



# TPS1HA08-Q1 40V、8mΩ のシングル・チャネル、スマート・ハイサイド・スイッチ

## 1 特長

- $R_{ON} = 8m\Omega$  ( $T_J = 25^\circ C$ ) のシングル・チャネル、スマート・ハイサイド・スイッチ
- 車載アプリケーション向けに認定済み
  - AEC Q-100 認定済み
  - デバイス温度グレード 1: 動作時周囲温度範囲  $-40^\circ C \sim +125^\circ C$
  - 40V の負荷ダンプへの耐性
- **機能安全対応**
  - 機能安全システムの設計に役立つ資料を利用可能
- 選択可能な電流制限による信頼性向上
  - 20A または 80A の電流制限設定ポイント
  - 過電流に対して電流クランピングまたは即時シャットダウンの応答
- 堅牢な出力保護機能を内蔵
  - 熱保護機能を内蔵
  - グランド/バッテリーへの短絡に対する保護
  - バッテリ逆接続時の自動スイッチ・オン
  - バッテリ/グランド喪失が発生した場合に自動シャットオフ
  - 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に設定可能
  - 負荷電流
  - 電源電圧
  - デバイス温度
- FLT 通知を MCU に返す
  - 開放負荷とバッテリー短絡の検出

## 2 アプリケーション

- 車体制御モジュール
- 白熱光および LED ライティング
- 発熱体
  - シート・ヒーター
  - グロー・プラグ
  - タンク・ヒーター
- トランスミッション制御ユニット
- 空調の自動制御
- インフォテインメント・ディスプレイ
- ADAS モジュール

## 3 概要

このデバイスは 12V 車載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されます。電流制限は、デバイスのバリエーションに応じて 80A および 20A を使用でき、過電流事象に対して即座にスイッチをオフにするか、出力電流を設定ポイントにレギュレートするかを設定できます。高電流制限オプションでは、大きな過渡電流を必要とする負荷を使用できます。低電流制限オプションは、大きなピーク電流を必要としない負荷で保護を強化できます。

また、この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。

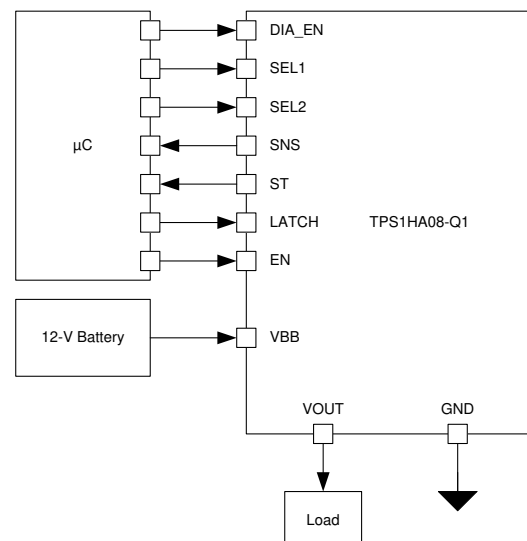
デバイスは小型の 16 ピン HTSSOP パッケージで供給されるため、PCB の占有面積を減らすことができます。

### 製品情報<sup>(1)</sup>

| 型番          | パッケージ       | 本体サイズ(公称)       |
|-------------|-------------|-----------------|
| TPS1HA08-Q1 | HTSSOP (16) | 5.00mm × 4.40mm |

(1) 提供されているすべてのパッケージについては、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。

### 概略回路図



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## 4 改訂履歴

### Revision C (May 2019) から Revision D に変更 Page

- 「[特長](#)」セクションに機能安全対応のリンクを追加 ..... **1**

### Revision B (January 2019) から Revision C に変更 Page

- 「[特長](#)」および「[概要](#)」セクションに参照用アプリ・ノートへのリンクを追加 ..... **1**
- Removed the Product Preview note from Device Version B,D,E in the [Device Comparison Table](#) ..... **3**
- Updated the *Absolute Maximum Ratings* and *Electrical Characteristics* tables in the [Specifications](#) section ..... **6**
- Updated [図 7](#) ..... **13**
- 追加 paragraph to the [Undervoltage Lockout \(UVLO\)](#) section ..... **22**
- Added app note link to [図 41](#) title ..... **24**

### Revision A (December 2018) から Revision B に変更 Page

- Deleted note from Device Version C in the [Device Comparison Table](#) ..... **3**

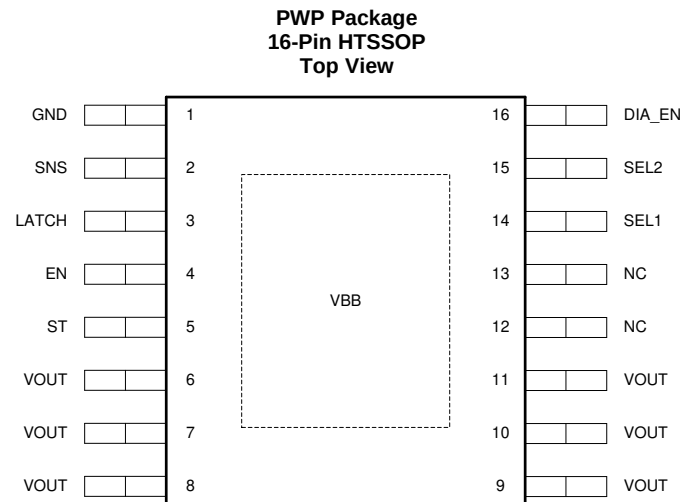
### 2017年9月発行のものから更新 Page

- 「事前情報」から「量産データ」に変更 ..... **1**

## 5 Device Comparison Table

| Device Version | Full Device Number    | Current Limit ( $I_{CL}$ ) | Overcurrent Behavior                             | Watchdog Feature |
|----------------|-----------------------|----------------------------|--------------------------------------------------|------------------|
| A              | TPS1HA08 <b>A</b> -Q1 | 20 A                       | Disable Switch Immediately                       | Disabled         |
| B              | TPS1HA08 <b>B</b> -Q1 | 80 A                       | Disable Switch Immediately                       | Disabled         |
| C              | TPS1HA08 <b>C</b> -Q1 | 20 A                       | Clamp Current at $I_{CL}$ until Thermal Shutdown | Disabled         |
| D              | TPS1HA08 <b>D</b> -Q1 | 80 A                       | Clamp Current at $I_{CL}$ until Thermal Shutdown | Disabled         |
| E              | TPS1HA08 <b>E</b> -Q1 | 20 A                       | Disable Switch Immediately                       | Enabled          |

## 6 Pin Configuration and Functions



**Pin Functions**

| PIN                |                        | I/O | DESCRIPTION                                          |
|--------------------|------------------------|-----|------------------------------------------------------|
| NO.                | NAME                   |     |                                                      |
| 1                  | GND                    | —   | Device ground                                        |
| 2                  | SNS                    | O   | Sense output                                         |
| 3                  | LATCH                  | I   | Sets fault handling behavior (latched or auto-retry) |
| 4                  | EN                     | I   | Switch control input, active high                    |
| 5                  | $\overline{\text{ST}}$ | O   | Switch diagnostic feedback, active low               |
| 6, 7, 8, 9, 10, 11 | VOUT                   | O   | Switch output                                        |
| 12                 | NC                     | --  | No 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                                   |

## 6.1 Recommended Connections for Unused Pins

The 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.

**Table 1. Connections for Optional Pins**

| PIN NAME        | CONNECTION IF NOT USED                             | IMPACT IF NOT USED                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SNS             | Ground through 1-k $\Omega$ 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.                                                                                                                                                                                         |
| $\overline{ST}$ | Float                                              | All faults are indicated by the analog SNS pin. The $\overline{ST}$ pin provides the additional benefits: <ul style="list-style-type: none"> <li>• Provide fault indication when DIA_EN = 0</li> <li>• Provide fault indication regardless of SELx pin conditions</li> <li>• Provide fault indication to a simple digital I/O (rather than ADC or comparator used with the SNS signal)</li> </ul> |
| SEL1            | Float or ground through R <sub>PROT</sub> resistor | SEL1 selects between the V <sub>BB</sub> and T <sub>J</sub> 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-battery diagnostics are not available.                                                                                                                                                                                                                                                                                                   |

R<sub>PROT</sub> is used to protect the pins from excess current flow during reverse battery conditions, for more information please see the section on [Reverse Battery](#) protection.

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                                          |                                                       |                                                                          | MIN | MAX              | UNIT |
|------------------------------------------|-------------------------------------------------------|--------------------------------------------------------------------------|-----|------------------|------|
| V <sub>BB</sub>                          | Maximum continuous supply voltage                     |                                                                          |     | 36               | V    |
| V <sub>LD</sub>                          | Load dump voltage                                     | ISO16750-2:2010(E)                                                       |     | 40               | V    |
| V <sub>Rev</sub>                         | Reverse battery voltage, V <sub>REV</sub> ≤ 3 minutes |                                                                          | –18 |                  | V    |
| V <sub>EN</sub>                          | Enable pin voltage                                    |                                                                          | –1  | 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> ,<br>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   |
| E <sub>TOFF</sub>                        | Energy dissipation during turn-off                    | Single pulse, L <sub>OUT</sub> = 5 mH, T <sub>A</sub> = 125°C            |     | 95               | mJ   |
|                                          |                                                       | Repetitive pulse, 10 Hz, L <sub>OUT</sub> = 5 mH, T <sub>A</sub> = 125°C |     | 56               | mJ   |
| T <sub>J</sub>                           | Maximum junction temperature                          |                                                                          |     | 150              | °C   |
| T <sub>stg</sub>                         | Storage temperature                                   |                                                                          | –65 | 150              | °C   |

- (1) 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.
- (2) 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.

### 7.2 ESD Ratings

|                    |                         |                                                         | VALUE | UNIT |
|--------------------|-------------------------|---------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup> | ±2000 | V    |
|                    |                         | Exposed pad and pins 6 to 11                            | ±4000 |      |
|                    |                         | Charged-device model (CDM), per AEC Q100-011            | ±750  |      |

- (1) 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   | 18                    | V    |
| V <sub>BB</sub>                          | Extended operating range <sup>(1)</sup> |                       | 3   | 28                    | 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> ,<br>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    |
| I <sub>MAX</sub>                         | Continuous load current                 | T <sub>A</sub> = 70°C | 0   | 10                    | A    |

- (1) Device will function within extended operating range, however some parametric values might not apply

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)(2)</sup> |                                              | TPS1HA08-Q1  | UNIT |
|----------------------------------|----------------------------------------------|--------------|------|
|                                  |                                              | PWP (HTSSOP) |      |
|                                  |                                              | 16 PINS      |      |
| $R_{\theta JA}$                  | Junction-to-ambient thermal resistance       | 32.8         | °C/W |
| $R_{\theta JC(top)}$             | Junction-to-case (top) thermal resistance    | 30.7         | °C/W |
| $R_{\theta JB}$                  | Junction-to-board thermal resistance         | 9.3          | °C/W |
| $\Psi_{JT}$                      | Junction-to-top characterization parameter   | 2.6          | °C/W |
| $\Psi_{JB}$                      | Junction-to-board characterization parameter | 9.4          | °C/W |
| $R_{\theta JC(bot)}$             | Junction-to-case (bottom) thermal resistance | 1.0          | °C/W |

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.
- (2) The thermal parameters are based on a 4-layer PCB according to the JESD51-5 and JESD51-7 standards.

## 7.5 Electrical Characteristics

 $V_{BB} = 8\text{ V to }18\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                       |                                                            | TEST CONDITIONS                                                                                                              | MIN | TYP  | MAX | UNIT |
|---------------------------------|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-----|------|-----|------|
| INPUT VOLTAGE AND CURRENT       |                                                            |                                                                                                                              |     |      |     |      |
| 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    |
| I <sub>SB</sub>                 | Standby current (includes MOSFET leakage)                  | V <sub>BB</sub> = 13.5 V, T <sub>J</sub> = 25°C<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V       |     |      | 0.5 | μA   |
|                                 |                                                            | V <sub>BB</sub> = 13.5 V, T <sub>J</sub> = 85°C<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V       |     |      | 0.5 | μA   |
|                                 |                                                            | V <sub>BB</sub> = 13.5 V, T <sub>J</sub> = 125°C,<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V     |     |      | 3   | μA   |
| I <sub>OUT(standby)</sub>       | Output leakage current                                     | V <sub>BB</sub> = 13.5 V, T <sub>J</sub> = 25°C<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V       |     | 0.01 | 0.5 | μA   |
|                                 |                                                            | V <sub>BB</sub> = 13.5 V, T <sub>J</sub> = 125°C<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 0 V, V <sub>OUT</sub> = 0 V      |     |      | 3   | μA   |
| I <sub>DIA</sub>                | Current consumption in diagnostic mode                     | V <sub>BB</sub> = 13.5 V, I <sub>SNS</sub> = 0 mA<br>V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 5 V, V <sub>OUT</sub> = 0V |     | 3    | 6   | mA   |
| I <sub>Q</sub>                  | Quiescent current                                          | V <sub>BB</sub> = 13.5 V<br>V <sub>EN</sub> = V <sub>DIA_EN</sub> = 5 V, I <sub>OUT</sub> = 0 A, V <sub>SELX</sub> = 0 V     |     | 3    | 6   | 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> CHARACTERISTICS |                                                            |                                                                                                                              |     |      |     |      |
| R <sub>ON</sub>                 | On-resistance<br>Includes MOSFET and package               | T <sub>J</sub> = 25°C, 6 V ≤ V <sub>BB</sub> ≤ 28 V                                                                          |     | 9    |     | mΩ   |
|                                 |                                                            | T <sub>J</sub> = 150°C, 6 V ≤ V <sub>BB</sub> ≤ 28 V                                                                         |     |      | 20  | mΩ   |
|                                 |                                                            | T <sub>J</sub> = 25°C, 3 V ≤ V <sub>BB</sub> ≤ 6 V                                                                           |     |      | 15  | mΩ   |
| R <sub>ON(REV)</sub>            | On-resistance during reverse polarity                      | T <sub>J</sub> = 25°C, -18 V ≤ V <sub>BB</sub> ≤ -8 V                                                                        |     | 9    |     | mΩ   |
|                                 |                                                            | T <sub>J</sub> = 105°C, -18 V ≤ V <sub>BB</sub> ≤ -8 V                                                                       |     |      | 20  | mΩ   |
| CURRENT SENSE CHARACTERISTICS   |                                                            |                                                                                                                              |     |      |     |      |
| K <sub>SNS</sub>                | Current sense ratio<br>I <sub>OUT</sub> / I <sub>SNS</sub> |                                                                                                                              |     | 4600 |     |      |

## Electrical Characteristics (continued)

 $V_{BB} = 8\text{ V to }18\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                             |                                                  | TEST CONDITIONS                                                                                                                                                  |                          | MIN  | TYP    | MAX   | UNIT  |
|---------------------------------------|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------|--------|-------|-------|
| I <sub>SNSI</sub>                     | Current sense current and current sense accuracy | V <sub>EN</sub> = V <sub>DIA_EN</sub> = 5 V, V <sub>SEL1</sub> = V <sub>SEL2</sub> = 0 V                                                                         | I <sub>OUT</sub> = 20 A  |      | 4.35   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  |                          | −5   |        | 5     | %     |
|                                       |                                                  |                                                                                                                                                                  | I <sub>OUT</sub> = 8 A   |      | 1.74   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  |                          | −5   |        | 5     | %     |
|                                       |                                                  |                                                                                                                                                                  | I <sub>OUT</sub> = 3 A   |      | 0.65   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  |                          | −5   |        | 5     | %     |
|                                       |                                                  |                                                                                                                                                                  | I <sub>OUT</sub> = 1 A   |      | 0.217  |       | mA    |
|                                       |                                                  |                                                                                                                                                                  |                          | −5   |        | 5     | %     |
|                                       | I <sub>OUT</sub> = 300 mA                        |                                                                                                                                                                  | 0.065                    |      | mA     |       |       |
|                                       |                                                  | −12                                                                                                                                                              |                          | 12   | %      |       |       |
|                                       | I <sub>OUT</sub> = 100 mA                        |                                                                                                                                                                  | 0.022                    |      | mA     |       |       |
|                                       |                                                  | −42                                                                                                                                                              |                          | 42   | %      |       |       |
| T <sub>J</sub> SENSE CHARACTERISTICS  |                                                  |                                                                                                                                                                  |                          |      |        |       |       |
| I <sub>SNST</sub>                     | Temperature sense current                        | 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    |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 25°C    |      | 0.85   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 85°C    |      | 1.52   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 150°C   |      | 2.25   |       | mA    |
| dI <sub>SNST</sub> /dT                | Coefficient                                      |                                                                                                                                                                  |                          |      | 0.0112 |       | mA/°C |
| V <sub>BB</sub> SENSE CHARACTERISTICS |                                                  |                                                                                                                                                                  |                          |      |        |       |       |
| I <sub>SNSV</sub>                     | Voltage sense current                            | V <sub>DIA_EN</sub> = 5 V, V <sub>SEL1</sub> = 5 V, V <sub>SEL2</sub> = 5 V                                                                                      | V <sub>BB</sub> = 3 V    |      | 0.26   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  | V <sub>BB</sub> = 8 V    |      | 0.69   |       | mA    |
|                                       |                                                  |                                                                                                                                                                  | 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    |
| dI <sub>SNSV</sub> /dV                | Coefficient                                      |                                                                                                                                                                  |                          |      | 0.0867 |       | mA/V  |
| SNS CHARACTERISTICS                   |                                                  |                                                                                                                                                                  |                          |      |        |       |       |
| I <sub>SNSFH</sub>                    | I <sub>SNS</sub> fault high level                | V <sub>DIA_EN</sub> = 5 V, V <sub>SEL1</sub> = 0 V, V <sub>SEL2</sub> = 0                                                                                        |                          | 6    | 6.9    | 7.6   | mA    |
| I <sub>SNSleak</sub>                  | I <sub>SNS</sub> leakage                         | V <sub>DIA_EN</sub> = 0 V                                                                                                                                        |                          | 0    |        | 1     | μA    |
| V <sub>SNSclamp</sub>                 | V <sub>SNS</sub> clamp                           |                                                                                                                                                                  |                          |      | 5.9    |       | V     |
| CURRENT LIMIT CHARACTERISTICS         |                                                  |                                                                                                                                                                  |                          |      |        |       |       |
| I <sub>CL</sub>                       | Current Limit                                    | Device Version B/D                                                                                                                                               | T <sub>J</sub> = −40°C   | 75.5 | 88.8   | 102.1 | A     |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 25°C    | 68   | 80     | 92    |       |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 150°C   | 51   | 60     | 69    |       |
|                                       |                                                  | Device Version A/C/E                                                                                                                                             | T <sub>J</sub> = −40°C   | 16   | 22.2   | 27.8  | A     |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 25°C    | 14.4 | 20     | 25    |       |
|                                       |                                                  |                                                                                                                                                                  | T <sub>J</sub> = 150°C   | 10.8 | 15     | 18.8  |       |
| ST PIN CHARACTERISTICS                |                                                  |                                                                                                                                                                  |                          |      |        |       |       |
| V <sub>OL</sub>                       | Open-load detection voltage                      | V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 5 V                                                                                                                 |                          | 2    | 2.5    | 4     | V     |
| t <sub>OL1</sub>                      | OL and STB indication time - switch disabled     | From falling edge of EN<br>V <sub>EN</sub> = 5 V to 0 V, V <sub>DIA_EN</sub> = 5 V, V <sub>SELx</sub> = 00<br>I <sub>OUT</sub> = 0 mA, V <sub>OUT</sub> = 4 V    |                          | 300  | 500    | 700   | μs    |
| t <sub>OL2</sub>                      | OL and STB indication time - switch disabled     | From rising edge of DIA_EN<br>V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 0 V to 5 V, V <sub>SELx</sub> = 00<br>I <sub>OUT</sub> = 0 mA, V <sub>OUT</sub> = 4 V |                          |      |        | 50    | μs    |
| t <sub>OL3</sub>                      | OL and STB indication time - switch disabled     | From rising edge of VOUT<br>V <sub>EN</sub> = 0 V, V <sub>DIA_EN</sub> = 5 V, V <sub>SELx</sub> = 00<br>I <sub>OUT</sub> = 0 mA, V <sub>OUT</sub> = 0 V to 4 V   |                          |      |        | 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    |
| t <sub>WD</sub>                       | Watchdog timer                                   | Device version E                                                                                                                                                 |                          | 350  | 400    | 450   | ms    |



## Electrical Characteristics (continued)

 $V_{BB} = 8\text{ V to }18\text{ V}$ ,  $T_J = -40^{\circ}\text{C to }150^{\circ}\text{C}$  (unless otherwise noted)

| PARAMETER                                              |                            | TEST CONDITIONS              | MIN | TYP | MAX | UNIT             |
|--------------------------------------------------------|----------------------------|------------------------------|-----|-----|-----|------------------|
| <b>EN PIN CHARACTERISTICS<sup>(1)</sup></b>            |                            |                              |     |     |     |                  |
| $V_{IL\_EN}$                                           | Input voltage low level    |                              |     |     | 0.8 | V                |
| $V_{IH\_EN}$                                           | Input voltage high level   | No GND network Diode         | 2   |     |     | V                |
| $V_{IHYS\_EN}$                                         | Input voltage hysteresis   | No GND network Diode         |     | 250 |     | mV               |
| $I_{IL\_EN}$                                           | Input current low level    | $V_{EN} = 0.8\text{ V}$      |     | 0.8 |     | $\mu\text{A}$    |
| $I_{IH\_EN}$                                           | Input current high level   | $V_{EN} = 2.0\text{ V}$      |     | 2   |     | $\mu\text{A}$    |
| $R_{EN}$                                               | Internal pulldown resistor |                              |     | 1   |     | $\text{M}\Omega$ |
| <b>DIA_EN PIN CHARACTERISTICS<sup>(1)</sup></b>        |                            |                              |     |     |     |                  |
| $V_{IL\_DIA\_EN}$                                      | Input voltage low level    | No GND network Diode         |     |     | 0.8 | V                |
| $V_{IH\_DIA\_EN}$                                      | Input voltage high level   | No GND network Diode         | 2   |     |     | V                |
| $V_{IHYS\_DIA\_EN}$                                    | Input voltage hysteresis   |                              |     | 250 |     | mV               |
| $I_{IL\_DIA\_EN}$                                      | Input current low level    | $V_{DIA\_EN} = 0.8\text{ V}$ |     | 0.8 |     | $\mu\text{A}$    |
| $I_{IH\_DIA\_EN}$                                      | Input current high level   | $V_{DIA\_EN} = 2.0\text{ V}$ |     | 2   |     | $\mu\text{A}$    |
| $R_{DIA\_EN}$                                          | Internal pulldown resistor |                              |     | 1   |     | $\text{M}\Omega$ |
| <b>SEL1 AND SEL2 PIN CHARACTERISTICS<sup>(1)</sup></b> |                            |                              |     |     |     |                  |
| $V_{IL\_SELx}$                                         | Input voltage low level    | No GND network Diode         |     |     | 0.8 | V                |
| $V_{IH\_SELx}$                                         | Input voltage high level   |                              | 2   |     |     | V                |
| $V_{IHYS\_SELx}$                                       | Input voltage hysteresis   |                              |     | 250 |     | mV               |
| $I_{IL\_SELx}$                                         | Input current low level    | $V_{SELx} = 0.8\text{ V}$    |     | 0.8 |     | $\mu\text{A}$    |
| $I_{IH\_SELx}$                                         | Input current high level   | $V_{SELx} = 2.0\text{ V}$    |     | 2   |     | $\mu\text{A}$    |
| $R_{SELx}$                                             | Internal pulldown resistor |                              |     | 1   |     | $\text{M}\Omega$ |
| <b>LATCH PIN CHARACTERISTICS<sup>(1)</sup></b>         |                            |                              |     |     |     |                  |
| $V_{IL\_LATCH}$                                        | Input voltage low level    | No GND network Diode         |     |     | 0.8 | V                |
| $V_{IH\_LATCH}$                                        | Input voltage high level   | No GND network Diode         | 2   |     |     | V                |
| $V_{IHYS\_LATCH}$                                      | Input voltage hysteresis   |                              |     | 250 |     | mV               |
| $I_{IL\_LATCH}$                                        | Input current low level    | $V_{LATCH} = 0.8\text{ V}$   |     | 0.8 |     | $\mu\text{A}$    |
| $I_{IH\_LATCH}$                                        | Input current high level   | $V_{LATCH} = 2.0\text{ V}$   |     | 2   |     | $\mu\text{A}$    |
| $R_{LATCH}$                                            | Internal pulldown resistor |                              |     | 1   |     | $\text{M}\Omega$ |
| <b>ST PIN CHARACTERISTICS<sup>(1)</sup></b>            |                            |                              |     |     |     |                  |
| $V_{OL\_ST}$                                           | Output voltage low level   | $I_{ST} = 1\text{ mA}$       |     |     | 0.4 | V                |
| $I_{STleak}$                                           | Leakage current            | $V_{ST} = 5\text{ V}$        |     |     | 2   | $\mu\text{A}$    |

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

## 7.6 Switching Characteristics

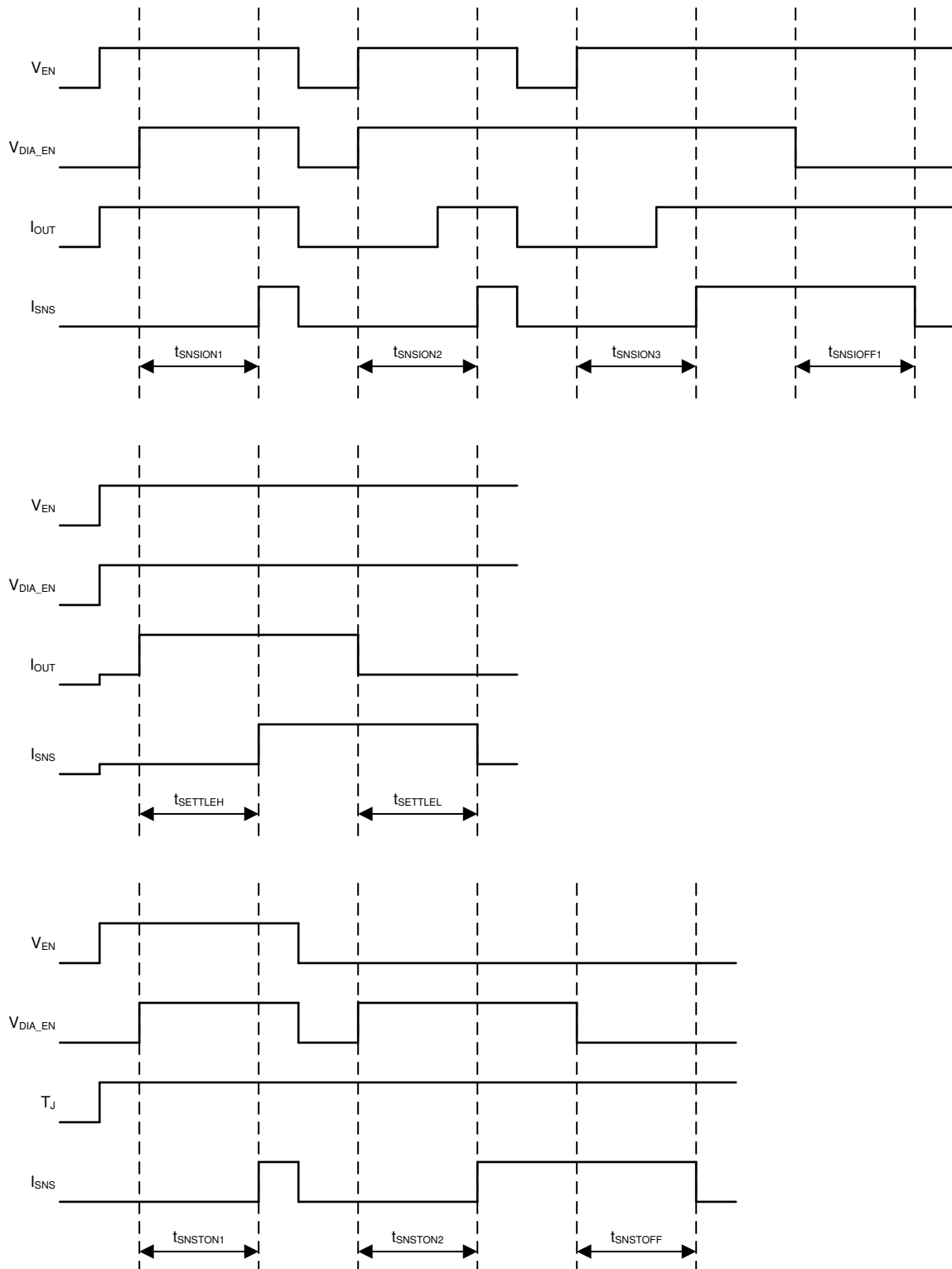
 $V_{BB} = 13.5\text{ V}$ ,  $T_J = -40^{\circ}\text{C to }150^{\circ}\text{C}$  (unless otherwise noted)

| PARAMETER          |                                         | TEST CONDITIONS                                                          | MIN | TYP  | MAX | UNIT             |
|--------------------|-----------------------------------------|--------------------------------------------------------------------------|-----|------|-----|------------------|
| $t_{DR}$           | Turn-on delay time                      | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           | 20  | 70   | 100 | $\mu\text{s}$    |
| $t_{DF}$           | Turn-off delay time                     | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           | 20  | 50   | 100 | $\mu\text{s}$    |
| $SR_R$             | VOUT rising slew rate                   | $V_{BB} = 13.5\text{ V}$ , 20% to 80% of $V_{OUT}$ , $R_L = 2.6\ \Omega$ | 0.1 | 0.35 | 0.7 | V/ $\mu\text{s}$ |
| $SR_F$             | VOUT falling slew rate                  | $V_{BB} = 13.5\text{ V}$ , 80% to 20% of $V_{OUT}$ , $R_L = 2.6\ \Omega$ | 0.1 | 0.5  | 0.7 | V/ $\mu\text{s}$ |
| $t_{ON}$           | Turn-on time                            | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           | 39  | 80   | 145 | $\mu\text{s}$    |
| $t_{OFF}$          | Turn-off time                           | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           | 39  | 75   | 145 | $\mu\text{s}$    |
| $t_{ON} - t_{OFF}$ | Turn-on and off matching                | 200- $\mu\text{s}$ enable pulse                                          | -50 | 0    | 50  | $\mu\text{s}$    |
| $E_{ON}$           | Switching energy losses during turn-on  | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           |     | 0.4  |     | mJ               |
| $E_{OFF}$          | Switching energy losses during turn-off | $V_{BB} = 13.5\text{ V}$ , $R_L = 2.6\ \Omega$                           |     | 0.4  |     | mJ               |

## 7.7 SNS Timing Characteristics

 $V_{BB} = 8 \text{ to } 18 \text{ V}$ ,  $T_J = -40^\circ\text{C to } 150^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                             |                                                       | TEST CONDITIONS                                                                                                                                                                                            | MIN | TYP | MAX | UNIT          |
|---------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|---------------|
| <b>SNS TIMING - CURRENT SENSE</b>     |                                                       |                                                                                                                                                                                                            |     |     |     |               |
| $t_{\text{SNSION1}}$                  | Settling time from rising edge of DIA_EN              | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$                                                            |     |     | 40  | $\mu\text{s}$ |
| $t_{\text{SNSION2}}$                  | Settling time from rising edge of EN                  | $V_{\text{EN}} = V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$                                                                            |     |     | 180 | $\mu\text{s}$ |
| $t_{\text{SNSION3}}$                  | Settling time from rising edge of EN                  | $V_{\text{EN}} = 0 \text{ V to } 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$                                                            |     |     | 180 | $\mu\text{s}$ |
| $t_{\text{SNSIOFF1}}$                 | Settling time from falling edge of DIA_EN             | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 5 \text{ V to } 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$                                                            |     |     | 20  | $\mu\text{s}$ |
| $t_{\text{SETTLEH}}$                  | Settling time from rising edge of load step           | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $I_{\text{OUT}} = 1 \text{ A to } 5 \text{ A}$                                                |     |     | 20  | $\mu\text{s}$ |
| $t_{\text{SETTLEL}}$                  | Settling time from falling edge of load step          | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $I_{\text{OUT}} = 5 \text{ A to } 1 \text{ A}$                                                |     |     | 20  | $\mu\text{s}$ |
| <b>SNS TIMING - TEMPERATURE SENSE</b> |                                                       |                                                                                                                                                                                                            |     |     |     |               |
| $t_{\text{SNSION1}}$                  | Settling time from rising edge of DIA_EN              | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                 |     |     | 40  | $\mu\text{s}$ |
| $t_{\text{SNSION2}}$                  | Settling time from rising edge of DIA_EN              | $V_{\text{EN}} = 0 \text{ V}$ , $V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                 |     |     | 70  | $\mu\text{s}$ |
| $t_{\text{SNSIOFF}}$                  | Settling time from falling edge of DIA_EN             | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V to } 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                           |     |     | 20  | $\mu\text{s}$ |
| <b>SNS TIMING - VOLTAGE SENSE</b>     |                                                       |                                                                                                                                                                                                            |     |     |     |               |
| $t_{\text{SNSVON1}}$                  | Settling time from rising edge of DIA_EN              | $V_{\text{EN}} = 5 \text{ V}$ , $V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                 |     |     | 40  | $\mu\text{s}$ |
| $t_{\text{SNSVON2}}$                  | Settling time from rising edge of DIA_EN              | $V_{\text{EN}} = 0 \text{ V}$ , $V_{\text{DIA\_EN}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                 |     |     | 70  | $\mu\text{s}$ |
| $t_{\text{SNSVOFF}}$                  | Settling time from falling edge of DIA_EN             | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V to } 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                                                                                           |     |     | 20  | $\mu\text{s}$ |
| <b>SNS TIMING - MULTIPLEXER</b>       |                                                       |                                                                                                                                                                                                            |     |     |     |               |
| $t_{\text{MUX}}$                      | Settling time from temperature sense to current sense | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = 5 \text{ V to } 0 \text{ V}$ , $V_{\text{SEL2}} = 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$ |     |     | 60  | $\mu\text{s}$ |
|                                       | Settling time from temperature sense to voltage sense | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = 5 \text{ V}$ , $V_{\text{SEL2}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                      |     |     | 60  | $\mu\text{s}$ |
|                                       | Settling time from voltage sense to temperature sense | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = 5 \text{ V}$ , $V_{\text{SEL2}} = 5 \text{ V to } 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$                      |     |     | 60  | $\mu\text{s}$ |
|                                       | Settling time from voltage sense to current sense     | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = V_{\text{SEL2}} = 5 \text{ V to } 0 \text{ V}$ ,<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$               |     |     | 60  | $\mu\text{s}$ |
|                                       | Settling time from current sense to temperature sense | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = 0 \text{ V to } 5 \text{ V}$ , $V_{\text{SEL2}} = 0 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$ |     |     | 60  | $\mu\text{s}$ |
|                                       | Settling time from current sense to voltage sense     | $V_{\text{EN}} = X$ , $V_{\text{DIA\_EN}} = 5 \text{ V}$<br>$V_{\text{SEL1}} = V_{\text{SEL2}} = 0 \text{ V to } 5 \text{ V}$<br>$R_{\text{SNS}} = 1 \text{ k}\Omega$ , $R_L = 2.6 \Omega$                 |     |     | 60  | $\mu\text{s}$ |

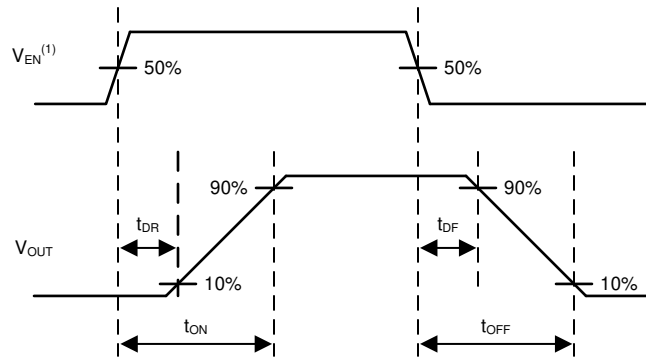


NOTES: Rise and fall times of control signals are 100 ns. Control signals include: EN, DIA\_EN, SEL1, SEL2.

SEL1 and SEL2 must be set to the appropriate values.

The temperature sense timing diagram can also be used to depict the voltage sense timings.

### 1. SNS Timing Characteristics Definitions



Rise and fall time of  $V_{EN}$  is 100 ns.

图 2. Switching Characteristics Definitions

## 7.8 Typical Characteristics

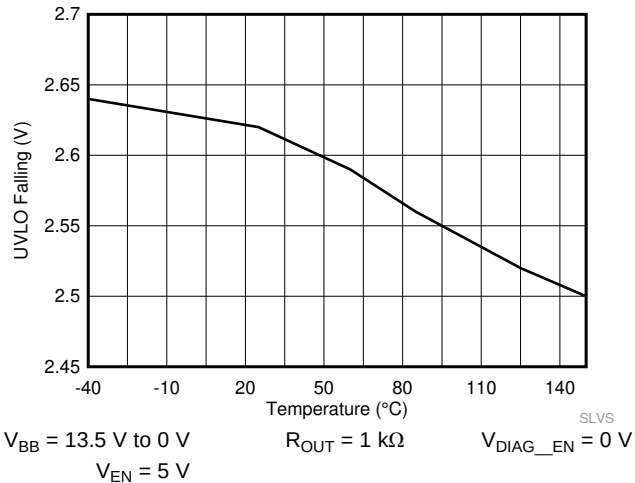


图 3. Falling Undervoltage Lockout ( $V_{UVLOF}$ ) vs Temperature

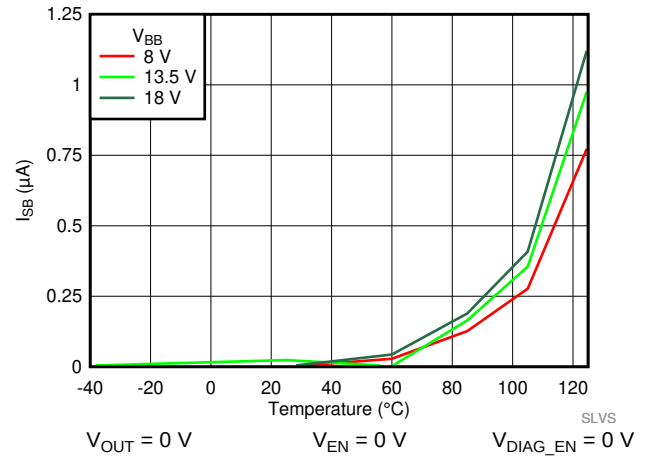


图 4. Standby Current ( $I_{SB}$ ) vs Temperature

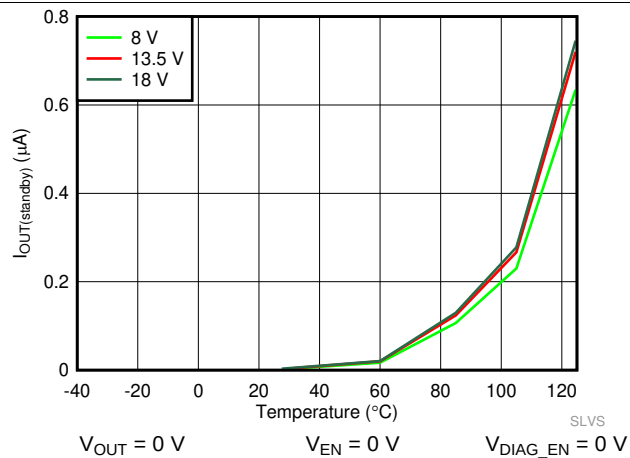


图 5. Output Leakage Current ( $I_{OUT(standby)}$ ) vs Temperature

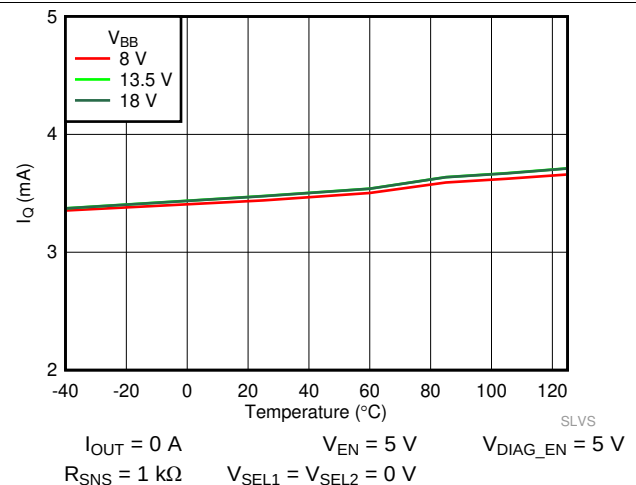


图 6. Quiescent Current ( $I_Q$ ) vs Temperature

## Typical Characteristics (continued)

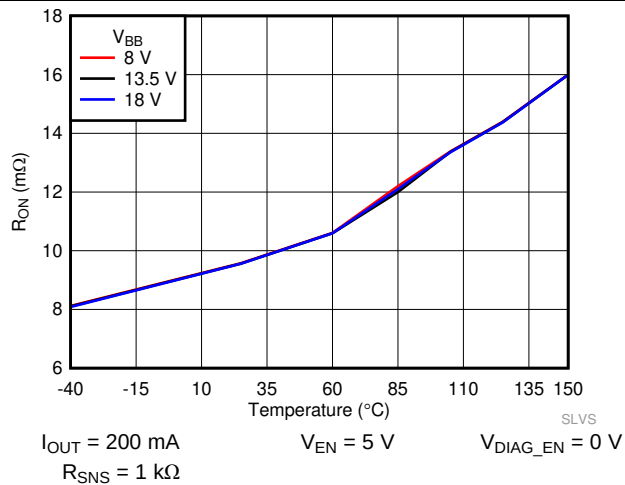


Figure 7. On Resistance ( $R_{ON}$ ) vs Temperature

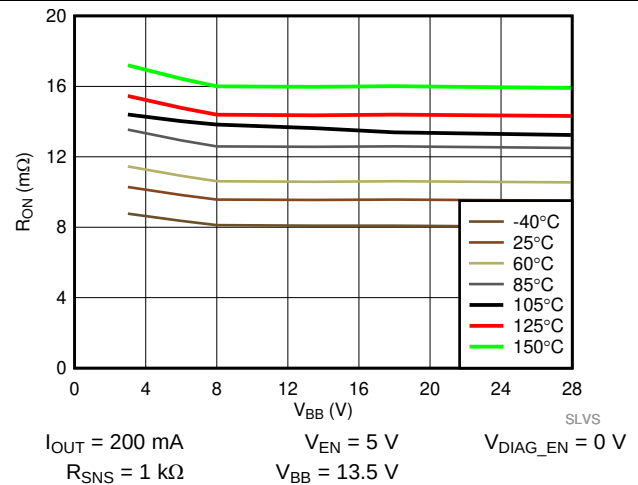


Figure 8. On Resistance ( $R_{ON}$ ) vs  $V_{BB}$

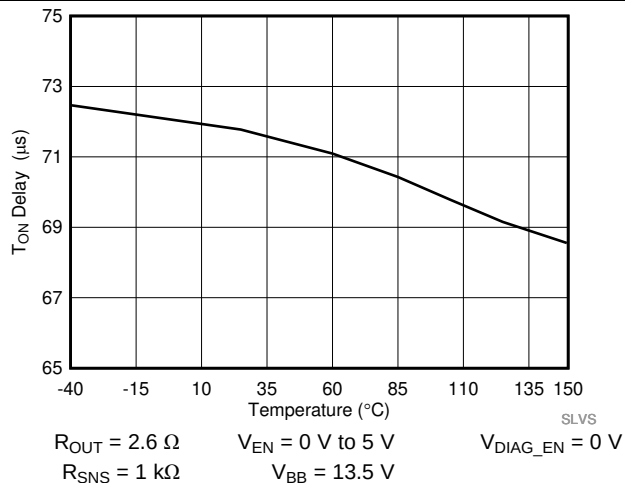


Figure 9. Turn-on Delay Time ( $t_{DR}$ ) vs Temperature

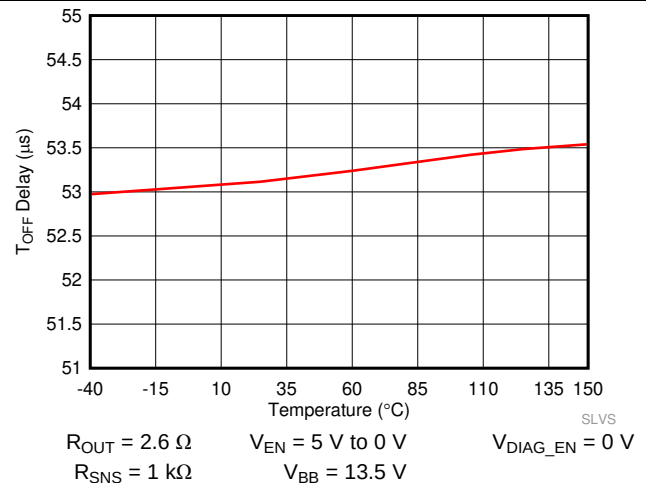


Figure 10. Turn-off Delay Time ( $t_{DF}$ ) vs Temperature

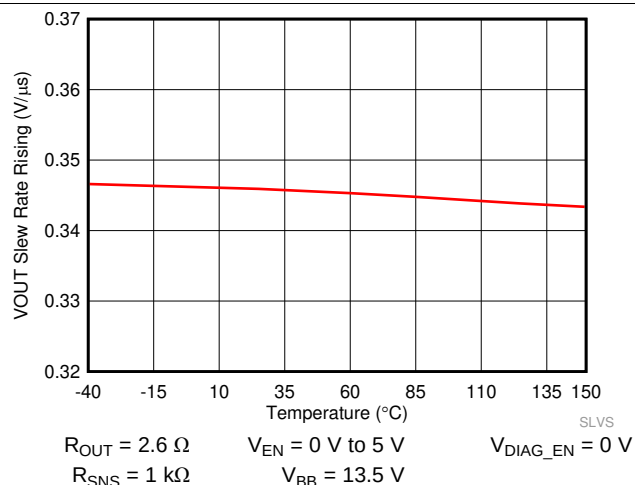


Figure 11.  $V_{OUT}$  Slew Rate Rising ( $SR_R$ ) vs Temperature

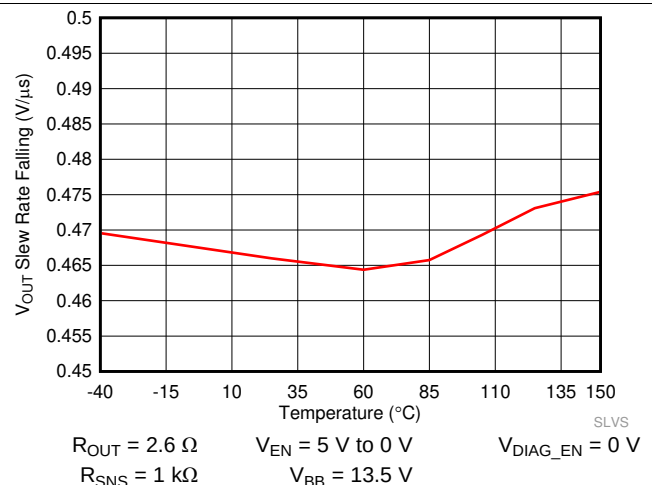


Figure 12.  $V_{OUT}$  Slew Rate Falling ( $SR_F$ ) vs Temperature

## Typical Characteristics (continued)

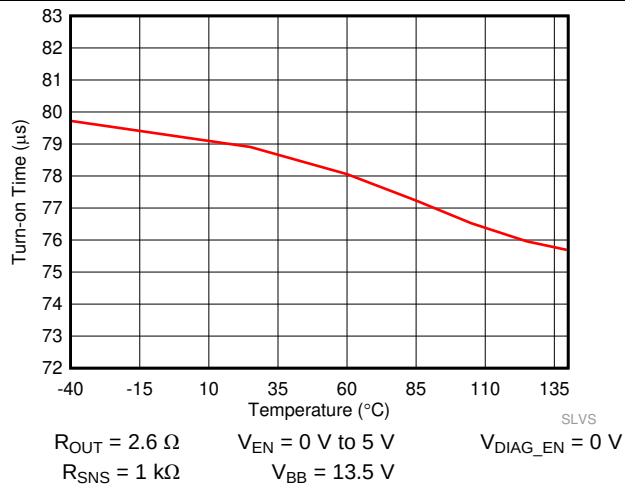


FIG 13. Turn-on Time ( $t_{\text{ON}}$ ) vs Temperature

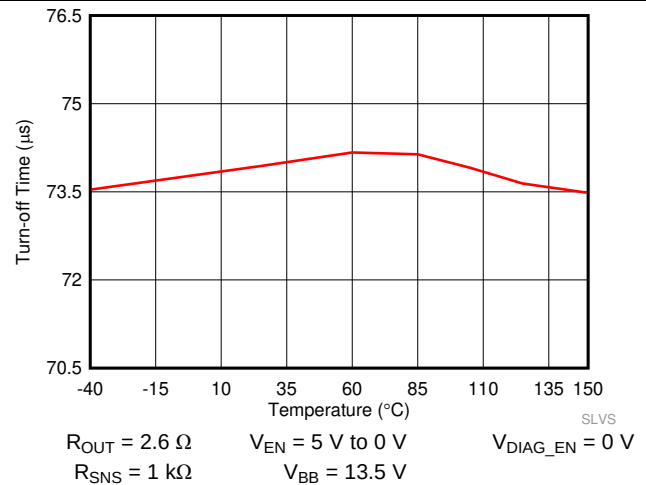


FIG 14. Turn-off Time ( $t_{\text{OFF}}$ ) vs Temperature

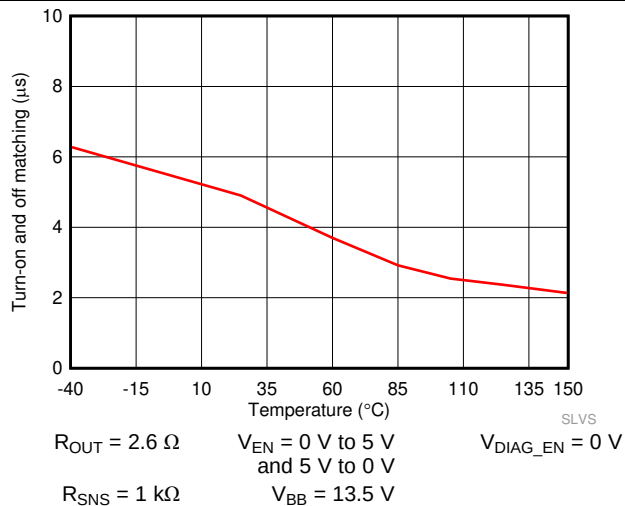


FIG 15. Turn-on and Turn-off Matching ( $t_{\text{ON}} - t_{\text{OFF}}$ ) vs Temperature

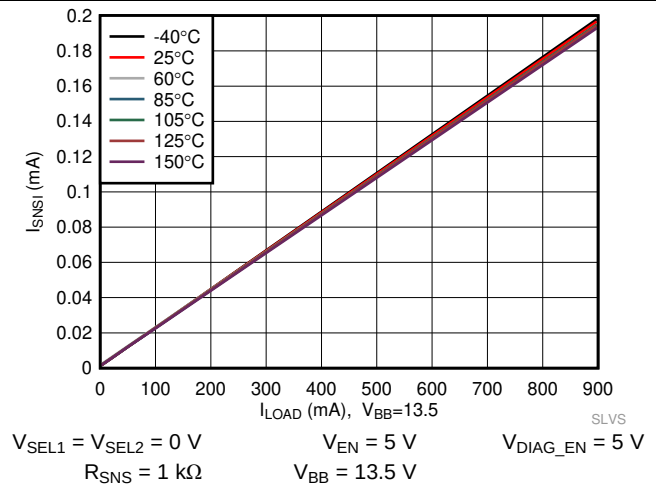


FIG 16. Current Sense Output Current ( $I_{\text{SNSI}}$ ) vs Load Current ( $I_{\text{OUT}}$ ) across Temperature

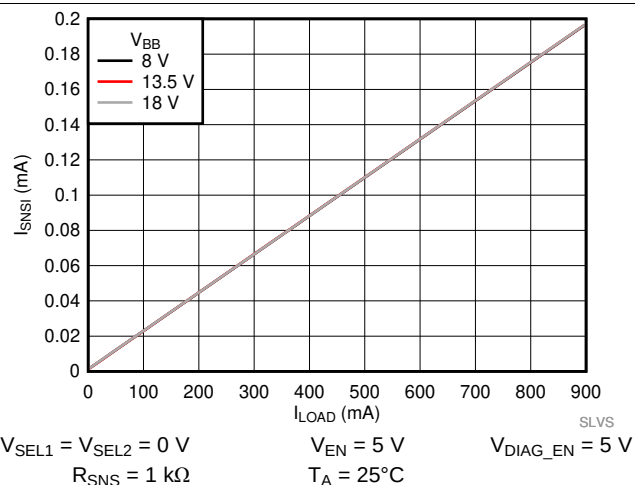


FIG 17. Current Sense Output Current ( $I_{\text{SNSI}}$ ) vs Load Current ( $I_{\text{OUT}}$ ) across  $V_{\text{BB}}$

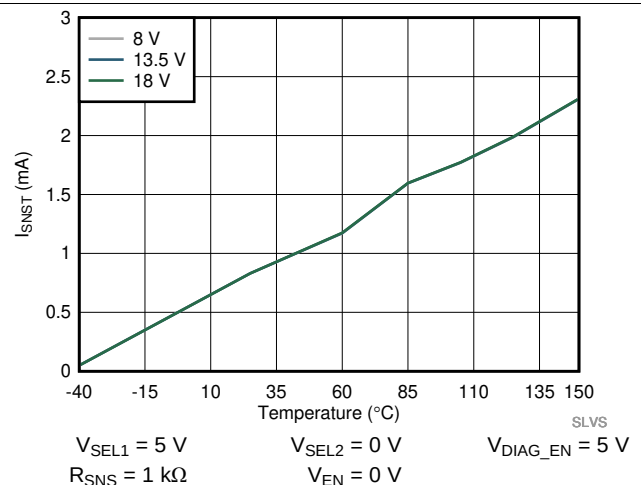
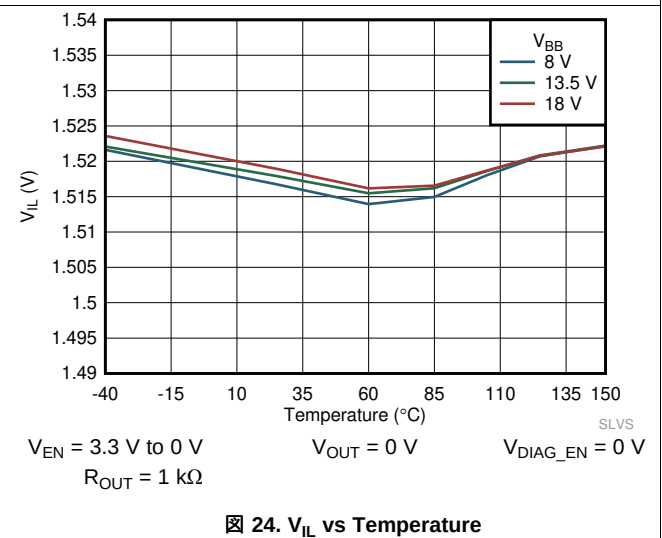
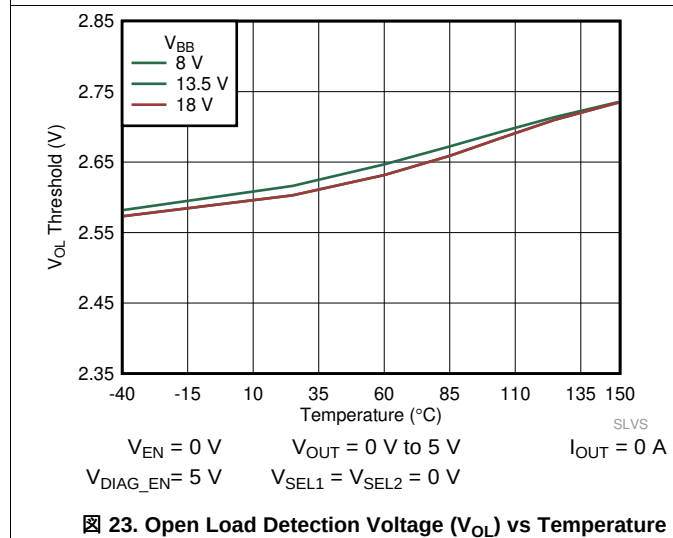
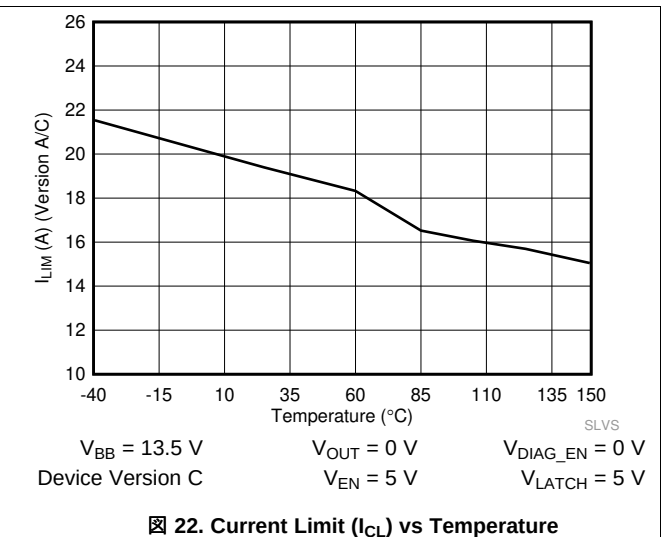
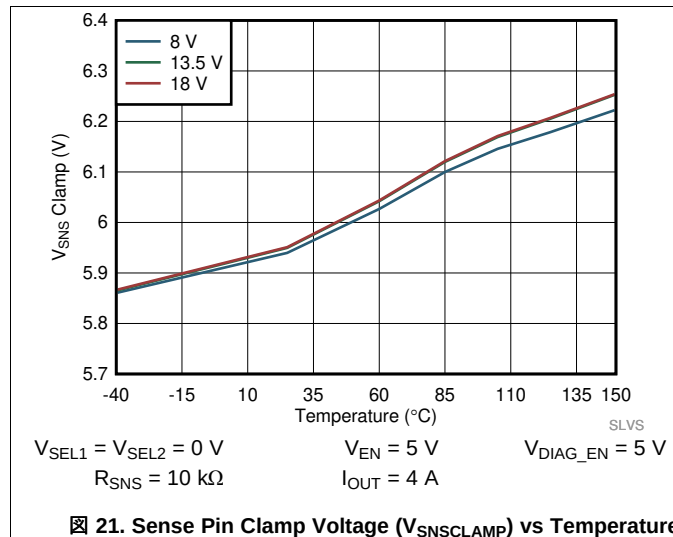
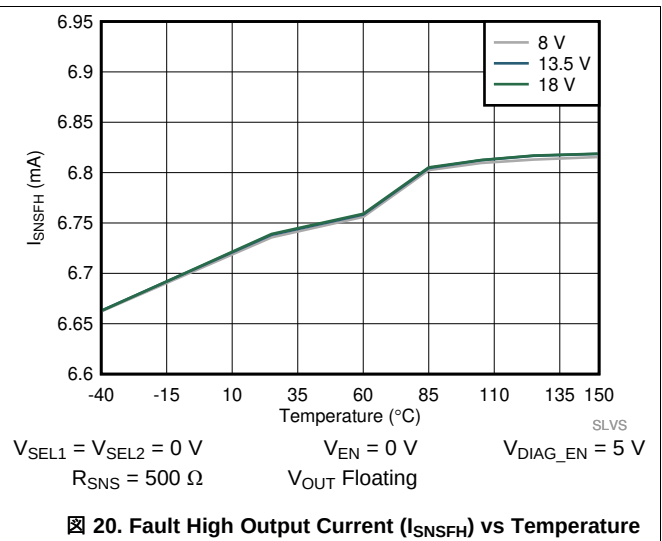
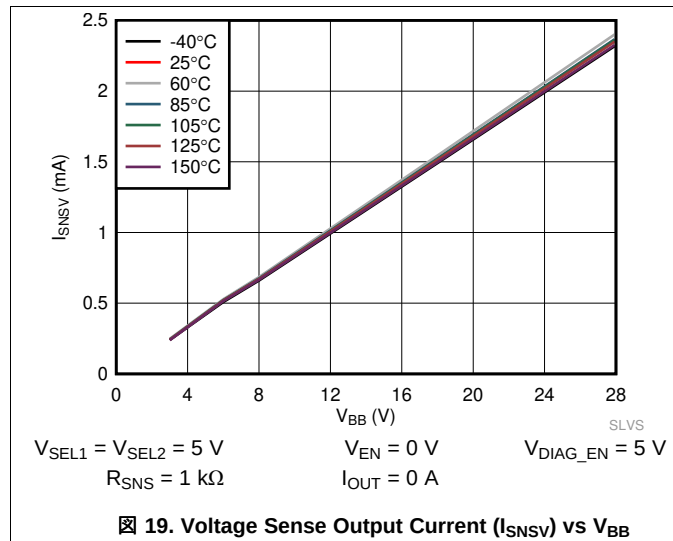
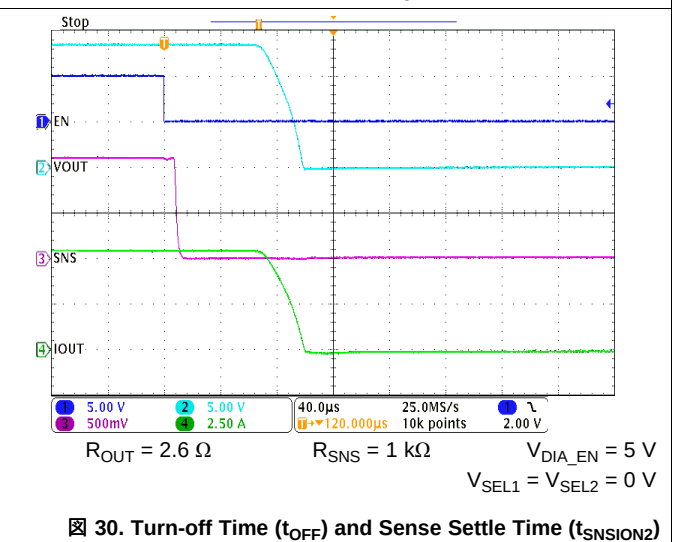
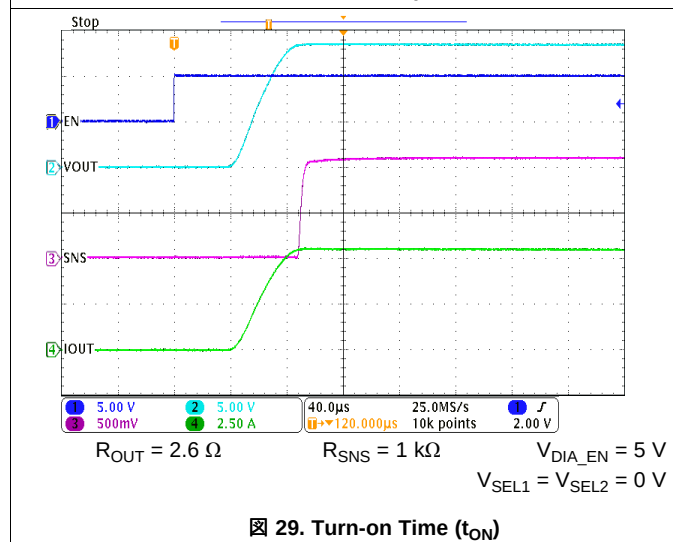
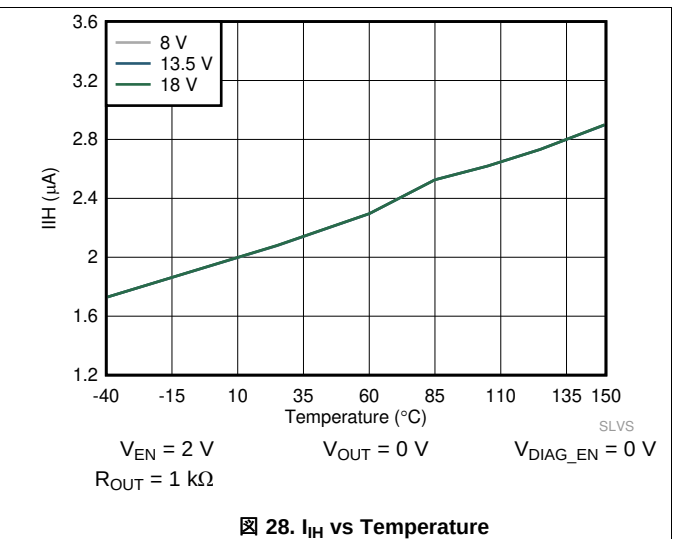
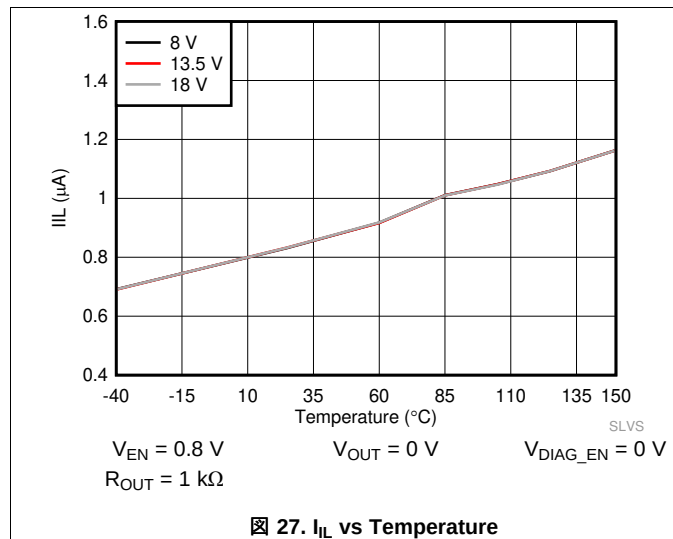
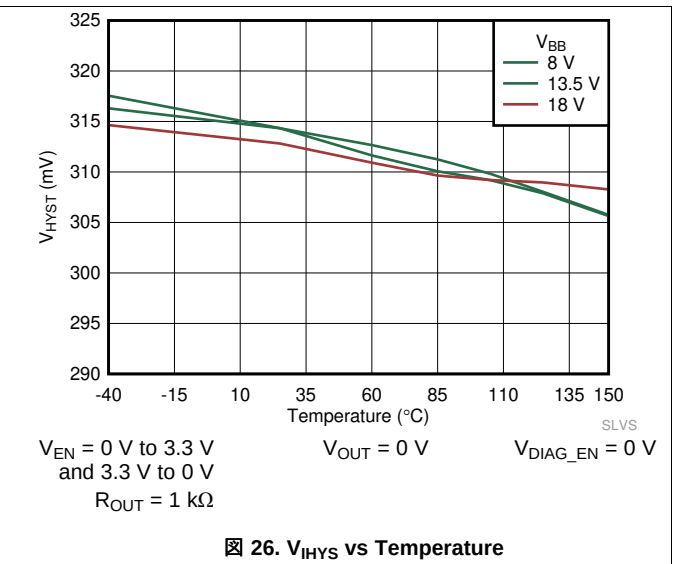
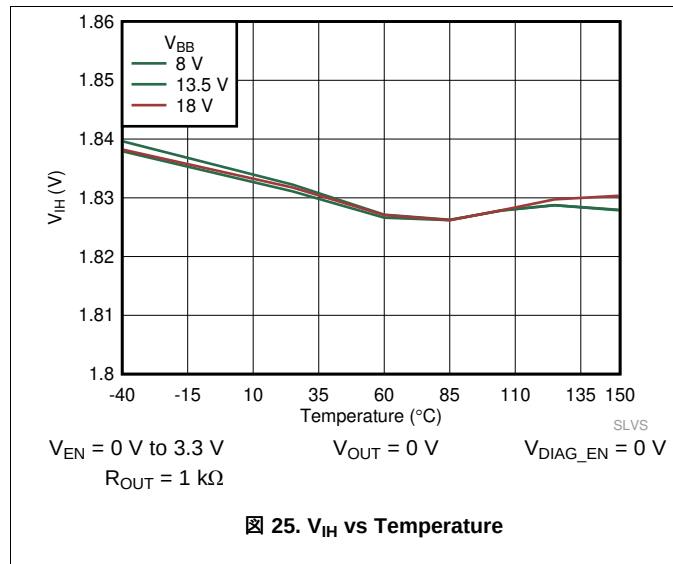


FIG 18. Temperature Sense Output Current ( $I_{\text{SNST}}$ ) vs Temperature

## Typical Characteristics (continued)

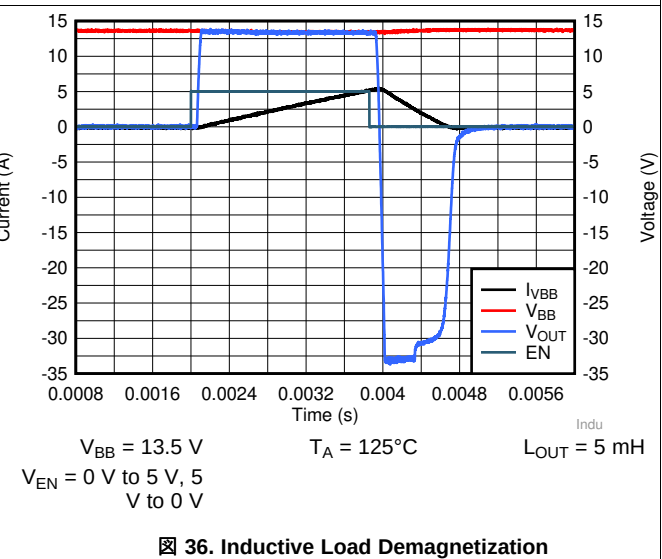
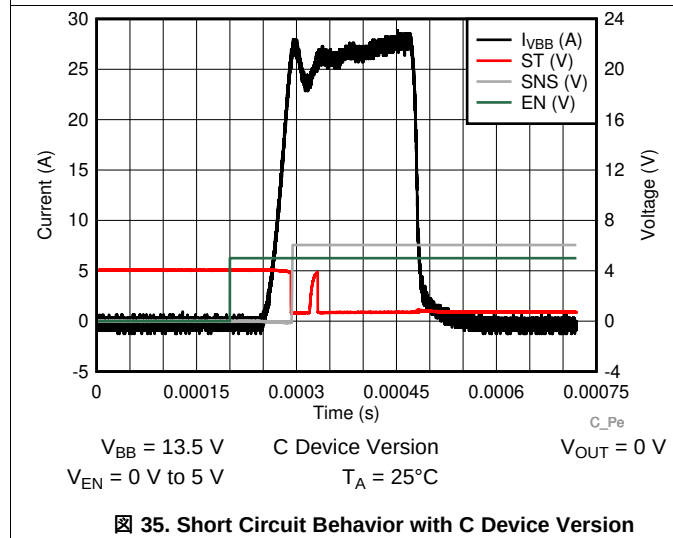
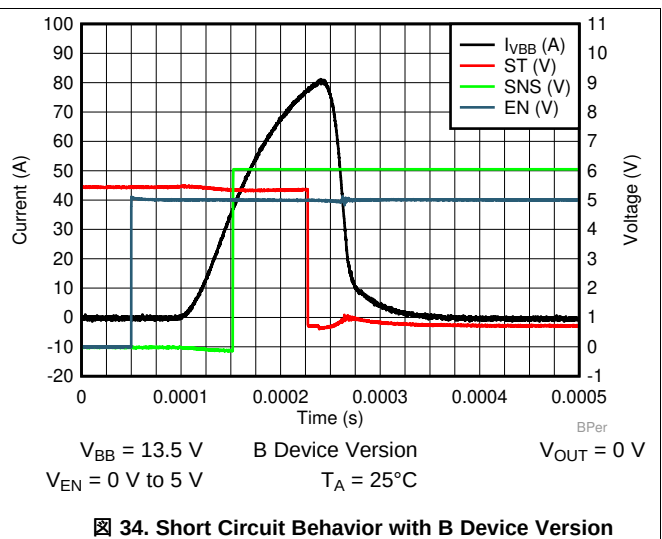
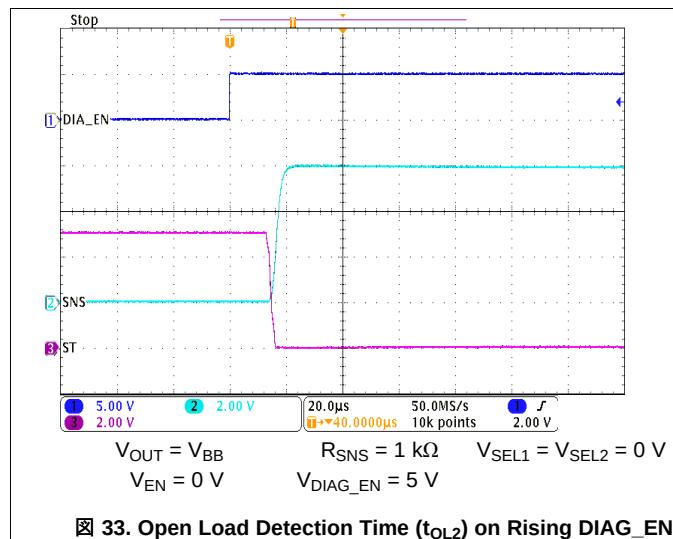
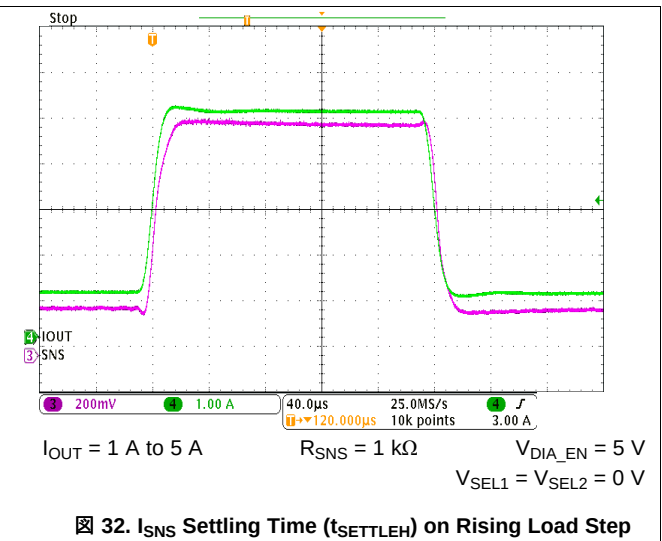
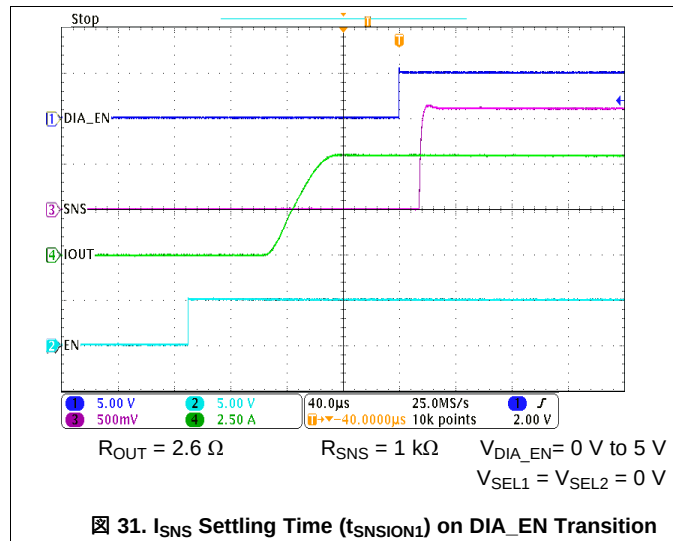


## Typical Characteristics (continued)

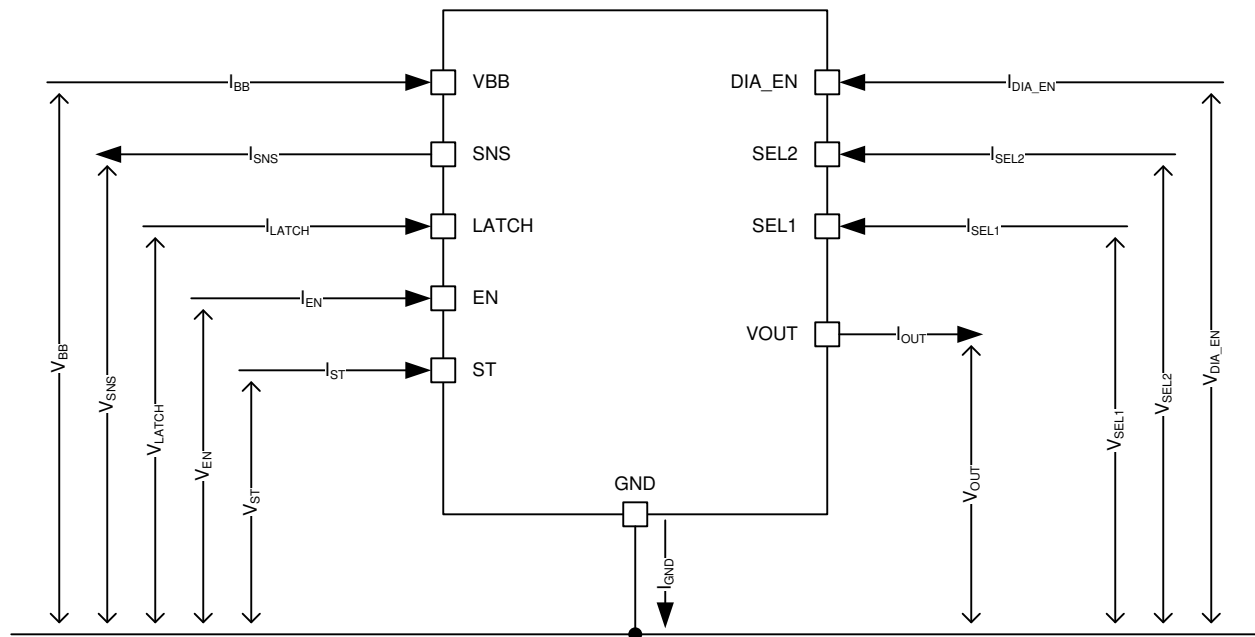




## Typical Characteristics (continued)



## 8 Parameter Measurement Information



✎ 37. Parameter Definitions

## 9 Detailed Description

### 9.1 Overview

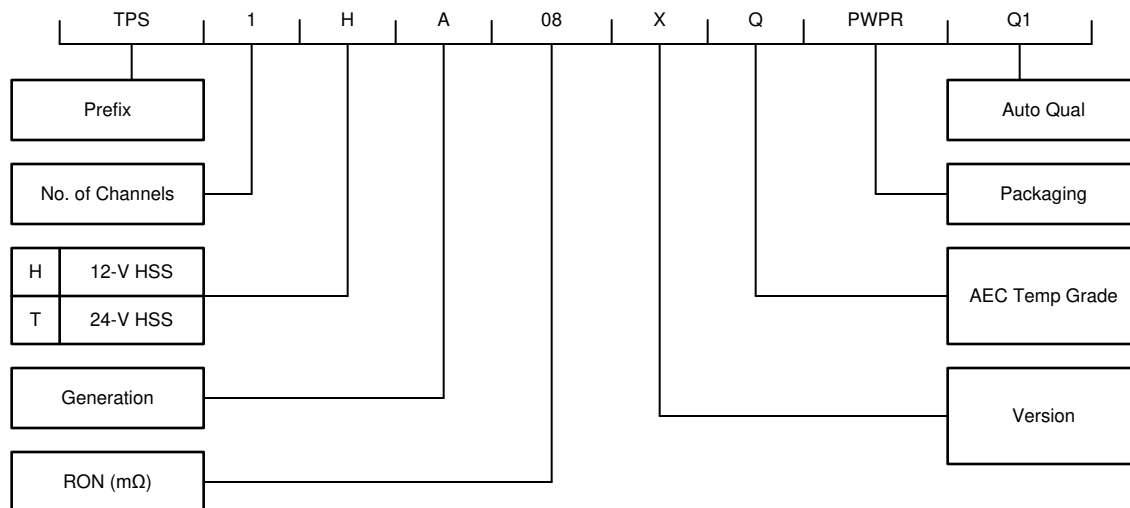
The device is a single-channel smart high-side power switch intended for use with 12 V automotive batteries. Many protection and diagnostic features are integrated in the device.

Diagnostics features include the analog SNS output and the open-drain fault indication ( $\overline{ST}$ ). 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 battery operation. For more details on the protection features, refer to the [Feature Description](#) and [Application Information](#) sections of the document.

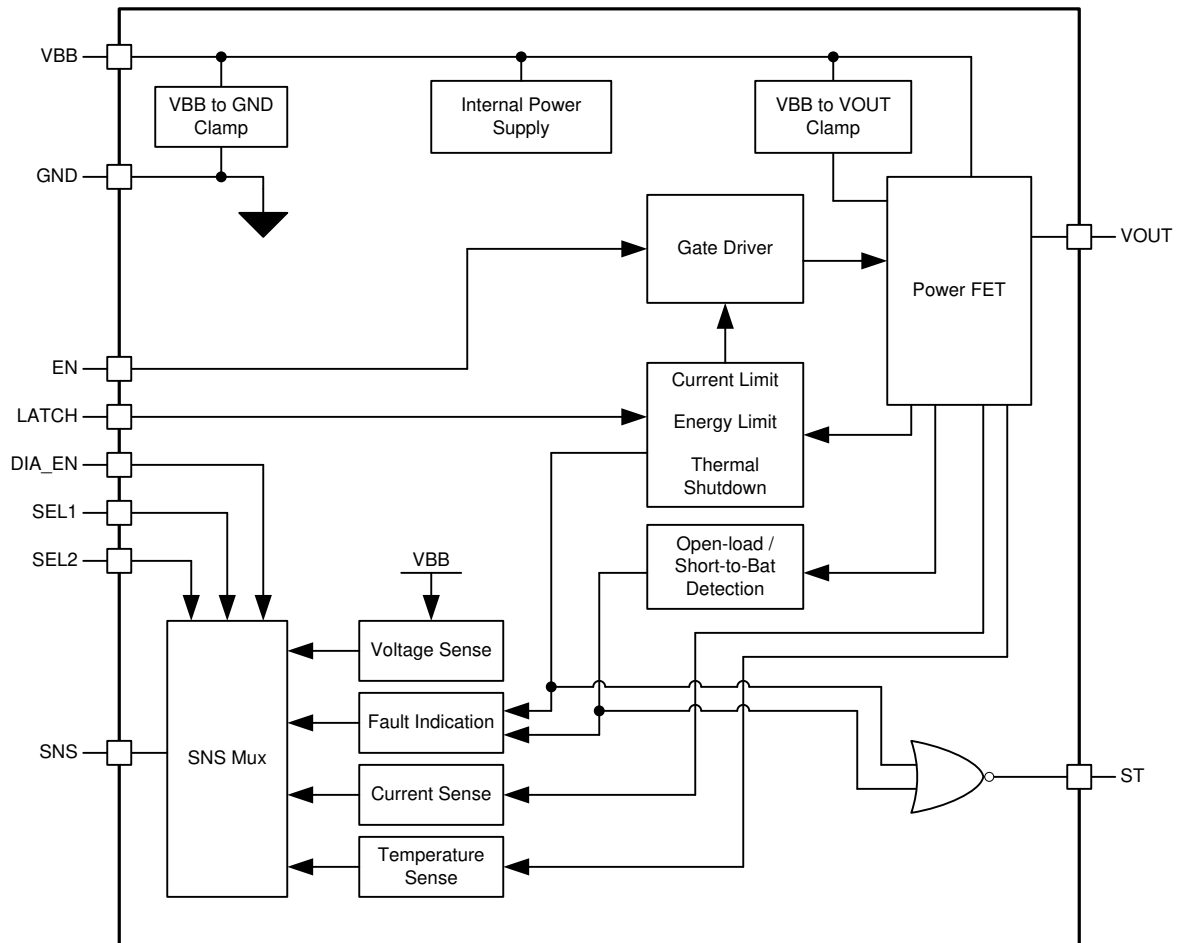
#### 9.1.1 Device Nomenclature

There is one device in the TI family of Smart High Side Switches. [Figure 38](#) shows the family part number nomenclature and explains how to determine device characteristics from the part number for TI Smart High Side Switches.



**Figure 38. Naming Convention**

## 9.2 Functional Block Diagram



## 9.3 Feature Description

### 9.3.1 Protection Mechanisms

The is designed to operate in the automotive environment. The protection mechanisms allow the device to be robust against many system-level events such as load dump, reverse battery, short-to-ground and more.

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

- Thermal Shutdown
- Current Limit (Versions A,B,E)
- 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 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
- $t_{RETRY}$  has expired
- All faults are cleared (thermal shutdown, current limit, energy limit)

#### 9.3.1.1 Thermal Shutdown

The 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 can switch off immediately (Versions A,B,E), or the device can remain enabled and limit  $I_{OUT}$  (Versions C/D) to  $I_{CL}$  (see [Device Comparison Table](#) section for more details). 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](#) (for the given device version) and then turn the output off or regulate the output current to protect the device. The device will register 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 deglitch filter and turn-off time. 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 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 Selectable Current Limit Threshold

The offers two current limit thresholds. The high threshold is designed to allow for a large transient load current (for example, inrush current of a 65-W bulb). The low threshold is designed to provide improved system-level protection for loads that do not have large transient currents (for example, heating element). The lower threshold can allow for reduced size/cost in the current carrying components such as PCB traces and module connectors. Version A (20 A current limit) is ideal for charging capacitors, as it will enable the device to prevent inrush current and clamp the overcurrent to linearly charge the capacitor.

## Feature Description (continued)

### 9.3.1.2.3 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.

### 9.3.1.2.4 $V_{BB}$ during Short-to-Ground

When  $V_{OUT}$  is shorted to ground, the module power supply ( $V_{BB}$ ) 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  $V_{BB} > 3$  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

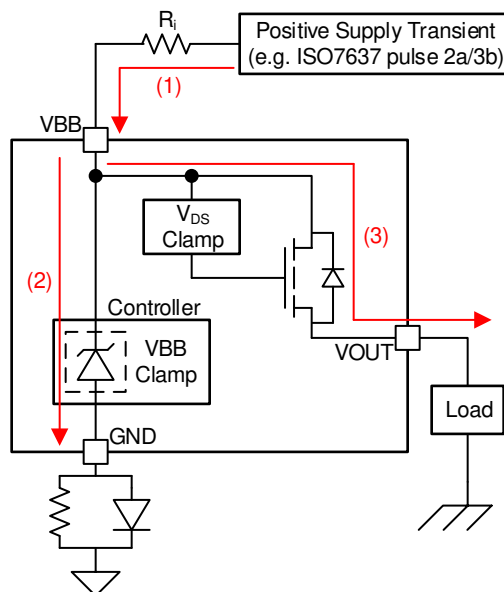
The energy limiting feature is implemented to protect the switch from excessive stress. The device will continuously monitor the amount of energy dissipated in the FET. If the energy limit threshold is reached, the switch will automatically disable. In practice, the energy limit will only be reached 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 contains two voltage clamps which protect the device against system-level voltage transients.

The clamp from  $V_{BB}$  to GND is primarily used to protect the controller from positive transients on the supply line (for example, ISO7637-2). The clamp from  $V_{BB}$  to  $V_{OUT}$  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  $V_{BB}$  to GND exceeds the  $V_{BB}$  clamp level, the clamp will allow current to flow through the device from  $V_{BB}$  to GND (Path 2). If the voltage potential from  $V_{BB}$  to  $V_{OUT}$  exceeds  $V_{CLAMP}$ , the power FET will allow current to flow from  $V_{BB}$  to  $V_{OUT}$  (Path 3).



✎ 39. Current Path During Supply Voltage Transient

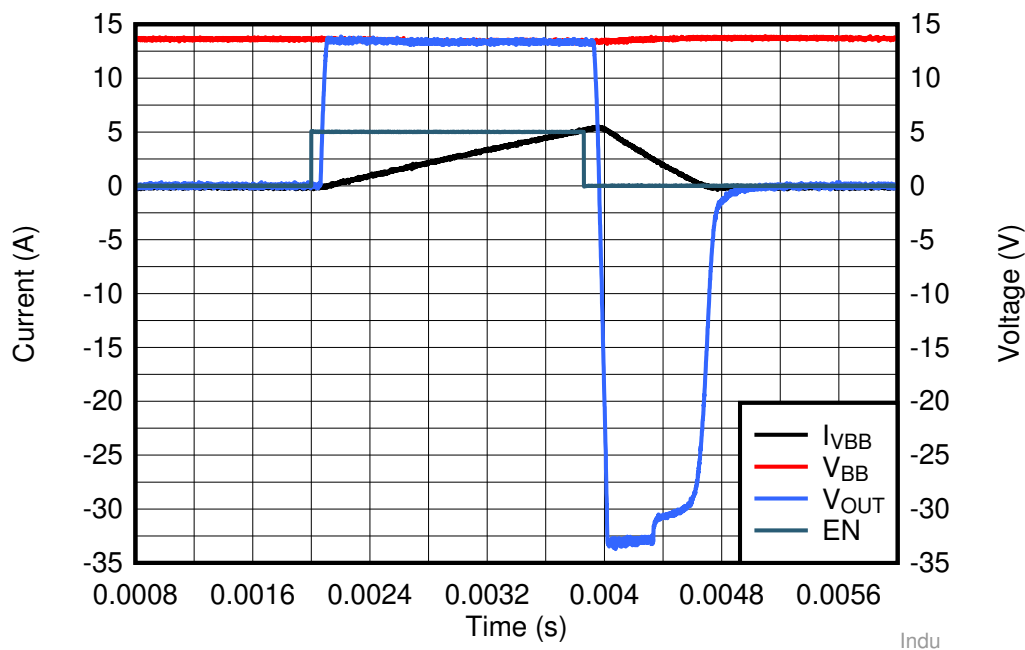
## Feature Description (continued)

### 9.3.1.4.1 Load Dump

The is tested according to ISO 16750-2:2010(E) suppressed load dump pulse. The device supports up to 40 V load dump transient. The switch will maintain normal operation during the load dump pulse. If the switch is enabled, it will stay enabled. If the switch is disabled, it will stay disabled.

### 9.3.1.4.2 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 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 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. [Figure 40](#) shows the discharging a 5 mH load that is driven at 5 A.



**Figure 40. Inductive Discharge (5 mH, 5 A)**

In addition, the 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 the low current limit device options the capacitive load can be safely charged.

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 Battery

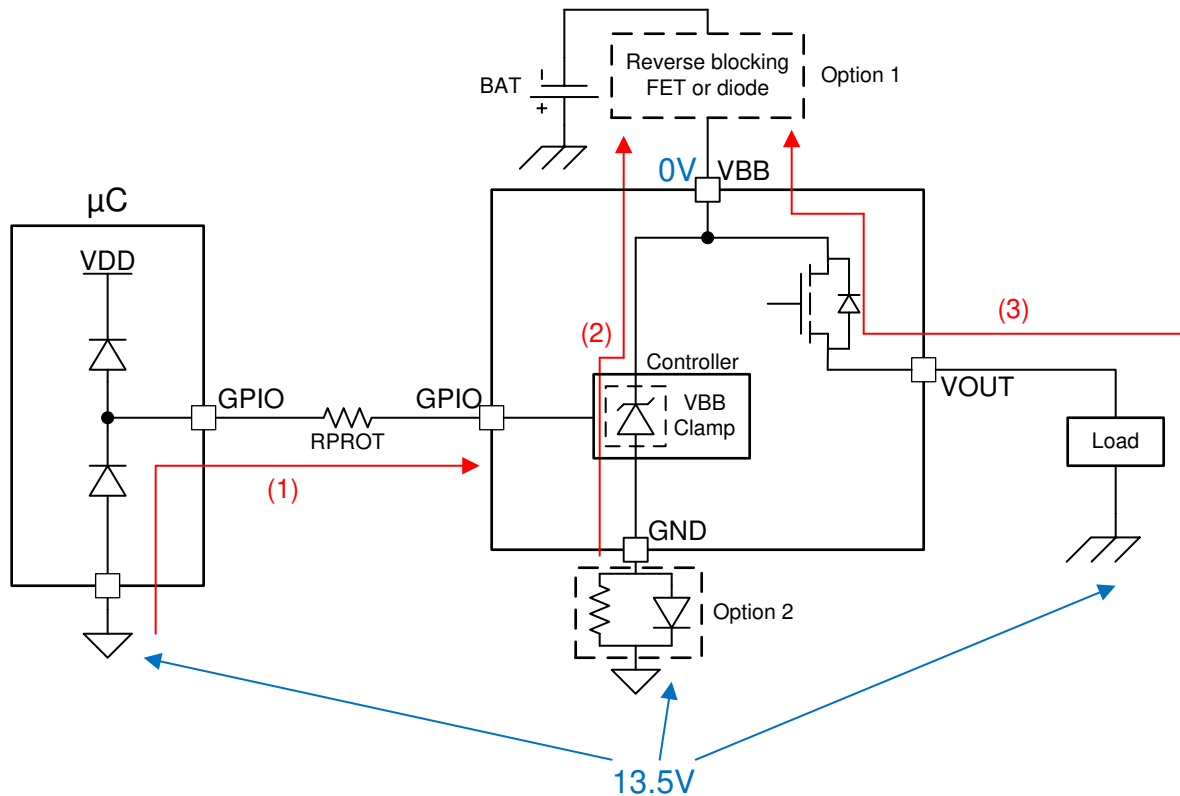
In the reverse battery condition, the switch will automatically be enabled (regardless of EN status) to prevent power dissipation inside the MOSFET body diode. In many applications (for example, resistive load), the full load current may be present during reverse battery. In order to activate the automatic 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 battery. Care must be taken to ensure that excessive power is not dissipated in the switch during the reverse battery condition.

## Feature Description (continued)

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 battery 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 [Figure 41](#) is blocked inside of the device.



**Figure 41. Current Path During Reverse Battery**

### 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.

[Figure 42](#) shows the immediate current limit switch off behavior of Versions A,B,E. The diagram also illustrates the retry behavior. As shown, the switch will remain latched off until the LATCH pin is low.



## Feature Description (continued)

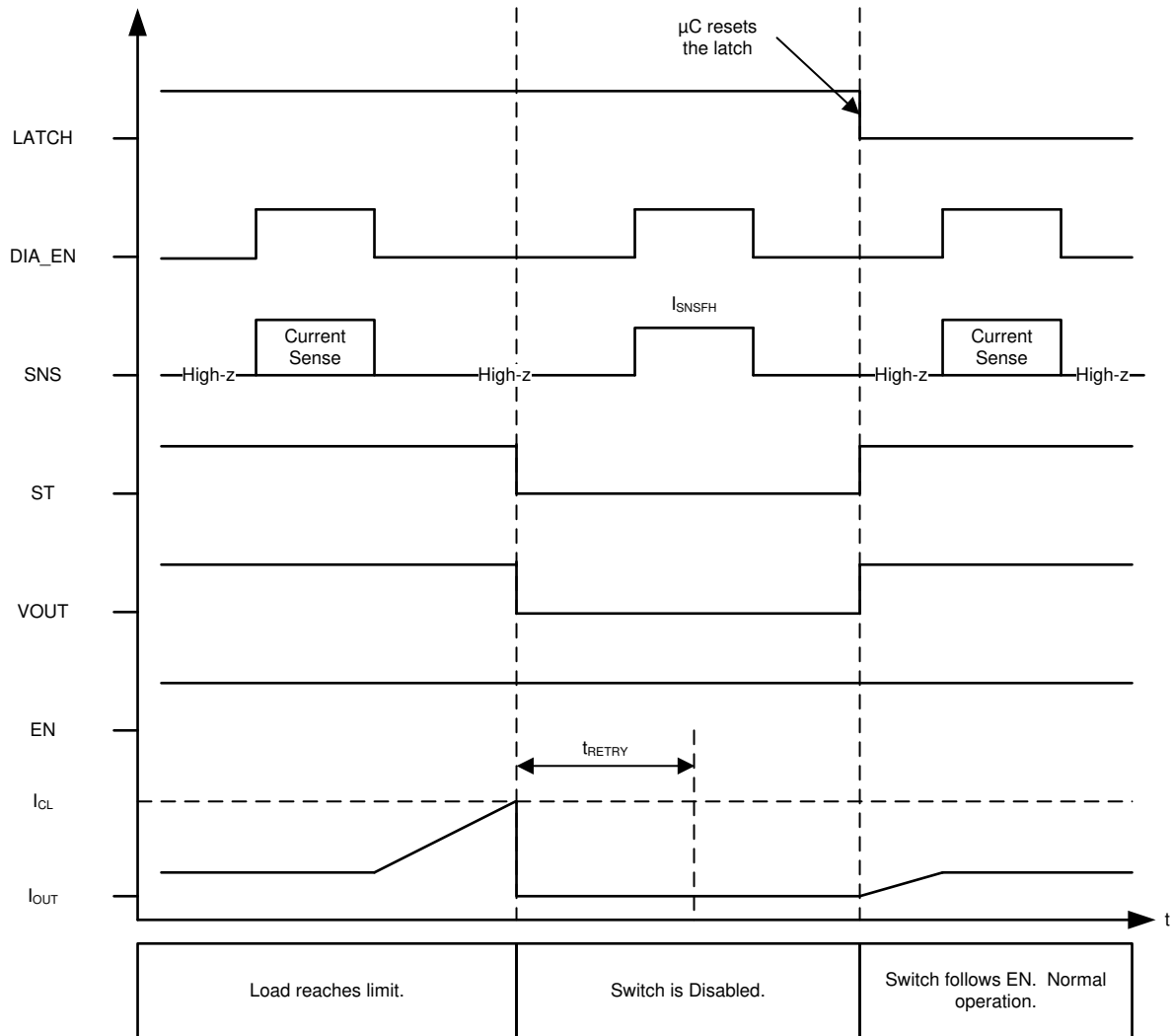
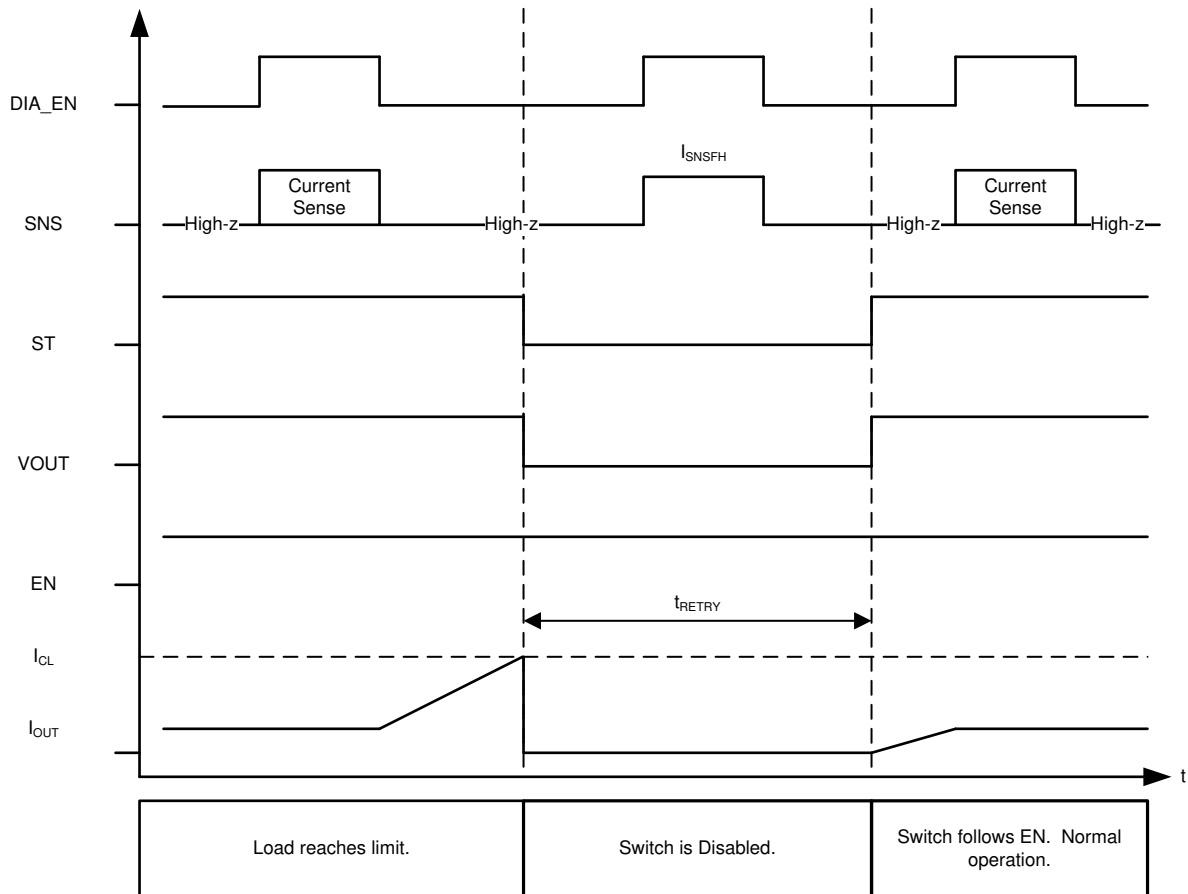


FIG 42. Current Limit – Version A,B,E - Latched Behavior

FIG 43 shows the immediate current limit switch off behavior of versions A,B,E. In this example, LATCH is tied to GND; hence, the switch will retry after the fault is cleared and  $t_{\text{RETRY}}$  has expired.

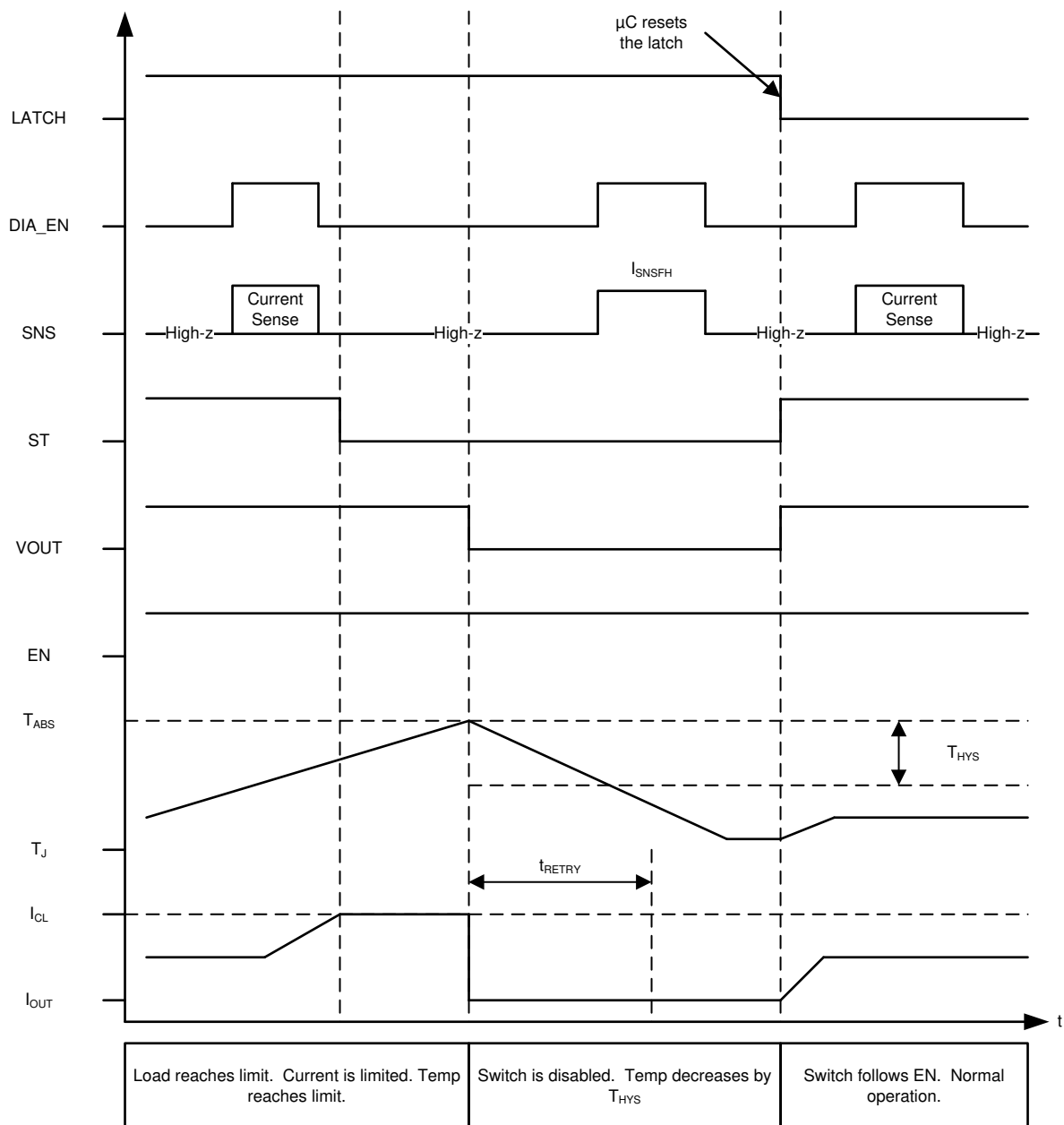
## Feature Description (continued)



**Figure 43. Current Limit – Version A,B,E - LATCH = 0**

Figure 44 shows the active current limiting behavior of versions C,D. In versions C,D, the switch will not shutdown until either the energy limit or the thermal shutdown is reached.

## Feature Description (continued)



ⓧ 44. Current Limit – Version C,D - Latched Behavior

ⓧ 45 shows the active current limiting behavior of versions C,D. The switch will not shutdown until either thermal shutdown or energy limit is tripped. In this example, LATCH is tied to GND.

## Feature Description (continued)

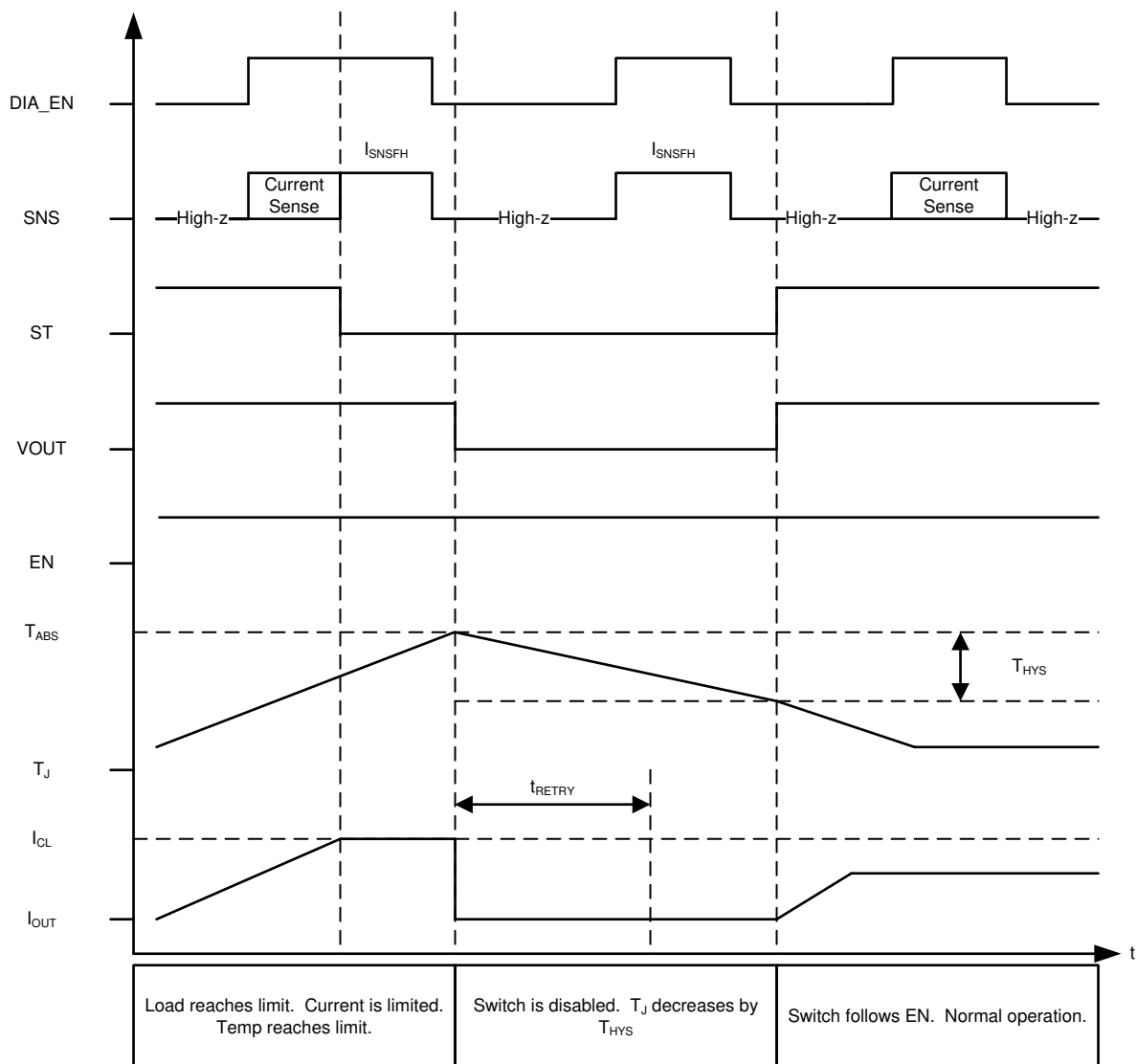


图 45. Current Limit – Version C,D - LATCH = 0

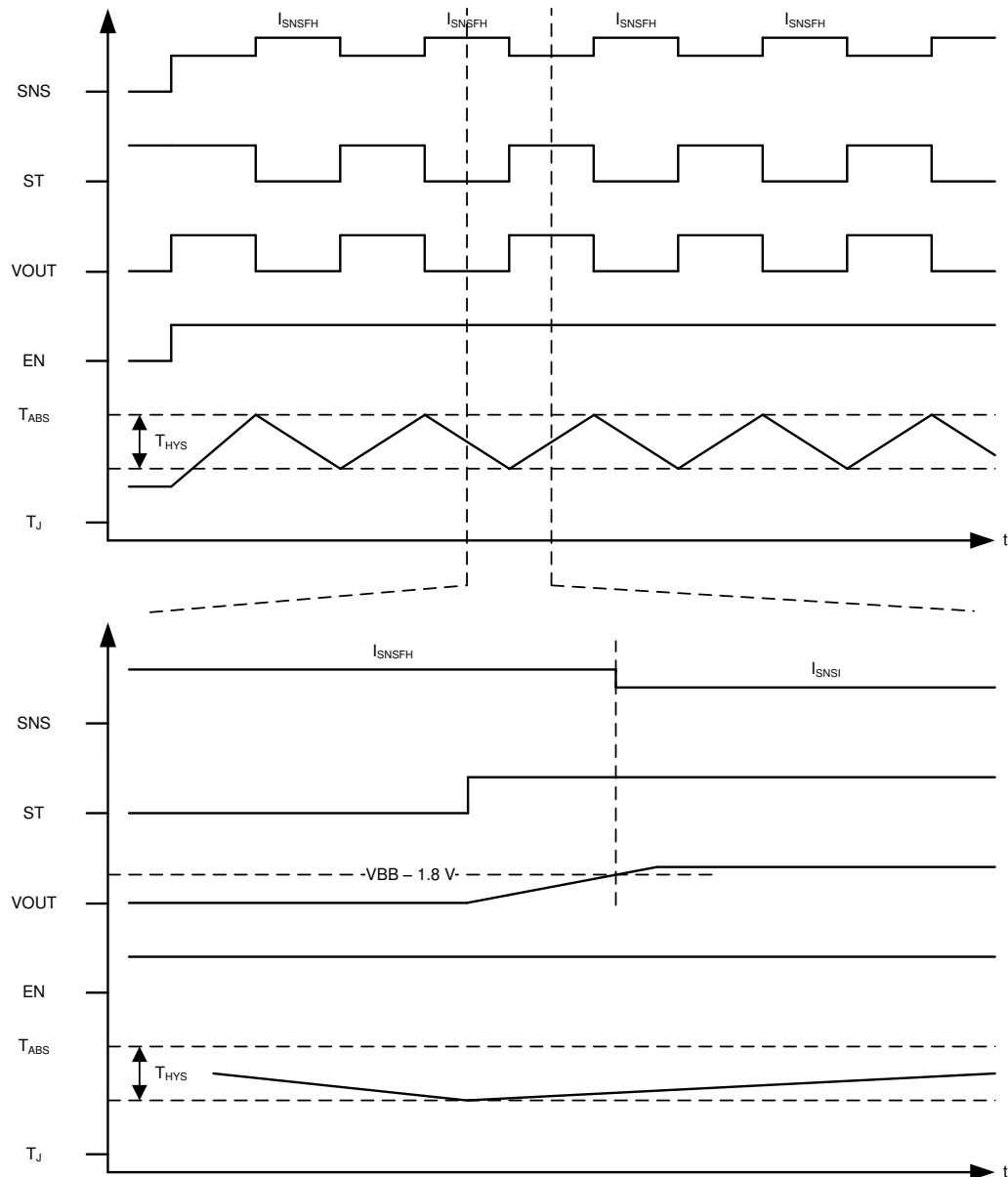
When the switch retries after a shutdown event, the SNS fault indication will remain until  $V_{OUT}$  has risen to  $V_{BB} - 1.8$  V. Once  $V_{OUT}$  has risen, the SNS fault indication is reset and current sensing is available. ST fault indication is reset as soon as the switch is re-enabled (does not wait for  $V_{OUT}$  to rise). If there is a short-to-ground 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

图 46 assumes that  $t_{RETRY}$  has expired by the time that  $T_J$  reaches the hysteresis threshold.

LATCH = 0 V and DIA\_EN = 5 V

## Feature Description (continued)



⊗ 46. Fault Indication During Retry

## 9.3.2 Diagnostic Mechanisms

### 9.3.2.1 $V_{OUT}$ Short-to-Battery and Open-Load

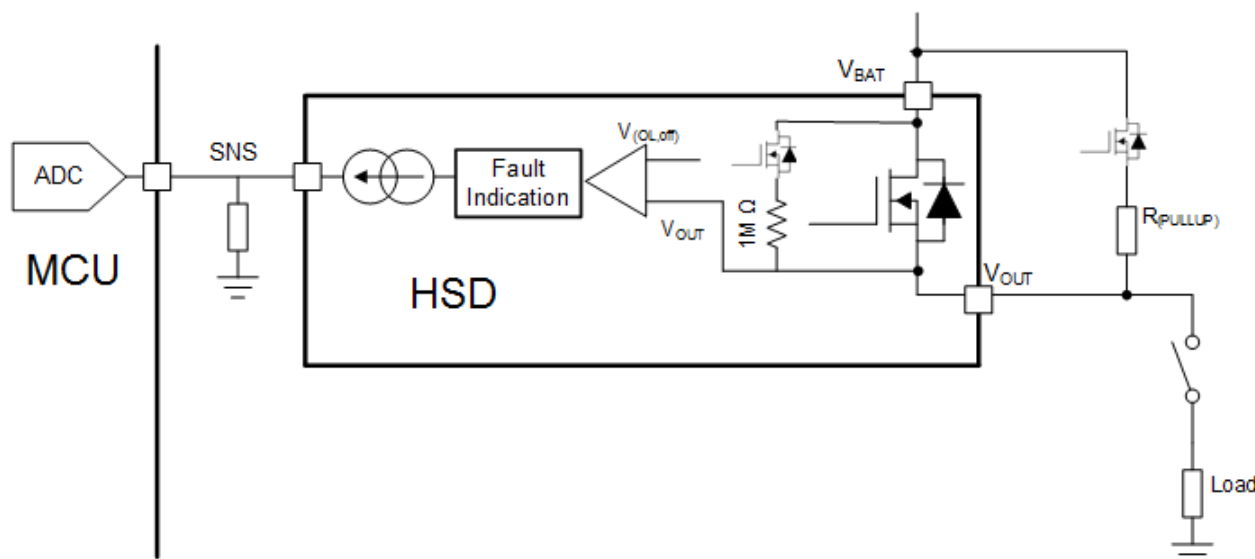
#### 9.3.2.1.1 Detection With Switch Enabled

When the switch is enabled, the  $V_{OUT}$  short-to-battery 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.

## Feature Description (continued)

### 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 battery the  $V_{OUT}$  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.



- (1) 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.

**FIG 47. Short to Battery 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.

## Feature Description (continued)

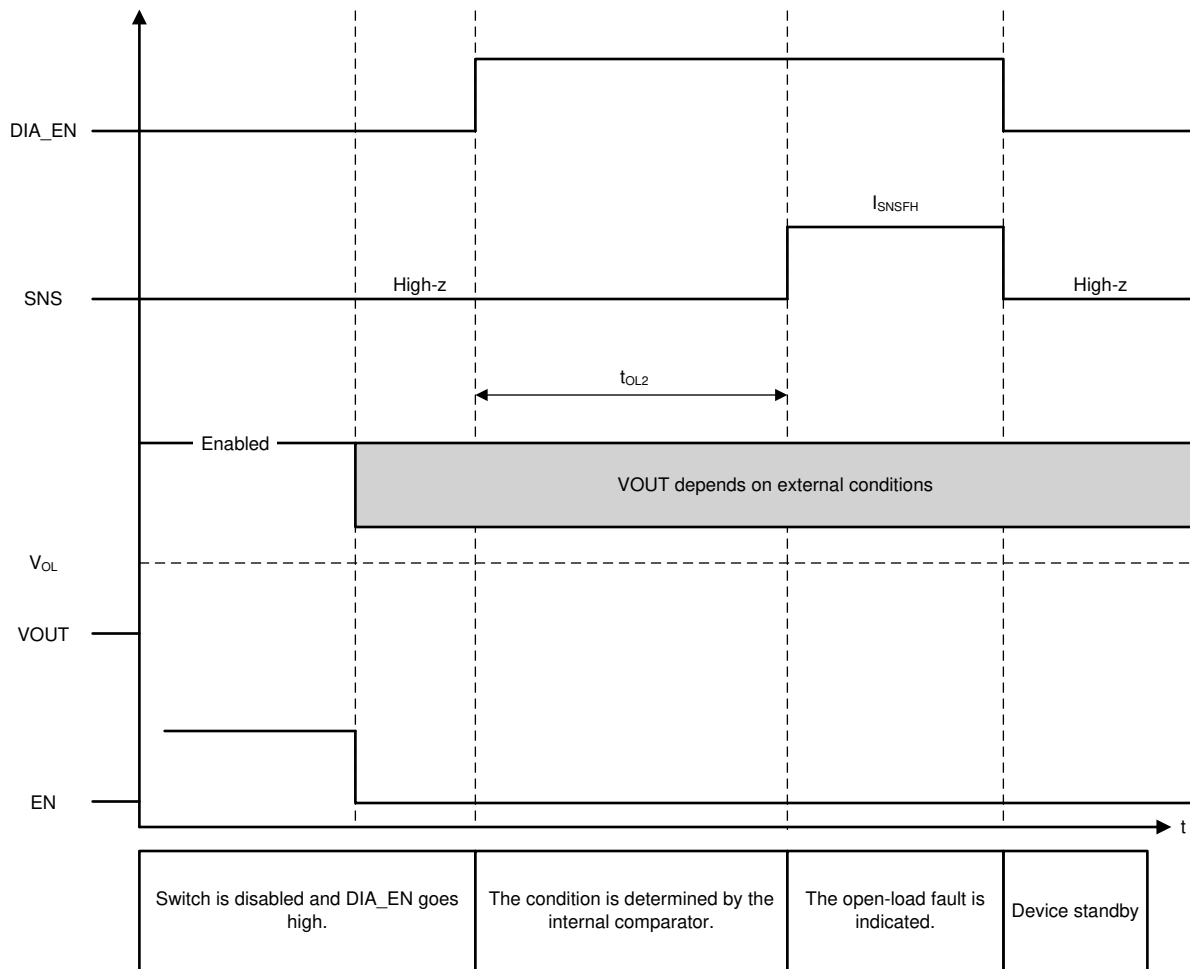


图 48. Open Load

### 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  $\mu\text{C}$  ADC.

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

表 2. Analog Sense Transfer Function

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

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

The SNS output will also be used to indicate system faults.  $I_{SNS}$  will go to the predefined level,  $I_{SNSFH}$ , when there is a fault. This level is defined in the electrical specifications.

#### 9.3.2.2.1 $R_{SNS}$ Value

The following factors should be considered when selecting the  $R_{SNS}$  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  $R_{SNS}$  value, reference [Selecting the  \$R\_{SNS}\$  Value](#) in the applications section of this data sheet.

#### 9.3.2.2.1.1 High Accuracy Load Current Sense

In many automotive modules, 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:

- **LED Lighting:** In many architectures, the Body Control Module must be compatible with both incandescent bulbs and also LED modules. The bulb may be relatively simple to diagnose. However, the LED module will consume less current and also can include multiple LED strings in parallel. The same BCM is used in both cases, so the high-side switch must be able to accurately diagnose both load types.
- **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 [Figure 54](#) and typical values for the resistor and capacitor are given. The designer should select a  $C_{SNS}$  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 $\overline{ST}$ Pin

The  $\overline{ST}$  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  $\overline{ST}$  outputs:

- Switch shutdown, due to:
  - Thermal Shutdown
  - Current limit
  - Energy limit
- Active current limiting
- Open-Load /  $V_{OUT}$  shorted-to-battery

Open-load / Short-to-battery 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  $SELx = 00$ .



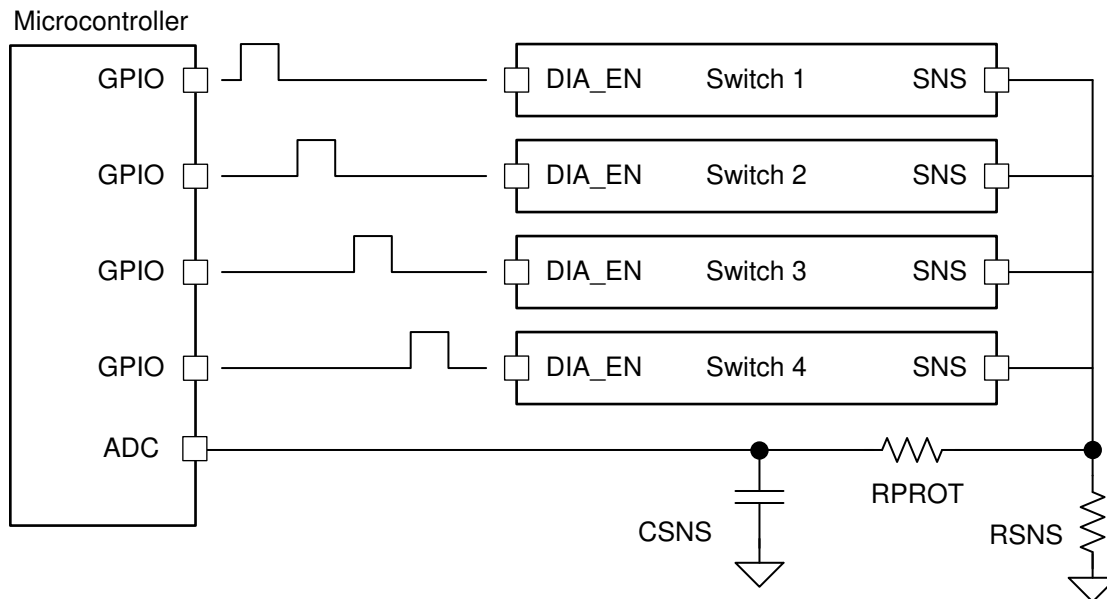
**表 3. SNS Mux**

| INPUTS |      |      |                             | OUTPUTS            |          |
|--------|------|------|-----------------------------|--------------------|----------|
| DIA_EN | SEL1 | SEL2 | FAULT DETECT <sup>(1)</sup> | SNS                | ST       |
| 0      | X    | X    | 0                           | High-z             | High-z   |
| 0      | X    | X    | 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:  
 (a) Switch shutdown and waiting for retry  
 (b) Active current limiting  
 (c) OL / STB

### 9.3.2.5 Resistor Sharing

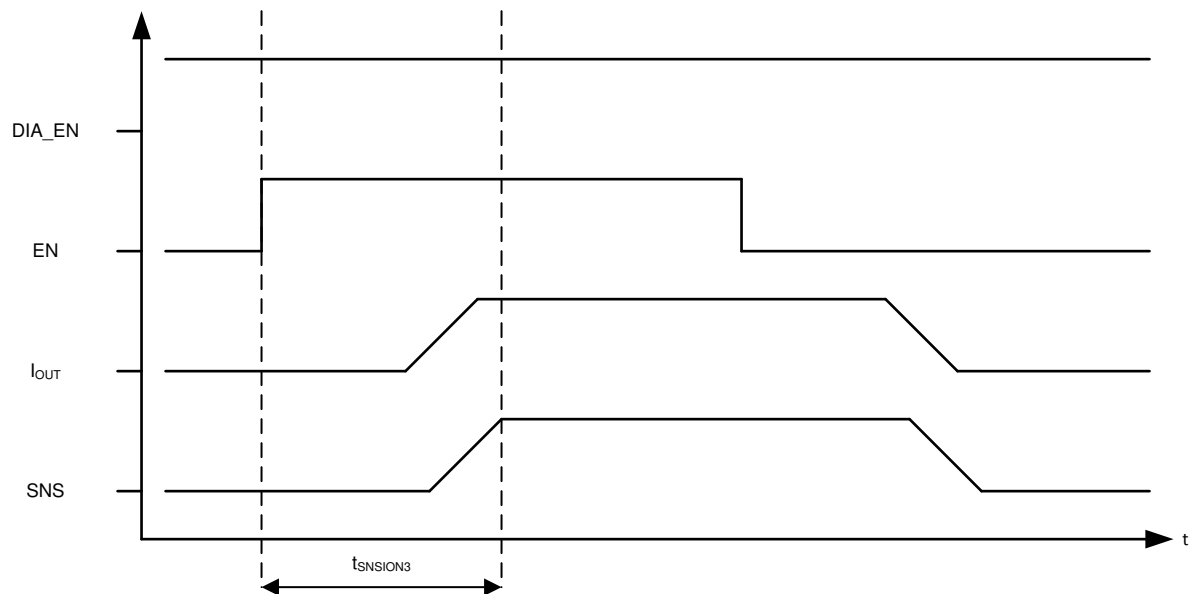
Multiple high-side switch channels may use the same SNS resistor as shown in [Figure 49](#) below. This reduces the total number of passive components in the system and the number of ADC terminals that are required of the microcontroller.



**Figure 49. 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<sub>SNSION3</sub>.

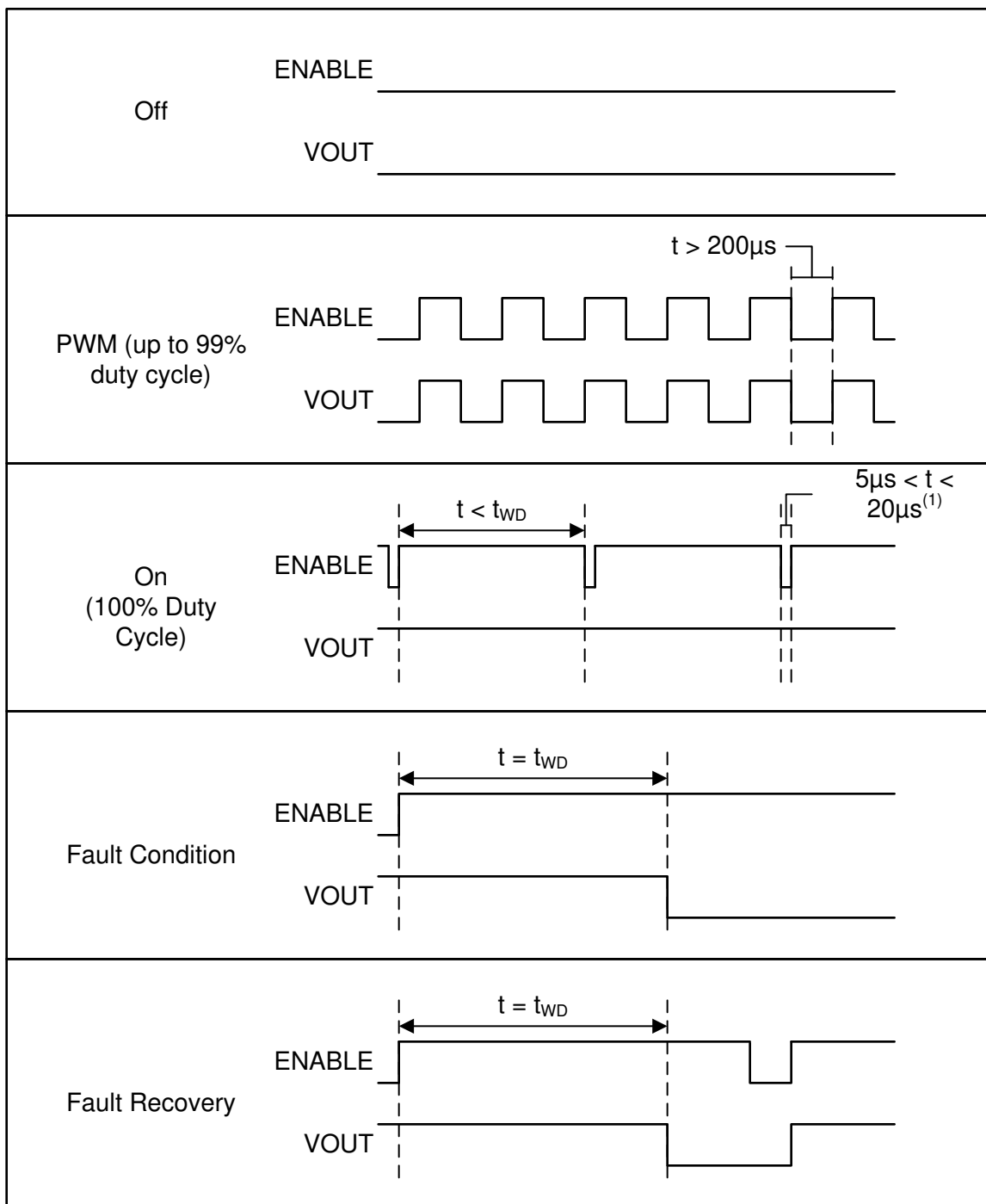


**图 50. Current Sensing in Low-Duty Cycle Applications**

### 9.3.3 Enable Watchdog

For some automotive applications, it is necessary to continuously verify that there is valid communication between the microcontroller and the switch enable pin. The purpose of this is to protect against possible communication faults (for example, microcontroller failure). The \ includes an optional watchdog feature which continuously polls the enable pin. Note that this feature is only activated for device version E, so the below information is only applicable to version E.

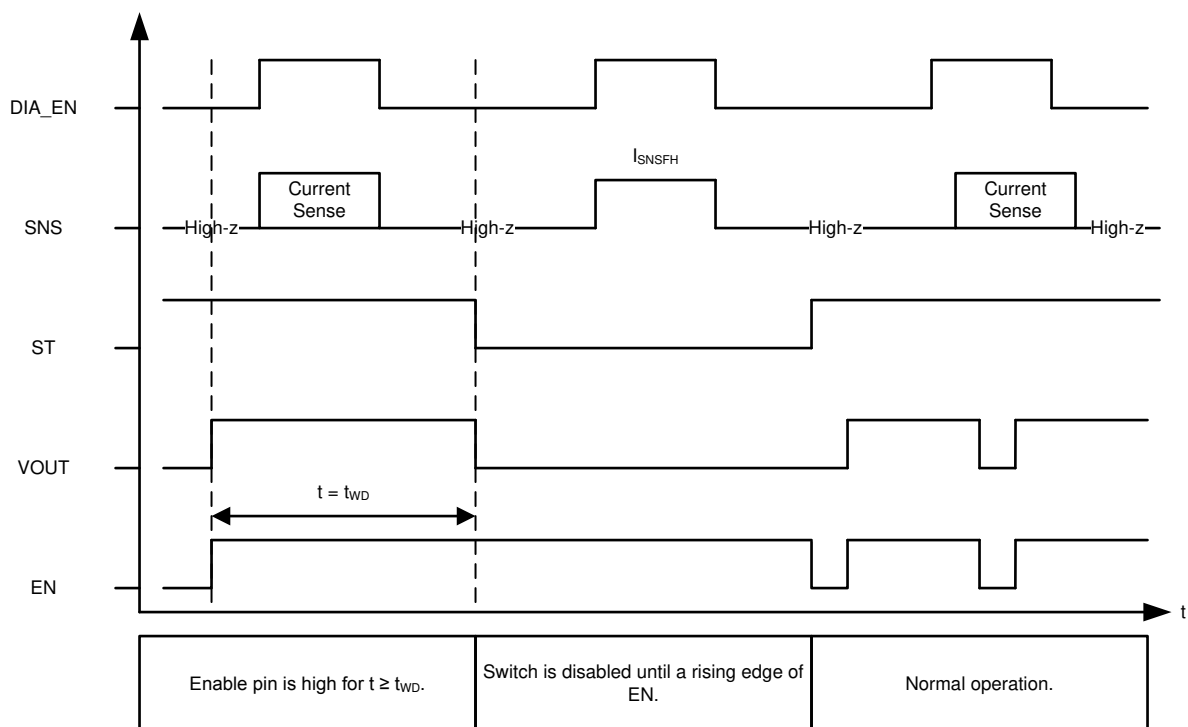
To use the watchdog feature, the microcontroller should apply a PWM to the switch enable pin. If this PWM is not present (EN is high continuously for  $\geq t_{WD}$ ) the switch will automatically be disabled. The watchdog timer is reset on the rising edge of EN. The fault indications are cleared upon the falling edge of EN. The following figure illustrates how the switch will respond to the EN PWM.



The watchdog feature requires that a PWM is applied to the switch enable pin. To maintain  $V_{OUT}$  at 100% duty cycle, the microcontroller should periodically apply a short pulse to the enable pin. This short pulse will reset the watchdog timer, but will not cause the switch to turn-off. The pulse must be  $>5\mu\text{s}$  to ensure that it is recognized by the device. There is no upper limit on the pulse width; however, if the pulse is longer than  $20\mu\text{s}$ , the switch may start to transition from enabled to disabled.

### 51. Enable Watchdog - Overview

52 illustrates the behavior of the watchdog feature.



**FIG 52. Enable Watchdog Timing Diagram**

## 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.

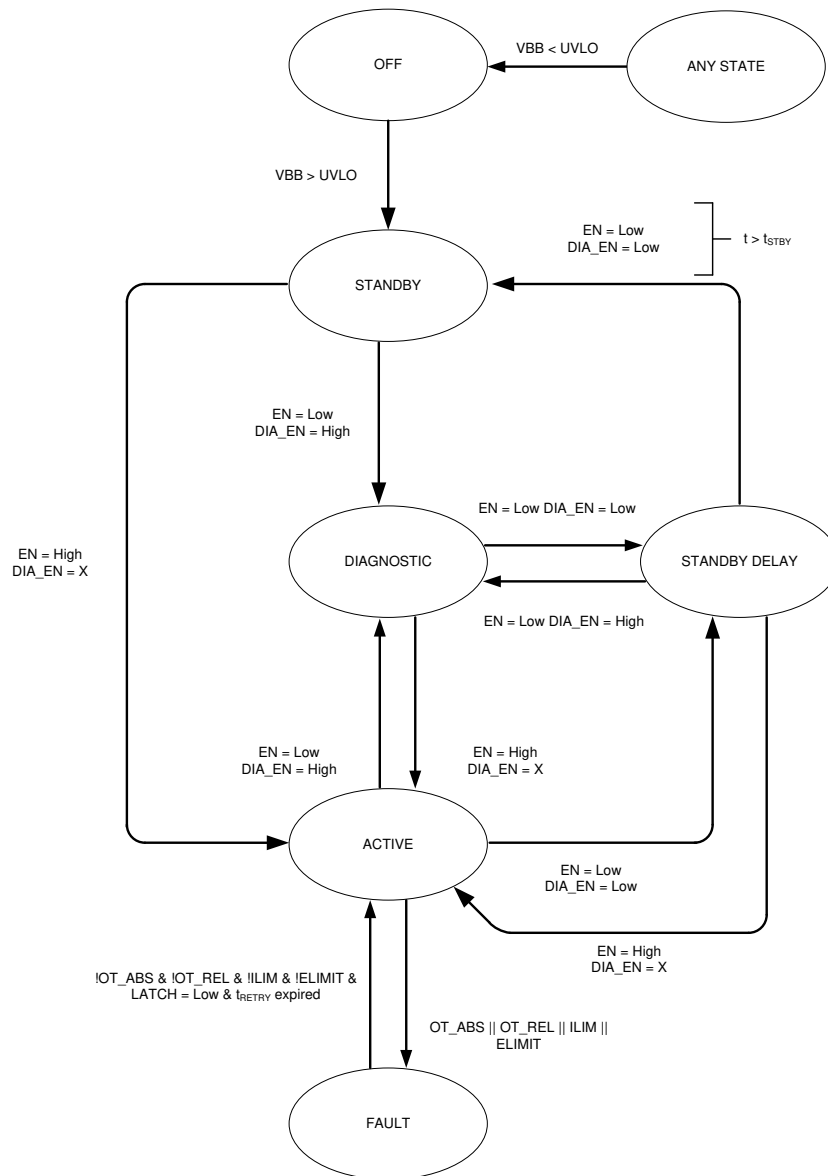
### 9.4.5 Active

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.

## Device Functional Modes (continued)



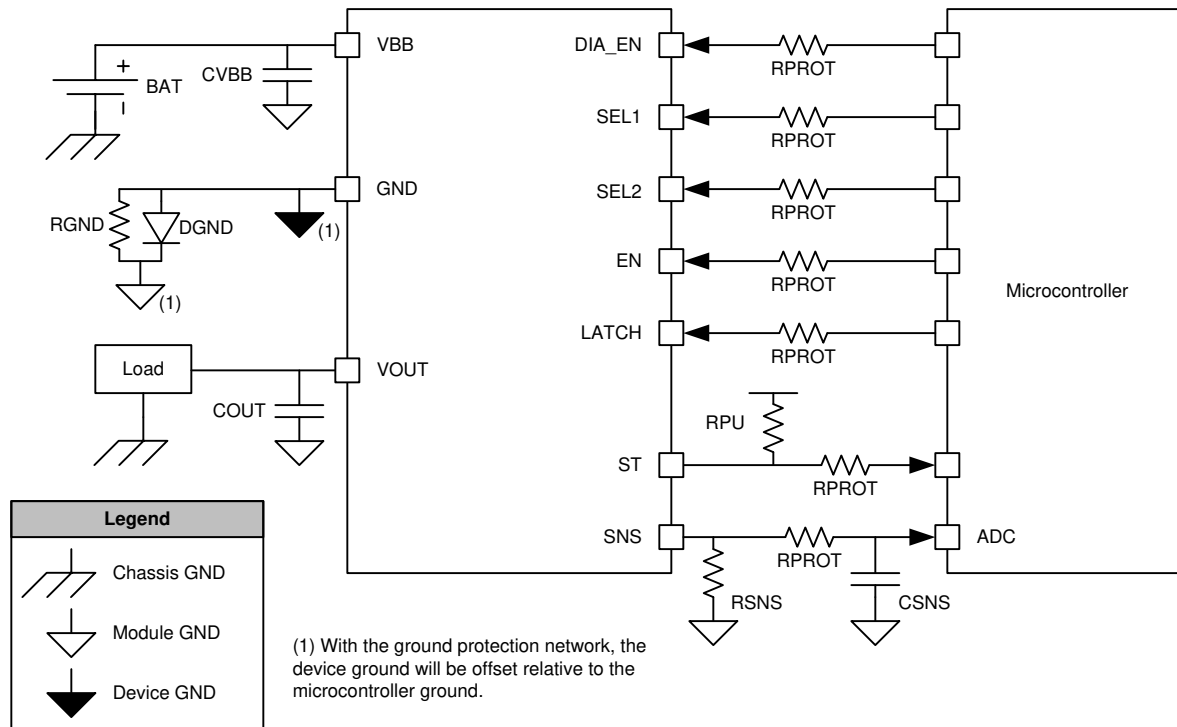
**FIG 53. State Diagram**

## 10 Application and Implementation

### 注

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

### 10.1 Application Information



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

图 54. System Diagram

表 4. Recommended External Components

| COMPONENT  | TYPICAL VALUE        | PURPOSE                                                                              |
|------------|----------------------|--------------------------------------------------------------------------------------|
| $R_{PROT}$ | 15 k $\Omega$        | Protect microcontroller and device I/O pins                                          |
| $R_{SNS}$  | 1 k $\Omega$         | Translate the sense current into sense voltage                                       |
| $R_{PU}$   | 10 k $\Omega$        | Provide pull-up source for open-drain output                                         |
| $C_{SNS}$  | 100 pF - 10 nF       | Low-pass filter for the ADC input                                                    |
| $R_{GND}$  | 4.7 k $\Omega$       | Stabilize GND potential during turn-off of inductive load                            |
| $D_{GND}$  | BAS21 Diode          | Protects device during reverse battery                                               |
| $C_{VBB}$  | 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.                       |
| $C_{OUT}$  | 22 nF                | Filtering of voltage transients (for example, ESD, ISO7637-2)                        |

### 10.1.1 Ground Protection Network

As discussed in the section regarding Reverse Battery,  $D_{GND}$  may be used to prevent excessive reverse current from flowing into the device during a reverse battery 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 battery condition,  $I_{GND} = V_{BB} / R_{GND}$ :

$$R_{GND} \geq V_{BB} / I_{GND}$$

- Set  $V_{BB} = -13.5 \text{ V}$
- Set  $I_{GND} = -50 \text{ mA}$  (absolute maximum rating)

$$R_{GND} \geq -13.5 \text{ V} / -50 \text{ mA} = 270 \text{ } \Omega \quad (1)$$

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

$$P_{RGND} = V_{BB}^2 / R_{GND} \quad (2)$$

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

In practice,  $R_{GND}$  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  $D_{GND}$ , 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

$R_{PROT}$  is used to protect the microcontroller I/O pins during system-level voltage transients such as ISO pulses or reverse battery. 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  $0 \text{ V} < V_{BB} < V_{OUT}$ . 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  $V_{BB}$ .

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 Automotive Standards

### 10.1.6.1 ISO7637-2

is tested according to the ISO7637-2:2011 (E) standard. The test pulses are applied both with the switches enabled and disabled. The test setup includes only the DUT and minimal external components:  $C_{VBB}$ ,  $C_{OUT}$ ,  $D_{GND}$ , and  $R_{GND}$ .

Status II is defined in ISO 7637-1 Function Performance Status Classification (FPSC) as: “The function does not perform as designed during the test but returns automatically to normal operation after the test”.

**表 5. ISO7637-2:2011 (E) Results**

| TEST PULSE | TEST PULSE SEVERITY LEVEL WITH STATUS II FUNCTIONAL PERFORMANCE |        | MINIMUM NUMBER OF PULSES OR TEST TIME | BURST CYCLE / PULSE REPETITION TIME |        |
|------------|-----------------------------------------------------------------|--------|---------------------------------------|-------------------------------------|--------|
|            | LEVEL                                                           | US     |                                       | MIN                                 | MAX    |
| 1          | IV                                                              | –150 V | 500 pulses                            | 0.5 s                               | --     |
| 2a         | III                                                             | +55 V  | 500 pulses                            | 0.20                                | 5 s    |
| 2b         | IV                                                              | +10 V  | 10 pulses                             | 0.5 s                               | 5 s    |
| 3a         | III                                                             | –165 V | 1 hour                                | 90 ms                               | 100 ms |
| 3b         | III                                                             | +112 V | 1 hour                                | 90 ms                               | 100 ms |

### 10.1.6.2 AEC – Q100-012 Short Circuit Reliability

The is tested according to the AEC - Q100-012 Short Circuit Reliability standard. This test is performed to demonstrate the robustness of the device against  $V_{OUT}$  short-to-ground events. Test results are summarized in [表 6](#). For further details, refer to the AEC - Q100-012 standard document or TI's [Short Circuit Reliability Test for Smart Power Switches](#) application report.

Test conditions:

- LATCH = 0 V
- $T_A = -40^\circ\text{C}$
- 10 units from 3 separate lots for a total of 30 units
- $L_{\text{supply}} = 5\ \mu\text{H}$ ,  $R_{\text{supply}} = 10\ \text{m}\Omega$
- $V_{BB} = 14\ \text{V}$

Test procedure:

- Parametric data is collected on each unit pre-stress
- Each unit is enabled into a short circuit with the required short circuit cycles or duration as specified
- Parametric data is re-collected on each unit post-stress to verify that no parametric shift is observed

The cold repetitive test is run at  $-40^\circ\text{C}$  which is the worst case condition for the . The current limit threshold is highest at cold temperature; hence, the short-circuit pulse contains more energy at cold temperature. The cold repetitive test refers to the device being given time to cool down between pulses, within than being run at a cold temperature. The load short circuit is the worst case situation, since the energy stored in the cable inductance can cause additional harm. The fast response of the device ensures current limiting occurs quickly and at a current close to the load short condition. In addition, the hot repetitive test is performed as well.

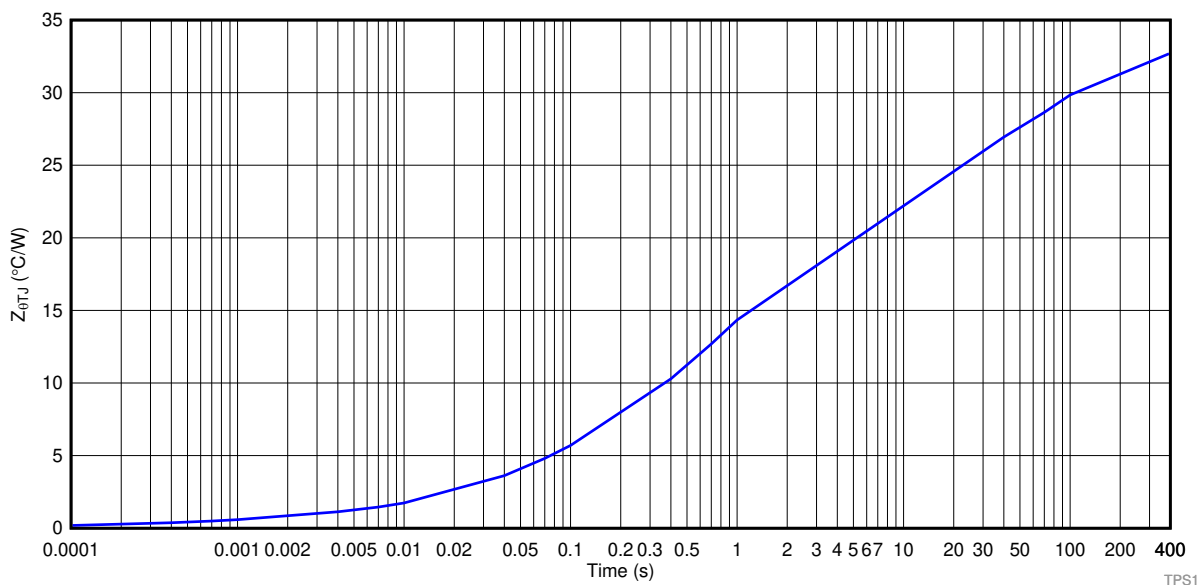
**表 6. AEC - Q100-012 Test Results**

| TEST                         | LOCATION OF SHORT                                                                                                                 | DEVICE VERSION | NO. OF CYCLES | NO. OF UNITS | NO. OF FAILS |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------|---------------|--------------|--------------|
| Cold Repetitive - Long Pulse | Load Short Circuit, $L_{\text{short}} = 5\ \mu\text{H}$ , $R_{\text{short}} = 100\ \text{m}\Omega$ , $T_A = -40^\circ\text{C}$    | D              | 200 k         | 30           | 0            |
| Hot Repetitive - Long Pulse  | Terminal Short Circuit, $L_{\text{short}} = 5\ \mu\text{H}$ , $R_{\text{short}} = 100\ \text{m}\Omega$ , $T_A = 25^\circ\text{C}$ | D              | 100 hours     | 30           | 0            |



### 10.1.7 Thermal Information

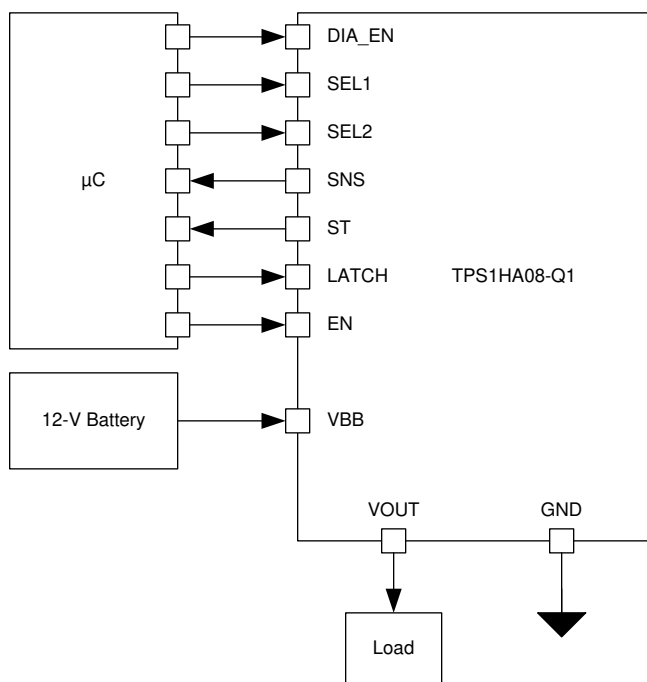
When outputting current, the will heat up due to the power dissipation. [Figure 55](#) shows the transient thermal impedance curve that can be used to determine the device temperature during 1 W pulse of a given length.



**Figure 55. Transient Thermal Impedance**

## 10.2 Typical Application

This application example demonstrates how the device can be used to power resistive heater loads as in seat heaters. [Figure 56](#) 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](#).



**Figure 56. Block Diagram for Powering Heater Loads**

## Typical Application (continued)

### 10.2.1 Design Requirements

For this design example, use the input parameters shown in 表 7.

**表 7. Design Parameters**

| DESIGN PARAMETER    | EXAMPLE VALUE               |
|---------------------|-----------------------------|
| $V_{BB}$            | 12.8 V                      |
| Heater Load         | 90 W max                    |
| Load Current Sense  | 100 mA to 20 A              |
| Ambient temperature | 85°C                        |
| $R_{\theta JA}$     | 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 式 3.  $R_{ON}$  is assumed to be 20 mΩ because this is the maximum specification. In practice,  $R_{ON}$  will be lower.

$$P_{FET} = I^2 \times R_{ON} \quad (3)$$

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

The junction temperature of the device can be calculated using 式 5 and the  $R_{\theta JA}$  value from the [Specifications](#) section.

$$T_J = T_A + R_{\theta JA} \times P_{FET} \quad (5)$$

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

The maximum junction temperature rating for device is  $T_J = 150^\circ\text{C}$ . 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 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 $R_{SNS}$ Value

表 8 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.

**表 8.  $R_{SNS}$  Calculation Parameters**

| PARAMETER                         | EXAMPLE VALUE |
|-----------------------------------|---------------|
| Current Sense Ratio ( $K_{SNS}$ ) | 4600          |
| Largest diagnosable load current  | 20 A          |
| Smallest diagnosable load current | 50 mA         |
| Full-scale ADC voltage            | 5 V           |
| ADC resolution                    | 10 bit        |

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.

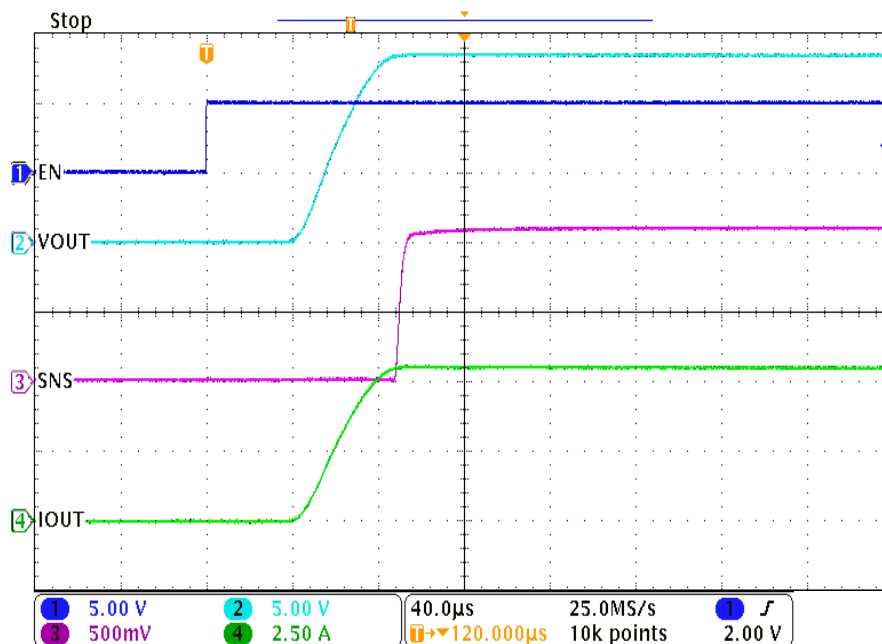
The  $R_{SNS}$  resistor value should be selected such that the largest diagnosable load current puts  $V_{SNS}$  at about 90% of the ADC full-scale. With this design, any ADC value above 90% can be considered a fault. Additionally, the  $R_{SNS}$  resistor value should ensure that the smallest diagnosable 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 表 9.

**表 9.  $V_{SNS}$  Calculation**

| LOAD (A) | SENSE RATIO | $I_{SNS}$ (mA) | $R_{SNS}$ ( $\Omega$ ) | $V_{SNS}$ (V) | % OF 5-V ADC |
|----------|-------------|----------------|------------------------|---------------|--------------|
| 0.050    | 4600        | 0.011          | 1000                   | 0.011         | 0.22%        |
| 20.000   | 4600        | 4.348          | 1000                   | 4.348         | 87%          |

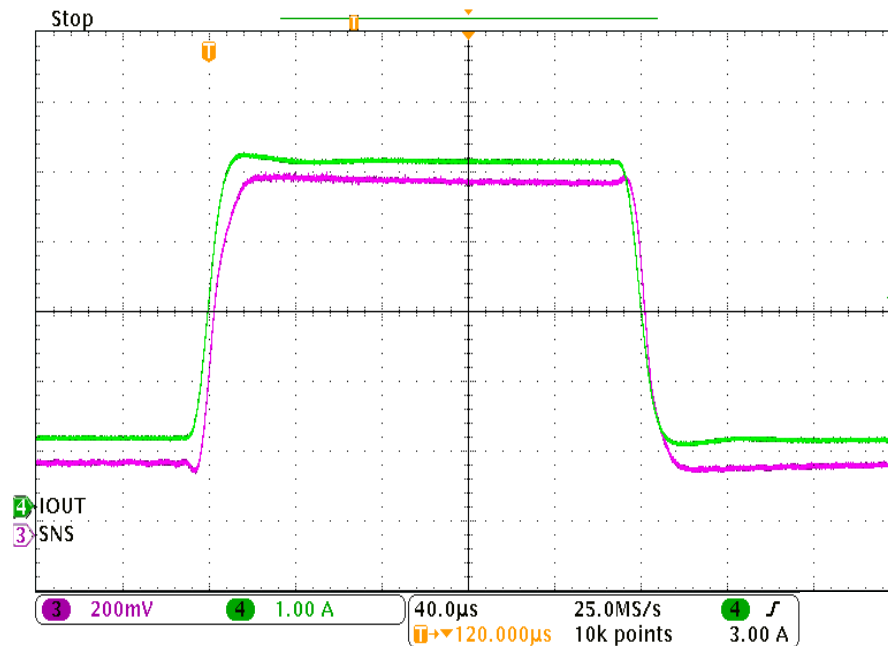
### 10.2.3 Application Curves

Figure 57 shows the behavior of the 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.



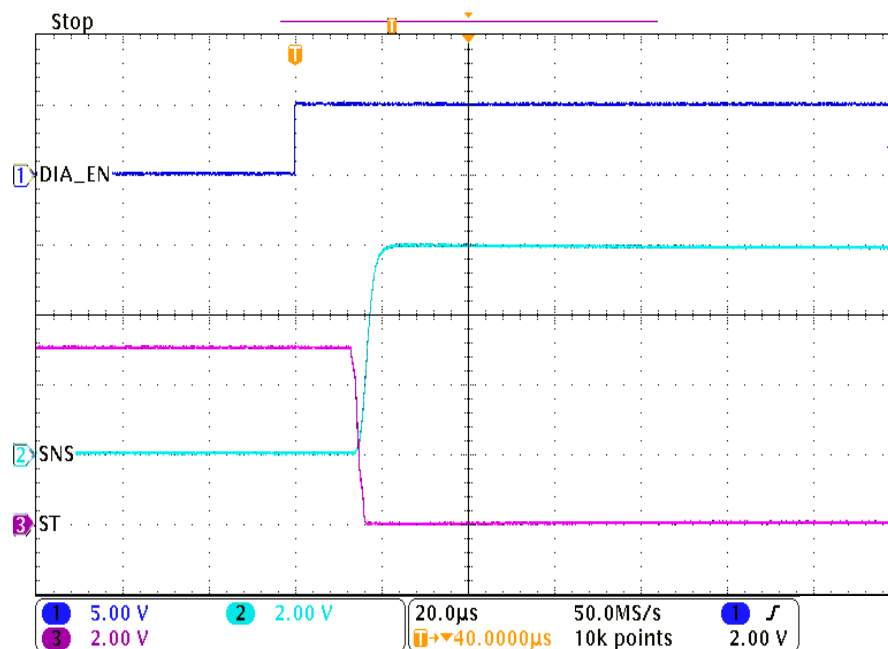
**图 57. Heater Turn-on Time**

By measuring the voltage on the SNS pin, the can communicate back to the system MCU what the load current is. Figure 58 shows that when the seat heater approaches full load and  $I_{OUT}$  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.



**58. 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 to recognize that the load has been removed and report a FLT to the MCU. 59 shows the behavior of the when there is no load attached. As soon as the DIAG\_EN pin is engaged, the SNS output goes high and the ST output engages low. By monitoring these pins, the MCU can recognize there is a fault and notify the user that maintenance is required.



**59. Open Load Detection If Heating Element is Missing**

Importantly, the will also protect the system in the event of a short-circuit. 60 shows the behavior of the device if it is enabled into a short circuit condition. If this is using the device option C, the current will be clamped to the current limit  $I_{CL}$  until it hits an over temperature event, at which point it will shut down. In this way, the system is protected from unchecked overcurrent in the event of a short circuit.

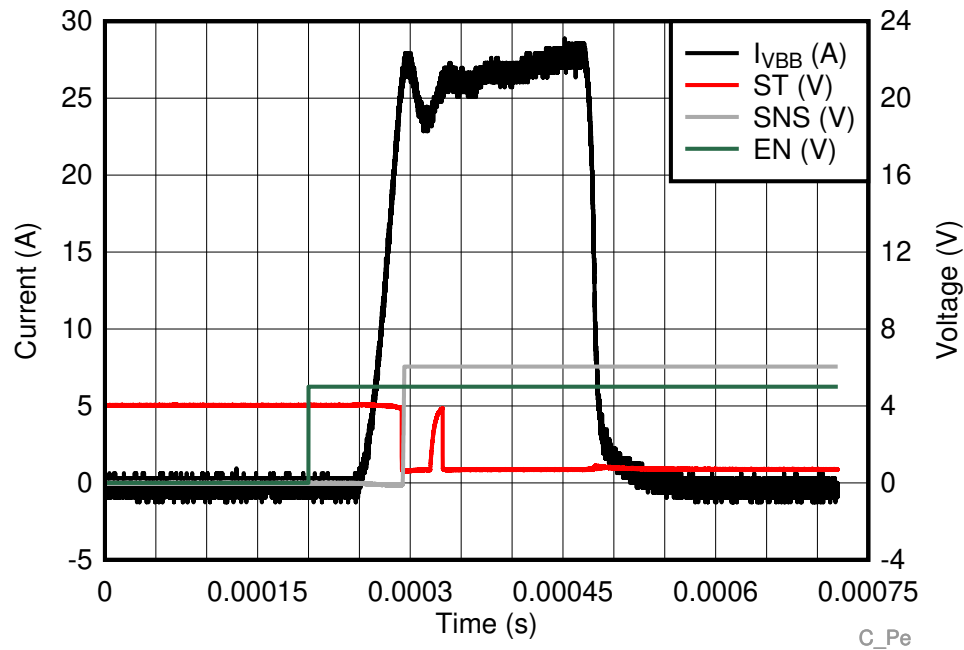


图 60. Overcurrent Behavior During Short Circuit Event

## 11 Power Supply Recommendations

The is designed to operate in a 12-V automotive system. The nominal supply voltage range is 8 V to 18 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.

表 10. Operating Voltage Range

| $V_{BB}$ Voltage Range | Note                                                                                                                                                                                         |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3 V to 8 V             | Transients such as cold crank and start-stop, functional operation guaranteed but some parametric specifications may not apply. The device is completely short-circuit protected up to 125°C |
| 8 V to 18 V            | Nominal supply voltage, all parametric specifications apply. The device is completely short-circuit protected up to 125°C                                                                    |
| 18 V to 40 V           | Transients such as jump-start and load-dump, functional operation guaranteed but some parametric specifications may not apply                                                                |

## 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.

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

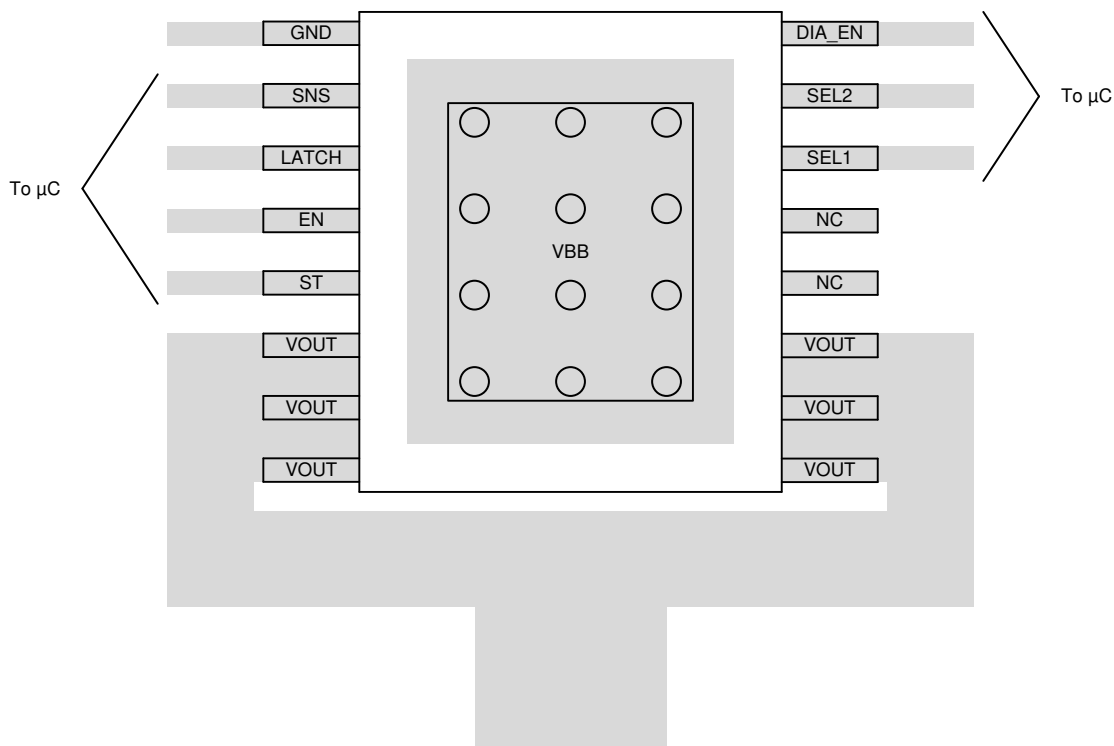


图 61. PWP Layout Example

## 13 デバイスおよびドキュメントのサポート

### 13.1 デバイス・サポート

#### 13.1.1 関連資料

関連資料については、以下を参照してください。

- [『How To Drive Inductive, Capacitive, and Lighting Loads With Smart High Side Switches』 \(英語\)](#)
- [『AEC-Q100-012 Short-Circuit Reliability Test Results for Smart Power Switches』 \(英語\)](#)
- [『Smart Power Switch Seat Heater Reference Design』 \(英語\)](#)
- [『Reverse battery protection for high side switches』 \(英語\)](#)

### 13.2 商標

All trademarks are the property of their respective owners.

### 13.3 静電気放電に関する注意事項



これらのデバイスは、限定的なESD（静電破壊）保護機能を内蔵しています。保存時または取り扱い時は、MOSゲートに対する静電破壊を防止するために、リード線同士をショートさせておくか、デバイスを導電フォームに入れる必要があります。

### 13.4 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 14 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

## PACKAGING INFORMATION

| Orderable part number            | Status<br>(1) | Material type<br>(2) | Package   Pins    | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|----------------------------------|---------------|----------------------|-------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TPS1HA08AQPWPRQ1</a> | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08A              |
| TPS1HA08AQPWPRQ1.A               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08A              |
| TPS1HA08AQPWPRQ1.B               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08A              |
| <a href="#">TPS1HA08BQPWPRQ1</a> | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08B              |
| TPS1HA08BQPWPRQ1.A               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08B              |
| TPS1HA08BQPWPRQ1.B               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08B              |
| <a href="#">TPS1HA08CQPWPRQ1</a> | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08C              |
| TPS1HA08CQPWPRQ1.A               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08C              |
| TPS1HA08CQPWPRQ1.B               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08C              |
| <a href="#">TPS1HA08DQPWPRQ1</a> | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08D              |
| TPS1HA08DQPWPRQ1.A               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08D              |
| TPS1HA08DQPWPRQ1.B               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08D              |
| <a href="#">TPS1HA08EQPWPRQ1</a> | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08E              |
| TPS1HA08EQPWPRQ1.A               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08E              |
| TPS1HA08EQPWPRQ1.B               | Active        | Production           | HTSSOP (PWP)   16 | 3000   LARGE T&R      | ROHS Exempt | NIPDAU                               | Level-3-260C-168HRS               | -40 to 125   | 1HA08E              |

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

<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.

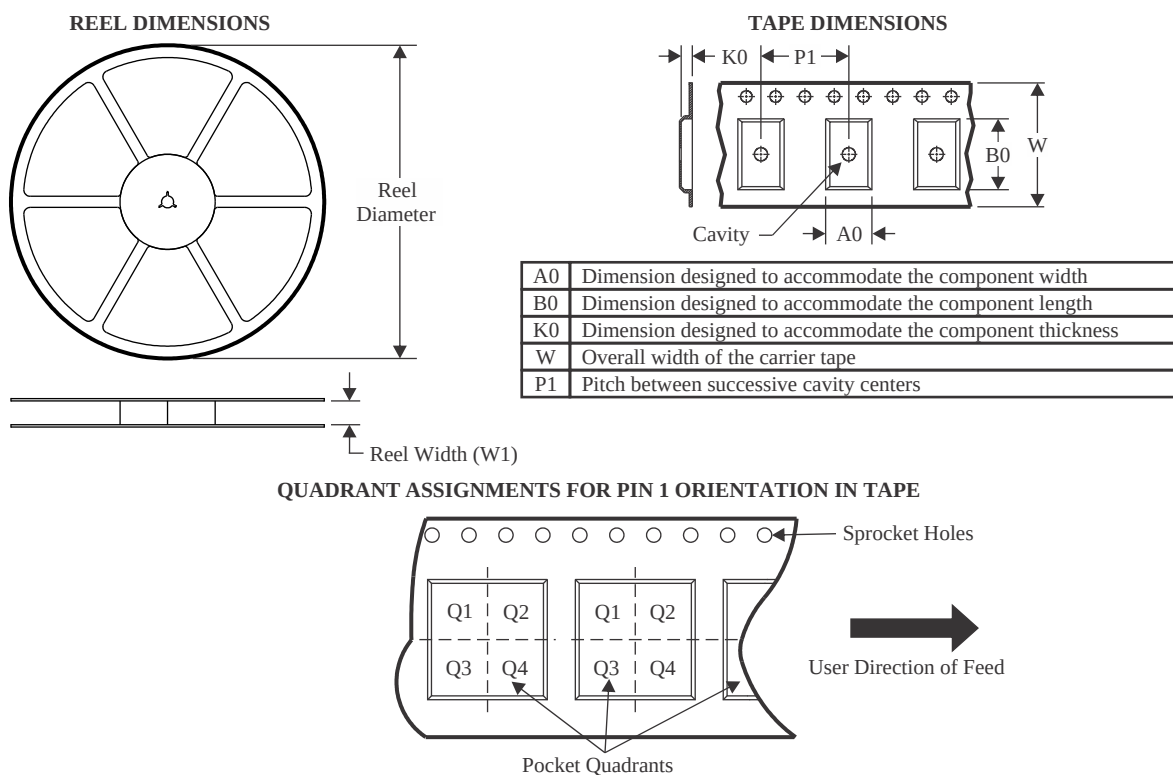
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.



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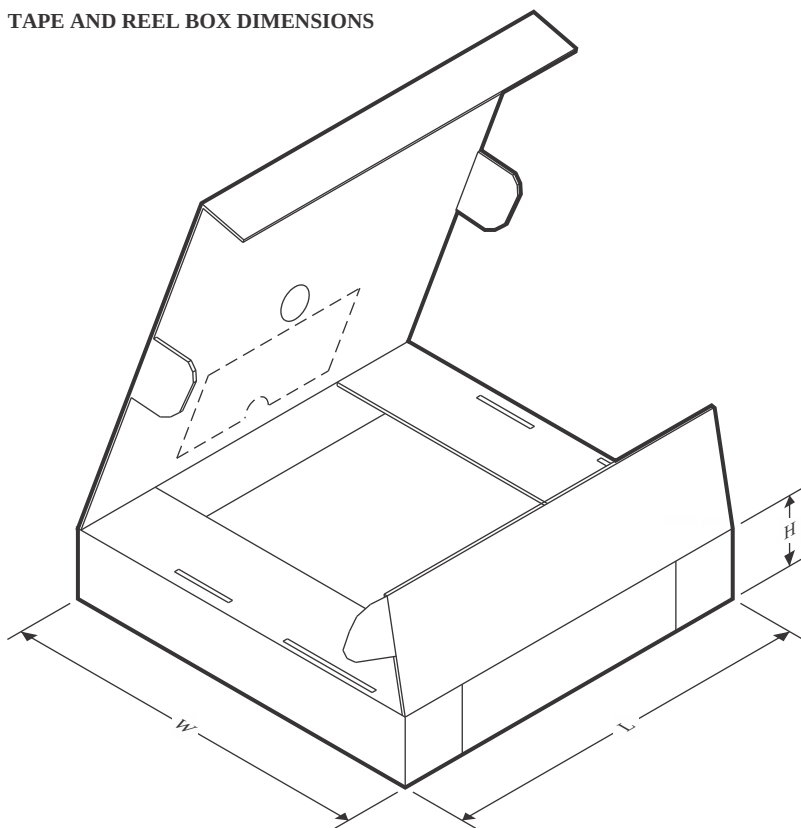
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

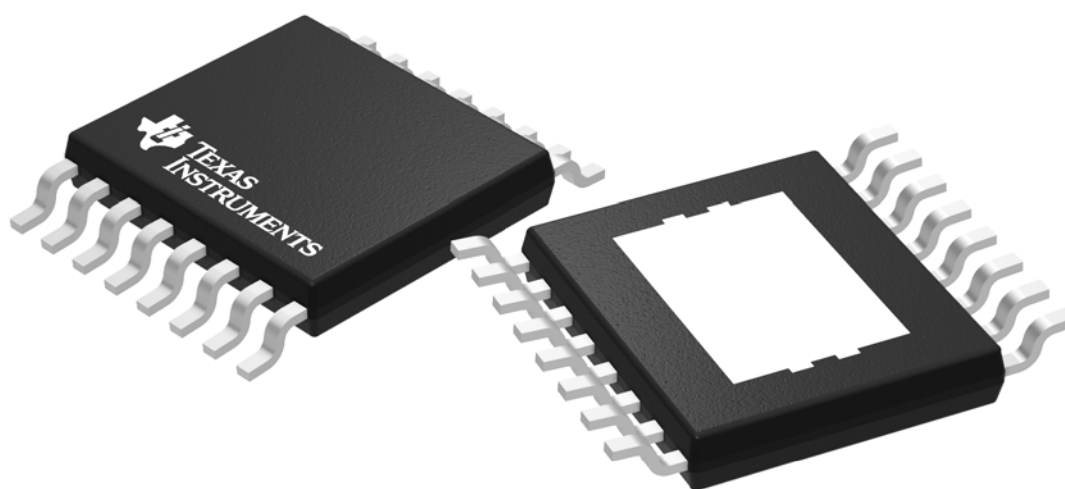
| Device           | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS1HA08AQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TPS1HA08BQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TPS1HA08CQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TPS1HA08DQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TPS1HA08EQWPRQ1  | HTSSOP       | PWP             | 16   | 3000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS1HA08AQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 350.0       | 350.0      | 43.0        |
| TPS1HA08BQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 350.0       | 350.0      | 43.0        |
| TPS1HA08CQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 350.0       | 350.0      | 43.0        |
| TPS1HA08DQPWPRQ1 | HTSSOP       | PWP             | 16   | 3000 | 350.0       | 350.0      | 43.0        |
| TPS1HA08EQWPRQ1  | HTSSOP       | PWP             | 16   | 3000 | 350.0       | 350.0      | 43.0        |



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

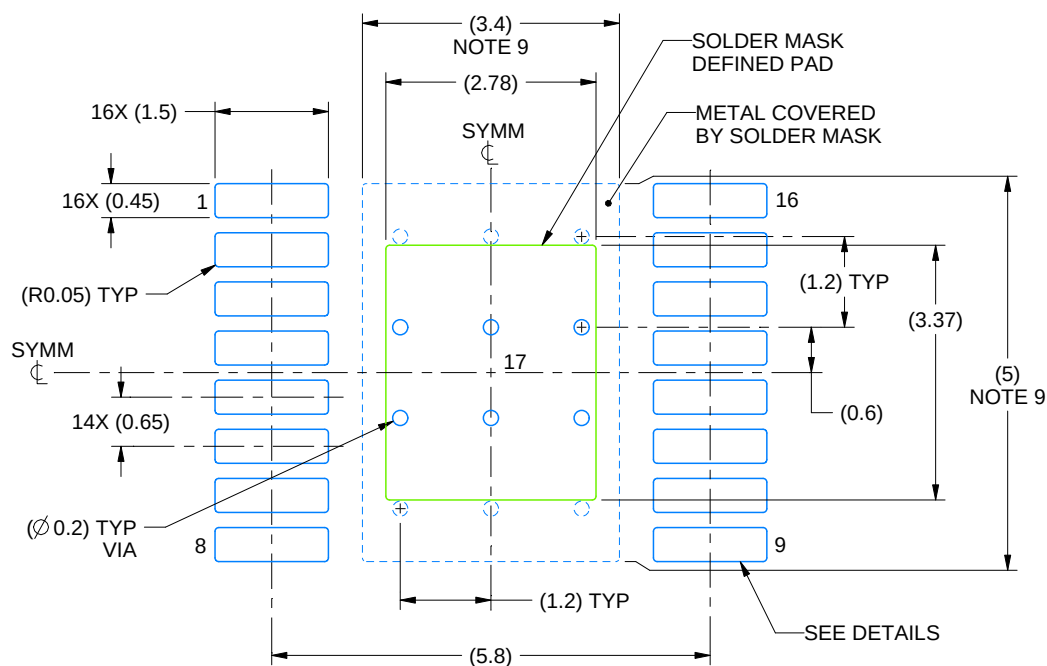


# EXAMPLE BOARD LAYOUT

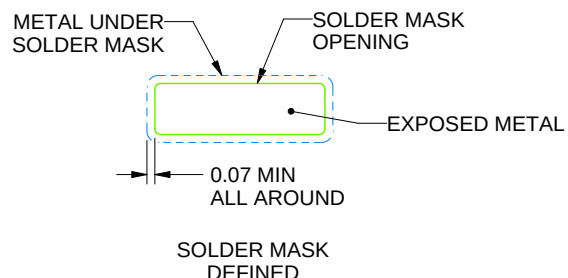
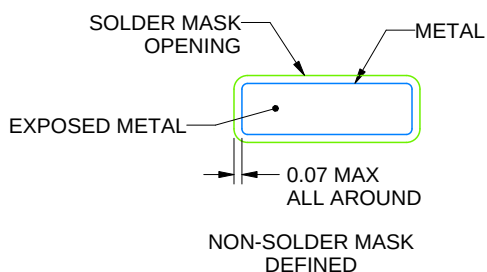
PWP0016M

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

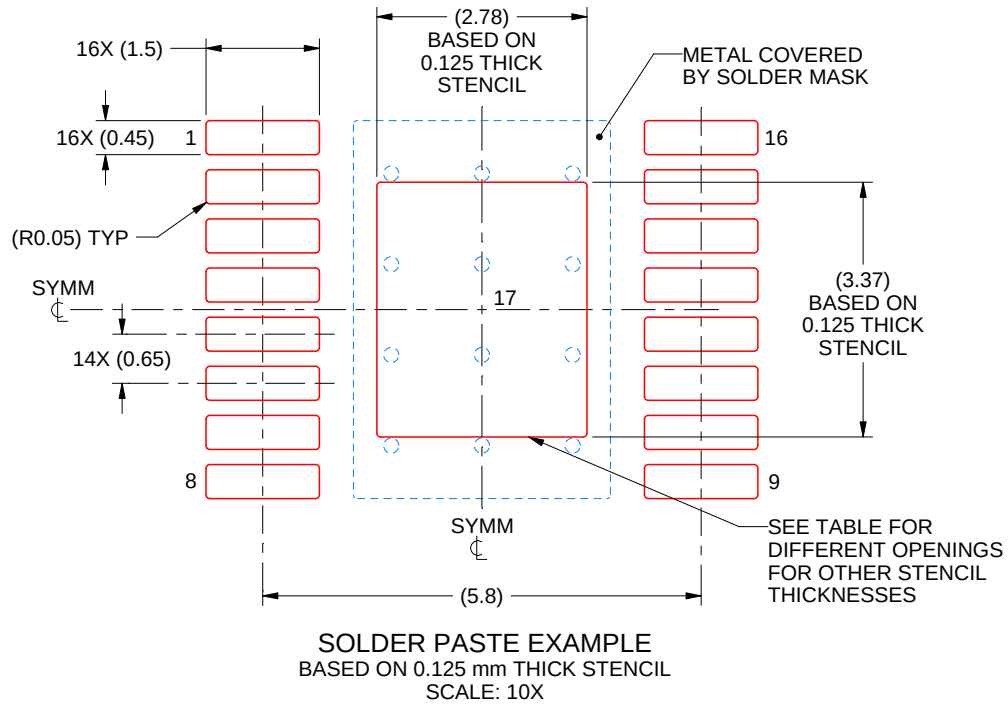
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 ([www.ti.com/lit/slma002](http://www.ti.com/lit/slma002)) and SLMA004 ([www.ti.com/lit/slma004](http://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.

# EXAMPLE STENCIL DESIGN

PWP0016M

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



| STENCIL THICKNESS | SOLDER STENCIL OPENING |
|-------------------|------------------------|
| 0.1               | 3.11 X 3.77            |
| 0.125             | 2.78 X 3.37 (SHOWN)    |
| 0.15              | 2.54 X 3.08            |
| 0.175             | 2.35 X 2.85            |

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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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