

**TPS27SA08** 

JAJSK93 - NOVEMBER 2020

# TPS27SA08 36V、10A、シングルチャネル・スマート・ハイサイド・スイッチ

### 1 特長

- $R_{ON} = 9m\Omega$  (標準値、 $T_J = 25^{\circ}C$ ) のシングル・チャネ ル、スマート・ハイサイド・スイッチ
- 過電流保護による信頼性の向上:
  - 20A (公称値) の電流制限スレッショルド
  - スレッショルドに達すると電流を制限 (クランプ)
- 堅牢な出力保護機能を内蔵
  - 熱保護機能を内蔵
  - グランド / 電源への短絡に対する保護
  - 電源逆接続時に FET スイッチを自動オン
  - 電源 / グランド喪失が発生した場合に自動シャット
  - 誘導性負荷の逆起電圧の発生を防止する出力クラ ンプを内蔵
  - フォルト処理を設定可能
- アナログ検出出力は、以下を正確に測定するよう設定 可能
  - 負荷電流
  - 電源電圧
  - デバイス温度
- FLT 通知を MCU に返す
  - オフ状態および GND への短絡時のオープン負荷 の検出

# 2 アプリケーション

- 産業用モータ駆動
- 発熱体
  - センサ素子ヒーター
  - タンク・ヒーター
- 大電流デジタル出力
- 誘導性負荷

### 3 概要

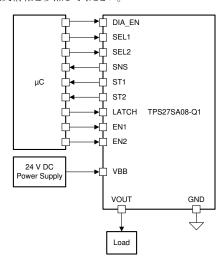
TPS27SA08 デバイスは、24V 電源システムでの使用を 目的としたシングル・チャネル・スマート・ハイサイド・スイッ チです。短絡など有害な事象の発生時でも出力ポートを 確実に保護できるよう、堅牢な保護および診断機能を内 蔵しています。このデバイスは、信頼性の高い電流制限に より、フォルトに対して保護しています。この電流制限は、 デバイス・バリアントに応じて、過電流事象に対する応答 方法を、即座にスイッチをオフにする方法と、出力電流を 設定点 (通常 20A) にレギュレートする方法のどちらかに 設定できます。また TPS27SA08 デバイスは、各種負荷 プロファイルを駆動する際に診断機能を強化できる高精 度アナログ電流検出機能も備えています。負荷電流、デ バイスの温度、電源電圧をシステムの MCU に報告するこ とで、予知保全や負荷診断が可能になり、システムの寿命 が長くなります。

TPS27SA08 デバイスは小型の 16 ピン HTSSOP パッケ ージで供給されるため、PCB の占有面積を減らすことが できます。

#### デバイス情報

	A	
部品番号	パッケージ <sup>(1)</sup>	本体サイズ (公称)
TPS27SA08	HTSSOP (16)	5.00mm × 4.40mm

利用可能なパッケージについては、このデータシートの末尾にあ る注文情報を参照してください。



簡略回路図



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**4 Revision History** 資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

DATE	REVISION	NOTES
November 2020	*	Initial release.



# **5 Device Summary Table**

Full Device Number	Current Limit (I <sub>CL</sub> )	Overcurrent Behavior	Device Qualification
TPS27SA08 <b>C</b>	20 A	Clamp Current at I <sub>CL</sub> until Thermal Shutdown	Industrial (–40°C to 125°C) Temperature Range

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# **6 Pin Configuration and Functions**

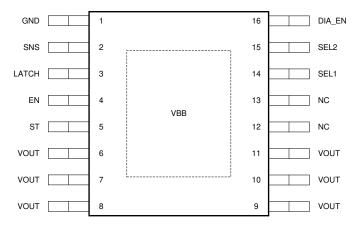


図 6-1. PWP Package 16-Pin HTSSOP Top View

表 6-1. Pin Functions

PII	N	I/O	DESCRIPTION	
NO.	NAME			
1	GND	_	Device ground	
2	SNS	0	Sense output	
3	LATCH	I	Sets fault handling behavior (latched or auto-retry)	
4	EN	I	Switch control input, active high	
5	ST	0	Switch diagnostic feedback, active low	
6, 7, 8, 9, 10, 11	VOUT	0	witch output	
12	NC		lo Connect	
13	NC		No Connect	
14	SEL1	I	Diagnostics Select 1	
15	SEL2	I	Diagnostics Select 2	
16	DIA_EN	I	Diagnostic enable, active high	
Exposed pad	VBB	I	Power supply input	

Product Folder Links: *TPS27SA08* 



### **6.1 Recommended Connections for Unused Pins**

The TPS27SA08 device is designed to provide an enhanced set of diagnostic and protection features. However, if the system design only allows for a limited number of I/O connections, some pins may be considered as optional.

表 6-2. Connections for Optional Pins

PIN NAME	CONNECTION IF NOT USED	IMPACT IF NOT USED		
SNS	Ground through 1-kΩ resistor	Analog sense is not available.		
LATCH	Float or ground through R <sub>PROT</sub> resistor	With LATCH unused, the device will auto-retry after a fault. If latched behavior is desired it is possible to use one microcontroller output to control the latch function of several high-side channels.		
		All faults are indicated by the analog SNS pin. The $\overline{\text{ST}}$ pin provides the additional benefits:		
	Float	Provide fault indication when DIA_EN = 0		
ST		Provide fault indication regardless of SELx pin conditions		
		Provide fault indication to a simple digital I/O (rather than ADC or		
		comparator used with the SNS signal)		
SEL1	Float or ground through R <sub>PROT</sub> resistor	SEL1 selects between the $\rm V_{BB}$ and $\rm T_{J}$ sensing features. With SEL1 unused, only load diagnostics are available.		
SEL2	Ground through R <sub>PROT</sub> resistor	With SEL2 = 0 V, V <sub>BB</sub> measurement diagnostics are not available.		
DIA_EN	Float or ground through R <sub>PROT</sub> resistor	With DIA_EN unused, analog sense, open-load and short-to-supply diagnostics are not available.		

R<sub>PROT</sub> is used to protect the pins from excess current flow during reverse supply conditions, for more information please see the section on *Reverse Supply* protection.



### 7 Specifications

### 7.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V <sub>BB</sub>	Maximum continuous supply voltage			36	V
V <sub>TR1</sub>	Maxium supply voltage - long tranisent	Duration < 300 ms		40	V
V <sub>TR2</sub>	Maxium transient voltage at the supply input	VBB to IC GND		54	V
V <sub>Rev</sub>	Reverse supply voltage, V <sub>REV</sub> ≤ 3 minutes	s, with GND network.	-36		V
V <sub>EN</sub>	Enable pin voltage	Enable pin voltage		7	V
V <sub>LATCH</sub>	LATCH pin voltage		-1	7	V
V <sub>ST</sub>	Status pin voltage		-1	7 <sup>(2)</sup>	V
V <sub>DIA_EN</sub>	Diagnostic Enable pin voltage		-1	7	V
V <sub>SNS</sub>	Sense pin voltage		-1	7	V
V <sub>SEL1</sub> , V <sub>SEL2</sub>	Select pin voltage		-1	7	V
I <sub>GND</sub>	Reverse ground current	V <sub>BB</sub> < 0 V		-50	mA
$T_{J}$	Maximum junction temperature			150	°C
T <sub>stg</sub>	Storage temperature		-65	150	°C

<sup>(1)</sup> Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability

### 7.2 ESD Ratings

				VALUE	UNIT
Electrostatic		Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup>	All pins except exposed pad and pins 6 to 11	±2000	.,
$V_{(ESD)}$	discharge		Exposed pad and pins 6 to 11	±4000	V
		Charged-device model (CDM), per AEC Q100-011	All pins	±750	
V <sub>(ESD1)</sub>	Electrostatic discharge	Contact/Air discharge, per IEC 61000-4-2 (2)	VBB (exposed pad) and VOUT pins	±8/±15	kV
V <sub>(surge)</sub>	Transient surge	Surge protection with 42 $\Omega$ , per IEC 61000-4-5; 1.2/50 $\mu s^{(2)}$	VBB (exposed pad) and VOUT pins	±1000	V

<sup>(1)</sup> AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V <sub>BB</sub>	Nominal supply voltage	8	36	V
V <sub>EN</sub>	Enable voltage	-1	5.5	V
V <sub>LATCH</sub>	LATCH voltage	-1	5.5	V
V <sub>DIA_EN</sub>	Diagnostic enable voltage	-1	5.5	V
V <sub>SEL1</sub> , V <sub>SEL2</sub>	Select voltage	-1	5.5	V
V <sub>ST</sub>	Status voltage	0	5.5	V
V <sub>SNS</sub>	Sense voltage	-1	V <sub>SNSclamp</sub>	V

<sup>(2)</sup> These pins are adjacent to pins that will handle high-voltages. In the event of a pin-to-pin short, there will not be device damage.

<sup>(2)</sup> Tested with the application circuit and supply voltage of 24-V DC input.



### 7.3 Recommended Operating Conditions (continued)

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

			MIN	MAX	UNIT
I <sub>MAX</sub>	Continuous load current	T <sub>A</sub> = 70°C	0	10	Α

#### 7.4 Thermal Information

		TPS27SA08	
	THERMAL METRIC <sup>(1)</sup> (2)	PWP (HTSSOP)	UNIT
		16 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	32.8	°C/W
R <sub>0JC(top)</sub>	Junction-to-case (top) thermal resistance	30.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	9.3	°C/W
ΨЈТ	Junction-to-top characterization parameter	2.6	°C/W
ΨЈВ	Junction-to-board characterization parameter	9.4	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	1.0	°C/W

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

#### 7.5 Electrical Characteristics

 $V_{BB}$  = 8 V to 36 V,  $T_{J}$  = -40°C to 125°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT VOL	TAGE AND CURRENT				<u>'</u>	
V <sub>Clamp</sub>	V <sub>DS</sub> clamp voltage		40		58	V
V <sub>UVLOF</sub>	V <sub>BB</sub> undervoltage lockout falling			2.5	3	V
V <sub>UVLOR</sub>	V <sub>BB</sub> undervoltage lockout rising			2.5	3	V
		V <sub>BB</sub> = 24 V, T <sub>J</sub> = 25°C V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V			0.8	μA
I <sub>SB</sub>	Standby current (includes MOSFET leakage)	V <sub>BB</sub> = 24 V, T <sub>J</sub> = 85°C V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V			1	μΑ
		V <sub>BB</sub> = 24 V, T <sub>J</sub> = 125°C, V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V			6	μΑ
1	Output leakage current	V <sub>BB</sub> = 24 V, T <sub>J</sub> = 25°C V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V		0.01	.01 0.5	μΑ
I <sub>OUT_OFF</sub>	Output leakage current	V <sub>BB</sub> = 24 V, T <sub>J</sub> = 125°C V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V			6	μΑ
I <sub>DIA</sub>	Current consumption in diagnostic mode	V <sub>BB</sub> = 24 V, I <sub>SNS</sub> = 0 mA V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 5 V, V <sub>OUT</sub> = 0 V		3	6	mA
ΙQ	Quiescent current	V <sub>BB</sub> = 24 V V <sub>EN</sub> = 5 V V <sub>DIA_EN</sub> = 0 V, I <sub>OUT</sub> = 0 A, V <sub>SELX</sub> = 0 V		2.4	5.2	mA
t <sub>STBY</sub>	Standby mode delay time	V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V to Standby		20		ms
R <sub>ON</sub> CHAR	ACTERISTICS				'	
	On-resistance	$T_J = 25^{\circ}C, 6 \text{ V} \le V_{BB} \le 36 \text{ V}$		9		mΩ
R <sub>ON</sub>	Includes MOSFET and	$T_J = 150$ °C, 6 V ≤ $V_{BB} \le 36$ V			20	mΩ
	package	$T_J = 25^{\circ}C, 3 V \le V_{BB} \le 6 V$		,	15	mΩ
Р	On-resistance during	$T_J = 25^{\circ}C$ , -18 V $\leq V_{BB} \leq -8$ V		9		mΩ
R <sub>ON(REV)</sub>	reverse polarity	$T_J = 105^{\circ}C, -18 \text{ V} \le V_{BB} \le -8 \text{ V}$			20	mΩ
CURRENT	SENSE CHARACTERISTICS	<b>,</b>				

<sup>(2)</sup> The thermal parameters are based on a 4-layer PCB according to the JESD51-5 and JESD51-7 standards.



### 7.5 Electrical Characteristics (continued)

 $V_{BB}$  = 8 V to 36 V,  $T_{I}$  = -40°C to 125°C (unless otherwise noted)

	PARAMETER	TEST CON	DITIONS	MIN	TYP	MAX	UNIT
K <sub>SNS</sub>	Current sense ratio				4600		
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 8 A		1.74		mA
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 8 A	-5		5	%
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 3 A		0.65		mA
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 3 A	-5		5	%
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 780 mA		0.217		mA
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 780 mA	-5		5	%
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 300 mA		0.065		mA
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 300 mA	-12		12	%
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 100 mA		0.022		mA
I <sub>SNSI</sub>	Current sense current and current sense accuracy	$V_{EN} = V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = V_{SEL2} = 0 \text{ V}$	I <sub>OUT</sub> = 100 mA	-42		42	%
T <sub>J</sub> SENSE (	CHARACTERISTICS			•			
		V <sub>DIA_EN</sub> = 5 V, V <sub>SEL1</sub> = 5 V, V <sub>SEL2</sub> = 0 V	T <sub>J</sub> = -40°C		0.12		mA
I <sub>SNST</sub>			T <sub>J</sub> = 25°C		0.85		mA
	Temperature sense current		T <sub>J</sub> = 85°C		1.52		mA
			T <sub>J</sub> = 150°C		2.25		mA
dl <sub>SNST</sub> /dT	Coefficient		0 11		0.0112		mA/°C
	CHARACTERISTICS						
188 02.102			V <sub>BB</sub> = 3 V		0.26		mA
			V <sub>BB</sub> = 8 V		0.20		mA
	Voltage conce current	V <sub>DIA EN</sub> = 5 V, V <sub>SEL1</sub> = 5 V,					
I <sub>SNSV</sub>	Voltage sense current	V <sub>SEL2</sub> = 5 V	V <sub>BB</sub> = 13.5 V		1.17		mA_
			V <sub>BB</sub> = 18 V		1.56		mA
			V <sub>BB</sub> = 28 V		2.43		mA
dl <sub>SNSV</sub> /dV	Coefficient				0.0867		mA/V
SNS CHAR	ACTERISTICS						
I <sub>SNSFH</sub>	I <sub>SNS</sub> fault high level	$V_{DIA\_EN} = 5 \text{ V}, V_{SEL1} = 0 \text{ V}, V_{S}$	<sub>EL2</sub> = 0	6	6.9	7.6	mA
I <sub>SNSleak</sub>	I <sub>SNS</sub> leakage	$V_{DIA\_EN} = 0 V$		0		1	μΑ
V <sub>SNSclamp</sub>	V <sub>SNS</sub> clamp				5.9		V
I <sub>CL</sub>	Current threshold at which current limit loop engages		T <sub>J</sub> = -40°C	17	22.2	27.8	Α
I <sub>CL</sub>	Current threshold at which current limit loop engages		T <sub>J</sub> = 25°C	15	20	25	Α
I <sub>CL_REG</sub>	Current limit regulation level		T <sub>J</sub> = 25°C		24		Α
I <sub>CL</sub>	Current threshold at which current limit loop engages		T <sub>J</sub> = 125°C	12.8	16	20	Α
CURRENT	LIMIT CHARACTERISTICS		1				
FAULT CHA	ARACTERISTICS						
V <sub>OL</sub>		V <sub>EN</sub> = 0 V V <sub>DIA</sub> = = 5 V		2	2.5	4	V
- UL	Open-load detection voltage V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 5 V				2.0	-r	٧



### 7.5 Electrical Characteristics (continued)

 $V_{BB} = 8 \text{ V to } 36 \text{ V}, T_{J} = -40^{\circ}\text{C to } 125^{\circ}\text{C} \text{ (unless otherwise noted)}$ 

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>OL1</sub>	OL and STB indication time - switch disabled	From falling edge of EN $V_{EN}$ = 5 V to 0 V, $V_{DIA\_EN}$ = 5 V, $V_{SELx}$ = 00 $I_{OUT}$ = 0 mA, $V_{OUT}$ = $\frac{1}{4}$ V	300	500	700	μs
t <sub>OL2</sub>	OL and STB indication time - switch disabled	From rising edge of DIA_EN $V_{EN} = 0 \text{ V}$ , $V_{DIA_EN} = 0 \text{ V}$ to 5 V, $V_{SELx} = 00$ OUT = 0 mA, $V_{OUT} = 4 \text{ V}$		50	μs	
t <sub>OL3</sub>	OL and STB indication time - switch disabled	From rising edge of VOUT $V_{EN} = 0 \text{ V, } V_{DIA\_EN} = 5 \text{ V, } V_{SELx} = 00$ $I_{OUT} = 0 \text{ mA, } V_{OUT} = 0 \text{ V to 4 V}$	<sub>EN</sub> = 0 V, V <sub>DIA</sub> <sub>EN</sub> = 5 V, V <sub>SELx</sub> = 00		50	μs
T <sub>ABS</sub>	Thermal shutdown		160			°C
T <sub>HYS</sub>	Thermal shutdown hysteresis			20		°C
t <sub>RETRY</sub>	Retry time	Minimum time from fault shutdown to switch re-enable (for thermal shutdown, current limit, and energy limit)	1	2	3	ms
EN PIN CHA	ARACTERISTICS(1)					
V <sub>IL, EN</sub>	Input voltage low level				8.0	V
V <sub>IH, EN</sub>	Input voltage high level	No GND network Diode	2			V
V <sub>IHYS, EN</sub>	Input voltage hysteresis	No GND network Diode		250		mV
I <sub>IL, EN</sub>	Input current low level	V <sub>EN</sub> = 0.8 V		0.8		μΑ
I <sub>IH, EN</sub>	Input current high level	V <sub>EN</sub> = 2.0 V		2		μΑ
R <sub>EN</sub>	Internal pulldown resistor			1		МΩ
DIA_EN PIN	CHARACTERISTICS (1)					
V <sub>IL, DIA_EN</sub>	Input voltage low level	No GND network Diode			0.8	V
V <sub>IH, DIA_EN</sub>	Input voltage high level	No GND network Diode	2			V
V <sub>IHYS,</sub> DIA_EN	Input voltage hysteresis			250		mV
I <sub>IL, DIA_EN</sub>	Input current low level	$V_{DIA\_EN} = 0.8 V$		8.0		μΑ
I <sub>IH, DIA_EN</sub>	Input current high level	$V_{DIA\_EN} = 2.0 \text{ V}$		2		μA
R <sub>DIA_EN</sub>	Internal pulldown resistor			1		МΩ
SEL1 AND	SEL2 PIN CHARACTERISTIC	<b>cs</b> <sup>(1)</sup>				
V <sub>IL, SELx</sub>	Input voltage low level	No GND network Diode			0.8	V
V <sub>IH, SELx</sub>	Input voltage high level		2			V
V <sub>IHYS, SELx</sub>	Input voltage hysteresis			250		mV
I <sub>IL, SELx</sub>	Input current low level	V <sub>SELx</sub> = 0.8 V		0.8		μA
I <sub>IH, SELx</sub>	Input current high level	V <sub>SELx</sub> = 2.0 V		2		μA
R <sub>SELx</sub>	Internal pulldown resistor			1		МΩ
LATCH PIN	CHARACTERISTICS (1)	· · · · · · · · · · · · · · · · · · ·				
V <sub>IL, LATCH</sub>	Input voltage low level	No GND network Diode			8.0	V
V <sub>IH, LATCH</sub>	Input voltage high level	No GND network Diode	2			V
V <sub>IHYS, LATCH</sub>	Input voltage hysteresis		,	250		mV
I <sub>IL, LATCH</sub>	Input current low level	V <sub>LATCH</sub> = 0.8 V		0.8		μA
I <sub>IH, LATCH</sub>	Input current high level	V <sub>LATCH</sub> = 2.0 V		2		μA
R <sub>LATCH</sub>	Internal pulldown resistor			1		ΜΩ
		1			I	
ST PIN CHA	RACTERISTICS (1)					



## 7.5 Electrical Characteristics (continued)

 $V_{BB}$  = 8 V to 36 V,  $T_{J}$  = -40°C to 125°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I <sub>STleak</sub>	Leakage current	V <sub>ST</sub> = 5 V			2	μΑ

(1)  $V_{BB} = 3 \text{ to } 28 \text{ V}$ 

### 7.6 Switching Characteristics

 $V_{BB}$  = 36 V,  $T_{J}$  = -40°C to 150°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>DR</sub>	Turn-on delay time	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω	20	70	100	μs
t <sub>DF</sub>	Turn-off delay time	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω	20	50	125	μs
SR <sub>R</sub>	VOUT rising slew rate	$V_{BB}$ = 24 V, 20% to 80% of $V_{OUT}$ , $R_L$ = 8 $\Omega$	0.1	0.35	0.8	V/µs
SR <sub>F</sub>	VOUT falling slew rate	$V_{BB}$ = 24 V, 80% to 20% of $V_{OUT}$ , $R_L$ = 8 $\Omega$	0.2	0.5	0.9	V/µs
t <sub>ON</sub>	Turn-on time	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω	39	100	180	μs
t <sub>OFF</sub>	Turn-off time	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω	39	90	180	μs
t <sub>ON</sub> - t <sub>OFF</sub>	Turn-on and off matching	200-µs enable pulse	-80	0	80	μs
E <sub>ON</sub>	Switching energy losses during turn-on	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω		0.4		mJ
E <sub>OFF</sub>	Switching energy losses during turn-off	V <sub>BB</sub> = 24 V, R <sub>L</sub> = 8 Ω		0.4		mJ

### 7.7 SNS Timing Characteristics

 $V_{BB} = 8$  to 36 V,  $T_{L} = -40$ °C to 150°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SNS TIMI	NG - CURRENT SENSE					
t <sub>SNSION1</sub>	Settling time from rising edge of DIA_EN	$V_{EN} = 5 \text{ V}, V_{DIA\_EN} = 0 \text{ V to } 5 \text{ V}$ $R_{SNS} = 1 \text{ k}\Omega, R_L = 2.6 \Omega$			40	μs
t <sub>SNSION2</sub>	Settling time from rising edge of EN	$V_{EN} = V_{DIA\_EN} = 0 \text{ V to 5 V}$ $R_{SNS} = 1 \text{ k}\overline{\Omega}, R_L = 2.6 \Omega$			180	μs
t <sub>snsion3</sub>	Settling time from rising edge of EN	$V_{EN}$ = 0 V to 5 V, $V_{DIA\_EN}$ = 5 V $R_{SNS}$ = 1 k $\Omega$ , $R_L$ = 2.6 $\Omega$			180	μs
t <sub>SNSIOFF1</sub>	Settling time from falling edge of DIA_EN	$V_{EN} = 5 \text{ V}, V_{DIA\_EN} = 5 \text{ V to } 0 \text{ V}$ $R_{SNS} = 1 \text{ k}\Omega, R_L = 2.6 \Omega$			20	μs
t <sub>SETTLEH</sub>	Settling time from rising edge of load step	$V_{EN} = 5 \text{ V}, V_{DIA\_EN} = 5 \text{ V}$ $R_{SNS} = 1 \text{ k}\Omega, I_{OUT} = 1 \text{ A to 5 A}$			20	μs
t <sub>SETTLEL</sub>	Settling time from falling edge of load step	$V_{EN} = 5 \text{ V}, V_{DIA\_EN} = 5 \text{ V}$ $R_{SNS} = 1 \text{ k}\Omega, I_{OUT} = 5 \text{ A to 1 A}$			20	μs
SNS TIMII	NG - TEMPERATURE SENSE					
t <sub>SNSTON1</sub>	Settling time from rising edge of DIA_EN	$V_{EN}$ = 5 V, $V_{DIA\_EN}$ = 0 V to 5 V R <sub>SNS</sub> = 1 k $\Omega$			40	μs
t <sub>SNSTON2</sub>	Settling time from rising edge of DIA_EN	$V_{EN} = 0 \text{ V}, _{VDIA\_EN} = 0 \text{ V to 5 V}$ $R_{SNS} = 1 \text{ k}\Omega$			70	μs
t <sub>SNSTOFF</sub>	Settling time from falling edge of DIA_EN	$V_{EN} = X$ , $V_{DIA\_EN} = 5 V$ to 0 V $R_{SNS} = 1 k\Omega$			20	μs
SNS TIMI	NG - VOLTAGE SENSE					
t <sub>SNSVON1</sub>	Settling time from rising edge of DIA_EN	$V_{EN}$ = 5 V, $V_{DIA\_EN}$ = 0 V to 5 V R <sub>SNS</sub> = 1 k $\Omega$			40	μs
t <sub>SNSVON2</sub>	Settling time from rising edge of DIA_EN	$V_{EN} = 0 \text{ V}, V_{DIA\_EN} = 0 \text{ V to 5 V}$ $R_{SNS} = 1 \text{ k}\Omega$			70	μs
	I .	· ·				

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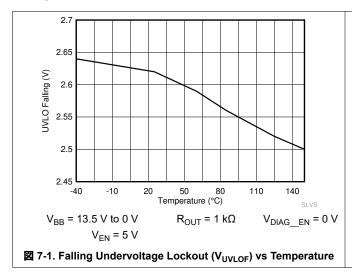


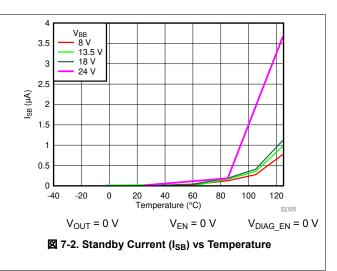
### 7.7 SNS Timing Characteristics (continued)

 $V_{BB}$  = 8 to 36 V,  $T_{J}$  = -40°C to 150°C (unless otherwise noted)

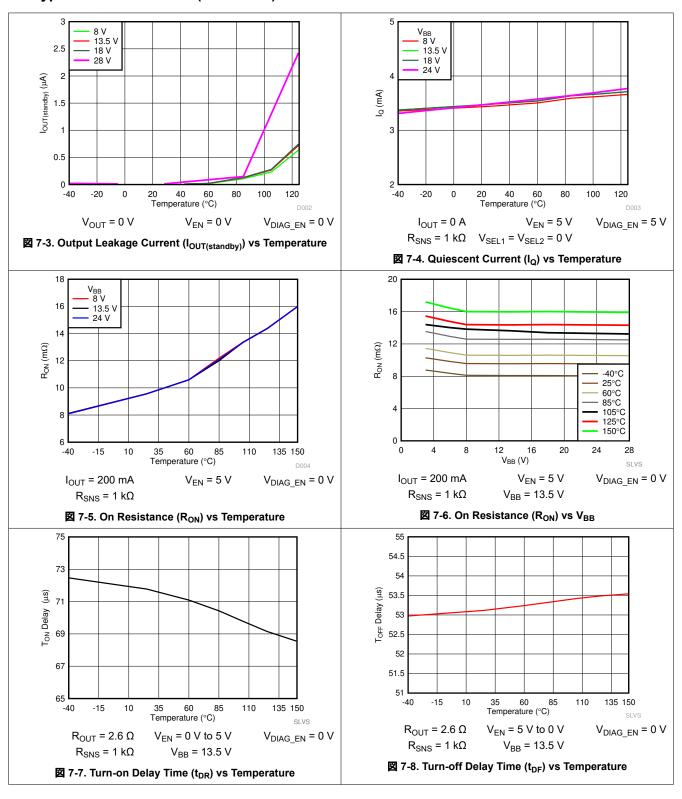
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>SNSVOFF</sub>	Settling time from falling edge of DIA_EN	$V_{EN} = X$ , $V_{DIA\_EN} = 5 V$ to 0 V $R_{SNS} = 1 k\Omega$			20	μs
SNS TIMIN	IG - MULTIPLEXER				'	
	Settling time from temperature sense to current sense	$V_{EN}$ = X, $V_{DIA\_EN}$ = 5 V $V_{SEL1}$ = 5 V to 0 V, $V_{SEL2}$ = 0 V $R_{SNS}$ = 1 k $\Omega$ , $R_L$ = 2.6 $\Omega$			60	μs
	voltage sense	$V_{EN} = X$ , $V_{DIA\_EN} = 5 V$ $V_{SEL1} = 5 V$ , $V_{SEL2} = 0 V$ to 5 V $R_{SNS} = 1 k\Omega$			60	μs
	Settling time from voltage sense to temperature sense	$V_{EN} = X$ , $V_{DIA\_EN} = 5 V$ $V_{SEL1} = 5 V$ , $V_{SEL2} = 5 V$ to 0 V $R_{SNS} = 1 k\Omega$			60	μs
MUX	Settling time from voltage sense to current sense	$V_{EN} = X$ , $V_{DIA\_EN} = 5$ V $V_{SEL1} = V_{SEL2} = 5$ V to 0 V, $R_{SNS} = 1$ k $\Omega$ , $R_L = 2.6$ $\Omega$			60	μs
temperature sense	Settling time from current sense to temperature sense	$V_{EN} = X$ , $V_{DIA\_EN} = 5$ V $V_{SEL1} = 0$ V to 5 V, $V_{SEL2} = 0$ V $R_{SNS} = 1$ k $\Omega$ , $R_L = 2.6$ $\Omega$			60	μs
	Settling time from current sense to voltage sense	$V_{EN} = X$ , $V_{DIA\_EN} = 5$ V $V_{SEL1} = V_{SEL2} = 0$ V to 5 V $R_{SNS} = 1$ k $\Omega$ , $R_L = 2.6$ $\Omega$			60	μs

## 7.8 Typical Characteristics

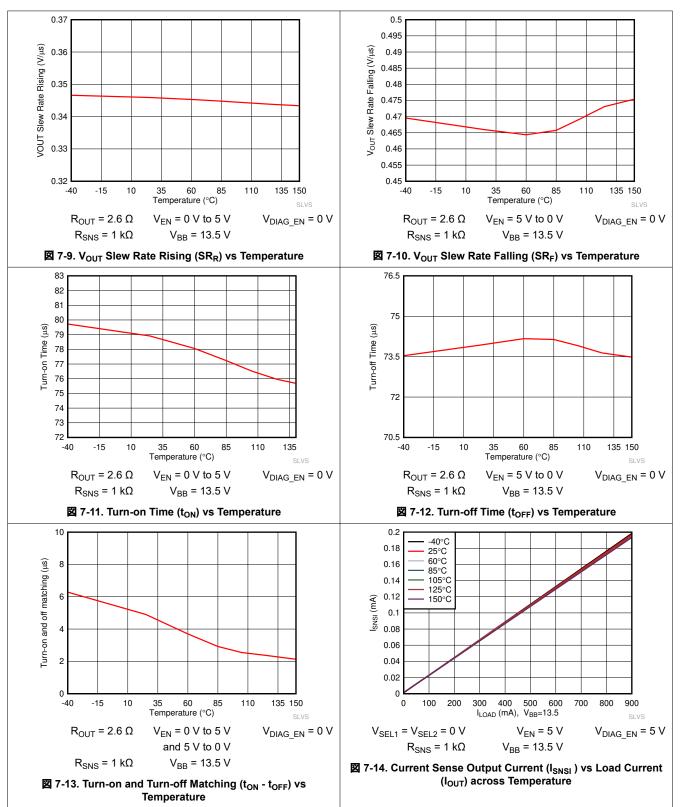




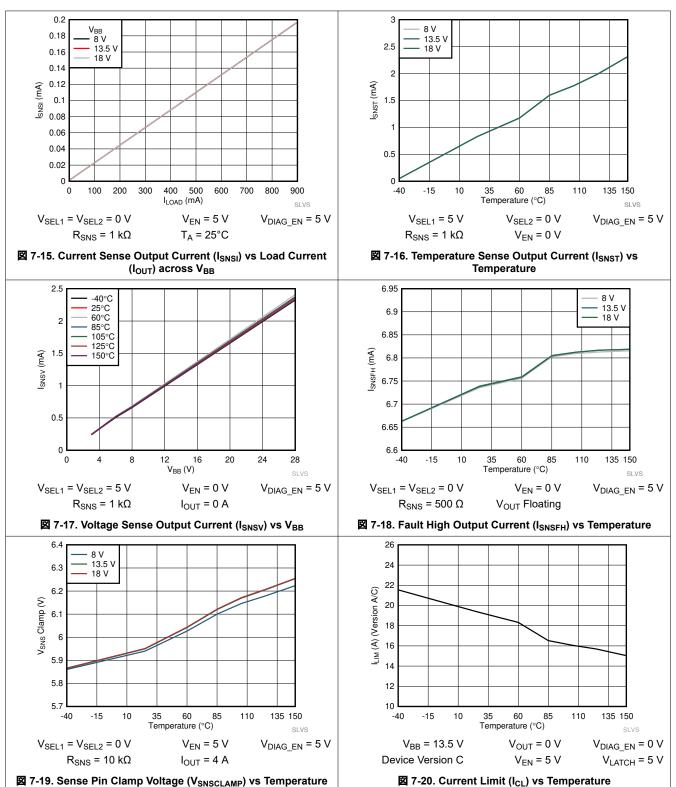




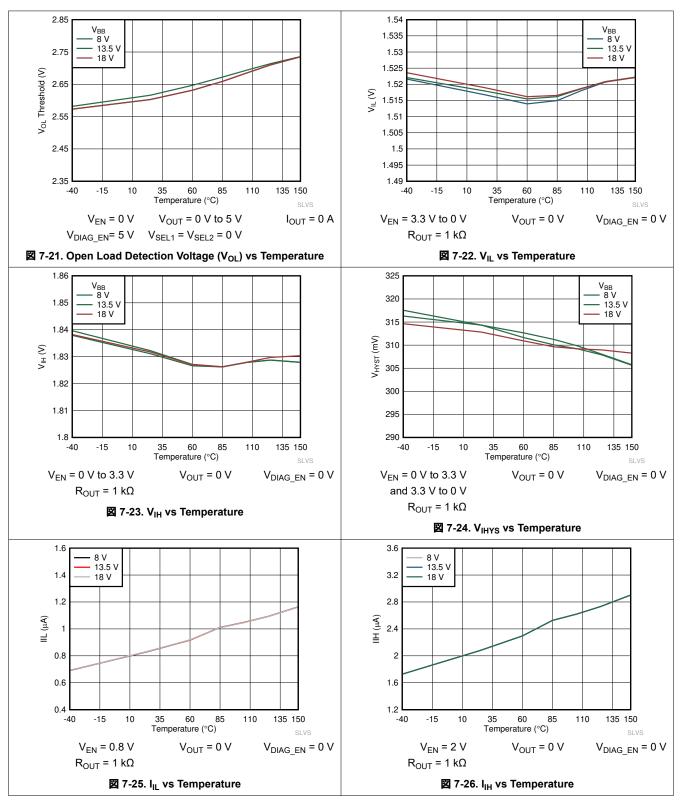


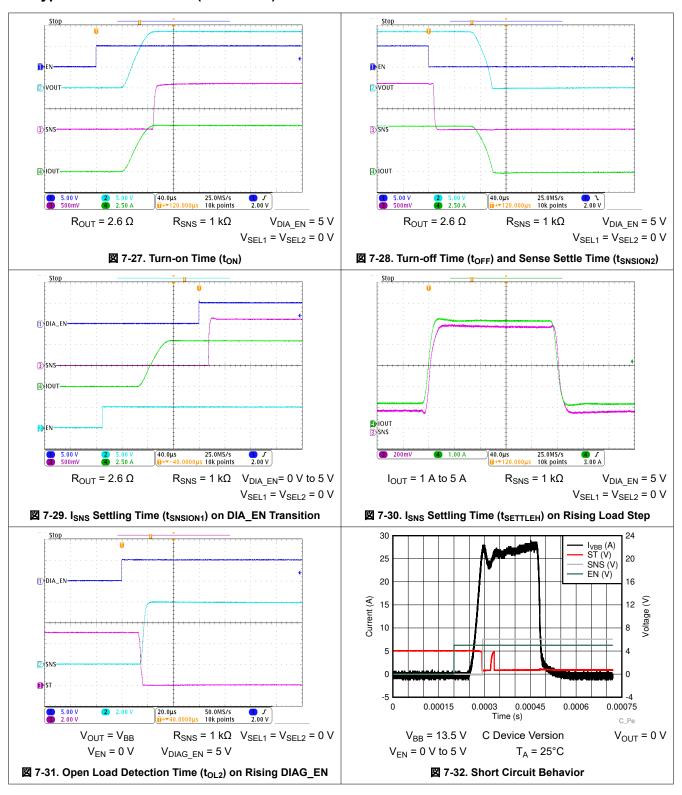




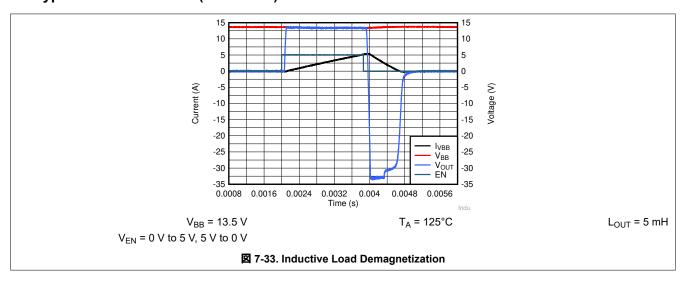














### **8 Parameter Measurement Information**

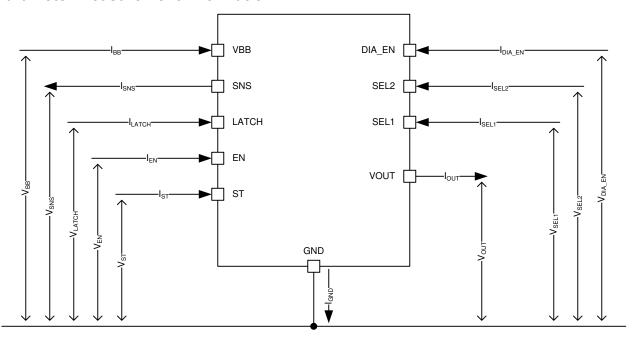


図 8-1. Parameter Definitions

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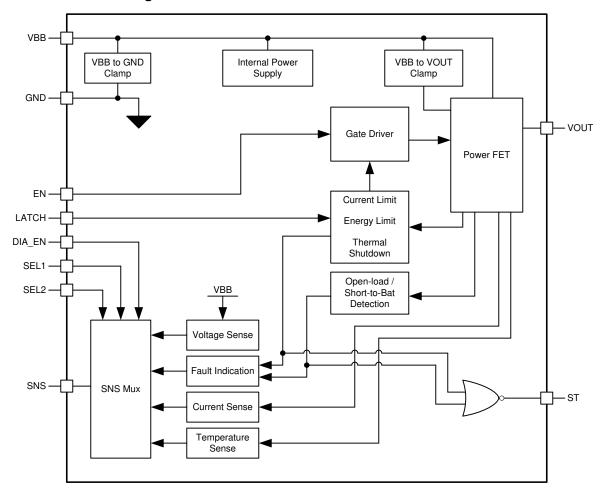
### 9 Detailed Description

#### 9.1 Overview

The TPS27SA08 device is a single-channel smart high-side power switch intended for use with 24-V supply industrial systems. Many protection and diagnostic features are integrated in the device. Diagnostics features include the analog SNS output and the open-drain fault indication (ST). The analog SNS output is capable of providing a signal that is proportional to device temperature, supply voltage, or load current. The high-accuracy load current sense allows for diagnostics of complex loads.

This device includes protection through thermal shutdown, current limit, transient withstand, and reverse supply operation. For more details on the protection features, refer to the Feature Description and Application Information sections of the document.

### 9.2 Functional Block Diagram





### 9.3 Feature Description

#### 9.3.1 Protection Mechanisms

The TPS27SA08 device is designed to operate in a rugged industrial environment. The protection mechanisms allow the device to be robust against many system-level events such as reverse supply, short-to-ground and more.

There are additional protection features which, if triggered, will cause the switch to automatically disable:

- Thermal Shutdown
- Energy Limit

When any of these protections are triggered, the device will enter the FAULT state. In the FAULT state, the fault indication will be available on both the SNS pin and the  $\overline{ST}$  pin (see the diagnostic section of the data sheet for more details).

The switch is no longer held off and the fault indication is reset when all of the below conditions are met:

- LATCH pin is low
- t<sub>RETRY</sub> has expired
- All faults are cleared (thermal shutdown, current limit, energy limit)

#### 9.3.1.1 Thermal Shutdown

The TPS27SA08 device includes temperature sensors on the FET and inside of the device controller. When  $T_{J,FET} > T_{ABS}$ , the device will see a thermal shutdown fault. After the fault is detected, the switch will turn off. The fault is cleared when the switch temperature decreases by the hysteresis value,  $T_{HYS}$ .

#### 9.3.1.2 Current Limit

When  $I_{OUT}$  reaches the current limit threshold,  $I_{CL}$ , the device remains enabled and limits the current  $I_{OUT}$  to close to the threshold,  $I_{CL}$ . In the case that the device remains enabled and limits  $I_{OUT}$ , the thermal shutdown and/or energy limit protection feature may be triggered due to the high amount of power dissipation in the device.

During a short circuit event, the device will hit the  $I_{CL}$  threshold that is listed in the *Specifications* and then regulate the output current close to the threshold value to protect the device. The device will detect a short circuit event when the output current exceeds  $I_{CL}$ , however the measured maximum current may exceed the  $I_{CL}$  threshold due to the finite response time of the TPS27SA08 device current limit regulation loop. The device is guaranteed to protect itself during a short circuit event over the nominal supply voltage range (as defined in the *Specifications* section) at 125°C.

#### 9.3.1.2.1 Current Limit Foldback

The TPS27SA08 device implements a current limit foldback feature that is designed to protect the device in the case of a long-term fault condition. If the device undergoes three consecutive fault shutdown events (any of thermal shutdown, current limit, or energy limit), the current limit will be reduced to half of the original value. The device will revert back to the original current limit threshold if either of the following occurs:

- The device goes to Standby Delay.
- The switch turns-on and turns-off without any fault occurring.

### 9.3.1.2.2 Undervoltage Lockout (UVLO)

The device monitors the supply voltage  $V_{BB}$  to prevent unpredicted behaviors in the event that the supply voltage is too low. When the supply voltage falls down to  $V_{UVLOF}$ , the output stage is shut down automatically. When the supply rises up to  $V_{UVLOR}$ , the device turns back on.

During an initial ramp of  $V_{BB}$  from 0 V at a ramp rate slower than 1 V/ms,  $V_{EN}$  pin will have to be held low until  $V_{BB}$  is above UVLO threshold (with respect to board ground) and the supply voltage to the device has reliably reached above the UVLO condition. For best operation, ensure that  $V_{BB}$  has risen above UVLO before setting the  $V_{EN}$  pin to high.

#### 9.3.1.2.3 V<sub>BB</sub> during Short-to-Ground

When V<sub>OUT</sub> is shorted to ground, the module power supply (V<sub>BB</sub>) can have a transient decrease. This is caused by the sudden increase in current flowing through the wiring harness cables. To achieve ideal system behavior, it is recommended that the module maintain  $V_{BB} > 3 \text{ V}$  during  $V_{OUT}$  short-to-ground. This is typically accomplished by placing bulk capacitance on the power supply node.

#### 9.3.1.3 Energy Limit

The energy limiting feature is implemented to protect the switch from excessive stress. The device will continuously monitor the amount of energy dissipated in the FET. If the energy limit threshold is reached, the switch will automatically disable. In practice, the energy limit will only be reached during a fault event such as short-to-ground.

Energy limit events have the same system-level behavior as thermal shutdown events.

### 9.3.1.4 Voltage Transients

The TPS27SA08 device contains two voltage clamps which protect the device against system-level voltage transients.

The clamp from V<sub>BB</sub> to GND is primarily used to protect the controller from positive transients on the supply line. The clamp from V<sub>BB</sub> to V<sub>OUT</sub> is primarily used to limit the voltage across the FET when switching off an inductive load. Both clamp levels are set to protect the device during these fault conditions. If the voltage potential from V<sub>BB</sub> to GND exceeds the V<sub>BB</sub> clamp level, the clamp will allow current to flow through the device from V<sub>BB</sub> to GND (Path 2). If the voltage potential from V<sub>BB</sub> to V<sub>OUT</sub> exceeds V<sub>CLAMP</sub>, the power FET will allow current to flow from  $V_{BB}$  to  $V_{OUT}$  (Path 3).

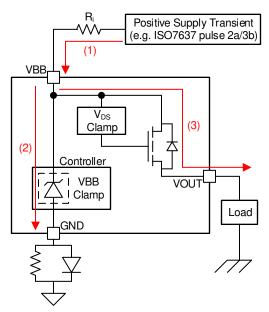


図 9-1. Current Path During Supply Voltage Transient

#### 9.3.1.4.1 Driving Inductive and Capacitive Loads

When switching off an inductive load, the inductor may impose a negative voltage on the output of the switch. The TPS27SA08 device includes a voltage clamp to limit voltage across the FET. The maximum acceptable load inductance is a function of the device robustness. With a 5-mH load, the TPS27SA08 device can withstand a single pulse of 95 mJ inductive dissipation at 125°C and can withstand 56 mJ of inductive dissipation with a 10-Hz repetitive pulse. If the application parameters exceed this device limit, it is necessary to use a protection device like a freewheeling diode to dissipate the energy stored in the inductor. Z 9-2 shows the TPS27SA08 device discharging a 5-mH load that is driven at 5 A.

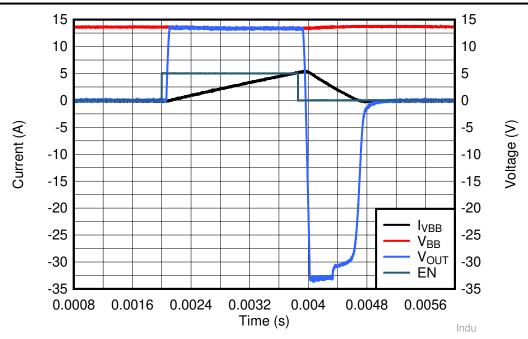


図 9-2. Inductive Discharge (5 mH, 5 A)

In addition, the TPS27SA08 device current limit provides an ideal way to charge a capacitive load safely with limited inrush current. With no protection, charging a large capacitive load can lead to high inrush currents that pull a supply down, however by using a relatively low current limit value (regulation around 24 A), the capacitive load can be charged without impact to the power supply.

For more information on driving inductive or capacitive loads, reference *TI's "How To Drive Inductive, Capacitive, and Lighting Loads with Smart High Side Switch* application report.

### 9.3.1.5 Reverse supply

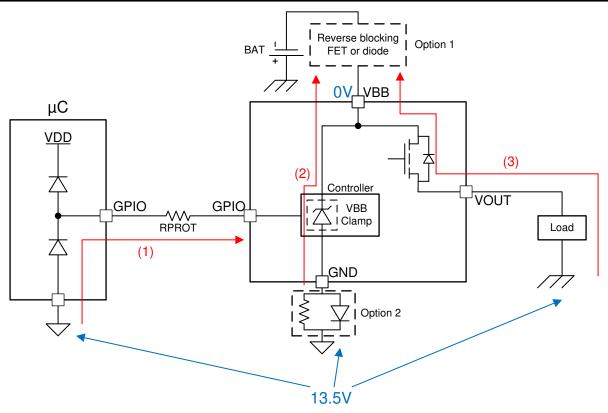
In the reverse supply condition, the switch will automatically be enabled (regardless of EN status) to prevent power dissipation inside the MOSFET body diode. In many applications (for example, resistive load), the full load current may be present during reverse supply. In order to activate the automatic switch on feature, the SEL2 pin must have a path to module ground. This may be path 1 as shown below, or, if the SEL2 pin is unused, the path may be through  $R_{PROT}$  to module ground.

Protection features (for example, thermal shutdown) are not available during reverse supply. Care must be taken to ensure that excessive power is not dissipated in the switch during the reverse supply condition.

There are two options for blocking reverse current in the system. Option 1 is to place a blocking device (FET or diode) in series with the supply. This will block all current paths. Option 2 is to place a blocking diode in series with the GND node of the high-side switch. This method will protect the controller portion of the switch (path 2), but it will not prevent current from flowing through the load (path 3). The diode used for Option 2 may be shared amongst multiple high-side switches.

Path 1 shown in 29-3 is blocked inside of the device.





**図 9-3. Current Path During Reverse supply** 

### 9.3.1.6 Fault Event - Timing Diagrams

注

All timing diagrams assume that the SELx pins are set to 00.

The LATCH, DIA\_EN, and EN pins are controlled by the user. The timing diagrams represent a possible use-case.

☑ 9-4 shows the active current limiting behavior of TPS27SA08 device and the LATCH pin functionality. The switch will not shutdown until either the energy limit or the thermal shutdown is reached.



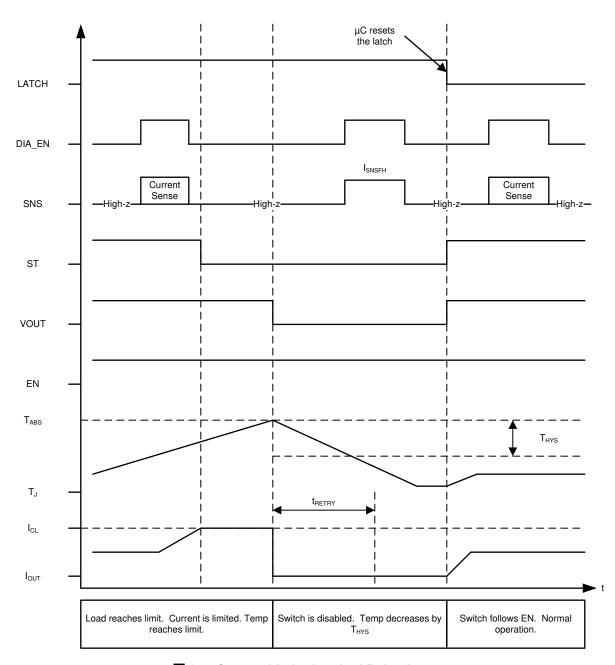


図 9-4. Current Limit - Latched Behavior

№ 9-5 shows the active current limiting behavior of TPS27SA08 device. The switch will not shutdown until either thermal shutdown or energy limit is tripped. In this example, LATCH is tied to GND and the switch is turned ON when the FET temperature is low enough.

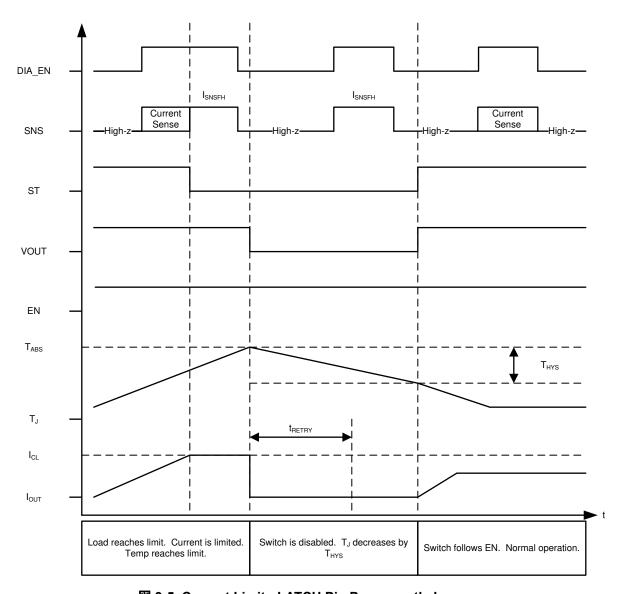


図 9-5. Current Limit - LATCH Pin Permanently Low

deWhen the switch retries after a shutdown event, the SNS fault indication will remain until  $V_{OUT}$  has risen to  $V_{BB}-1.8$  V. Once  $V_{OUT}$  has risen, the SNS fault indication is reset and current sensing is available.  $\overline{ST}$  fault indication is reset as soon as the switch is re-enabled (does not wait for  $V_{OUT}$  to rise). If there is a short-toground and  $V_{OUT}$  is not able to rise, the SNS fault indication will remain indefinitely. The following diagram illustrates auto-retry behavior and provides a zoomed-in view of the fault indication during retry.

注

LATCH = 0 V and DIA\_EN = 5 V

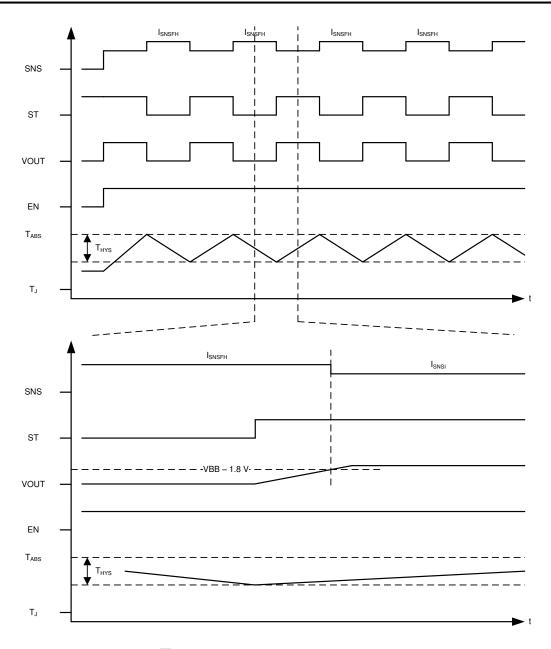


図 9-6. Fault Indication During Retry

### 9.3.2 Diagnostic Mechanisms

### 9.3.2.1 V<sub>OUT</sub> Short-to-supply and Open-Load

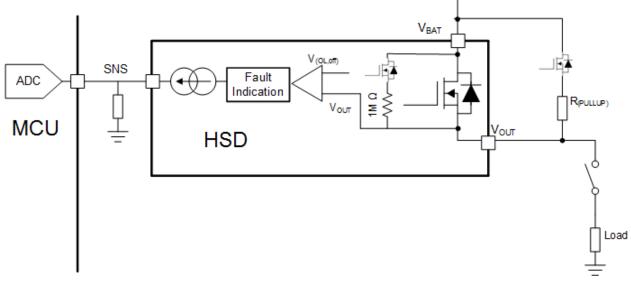
### 9.3.2.1.1 Detection With Switch Enabled

When the switch is enabled, the  $V_{OUT}$  short-to-supply and open-load conditions can be detected with the current sense feature. In both cases, the load current will be measured through the SNS pin and will be below the expected value.



#### 9.3.2.1.2 Detection With Switch Disabled

While the switch is disabled, if DIA\_EN is high, an internal comparator will detect the condition of  $V_{OUT}$ . If the load is disconnected (open load condition) or there is a short to supply the OUT voltage will be higher than the open load threshold ( $V_{OL,off}$ ) and a fault is indicated on the SNS pin. An internal pull-up of 1 M $\Omega$  is in series with an internal MOSFET switch, so no external component is required if only a completely open load needs to be detected. However, if there is significant leakage or other current draw even when the load is disconnected, a lower value pull-up resistor and switch can be added externally to set the  $V_{OUT}$  voltage above the  $V_{OL,off}$  during open load conditions.



A. This figure assumes that the device ground and the load ground are at the same potential. In application, there may be a ground shift voltage of 1 V to 2 V.

### 図 9-7. Short to supply and Open Load Detection

The detection circuitry is only enabled when DIA\_EN = HIGH and EN = LOW.

If  $V_{OUT} > V_{OL}$ , the SNS pin will go to the fault level.

If  $V_{OUT} < V_{OL}$ , then there is no fault indication.

The fault indication will only occur if the SEL1 pin is set to diagnose the channel.

While the switch is disabled and DIA\_EN is high, the fault indication mechanisms will continuously represent the present status. For example, if  $V_{OUT}$  decreases from  $>V_{OL}$  to  $<V_{OL}$ , the fault indication is reset. Additionally, the fault indication is reset upon the falling edge of DIA\_EN or the rising edge of EN.



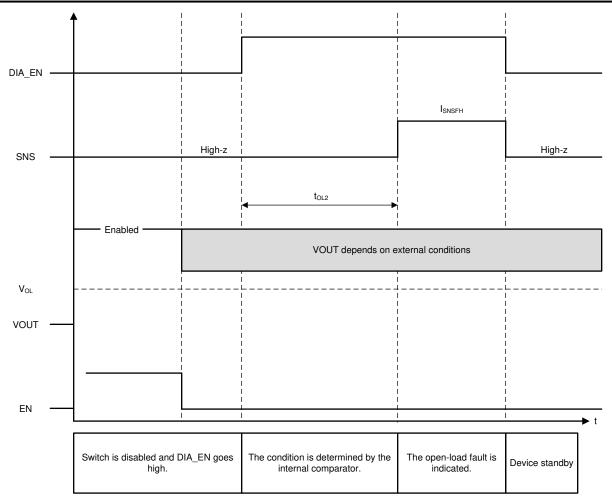


図 9-8. Open Load

#### 9.3.2.2 SNS Output

The SNS output may be used to sense the load current, supply voltage, or device temperature. The SELx pins will select the desired sense signal. The sense circuit will provide a current that is proportional to the selected parameter. This current will be sourced into an external resistor to create a voltage that is proportional to the selected parameter. This voltage may be measured by an ADC or comparator.

To ensure accurate sensing measurement, the sensing resistor should be connected to the same ground potential as the  $\mu C$  ADC.

The SNS Output includes an internal clamp,  $V_{SNSclamp}$ . This clamp is designed to prevent a high voltage at the SNS output and the ADC input.

表 9-1. Analog Sense Transfer Function

PARAMETER	TRANSFER FUNCTION
Load current	I <sub>SNSI</sub> = I <sub>OUT</sub> / 4600
Supply voltage <sup>(1)</sup>	$I_{SNSV} = (V_{BB}) \times dI_{SNSV} / dV$
Device temperature	$I_{SNST} = (T_J - 25^{\circ}C) \times dI_{SNST} / dT + 0.85$

(1) Voltage potential between the  $V_{BB}$  pin and the GND pin.

The SNS output will also be used to indicate system faults. I<sub>SNS</sub> will go to the predefined level, I<sub>SNSFH</sub>, when there is a fault. This level is defined in the electrical specifications.

#### 9.3.2.2.1 R<sub>SNS</sub> Value

The following factors should be considered when selecting the R<sub>SNS</sub> value:

- · Current sense ratio
- · Largest and smallest diagnosable load current
- Full-scale voltage of the ADC
- Resolution of the ADC

For an example of selecting R<sub>ISNS</sub> value, reference in the applications section of this data sheet.

#### 9.3.2.2.1.1 High Accuracy Load Current Sense

In many systems, it is required that the high-side switch provide diagnostic information about the downstream load. With more complex loads, high accuracy sensing is required. A few examples follow:

• **Solenoid Protection**: Often solenoids are precisely controlled by low-side switches. However, in a fault event, the low-side switch cannot disconnect the solenoid from the power supply. A high-side switch can be used to continuously monitor several solenoids. If the system current becomes higher than expected, the high-side switch can disable the module.

#### 9.3.2.2.1.2 SNS Output Filter

To achieve the most accurate current sense value, it is recommended to apply filtering to the SNS output. There are two methods of filtering:

- Low-Pass RC filter between the SNS pin and the ADC input. This filter is illustrated in 
   \( \text{\text{\text{2}}} \) 10-1 and typical values for the resistor and capacitor are given. The designer should select a C<sub>SNS</sub> capacitor value based on system requirements. A larger value will provide improved filtering. A smaller value will allow for faster transient response.
- The ADC and microcontroller can also be used for filtering. It is recommended that the ADC collects several
  measurements of the SNS output. The median value of this data set should be considered as the most
  accurate result. By performing this median calculation, the microcontroller is able to filter out any noise or
  outlier data.

#### 9.3.2.3 ST Pin

The ST pin is an open-drain output. The pin indicates the status of the switch channel. The output is high-z when there is no fault condition. The output is pulled low when there is a fault condition.

#### 9.3.2.4 Fault Indication and SNS Mux

The following faults will be communicated via the SNS and ST outputs:

- · Switch shutdown, due to:
  - Thermal Shutdown
  - Current limit
  - Energy limit
- · Active current limiting
- Open-Load / V<sub>OUT</sub> shorted-to-supply

Open-load / Short-to-supply are not indicated while the switch is enabled (though these conditions can be detected via the sense current). Hence, if there is a fault indication corresponding to an enabled channel, then it must be either switch shutdown or active current limiting.

The SNS pin will only indicate the fault if the SELx = 00. Switch shutdown fault indication will occur on the  $\overline{ST}$  pin regardless of the SELx pins; however, OL/STB fault indication is only available when the SELx = 00.

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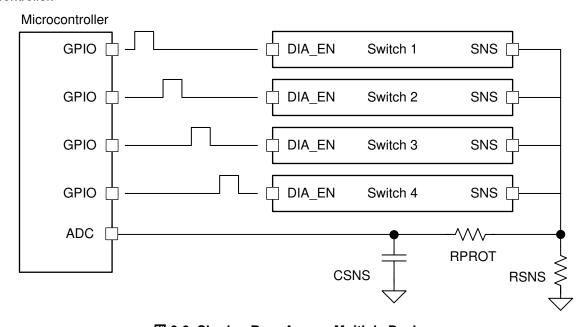
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INPUTS		OUTPUTS			
DIA_EN	SEL1	SEL2	FAULT DETECT(1)	SNS	ST
0	X	X	0	High-z	High-z
0	Х	Х	1	High-z	Pull low
1	0	0	0	Load current	High-z
1	0	1	0	Not Used	Not Used
1	1	0	0	Device temperature	High-z
1	1	1	0	Supply voltage	High-z
1	0	0	1	I <sub>SNSFH</sub>	Pull low
1	0	1	1	Not Used	Not Used
1	1	0	1	Device temperature	Pull low
1	1	1	1	Supply voltage	Pull low

- (1) Fault Detect encompasses the below conditions:
  - · Switch shutdown and waiting for retry
  - · Active current limiting
  - · OL / STB

### 9.3.2.5 Resistor Sharing

Multiple high-side switch channels may use the same SNS resistor as shown in  $\boxtimes$  9-9 below. This reduces the total number of passive components in the system and the number of ADC terminals that are required of the microcontroller.



☑ 9-9. Sharing R<sub>SNS</sub> Among Multiple Devices

### 9.3.2.6 High-Frequency, Low Duty-Cycle Current Sensing

Some applications will operate with a high-frequency, low duty-cycle PWM. Such applications require fast settling of the SNS output. For example, a 250-Hz, 5% duty cycle PWM will have an on-time of only 200  $\mu$ s. The microcontroller ADC may sample the SNS signal after the defined settling time,  $t_{SNSION3}$ .

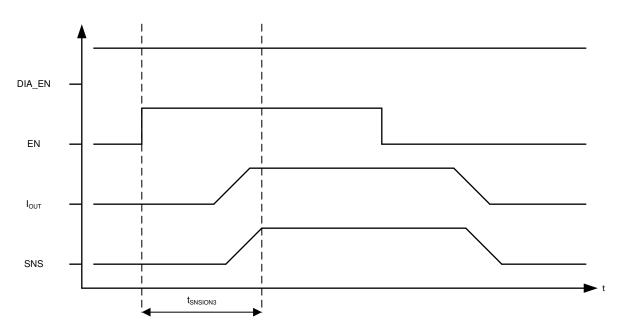


図 9-10. Current Sensing in Low-Duty Cycle Applications

#### 9.4 Device Functional Modes

#### 9.4.1 Off

Off state occurs when the device is not powered.

#### 9.4.2 Standby

Standby state is a low-power mode used to reduce power consumption to the lowest level. Diagnostic capabilities are not available in Standby mode.

### 9.4.3 Diagnostic

Diagnostic state may be used to perform diagnostics while the switch is disabled.

### 9.4.4 Standby Delay

The Standby Delay state is entered when EN and DIA\_EN are low. After  $t_{STBY}$ , if the EN and DIA\_EN pins are still low, the device will go to Standby State.

#### 9.4.5 Active

In Active state, the switch is enabled. The diagnostic functions may be turned on or off during Active state.

### 9.4.6 Fault

The Fault state is entered if a fault shutdown occurs (thermal shutdown, current limit, energy limit). After all faults are cleared, the LATCH pin is low, and the retry timer has expired, the device will transition out of Fault state. If the Enable pin is high, the switch will re-enable. If the Enable pin is low, the switch will remain off.



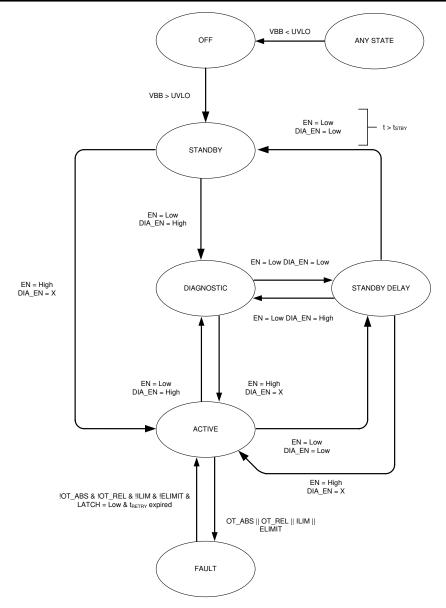


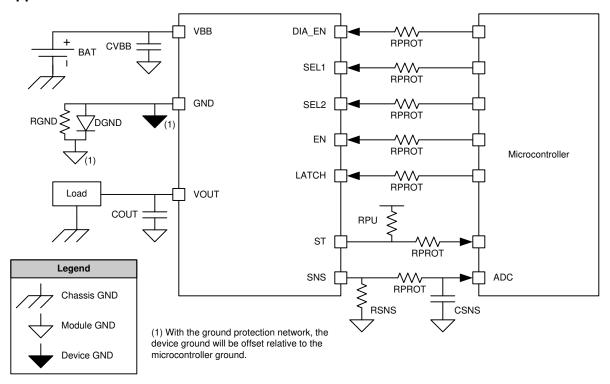
図 9-11. State Diagram

# 10 Application and Implementation

#### 注

以下のアプリケーション情報は、TIの製品仕様に含まれるものではなく、TIではその正確性または完全性を保証いたしません。個々の目的に対する製品の適合性については、お客様の責任で判断していただくことになります。お客様は自身の設計実装を検証しテストすることで、システムの機能を確認する必要があります。

### 10.1 Application Information



With the ground protection network, the device ground will be offset relative to the microcontroller ground.

### 図 10-1. System Diagram

表 10-1. Recommended External Components

COMPONENT	TYPICAL VALUE	PURPOSE
R <sub>PROT</sub>	15 kΩ	Protect microcontroller and device I/O pins
R <sub>SNS</sub>	1 kΩ	Translate the sense current into sense voltage
R <sub>PU</sub>	10 kΩ	Provide pull-up source for open-drain output
C <sub>SNS</sub>	100 pF - 10 nF	Low-pass filter for the ADC input
R <sub>GND</sub>	4.7 kΩ	Stabilize GND potential during turn-off of inductive load
$D_{GND}$	BAS21 Diode	Protects device during reverse supply
C <sub>VBB</sub>	220 nF to Device GND	Filtering of voltage transients (for example, ESD, ISO7637-2) and improved emissions
	100 nF to Module GND	Stabilize the input supply and filter out low frequency noise.
C <sub>OUT</sub>	22 nF	Filtering of voltage transients (for example, ESD, ISO7637-2)

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#### 10.1.1 Ground Protection Network

As discussed in the section regarding Reverse supply,  $D_{GND}$  may be used to prevent excessive reverse current from flowing into the device during a reverse supply event. Additionally,  $R_{GND}$  is placed in parallel with  $D_{GND}$  if the switch is used to drive an inductive load. The ground protection network ( $D_{GND}$  and  $R_{GND}$ ) may be shared amongst multiple high-side switches.

A minimum value for  $R_{GND}$  may be calculated by using the absolute maximum rating for  $I_{GND}$ . During the reverse supply condition,  $I_{GND} = V_{BB} / R_{GND}$ :

$$R_{GND} \ge V_{BB} / I_{GND}$$
 (1)

- Set V<sub>BB</sub> = -13.5 V
- Set I<sub>GND</sub> = -50 mA (absolute maximum rating)

$$R_{GND} \ge -13.5 \text{ V} / -50 \text{ mA} = 270 \Omega$$

In this example, it is found that  $R_{GND}$  must be at least 270  $\Omega$ . It is also necessary to consider the power dissipation in  $R_{GND}$  during the reverse supply event:

$$P_{RGND} = V_{BB}^2 / R_{GND} \tag{2}$$

 $P_{RGND} = (13.5 \text{ V})^2 / 270 \Omega = 0.675 \text{ W}$ 

In practice, R<sub>GND</sub> may not be rated for such a high power. In this case, a larger resistor value should be selected.

#### 10.1.2 Interface With Microcontroller

The ground protection network will cause the device ground to be at a higher potential than the module ground (and microcontroller ground). This offset will impact the interface between the device and the microcontroller.

Logic pin voltage will be offset by the forward voltage of the diode. For input pins (for example, EN), the designer must consider the  $V_{IH}$  specification of the switch and the  $V_{OH}$  specification of the microcontroller. For a system that *does not* include  $D_{GND}$ , it is required that  $V_{OH} > V_{IH}$ . For a system that *does* include  $D_{GND}$ , it is required that  $V_{OH} > (V_{IH} + V_F)$ .  $V_F$  is the forward voltage of  $D_{GND}$ .

For use of the status pin, ST, a similar consideration is necessary. The designer must consider the  $V_{OL, ST}$  specification and the  $V_{IL}$  specification of the microcontroller. For a system that includes DGND, it is required that  $V_{OL, ST} + V_F < V_{IL, \mu C}$ .

The sense resistor,  $R_{SNS}$ , should be terminated to the microcontroller ground. In this case, the ADC can accurately measure the SNS signal even if there is an offset between the microcontroller ground and the device ground.

#### 10.1.3 I/O Protection

R<sub>PROT</sub> is used to protect the microcontroller I/O pins during system-level voltage transients such as ISO pulses or reverse supply. A large resistance value ensures that current through the pin is limited to a safe level.

#### 10.1.4 Inverse Current

Inverse current occurs when 0 V <  $V_{BB}$  <  $V_{OUT}$ . In this case, current may flow from  $V_{OUT}$  to  $V_{BB}$ . Inverse current cannot be caused by a purely resistive load. However, a capacitive or inductive load can cause inverse current. For example, if there is a significant amount of load capacitance and the  $V_{BB}$  node has a transient droop,  $V_{OUT}$  may be greater than  $V_{BB}$ .

TPS27SA08 device will not detect inverse current. When the switch is enabled, inverse current will pass through the switch. When the switch is disabled, inverse current may pass through the MOSFET body diode. The device will continue operating in the normal manner during an inverse current event.

#### 10.1.5 Loss of GND

The ground connection may be lost either on the device level or on the module level. If the ground connection is lost, both switches will be disabled. If the switch was already disabled when the ground connection was lost, the switch will remain disabled. When the ground is reconnected, normal operation will resume.

#### 10.1.6 Thermal Information

When outputting current, the TPS27SA08 device will heat up due to the power dissipation. ☒ 10-2 shows the transient thermal impedance curve that can be used to determine the device temperature during 1-W pulse of a given length.

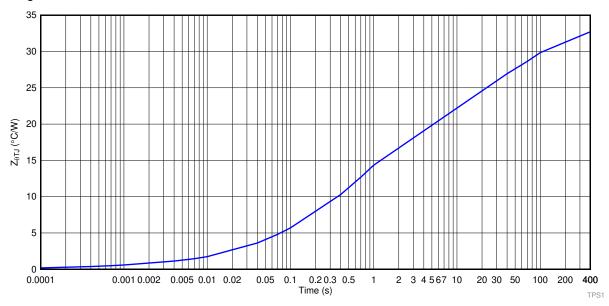


図 10-2. Transient Thermal Impedance

#### **10.2 Typical Application**

This application example demonstrates how the TPS27SA08 device can be used to power resistive heater loads as in seat heaters. 🗵 10-3 shows a typical application where the load is a resistive seat heater. This document highlights the basics of this type of application, however for a more detailed discussion reference *TI's Smart Power Switch Seat Heater Reference Design*.



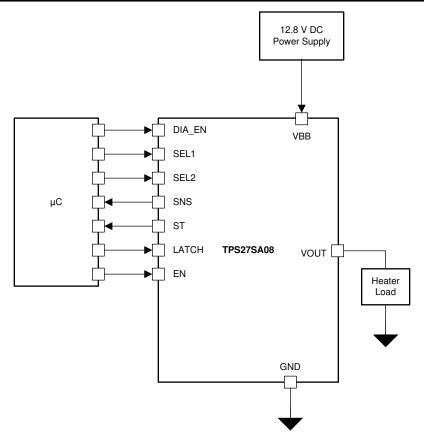


図 10-3. Block Diagram for Powering Heater Loads

#### 10.2.1 Design Requirements

For this design example, use the input parameters shown in 表 10-2.

表 10-2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V <sub>BB</sub>	12.8 V
Heater Load	90-W max
Load Current Sense	100 mA to 20 A
Ambient temperature	85°C
R <sub>θJA</sub>	32.8°C/W (depending on PCB)

#### 10.2.2 Detailed Design Procedure

#### 10.2.2.1 Thermal Considerations

The DC current under maximum load power condition will be around 7.03 A. Power dissipation in the switch is calculated in  $\gtrsim$  3.  $R_{ON}$  is assumed to be 20 m $\Omega$  because this is the maximum specification. In practice,  $R_{ON}$  will be lower.

$$P_{\text{FFT}} = I^2 \times R_{\text{ON}} \tag{3}$$

$$P_{FET} = (7.03 \text{ A})^2 \times 20 \text{ m}\Omega = 0.988 \text{ W}$$
 (4)

The junction temperature of the device can be calculated using  $\not\equiv$  5 and the R<sub> $\theta$ JA</sub> value from the *Specifications* section.

$$T_{J} = T_{A} + R_{\theta JA} \times P_{FET} \tag{5}$$

 $T_J = 85^{\circ}C + 32.8^{\circ}C/W \times 0.988 W = 117.4^{\circ}C$ 

The maximum junction temperature rating for TPS27SA08 device is  $T_J = 150$ °C. Based on the above example calculation, the device temperature will stay below the maximum rating.

#### 10.2.2.2 Diagnostics

If the resistive heating load is disconnected (heater malfunction), an alert is desired. Open-load detection can be performed in the switch-enabled state via the current sense feature of the TPS27SA08 device. Alternatively, under open load condition in off-state with diagnostics enabled, the current in the SNS pin will be the fault current and the can be detected from the sense voltage measurement.

### 10.2.2.2.1 Selecting the R<sub>ISNS</sub> Value

 $\gtrsim$  10-3 shows the requirements for the load current sense in this application. The  $K_{SNS}$  value is specified for the device and can be found in the *Specifications* section.

 PARAMETER
 EXAMPLE VALUE

 Current Sense Ratio (K<sub>SNS</sub>)
 4600

 Largest diagnosable load current
 20 A

 Smallest diagnosable load current
 50 mA

 Full-scale ADC voltage
 5 V

 ADC resolution
 10 bit

表 10-3. R<sub>SNS</sub> Calculation Parameters

The load current measurement requirements of 20 A ensures that current can be sensed up to the 20-A current limit, while the low level of 100 mA allows for accurate measurement of low load currents.

The  $R_{SNS}$  resistor value should be selected such that the largest diagnosable load current puts  $V_{SNS}$  at about 90% of the ADC full-scale. With this design, any ADC value above 90% can be considered a fault. Additionally, the  $R_{SNS}$  resistor value should ensure that the smallest diagnosable load current does not cause  $V_{SNS}$  to fall below 1 LSB of the ADC. With the given example values, a 1-kΩ sense resistor satisfies both requirements shown in  $\pm$  10-4.

% OF 5-V ADC LOAD (A) **SENSE RATIO** I<sub>SNS</sub> (mA) R<sub>SNS</sub> (Ω) V<sub>SNS</sub> (V) 0.22% 0.050 4600 0.011 1000 0.011 20.000 4600 4.348 1000 4.348 87%

表 10-4. V<sub>SNS</sub> Calculation

#### 10.2.3 Application Curves

☑ 10-4 shows the behavior of the TPS27SA08 device in this application when the MCU provides an enable pulse to beginning heating the resistive element. Shortly after the EN pin goes high, the load current begins to flow and the SNS pin measures the output current.

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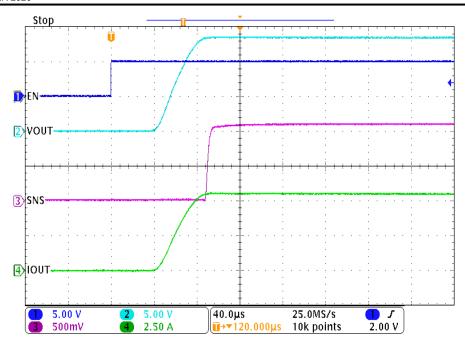


図 10-4. Heater Turn-on Time

By measuring the voltage on the SNS pin, the TPS27SA08 device can communicate back to the system MCU what the load current is.  $\boxtimes$  10-5 shows that when the seat heater approaches full load and I<sub>OUT</sub> jumps from a low load current of 1 A up to a 5-A load current, the load step is mirrored on the SNS pin.

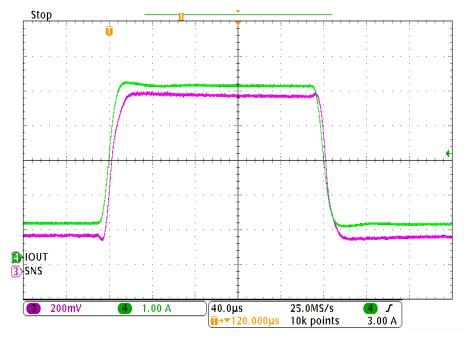


図 10-5. SNS Response During Heater Load Step

One common concern in these type of applications is that the heating element can accidentally lose connection, creating an open load situation. In this case, it is ideal for the TPS27SA08 device to recognize that the load has been removed and report a FLT to the MCU.  $\boxtimes$  10-6 shows the behavior of the TPS27SA08 device when there is no load attached. As soon as the DIAG\_EN pin is engaged, the SNS output goes high and the  $\overline{\text{ST}}$  output engages low. By monitoring these pins, the MCU can recognize there is a fault and notify the user that maintenance is required.

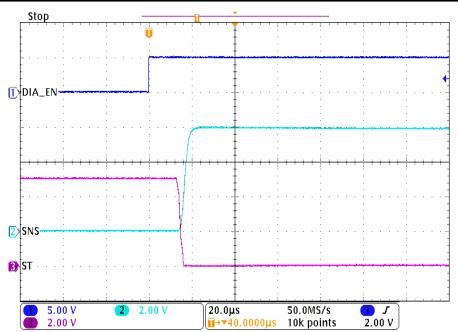


図 10-6. Open Load Detection If Heating Element is Missing

Importantly, the TPS27SA08 device will also protect the system in the event of a short-circuit.  $\boxtimes$  10-7 shows the behavior of the device if it is enabled into a short circuit condition. The current will be clamped to near the current limit threshold ( $I_{CL}$ ) until it hits an over temperature event, at which point the FET will be turned off. In this way, the system is protected from unchecked overcurrent in the event of a short circuit.

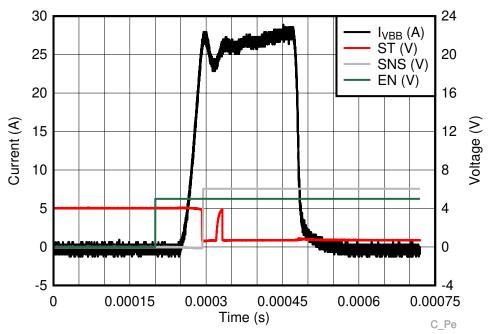


図 10-7. Overcurrent Behavior During Short Circuit Event

## 11 Power Supply Recommendations

The TPS27SA08 device is designed to operate in a 24-V system. The nominal supply voltage range is 8 V to 36 V. The device is also designed to withstand voltage transients beyond this range. When operating outside of the nominal voltage range, the device will exhibit normal functional behavior. However, parametric specifications may not be guaranteed.



## 12 Layout

## 12.1 Layout Guidelines

To achieve optimal thermal performance, connect the exposed pad to a large copper pour. On the top PCB layer, the pour may extend beyond the pad dimensions as shown in the example below. In addition to this, it is recommended to also have a  $V_{BB}$  plane either on one of the internal PCB layers or on the bottom layer. Vias should connect this plane to the top  $V_{BB}$  pour.

TPS27SA08 device has 6  $V_{OUT}$  pins. All  $V_{OUT}$  pins must be shorted together on the PCB. Additionally, the layout should ensure that the current path is symmetrical for both sides of the device. If the path is not symmetrical, there will be some imbalance in current spreading across the power FET. This can impact accuracy of the current sense measurement.

## 12.2 Layout Example

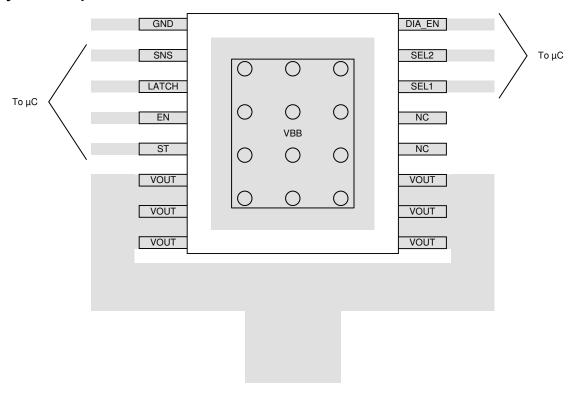


図 12-1. PWP Layout Example



## 13 Device and Documentation Support

## 13.1 Device Support

#### 13.1.1 Related Documentation

For related documentation see the following:

- TI's "How To Drive Inductive, Capacitive, and Lighting Loads with Smart High Side Switch
- Short Circuit Reliability Test for Smart Power Switches
- TI's Smart Power Switch Seat Heater Reference Design
- Reverse Battery Protection for High Side Switches

### 13.2 Trademarks

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## 13.4 用語集

テキサス・インスツルメンツ用語集 この用語集には、用語や略語の一覧および定義が記載されています。



# 14 Mechanical, Packaging, and Orderable Information

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

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#### PACKAGING INFORMATION

Orderable part number	Status	Material type	Package   Pins	Package qty   Carrier	<b>RoHS</b> (3)	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
TPS27SA08CPWPR	Active	Production	HTSSOP (PWP)   16	3000   LARGE T&R	ROHS Exempt	NIPDAU	Level-3-260C-168HRS	-40 to 125	27SA08C
TPS27SA08CPWPR.A	Active	Production	HTSSOP (PWP)   16	3000   LARGE T&R	ROHS Exempt	NIPDAU	Level-3-260C-168HRS	-40 to 125	27SA08C
TPS27SA08CPWPR.B	Active	Production	HTSSOP (PWP)   16	3000   LARGE T&R	-	Call TI	Call TI	-40 to 125	

<sup>(1)</sup> Status: For more details on status, see our product life cycle.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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.

#### OTHER QUALIFIED VERSIONS OF TPS27SA08:

Automotive: TPS27SA08-Q1

<sup>(2)</sup> Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> RoHS values: Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

<sup>(4)</sup> Lead finish/Ball material: Parts 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.

<sup>(5)</sup> MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.



# **PACKAGE OPTION ADDENDUM**

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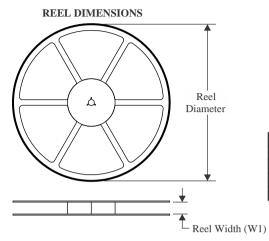
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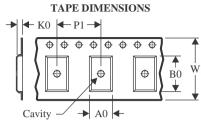
• Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

# **PACKAGE MATERIALS INFORMATION**

www.ti.com 5-Dec-2023

## TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

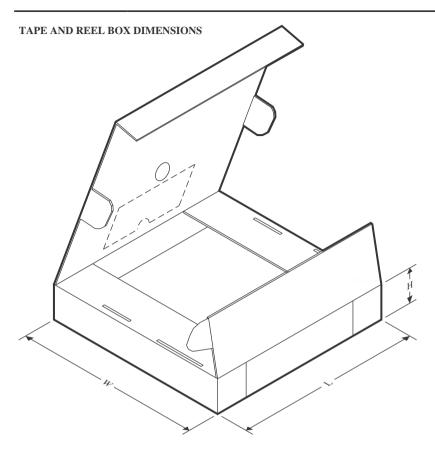


#### \*All dimensions are nominal

Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS27SA08CPWPR	HTSSOP	PWP	16	3000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

# **PACKAGE MATERIALS INFORMATION**

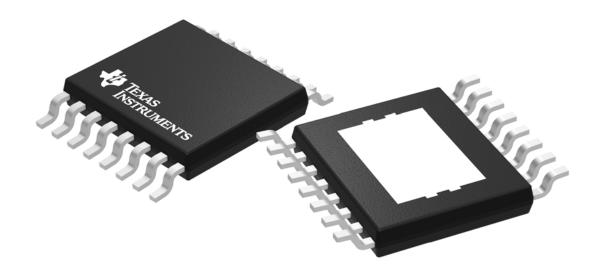
www.ti.com 5-Dec-2023



## \*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS27SA08CPWPR	HTSSOP	PWP	16	3000	350.0	350.0	43.0

PLASTIC SMALL OUTLINE



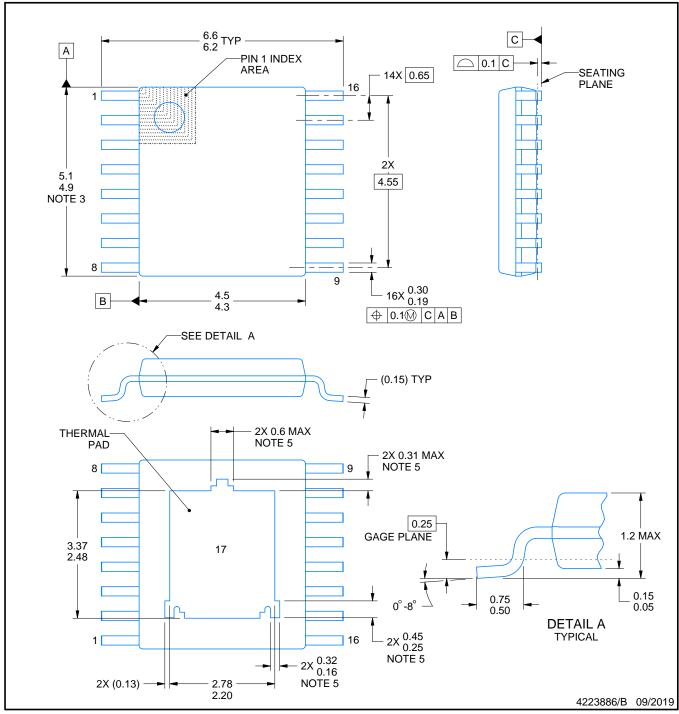
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.





# PowerPAD<sup>™</sup> TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



### NOTES:

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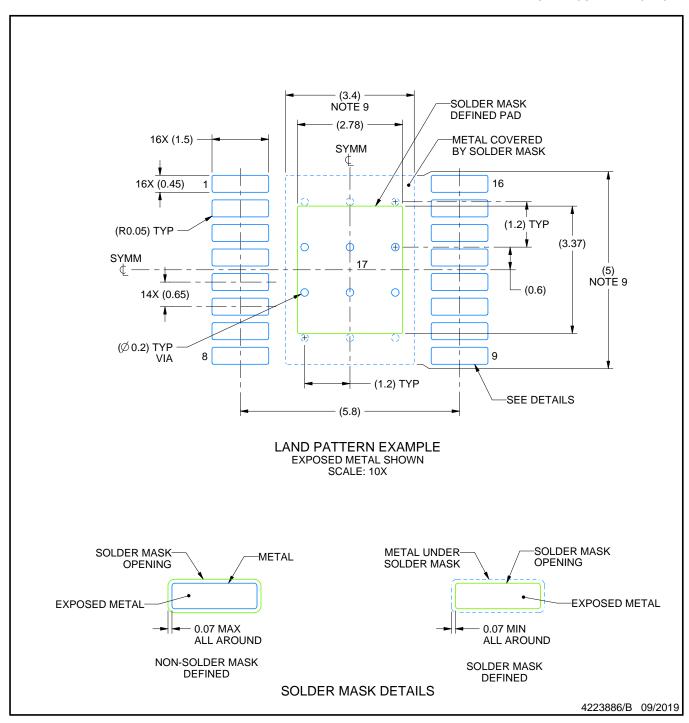
- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

  2. This drawing is subject to change without notice.

  3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.
  4. Reference JEDEC registration MO-153.
- 5. Features may differ or may not be present.



SMALL OUTLINE PACKAGE

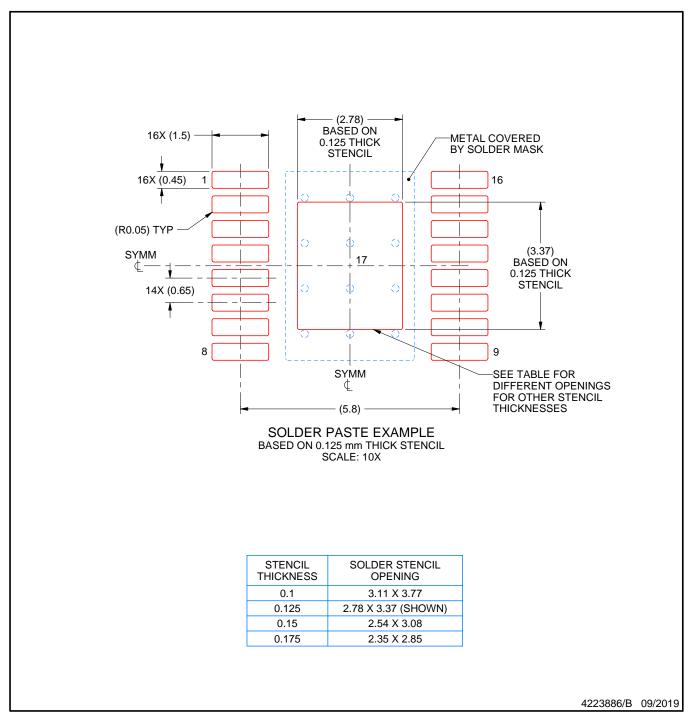


NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
- 8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
- 9. Size of metal pad may vary due to creepage requirement.
- 10. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.



SMALL OUTLINE PACKAGE



NOTES: (continued)

- 11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 12. Board assembly site may have different recommendations for stencil design.



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