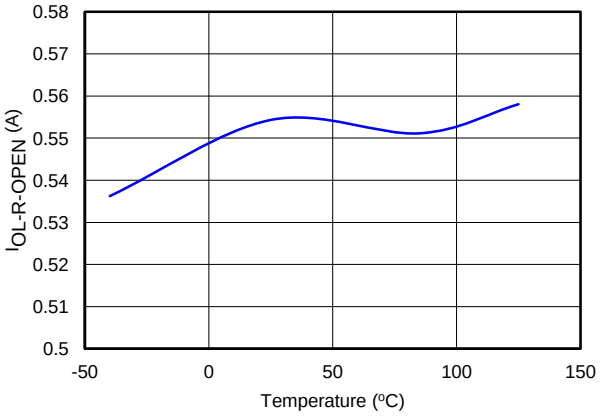


Figure 34. $I_{OL\text{-}R\text{-}Open}$ vs TEMPERATURE (R_{ILIM} = OPEN)

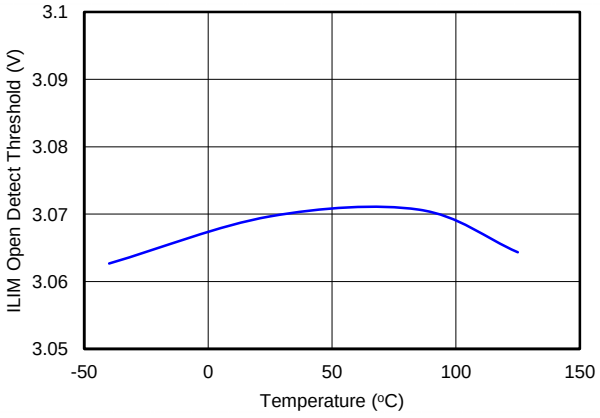


Figure 35. $V_{OpenILIM}$ vs TEMPERATURE

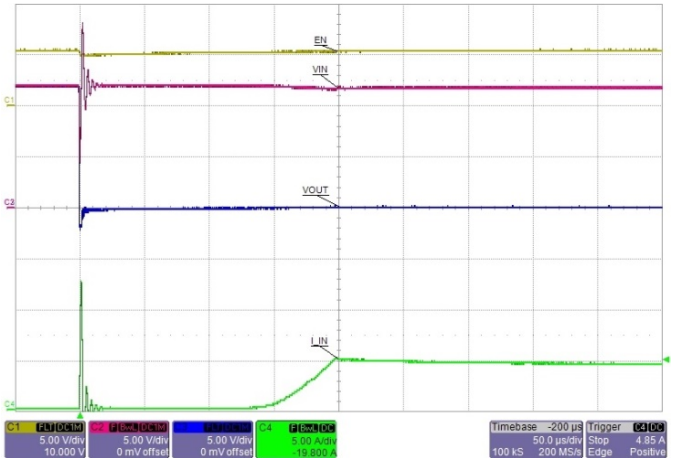


Figure 36. TRANSIENT: OUTPUT SHORT CIRCUIT

TYPICAL CHARACTERISTICS (continued)

T_J = 25°C, V_{VIN} = 12 V for TPS2592Ax, V_{VIN} = 5 V for TPS2592Bx, $V_{EN/UVLO}$ = 2 V, R_{ILIM} = 100 kΩ, C_{VIN}=0.1 µF, C_{OUT}=1µF, C_{dVdT} = OPEN (unless stated otherwise)

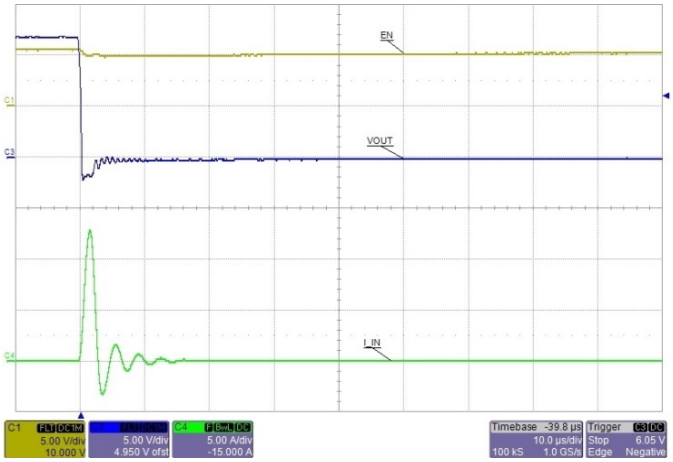


Figure 37. SHORT CIRCUIT (Zoom): FAST-TRIP COMPARATOR

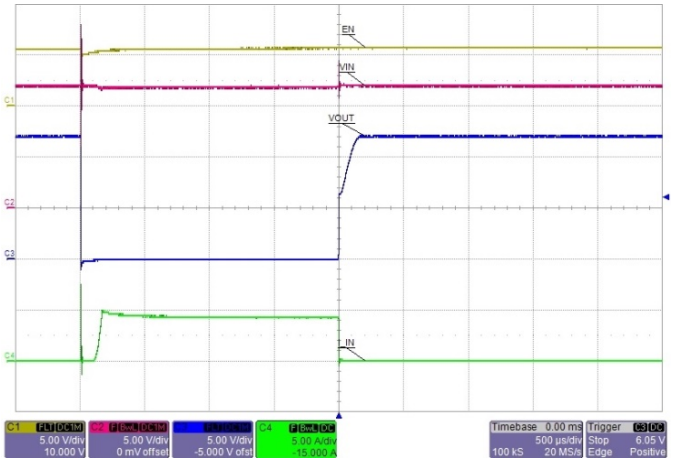


Figure 38. TRANSIENT: RECOVERY FROM SHORT CIRCUIT

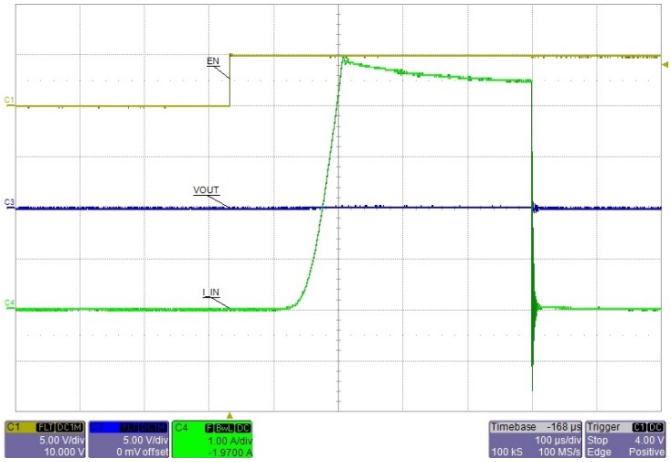


Figure 39. TRANSIENT: WAKE UP TO SHORT CIRCUIT

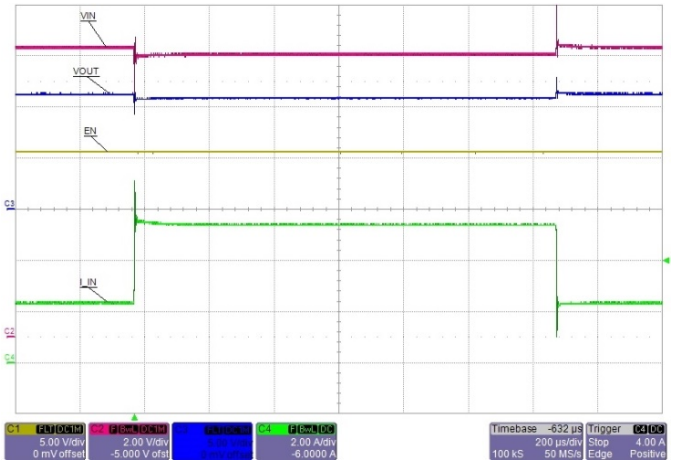


Figure 40. TRANSIENT: OVERLOAD CURRENT LIMIT: (I_{LOAD} stepped from 50% to 120%, back to 50%)

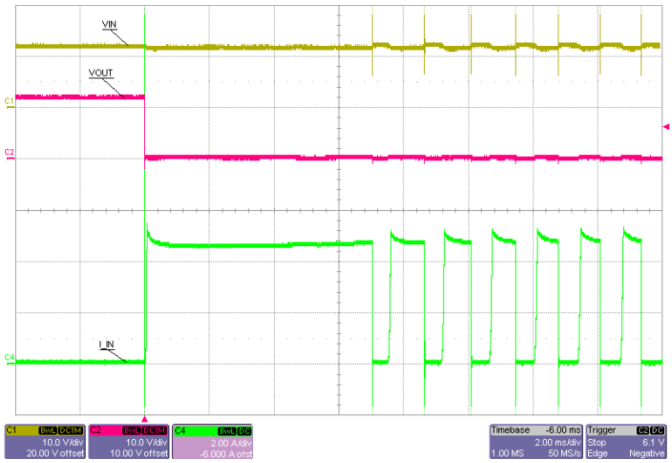


Figure 41. TRANSIENT: THERMAL FAULT AUTO-RETRY (TPS2592xA)

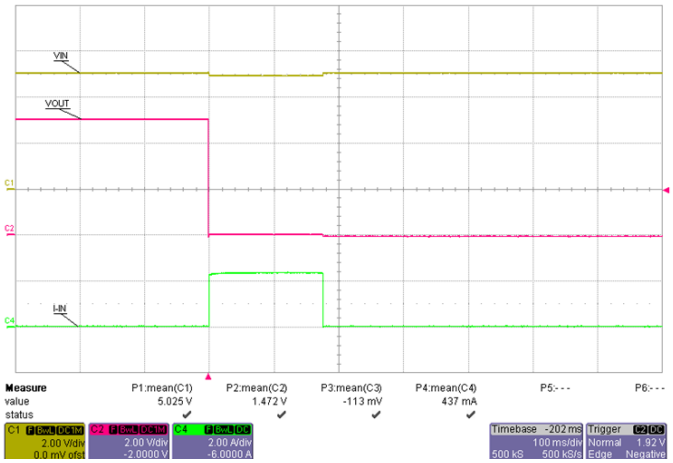
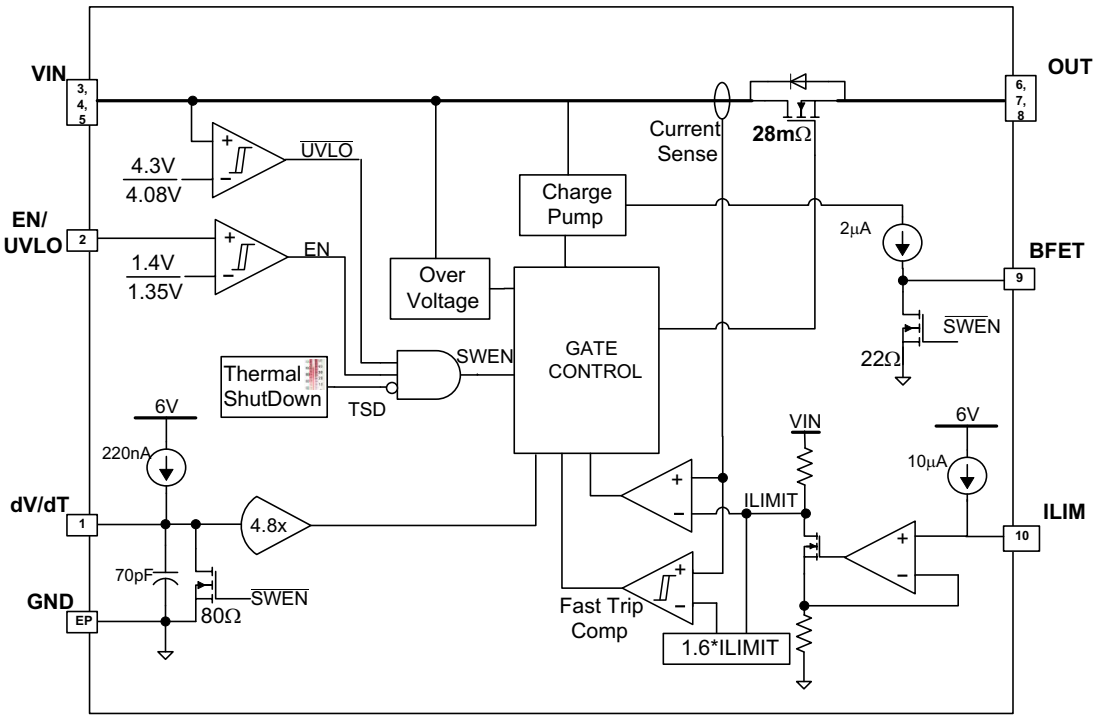
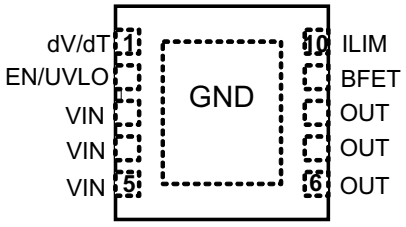


Figure 42. TRANSIENT: THERMAL FAULT LATCHED (TPS2592xL)

FUNCTIONAL BLOCK DIAGRAM



DRC PACKAGE
(TOP VIEW)



PIN DESCRIPTIONS

PIN		DESCRIPTION
NAME	NO.	
SUPPLY PINS		
VIN	3-5	Input Supply Voltage
GND	Power Pad	GND
CONTROL PINS		
dV/dT	1	Tie a capacitor from this pin to GND to control the ramp rate of OUT at device turn-on.
EN/UVLO	2	This is a dual function control pin. When used as an ENABLE pin and pulled down, it shuts off the internal pass MOSFET and pulls BFET to GND. When pulled high, it enables the device and BFET. As an UVLO pin, it can be used to program different UVLO trip point via external resistor divider.
BFET	9	Connect this pin to the gate of a blocking NFET. See detailed pin description and application note in this datasheet.
ILIM	10	A resistor from this pin to GND will set the overload and short circuit limit.
LOAD PINS		
OUT	6-8	Output of the device

DEVICE OPERATION

The TPS2592xx is a hot-swap controller with integrated power switch that is used to manage current/voltage/start-up voltage ramp to a connected load. The device starts its operation by monitoring the VIN bus. When VIN exceeds the undervoltage threshold (V_{UVLO}), the device samples the EN/UVLO pin. A high level on this pin will enable the internal MOSFET and also start charging the gate of external blocking FET (if connected) via the BFET pin. As VIN rises, the internal MOSFET of the device and external FET (if connected) will start conducting and allow current to flow from VIN to OUT. When EN/UVLO is held low (i.e., below V_{ENF}), the internal MOSFET is turned off and BFET pin is discharged, thereby blocking the flow of current from VIN to OUT. User also has the ability to modify the output voltage ramp time by connecting a capacitor between dV/dT pin and GND.

Having successfully completed its start-up sequence, the device now actively monitors its load current and input voltage, ensuring that the adjustable overload current limit I_{OL} is not exceeded and input voltage spikes are safely clamped to V_{OVC} level at the output. This keeps the output device safe from harmful voltage and current transients. The device also has built-in thermal sensor. In the event device temperature (T_J) exceeds T_{SHDN} , typically 160°C, the thermal shutdown circuitry will shut down the internal MOSFET thereby disconnecting the load from the supply. In the TPS2592xL, the output will remain disconnected (MOSFET open) until power to device is recycled or EN/UVLO is toggled (pulled low and then high). The TPS2592xA device will remain off during a cooling period until device temperature falls below T_{SHDN} – 10°C, after which it will attempt to restart. This ON and OFF cycle will continue until fault is cleared.

DETAILED PIN DESCRIPTION

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

VIN: Input voltage to the TPS2592xx. A ceramic bypass capacitor close to the device from VIN to GND is recommended to alleviate bus transients. The recommended operating voltage range is 4.5V – 13.8V for TPS2592Ax and 4.5V – 5.5V for TPS2592Bx. The device can continuously sustain a voltage of 20V on VIN pin. However, above the recommended maximum bus voltage, the device will be in over-voltage protection (OVP) mode, limiting the output voltage to V_{OVC}. The power dissipation in OVP mode is $P_{D\_OVP} = (V_{VIN} - V_{OVC})*I_{OUT}$, which can potentially heat up the device and cause thermal shutdown.

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

$$I_{dVdT} = (C_{EXT} + C_{INT}) \times \frac{\left(\frac{dV_{OUT}}{dT}\right)}{GAIN_{dVdT}} \quad (1)$$

Where:

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

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

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

For details on how to select an appropriate charging time/rate, refer to the applications section: "INRUSH CURRENT AND POWER DISSIPATION DURING START-UP".

BFET: Connect this pin to an external NFET that can be used to disconnect input supply from rest of the system in the event of power failure at VIN. BFET pin is controlled by either UVLO event or EN/UVLO (see table below). BFET can source charging current of 2µA (TYP) and sink (discharge) current from the gate of the external FET via a 26Ω internal discharge resistor to initiate fast turn-off, typically <1 µs.

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

EN/UVLO: As an input pin, it controls both the ON/OFF state of the internal MOSFET and that of the external blocking FET. In its high state, the internal MOSFET is enabled and charging begins for the gate of external FET. A low on this pin will turn off the internal MOSFET and pull the gate of the external FET to GND via the built-in discharge resistor. High and Low levels are specified in the parametric table of the datasheet. The EN/UVLO pin is also used to clear a thermal shutdown latch in the TPS2592xL by toggling this pin (H→L).

The internal de-glitch delay on EN/UVLO falling edge is intentionally kept low (1us typical) for quick detection of power failure. When used with a resistor divider from supply to EN/UVLO to GND, power-fail detection on EN/UVLO helps in quick turn-off of the BFET driver, thereby stopping the flow of reverse current (see typical application diagram, Figure 47). For applications where a higher de-glitch delay on EN/UVLO is desired, or when the supply is particularly noisy, it is recommended to use an external bypass capacitor from EN/UVLO to GND

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

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

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

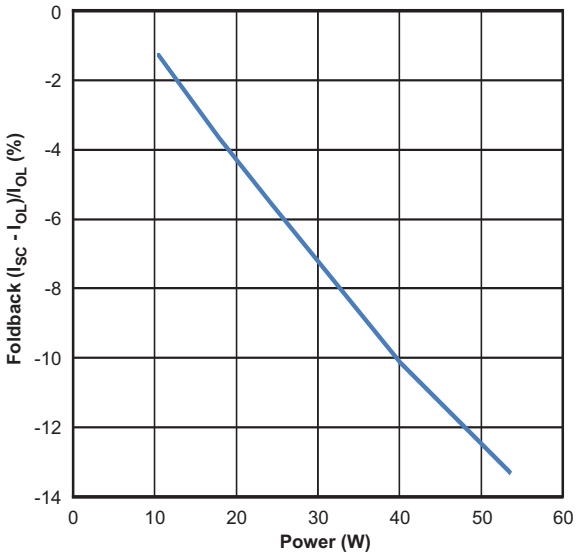


Figure 43. Thermal Foldback in Current Limit

During a transient short circuit event, the current through the device increases very rapidly. The current-limit amplifier cannot respond very quickly to this event due to its limited bandwidth. Therefore, the TPS2592 incorporates a fast-trip comparator, which shuts down the pass device very quickly when $I_{OUT} > I_{FASTRIP}$, and terminates the rapid short-circuit peak current. The trip threshold is set to 60% higher than the programmed over-load current limit ($I_{FASTRIP}$ = 1.6 x I_{OL}). After the transient short-circuit peak current has been terminated by the fast-trip comparator, the current limit amplifier smoothly regulates the output current to I_{OL} (see figure below).

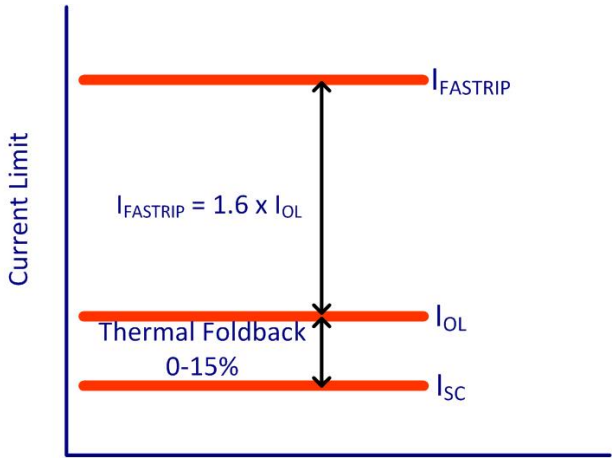


Figure 44. Fast-Trip Current

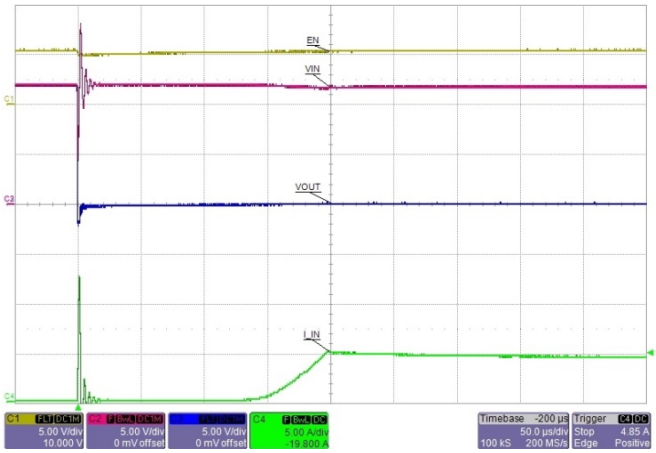


Figure 45. Fast-Trip and Current Limit Amplifier Response for Short Circuit

TYPICAL APPLICATIONS

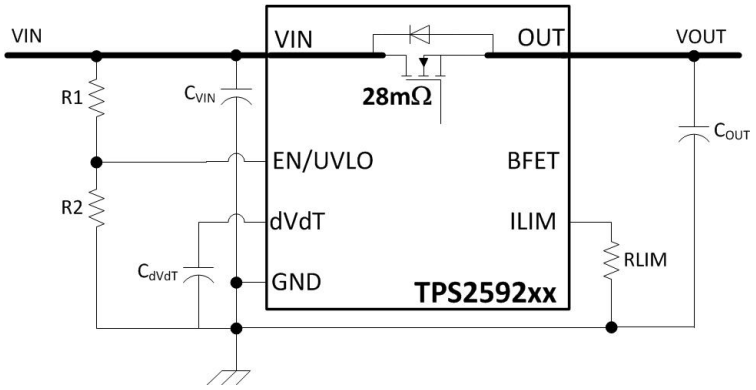


Figure 46. Simple e-Fuse (Current-Limiter): Application with Output Ramp-Rate Control

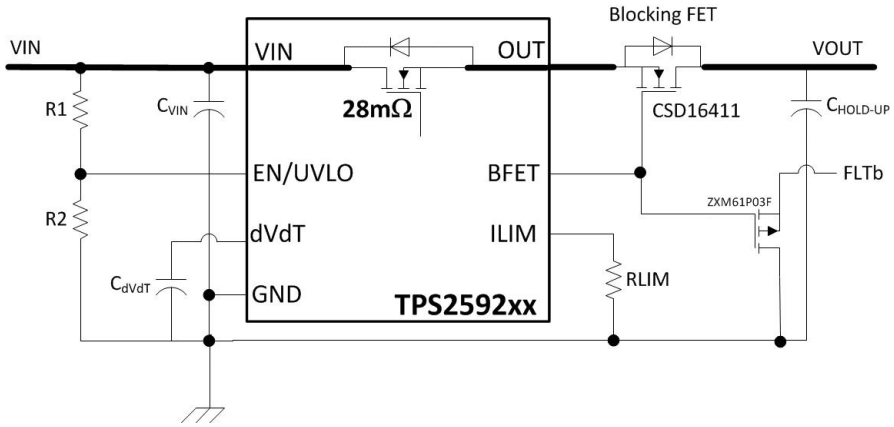


Figure 47. Reverse Current Protection (e.g., SSD) Application with Blocking FET $C_{HOLD-UP}$ (TPS2592 UVLO is used as power fail comparator)

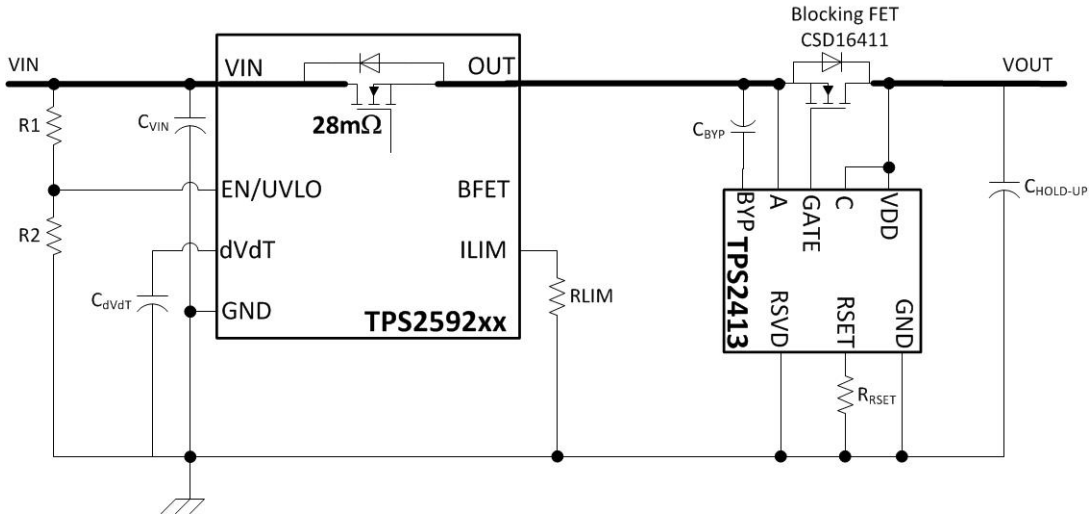


Figure 48. Reverse Current Protection Application with External Blocking Controller (TPS2413 is used as reverse current comparator)

APPLICATION INFORMATION

INRUSH CURRENT AND POWER DISSIPATION DURING START-UP

A successful design needs to keep the junction temperature of TPS2592 well below the absolute-maximum rating during both dynamic (start-up) and steady state conditions. Dynamic power stresses often are an order of magnitude greater than the static stresses, so it is important to determine the right start-up time and in-rush current limit required with system capacitance to avoid thermal shutdown during start-up.

During start-up, as the output capacitor charges, the voltage difference across the internal FET decreases, and the power dissipated decreases as well. Typical ramp-up of output voltage V_{OUT} with inrush current limit is shown in Figure 49 and variation of power dissipation with ramp-up time is plotted in Figure 50. The average power dissipated in the device during start-up is equal to area of triangular plot as highlighted.

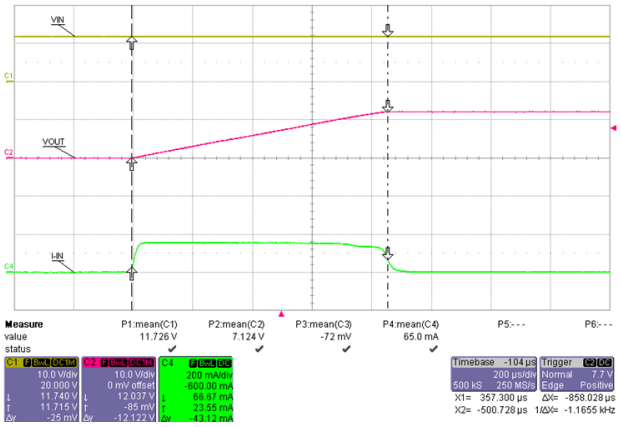


Figure 49. Start-Up Waveform

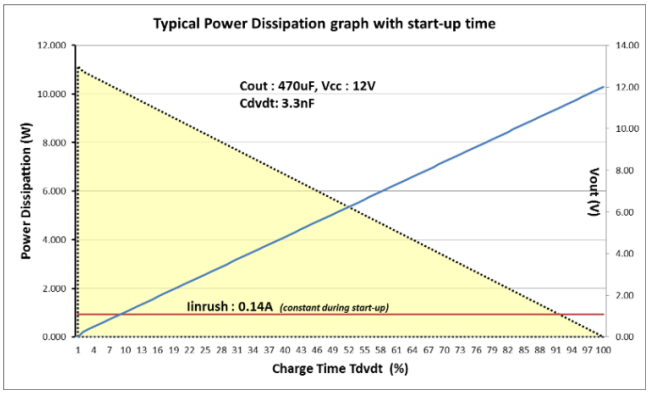


Figure 50. P_{DISS} During Start-Up

For the TPS2592, the inrush current is determined as:

$$I = C \times \frac{dv}{dt} \Rightarrow I_{INRUSH} = C_{OUT} \times \frac{V_{VIN}}{T_{dvdt}} \quad (4)$$

Power dissipation during start-up will be:

$$P_{INRUSH} = 0.5 \times V_{VIN} \times I_{INRUSH} \quad (5)$$

The above calculation assumes that load does not draw any current until the output voltage has reached its final value.

If the load draws current during the turn-on sequence, there will be additional power dissipated during the start-up phase. Considering a resistive load R_L, load current ramps up proportionally with increase in output voltage during T_{dvdt} time. Typical ramp-up of output voltage V_{OUT} and Load current is shown in Figure 51 and variation of power dissipation with ramp-up time is plotted in Figure 52. The additional power dissipation during start-up phase is represented and calculated as follows:

$$V_{DS}(t) = V_{VIN} \times \left(1 - \frac{t}{T_{dvdt}}\right) \quad (6)$$

$$I_{LOAD}(t) = \left(\frac{V_{VIN}}{R_L}\right) \times \frac{t}{T_{dvdt}} \quad (7)$$

Average energy loss due in FET during charging time due to resistive load is given by:

$$W_{Tdvdt} = \int_0^{Tdvdt} V_{VIN} \times \left(1 - \frac{t}{T_{dvdt}}\right) \times \left(\frac{V_{VIN}}{R_L} \times \frac{t}{T_{dvdt}}\right) dt \quad (8)$$

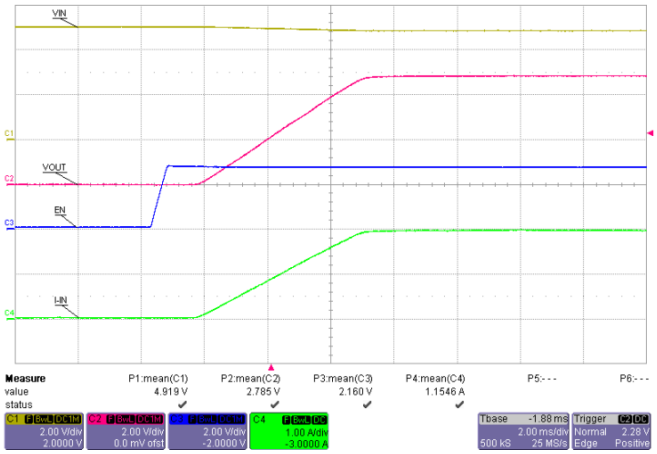


Figure 51. Start-up Waveform with Load (2.5W)

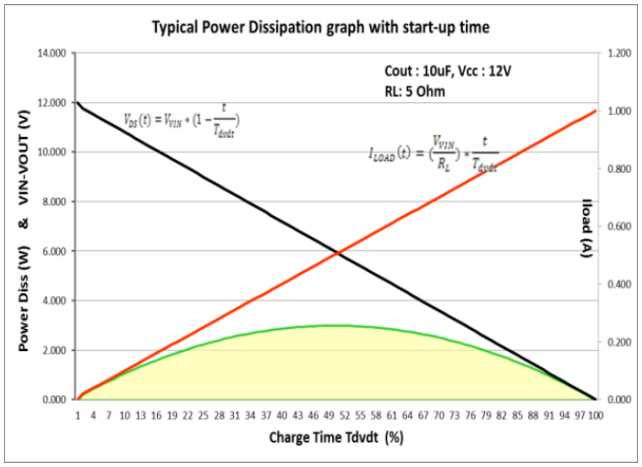


Figure 52. P_{DISS} During Due to Load Current

Linearizing the parabolic equation and representing as triangle, the average power loss is:

$$P_{DISS\_LOAD} = \left(\frac{1}{6}\right) \times \frac{V_{VIN}^2}{R_L} \quad (9)$$

Total power dissipated in the device during startup is:

$$P_{STARTUP} = P_{INRUSH} + P_{DISS\_LOAD} \quad (10)$$

Total current during startup is given by:

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

If $I_{STARTUP} > I_{LIM}$, the device limits the current to I_{LIM} and the minimum charging time is determined by:

$$T_{dvdt\_min} = C_{OUT} \times \frac{V_{VIN}}{I_{LIM}} \quad (12)$$

Power dissipation for a selected start-up time should not exceed the limits shown in below plots as shaded area. Typical curves for no load and load are shown in Figure 53 and Figure 54.

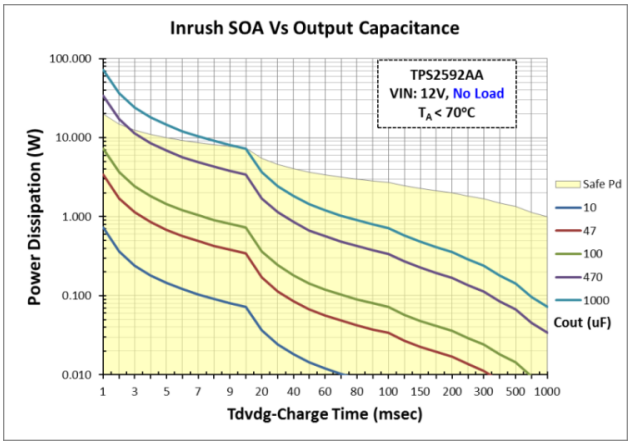


Figure 53. I_{INRUSH} SOA Variation with C_{OUT} and T_{dvdt} (NO Load)

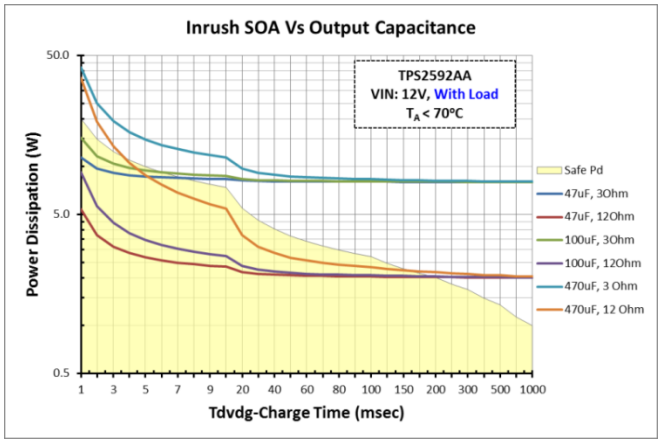


Figure 54. I_{INRUSH} SOA Variation with C_{OUT} and T_{dvdt} (with Load)

Example:

V_{VIN} = 12V, C_{OUT} = 470uF, and Load: R_L = 12Ω

As a first choice, let C_{EXT} = C_{dVdT} = 3.3nF:

$$T_{dvdt} = 10^6 \times 12 \times (100pF + 70pF) = 2.04ms \quad (13)$$

$$I_{INRUSH} = \left(470 \times 10^{-6}\right) \times \left(\frac{12}{2.04 \times 10^{-3}}\right) = 2.764A \quad (14)$$

$$P_{INRUSH} = 0.5 \times 12 \times 2.764 = 16.584W \quad (15)$$

$$P_{DISS\_LOAD} = \left(\frac{1}{6}\right) \times \left(\frac{(12 \times 12)}{3}\right) = 2.00W \quad (16)$$

$$P_{STARTUP} = (16.584 + 2.00) = 18.84W \quad (17)$$

The power dissipated is well above the shaded area of power dissipation graph; to have safe operating power area, increase the capacitance

As a second choice, let C_{EXT} = C_{dVdT} = 0.47 nF:

$$T_{dvdt} = 10^6 \times 12 \times (470pF + 70pF) = 6.48ms \quad (18)$$

$$I_{INRUSH} = \left(470 \times 10^{(-6)}\right) \times \left(\frac{12}{6.48 \times 10^{(-3)}}\right) = 0.87A \quad (19)$$

$$P_{INRUSH} = 0.5 \times 12 \times 0.87 = 5.22W \quad (20)$$

$$P_{DISS\_LOAD} = \left(\frac{1}{6}\right) \times \left(\frac{(12 \times 12)}{12}\right) = 2.00W \quad (21)$$

$$P_{STARTUP} = (5.22 + 2.00) = 7.22W \quad (22)$$

The power dissipated is well below the shaded area of the power dissipation graph. The following table illustrates the acceptability for different C_{dVdT} capacitances.

Capacitance C_{dVdT} (nF)	0.10	0.47	3.30	27.0
Charging Time T_{dvdt} (ms)	2.0	6.5	40.5	325
Power Dissipation (W)	18.84	7.22	2.84	2.10
Limits	Not OK	OK	OK	Not OK

REVISION HISTORY

Changes from Original (June 2013) to Revision A	Page
• Changed from Product Preview to Production Data	1

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS2592AADRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2592AA	Samples
TPS2592AADRCT	ACTIVE	SON	DRC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2592AA	Samples
TPS2592BLDRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2592BL	Samples
TPS2592BLDRCT	ACTIVE	SON	DRC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2592BL	Samples

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

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

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

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

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

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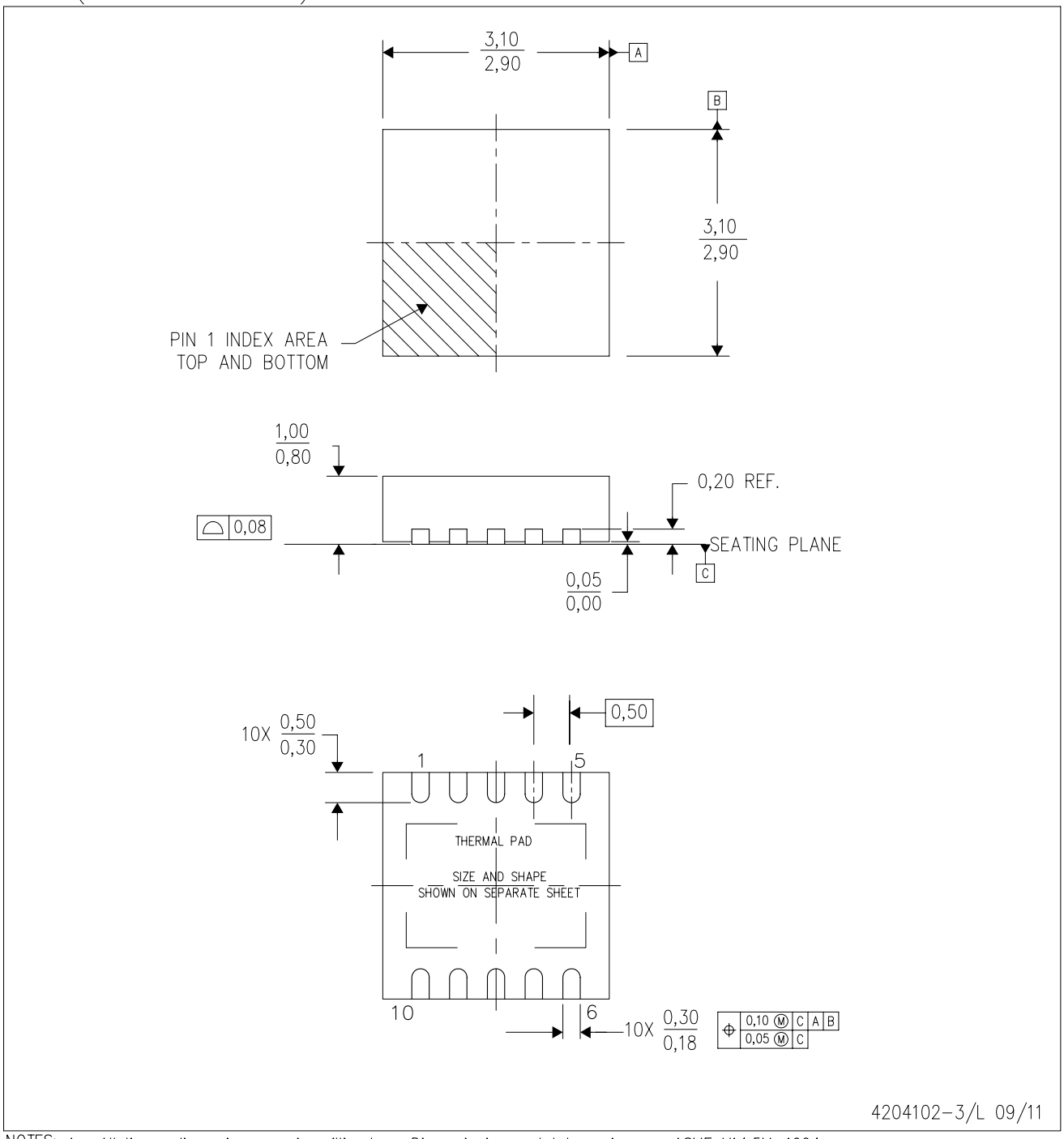
DRC (S–PVSON–N10) PLASTIC SMALL OUTLINE NO–LEAD



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

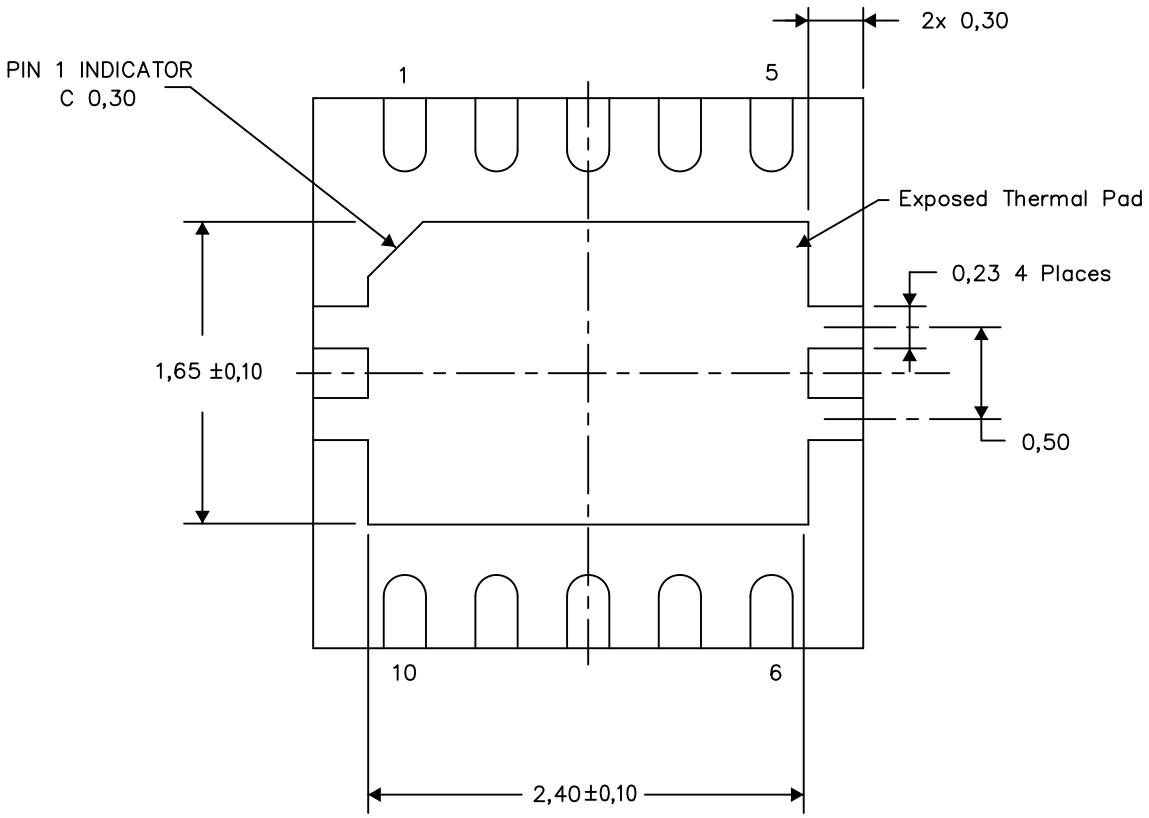
DRC (S–PVSON–N10) PLASTIC SMALL OUTLINE NO–LEAD

THERMAL INFORMATION

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

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

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



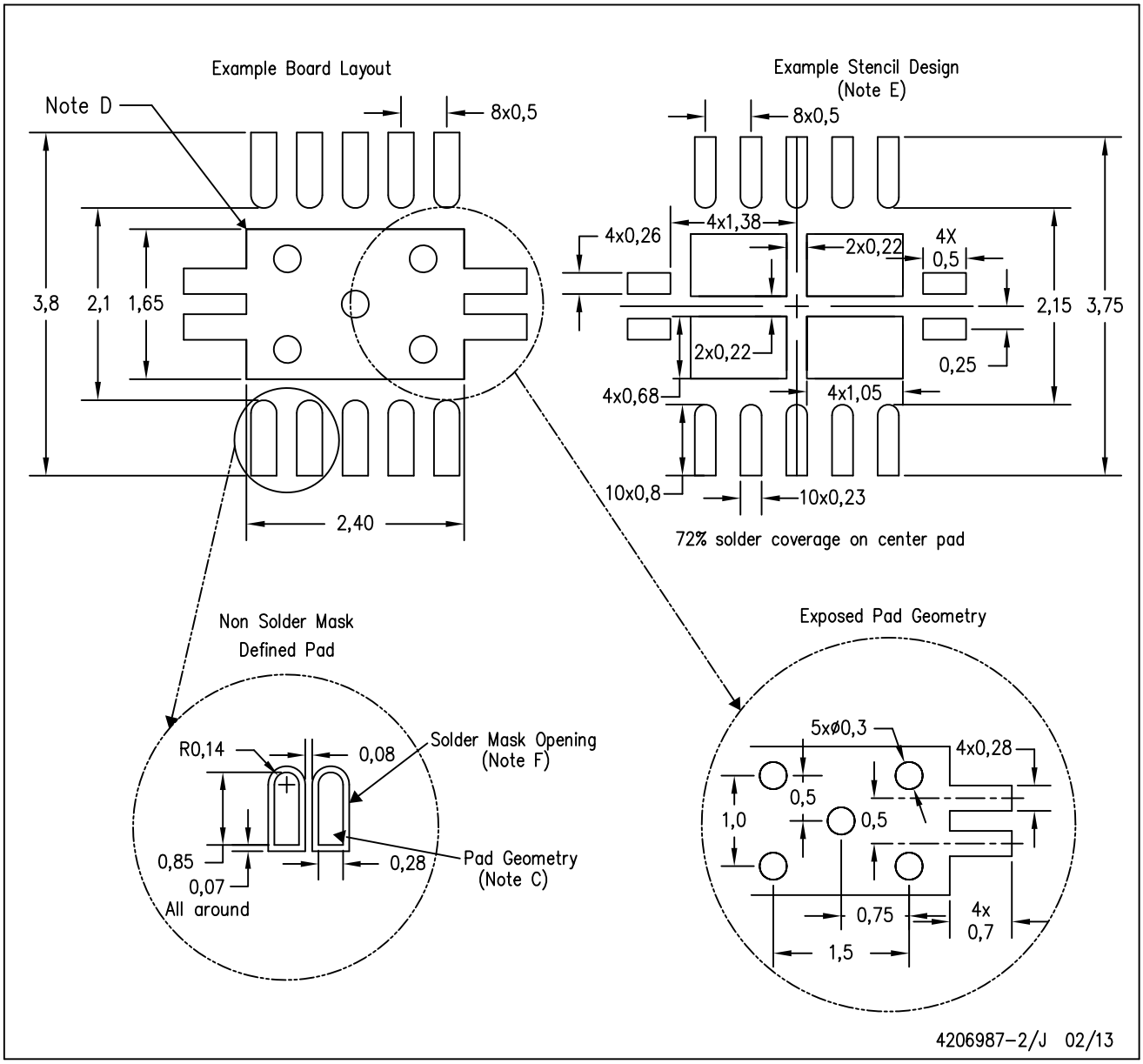
Bottom View

Exposed Thermal Pad Dimensions

4206565–3/R 03/13

NOTE: A. All linear dimensions are in millimeters

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



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

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