

TPS1HB08-Q1 40V, 8mΩ Single-Channel Automotive Smart High-Side Switch

1 Features

- AEC-Q100 qualified for automotive applications
 - Temperature grade 1: –40°C to 125°C
 - Device HBM ESD classification level 2
 - Device CDM ESD classification level C4B
 - Withstands 40V load dump
- **Functional Safety-Capable**
 - Documentation available to aid functional safety system design
- Single-channel smart high-side switch with 8mΩ R_{ON} ($T_J = 25^\circ\text{C}$)
- Improve system-level reliability through **adjustable current limiting**
 - Current limit set-point from 6.4A to 70A
 - Version F: 94A fixed I_{LIM}
- Robust integrated output protection:
 - Integrated thermal protection
 - Protection against short to ground and battery
 - Protection against **reverse battery** events including automatic switch on of FET with reverse voltage
 - Automatic shut off on loss of battery and ground
 - Integrated output clamp to demagnetize inductive loads
 - Configurable fault handling
- Analog sense output is configurable to accurately measure:
 - Load current
 - Device temperature
- Provides fault indication through SNS pin or $\overline{\text{FLT}}$ pin
 - Detection of open load and short-to-battery

2 Applications

- Automotive display module
- 65W Automotive headlight
- ADAS modules
- Seat comfort module
- Transmission control unit
- HVAC control module
- Body control modules
- Incandescent and LED lighting

3 Description

The TPS1HB08-Q1 device is a smart high-side switch intended for use in 12V automotive systems. The device integrates robust protection and diagnostic features to establish output port protection even during harmful events like short circuits in automotive systems. The device protects against faults through a **reliable current limit**, which, depending on device variant, is adjustable from 6.4A to 70A or set at 94A. The high current limit range allows for usage in loads that require large transient currents. The low current limit range provides improved protection for loads that do not require high peak current. The device can reliably drive a wide range of **load profiles**.

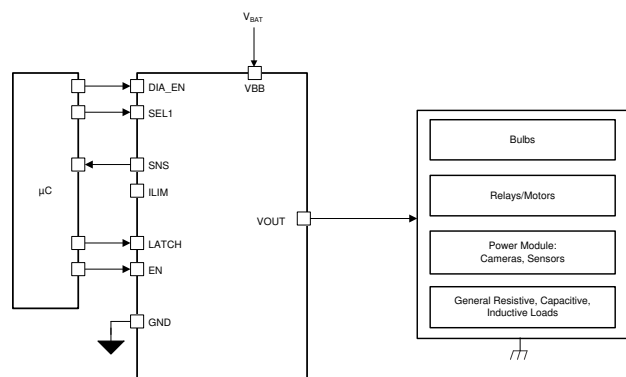
The TPS1HB08-Q1 also provides a high accuracy analog current sense that allows for improved load diagnostics. By reporting load current and device temperature to a system MCU, the device enables predictive maintenance and load diagnostics that improves the system lifetime.

The TPS1HB08-Q1 is available in a HTSSOP package which allows for reduced PCB footprint.

Package Information

PART NUMBER ⁽¹⁾	PACKAGE	PACKAGE SIZE ⁽²⁾
TPS1HB08-Q1	HTSSOP (16)	5.00mm × 4.40mm

- (1) For all available packages, see the orderable addendum at the end of the datasheet.
- (2) The package size (length × width) is a nominal value and includes pins, where applicable.



Simplified Schematic



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4 Device Comparison Table

Table 4-1. Device Options

DEVICE VERSION	PART NUMBER	CURRENT LIMIT	CURRENT LIMIT RANGE	OVERCURRENT BEHAVIOR
A	TPS1HB08A-Q1	Resistor Programmable	6.4A to 32A	Disable switch immediately
B	TPS1HB08B-Q1	Resistor Programmable	14A to 70A	Disable switch immediately
F	TPS1HB08F-Q1	Internally Set	94A	Disable switch immediately

5 Pin Configuration and Functions

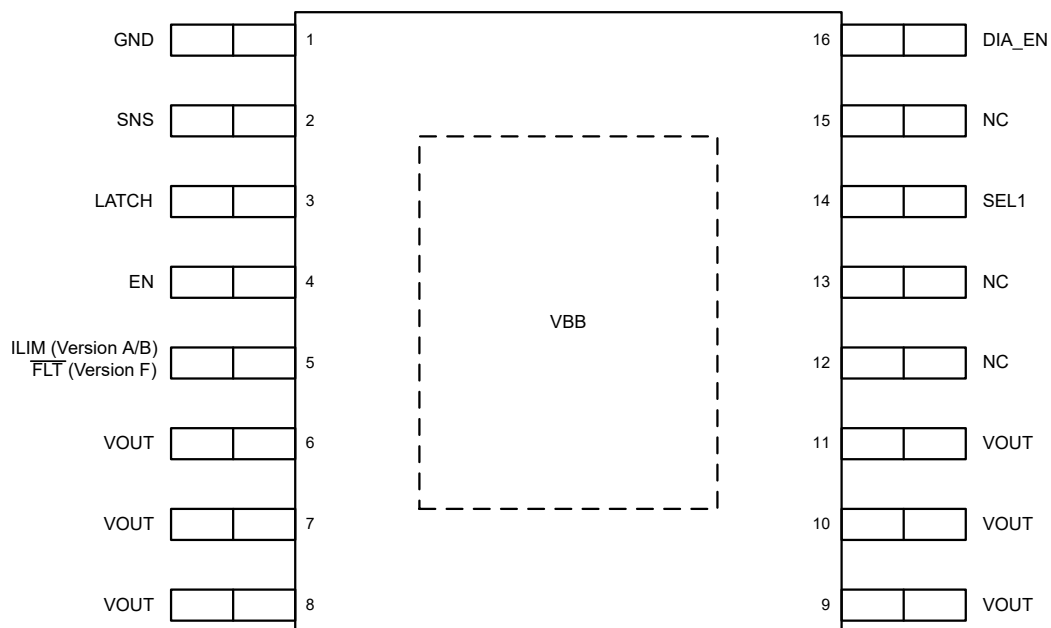


Figure 5-1. PWP Package 16-Pin HTSSOP Top View

Table 5-1. Pin Functions

PIN			TYPE ⁽¹⁾	DESCRIPTION
NAME	Version A, B	Version F		
GND	1	1	—	Device ground
SNS	2	2	O	Sense output
LATCH	3	3	I	Sets fault handling behavior (latched or auto-retry)
EN	4	4	I	Control input, active high
ILIM	5	—	O	Connect resistor to set current-limit threshold
FLT	—	5	O	Open drain output with pulldown to signal fault.
VOUT	6 - 11	6 - 11	O	Channel output
NC	12 - 13, 15	12 - 13, 15	I	No Connect, leave floating
SEL1	14	14	I	Diagnostics select. No functionality on device version F; connect to IC GND through R _{PROT} resistor
DIA_EN	16	16	I	Diagnostic enable, active high
VBB	Exposed pad	Exposed pad	I	Power supply input

(1) I = input, O = output

5.1 Recommended Connections for Unused Pins

The TPS1HB08-Q1 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 can be considered as optional.

Table 5-2. Connections For Optional Pins

PIN NAME	CONNECTION IF NOT USED	IMPACT IF NOT USED
SNS	Ground through 1kΩ resistor	Analog sense is not available.
LATCH	Float or ground through R _{PROT} resistor	With LATCH unused, the device auto-retries after a fault. If latched behavior is desired, but the system describes limited I/O, it is possible to use one microcontroller output to control the latch function of several high-side channels.
ILIM (Version A/B)	Float	If the ILIM pin is left floating, the device is set to the default internal current-limit threshold.
FAULT (Version F)	Float	Open drain FAULT signal is not able to be used
SEL1	Ground through R _{PROT}	SEL1 selects the TJ sensing feature. With SEL1 unused, only current sensing and open load detection are available. If unused, must be grounded through a resistor to engage FET turn-on during reverse battery.
DIA_EN	Float or ground through R _{PROT} resistor	With DIA_EN unused, the analog sense, open-load, and short-to-battery diagnostics are not available.

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Maximum continuous supply voltage, V_{BB}			36	V
Load dump voltage, V_{LD}	ISO16750-2:2010(E)		40	V
Reverse battery voltage, V_{Rev} , $t \leq 3$ minutes		-18		V
Enable pin voltage, V_{EN}		-1	7	V
LATCH pin voltage, V_{LATCH}		-1	7	V
Diagnostic Enable pin voltage, V_{DIA_EN}		-1	7	V
Sense pin voltage, V_{SNS}		-1	18	V
Select pin voltage, V_{SEL}		-1	7	V
Reverse ground current, I_{GND}	$V_{BB} < 0V$		-50	mA
Energy dissipation during turnoff, E_{TOFF}	Single pulse, $L_{OUT} = 5mH$, $T_{J,start} = 125^{\circ}C$		95 ⁽²⁾	mJ
Energy dissipation during turnoff, E_{TOFF}	Repetitive pulse, $L_{OUT} = 5mH$, $T_{J,start} = 125^{\circ}C$		56 ⁽²⁾	mJ
Maximum junction temperature, T_J			150	$^{\circ}C$
Storage temperature, T_{stg}		-65	150	$^{\circ}C$

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this can affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) For further details, see the section regarding switch-off of an inductive load.

6.2 ESD Ratings

				VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 ⁽¹⁾	All pins except VBB and VOUT	±2000	V
			VBB and VOUT	±4000	
		Charged-device model (CDM), per AEC Q100-011	All pins	±750	

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

6.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{BB}	Nominal supply voltage ⁽¹⁾	6	18	V
V_{BB}	Extended lower supply voltage	3	6	V
V_{BB}	Extended higher supply voltage ⁽²⁾	18	28	V
V_{EN}	Enable voltage	-1	5.5	V
V_{LATCH}	LATCH voltage	-1	5.5	V
V_{DIA_EN}	Diagnostic Enable voltage	-1	5.5	V
V_{SEL1}	Select voltage	-1	5.5	V
V_{SNS}	Sense voltage	-1	7	V

- (1) All operating voltage conditions are measured with respect to device GND.
- (2) All parameters specified remain valid, short-circuit protection value to value specified by V_{SC} parameter.

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾ ⁽²⁾		TPS1HB08-Q1	UNIT
		PWP (HTSSOP)	
		16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	32.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	25.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	9.2	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	2.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	9.3	°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 note](#).
(2) The thermal parameters are based on a 4-layer PCB according to the JESD51-5 and JESD51-7 standards.

6.5 Electrical Characteristics

$V_{BB} = 6V$ to $18V$, $T_J = -40^{\circ}C$ to $150^{\circ}C$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT VOLTAGE AND CURRENT						
V _{DSCLAMP}	V _{DS} clamp voltage		40		46	V
V _{BBCLAMP}	V _{BB} clamp voltage		58		76	V
V _{UVLOF}	V _{BB} undervoltage lockout falling	Measured with respect to the GND pin of the device	2.0		3	V
V _{UVLOR}	V _{BB} undervoltage lockout rising	Measured with respect to the GND pin of the device	2.2		3	V
I _{SB}	Standby current (total device leakage including MOSFET channel)	V _{BB} = 13.5V, T _J = 25°C V _{EN} = V _{DIA_EN} = 0V, V _{OUT} = 0V			0.1	μA
		V _{BB} = 13.5V, T _J = 85°C, V _{EN} = V _{DIA_EN} = 0V, V _{OUT} = 0V			0.5	μA
I _{L_NOM}	Continuous load current	T _{AMB} = 70°C		7		A
I _{OUT(standby)}	Output leakage current	V _{BB} = 13.5V, T _J = 25°C V _{EN} = V _{DIA_EN} = 0V, V _{OUT} = 0V		0.01	0.1	μA
		V _{BB} = 13.5V, T _J = 125°C V _{EN} = V _{DIA_EN} = 0V, V _{OUT} = 0V			1.5	μA
I _{DIA}	Current consumption in diagnostic mode	V _{BB} = 13.5V, I _{SNS} = 0mA V _{EN} = 0V, V _{DIA_EN} = 5V, V _{OUT} = 0V		3	6	mA
I _Q	Quiescent current	V _{BB} = 13.5V V _{EN} = V _{DIA_EN} = 5V, I _{OUT} = 0A		3	6	mA
t _{STBY}	Standby mode delay time	V _{EN} = V _{DIA_EN} = 0V to standby	12	17	22	ms
RON CHARACTERISTICS						
R _{ON}	On-resistance (Includes MOSFET and package)	T _J = 25°C, 6V ≤ V _{BB} ≤ 28V		16		mΩ
		T _J = 150°C, 6V ≤ V _{BB} ≤ 28V			32	mΩ
		T _J = 25°C, 3V ≤ V _{BB} ≤ 6V			30	mΩ
R _{ON(REV)}	On-resistance during reverse polarity	T _J = 25°C, -18V ≤ V _{BB} ≤ -8V		16		mΩ
		T _J = 105°C, -18V ≤ V _{BB} ≤ -8V			39	mΩ
CURRENT SENSE CHARACTERISTICS						
K _{SNS}	Current sense ratio I _{OUT} / I _{SNS}	I _{OUT} = 1A		3000		

6.5 Electrical Characteristics (continued)

$V_{BB} = 6V$ to $18V$, $T_J = -40^{\circ}C$ to $150^{\circ}C$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I _{SNSI}	Current sense current and accuracy	V _{EN} = V _{DIA_EN} = 5V, V _{SEL1} = 0V	I _{OUT} = 8A	2.6			mA
				-5			5
			I _{OUT} = 3A	1.000			mA
				-5			5
			I _{OUT} = 1A	0.333			mA
				-5			5
			I _{OUT} = 300mA	0.101			mA
				-6			6
			I _{OUT} = 100mA	0.03438			mA
				-11			11
I _{OUT} = 50mA	0.0174			mA			
	-18			18	%		
I _{OUT} = 20mA	0.00737			mA			
	-38			38	%		
TJ SENSE CHARACTERISTICS							
I _{SNST}	Temperature sense current	V _{DIA_EN} = 5V, V _{SEL1} = 5V	T _J = -40°C	0.01	0.12	0.38	mA
			T _J = 25°C	0.72	0.85	0.98	mA
			T _J = 85°C	1.25	1.52	1.79	mA
			T _J = 125°C	1.61	1.96	2.31	mA
			T _J = 150°C	1.80	2.25	2.70	mA
dI _{SNST} /dT	Coefficient	0.0112			mA/°C		
SNS CHARACTERISTICS							
I _{SNSFH}	I _{SNS} fault high-level	V _{DIA_EN} = 5V, V _{SEL1} = 0V		4	4.5	5.3	mA
I _{SNSleak}	I _{SNS} leakage	V _{DIA_EN} = 0V		1			µA
CURRENT LIMIT CHARACTERISTICS							
V _{SC}	Short Circuit Maximum Supply Voltage	Version A		18			V
		Version B		18			V
		Version F		18			V
I _{CL}	Current limit threshold	Device Version A, T _J = -40°C to 150°C	R _{ILIM} = GND, open, or out of range	28.6			A
			R _{ILIM} = 5kΩ	18.16	22	28	A
			R _{ILIM} = 25kΩ	2.62	4.4	5.7	A
		Device Version B, T _J = -40°C to 150°C	R _{ILIM} = GND, open, or out of range	70			A
			R _{ILIM} = 5kΩ	40.44	49	62.4	A
			R _{ILIM} = 25kΩ	8	9.8	11.76	A
		Device Version F	T _J = 25°C	53	60	72	A
			T _J = 150°C	42	47	56	A
K _{CL}	Current Limit Ratio	Version A		110			A * kΩ
		Version B		245			A * kΩ
FAULT CHARACTERISTICS							
V _{OL}	Open-load (OL) detection voltage	V _{EN} = 0V, V _{DIA_EN} = 5V, V _{SEL1} = 0V		2	3	4	V
t _{OL1}	OL and STB indication-time from EN falling	V _{EN} = 5V to 0V, V _{DIA_EN} = 5V, V _{SEL1} = 0V I _{OUT} = 0mA, V _{OUT} = 4V		300	500	700	µs

6.5 Electrical Characteristics (continued)

$V_{BB} = 6V$ to $18V$, $T_J = -40^{\circ}C$ to $150^{\circ}C$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{OL2}	OL and STB indication-time from DIA_EN rising	$V_{EN} = 0V$, $V_{DIA_EN} = 0V$ to $5V$, $V_{SEL1} = 0V$ $I_{OUT} = 0mA$, $V_{OUT} = 4V$	2	20	50	μs
t_{OL3}	OL and STB indication-time from VOUT rising	$V_{EN} = 0V$, $V_{DIA_EN} = 5V$, $V_{SEL1} = 0V$ $I_{OUT} = 0mA$, $V_{OUT} = 0V$ to $4V$	2	20	50	μs
T_{ABS}	Thermal shutdown		150			$^{\circ}C$
T_{HYS}	Thermal shutdown hysteresis		20	25	30	$^{\circ}C$
t_{FAULT}	Fault shutdown indication-time	$V_{DIA_EN} = 5V$ Time between switch shutdown and I_{SNS} settling at I_{SNSFH}			50	μs
t_{RETRY}	Retry time	Time from fault shutdown until switch re-enable (thermal shutdown or current limit).	1	2	3	ms
EN PIN CHARACTERISTICS						
$V_{IL, EN}$	Input voltage low-level	No GND network diode			0.8	V
$V_{IH, EN}$	Input voltage high-level	No GND network diode	2.0			V
$V_{IHYS, EN}$	Input voltage hysteresis			350		mV
R_{EN}	Internal pulldown resistor		0.5	1	2	$M\Omega$
$I_{IL, EN}$	Input current low-level	$V_{EN} = 0.8V$		0.8		μA
$I_{IH, EN}$	Input current high-level	$V_{EN} = 5V$		5.0		μA
DIA_EN PIN CHARACTERISTICS						
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	2.0			V
V_{IHYS, DIA_EN}	Input voltage hysteresis			350		mV
R_{DIA_EN}	Internal pulldown resistor		0.5	1	2	$M\Omega$
I_{IL, DIA_EN}	Input current low-level	$V_{DIA_EN} = 0.8V$		0.8		μA
I_{IH, DIA_EN}	Input current high-level	$V_{DIA_EN} = 5V$		5.0		μA
SEL1 PIN CHARACTERISTICS						
$V_{IL, SEL1}$	Input voltage low-level	No GND network diode			0.8	V
$V_{IH, SEL1}$	Input voltage high-level	No GND network diode	2.0			V
$V_{IHYS, SEL1}$	Input voltage hysteresis			350		mV
R_{SEL1}	Internal pulldown resistor		0.5	1	2	$M\Omega$
$I_{IL, SEL1}$	Input current low-level	$V_{SEL1} = 0.8V$		0.8		μA
$I_{IH, SEL1}$	Input current high-level	$V_{SEL1} = 5V$		5.0		μA
LATCH PIN CHARACTERISTICS						
$V_{IL, LATCH}$	Input voltage low-level	No GND network diode			0.8	V
$V_{IH, LATCH}$	Input voltage high-level	No GND network diode	2.0			V
$V_{IHYS, LATCH}$	Input voltage hysteresis			350		mV
R_{LATCH}	Internal pulldown resistor		0.5	1	2	$M\Omega$
$I_{IL, LATCH}$	Input current low-level	$V_{LATCH} = 0.8V$		0.8		μA
$I_{IH, LATCH}$	Input current high-level	$V_{LATCH} = 5V$		5		μA

6.6 SNS Timing Characteristics

$V_{BB} = 6V$ to $18V$, $T_J = -40^{\circ}C$ to $+150^{\circ}C$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SNS TIMING - CURRENT SENSE						
$t_{SNSION1}$	Settling time from rising edge of DIA_EN	$V_{EN} = 5V$, $V_{DIA_EN} = 0V$ to $5V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			40	μs
$t_{SNSION2}$	Settling time from rising edge of EN and DIA_EN	$V_{EN} = V_{DIA_EN} = 0V$ to $5V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			200	μs
$t_{SNSION3}$	Settling time from rising edge of EN	$V_{EN} = 0V$ to $5V$, $V_{DIA_EN} = 5V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			165	μs
$t_{SNSIOFF1}$	Settling time from falling edge of DIA_EN	$V_{EN} = 5V$, $V_{DIA_EN} = 5V$ to $0V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			20	μs
$t_{SETTLEH}$	Settling time from rising edge of load step	$V_{EN} = 5V$, $V_{DIA_EN} = 5V$ $R_{SNS} = 1k\Omega$, $I_{OUT} = 1A$ to $5A$			20	μs
$t_{SETTLEL}$	Settling time from falling edge of load step	$V_{EN} = 5V$, $V_{DIA_EN} = 5V$ $R_{SNS} = 1k\Omega$, $I_{OUT} = 5A$ to $1A$			20	μs
SNS TIMING - TEMPERATURE SENSE						
$t_{SNSTON1}$	Settling time from rising edge of DIA_EN	$V_{EN} = 5V$, $V_{DIA_EN} = 0V$ to $5V$ $R_{SNS} = 1k\Omega$			40	μs
$t_{SNSTON2}$	Settling time from rising edge of DIA_EN	$V_{EN} = 0V$, $V_{DIA_EN} = 0V$ to $5V$ $R_{SNS} = 1k\Omega$			70	μs
$t_{SNSTOFF}$	Settling time from falling edge of DIA_EN	$V_{EN} = X$, $V_{DIA_EN} = 5V$ to $0V$ $R_{SNS} = 1k\Omega$			20	μs
SNS TIMING - MULTIPLEXER						
t_{MUX}	Settling time from temperature sense to current sense	$V_{EN} = 5V$, $V_{DIA_EN} = 5V$ $V_{SEL1} = 5V$ to $0V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			60	μs
	Settling time from current sense to temperature sense	$V_{EN} = 5V$, $V_{DIA_EN} = 5V$ $V_{SEL1} = 0V$ to $5V$ $R_{SNS} = 1k\Omega$, $R_L = 2.6\Omega$			60	μs

6.7 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{DR}	Turnon delay time (from Active)	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$, 50% EN rising to 10% V_{OUT} rising	20	60	100	μs
t_{DF}	Turnoff delay time	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$, 50% EN falling to 90% V_{OUT} Falling	20	60	100	μs
SR_R	V_{OUT} rising slew rate	$V_{BB} = 13.5V$, 20% to 80% of V_{OUT} , $R_L = 2.6\Omega$	0.1	0.4	0.7	$V/\mu s$
SR_F	V_{OUT} falling slew rate	$V_{BB} = 13.5V$, 80% to 20% of V_{OUT} , $R_L = 2.6\Omega$	0.1	0.4	0.7	$V/\mu s$
t_{ON}	Turnon time (active)	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$, 50% EN rising to 80% V_{OUT} rising	39	94	235	μs
t_{OFF}	Turnoff time	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$, 50% EN falling to 20% V_{OUT} falling	39	94	235	μs
Δ_{PWM}	PWM accuracy - average load current	200 μs enable pulse, $V_S = 13.5V$, $R_L = 2.6\Omega$	-25	0	25	%
$t_{ON} - t_{OFF}$	Turnon and turnoff matching	200 μs enable pulse	-85	0	85	μs
E_{ON}	Switching energy losses during turnon	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$		0.8		mJ

6.7 Switching Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
E_{OFF}	Switching energy losses during turnoff	$V_{BB} = 13.5V$, $R_L = 2.6\Omega$		0.8		mJ

6.8 Typical Characteristics

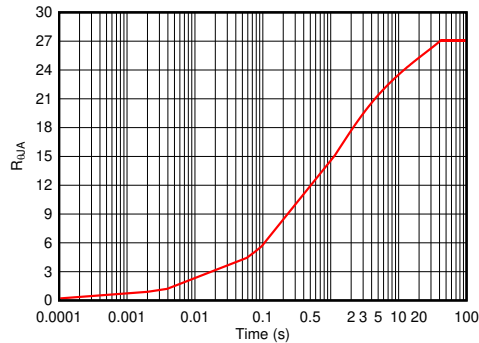


Figure 6-1. Transient Thermal Impedance

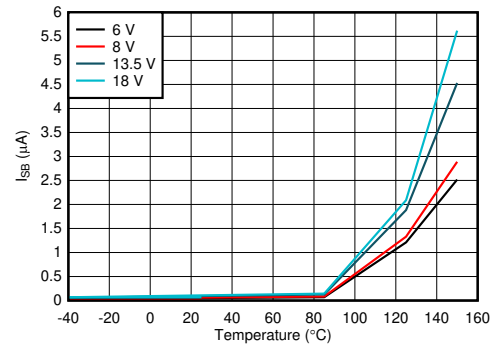


Figure 6-2. Standby Current (I_{SB}) vs Temperature

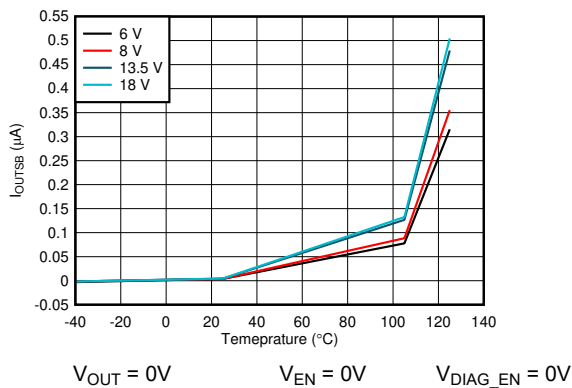


Figure 6-3. Output Leakage Current ($I_{OUT(standby)}$) vs Temperature

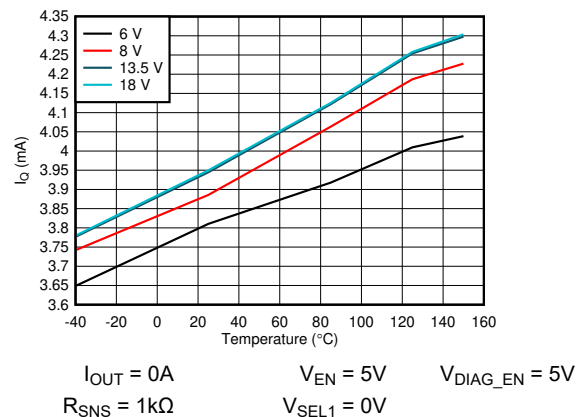


Figure 6-4. Quiescent Current (I_Q) vs Temperature

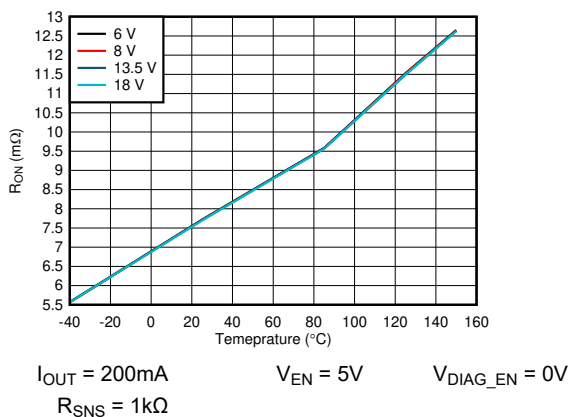


Figure 6-5. On Resistance (R_{ON}) vs Temperature

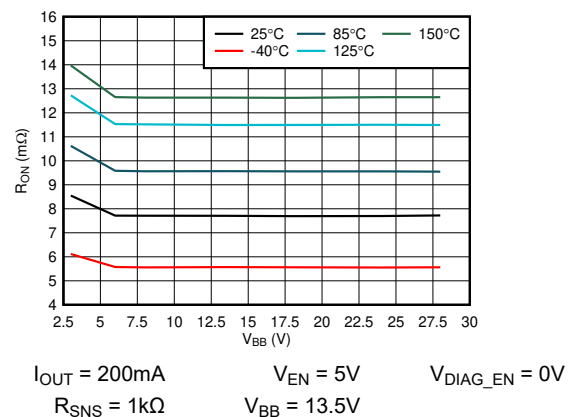
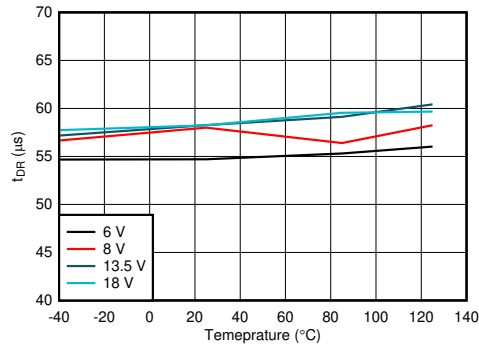


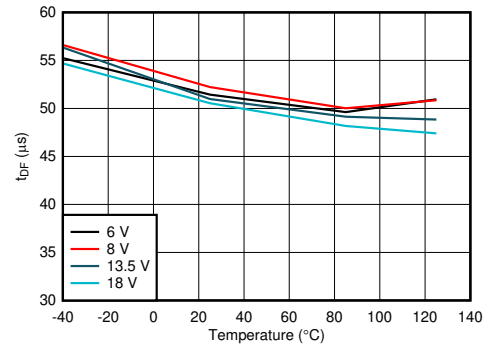
Figure 6-6. On Resistance (R_{ON}) vs V_{BB}

6.8 Typical Characteristics (continued)



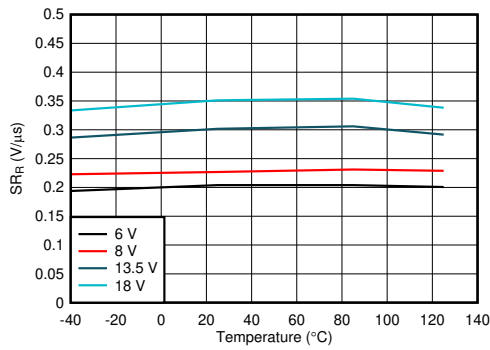
$R_{OUT} = 2.6\Omega$ $V_{EN} = 0V \text{ to } 5V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-7. Turn-on Delay Time (t_{DR}) vs Temperature



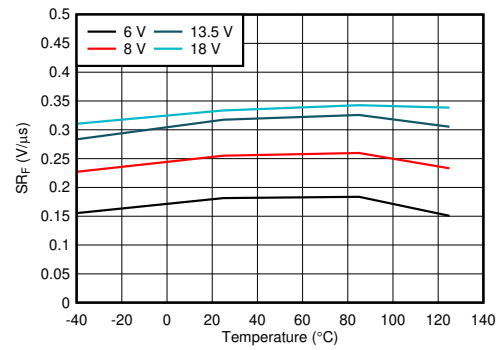
$R_{OUT} = 2.6\Omega$ $V_{EN} = 5V \text{ to } 0V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-8. Turn-off Delay Time (t_{DF}) vs Temperature



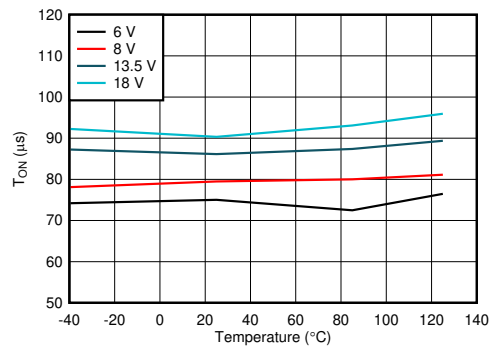
$R_{OUT} = 2.6\Omega$ $V_{EN} = 0V \text{ to } 5V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-9. V_{OUT} Slew Rate Rising (SR_R) vs Temperature



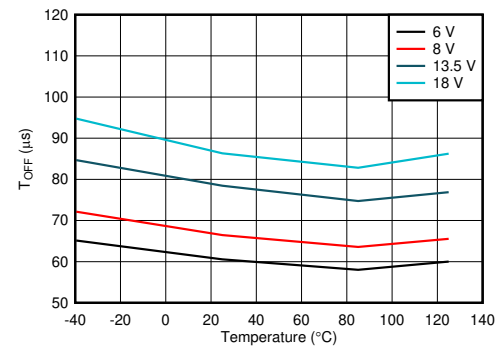
$R_{OUT} = 2.6\Omega$ $V_{EN} = 5V \text{ to } 0V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-10. V_{OUT} Slew Rate Falling (SR_F) vs Temperature



$R_{OUT} = 2.6\Omega$ $V_{EN} = 0V \text{ to } 5V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

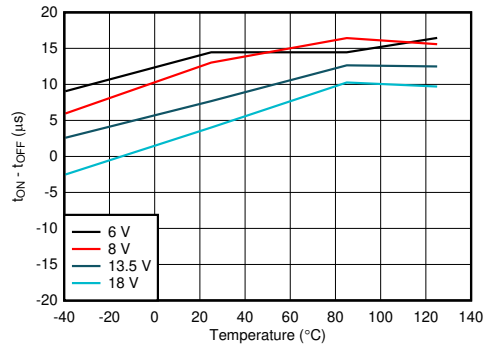
Figure 6-11. Turn-on Time (t_{ON}) vs Temperature



$R_{OUT} = 2.6\Omega$ $V_{EN} = 5V \text{ to } 0V$ $V_{DIAG_EN} = 0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

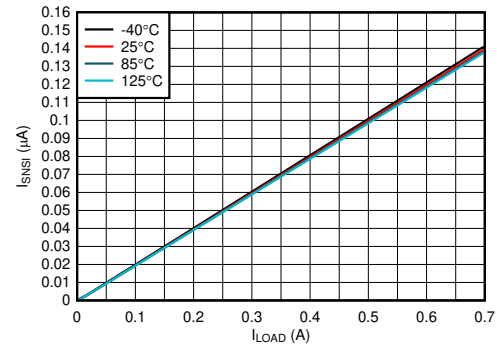
Figure 6-12. Turn-off Time (t_{OFF}) vs Temperature

6.8 Typical Characteristics (continued)



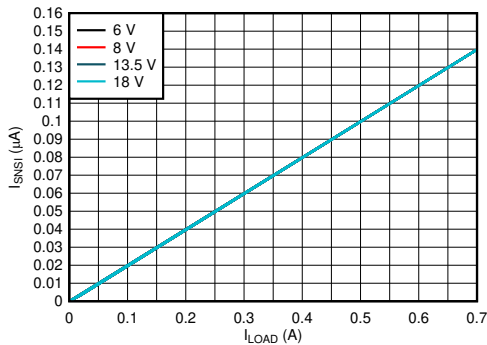
$R_{OUT} = 2.6\Omega$ $V_{EN} = 0V$ to $5V$ and $V_{DIAG_EN} = 0V$
 $5V$ to $0V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-13. Turn-on and Turn-off Matching ($t_{ON} - t_{OFF}$) vs Temperature



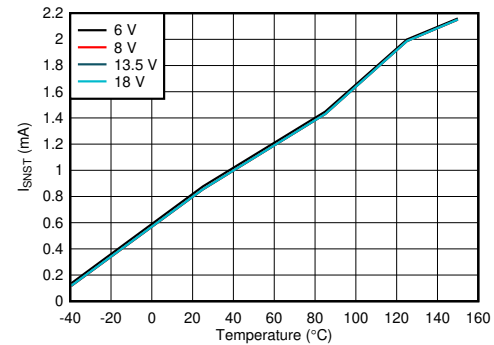
$V_{SEL1} = 0V$ $V_{EN} = 5V$ $V_{DIAG_EN} = 5V$
 $R_{SNS} = 1k\Omega$ $V_{BB} = 13.5V$

Figure 6-14. Current Sense Output Current (I_{SNSI}) vs Load Current (I_{OUT}) Across Temperature



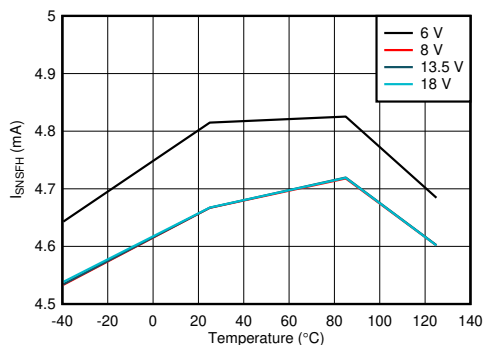
$V_{SEL1} = 0V$ $V_{EN} = 5V$ $V_{DIAG_EN} = 5V$
 $R_{SNS} = 1k\Omega$ $T_A = 25^\circ C$

Figure 6-15. Current Sense Output Current (I_{SNSI}) vs Load Current (I_{OUT}) Across V_{BB}



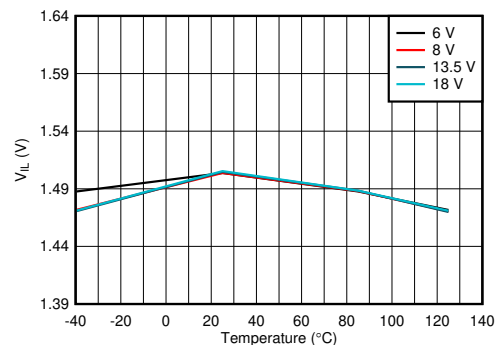
$V_{SEL1} = 5V$ $V_{EN} = 0V$ $V_{DIAG_EN} = 5V$
 $R_{SNS} = 1k\Omega$

Figure 6-16. Temperature Sense Output Current (I_{SNST}) vs Temperature



$V_{SEL1} = 0V$ $V_{EN} = 0V$ $V_{DIAG_EN} = 5V$
 $R_{SNS} = 500\Omega$ V_{OUT} Floating

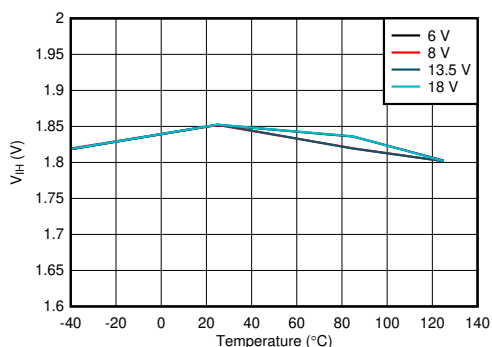
Figure 6-17. Fault High Output Current (I_{SNSFH}) vs Temperature



$V_{EN} = 3.3V$ to $0V$ $V_{OUT} = 0V$ $V_{DIAG_EN} = 0V$
 $R_{OUT} = 1k\Omega$

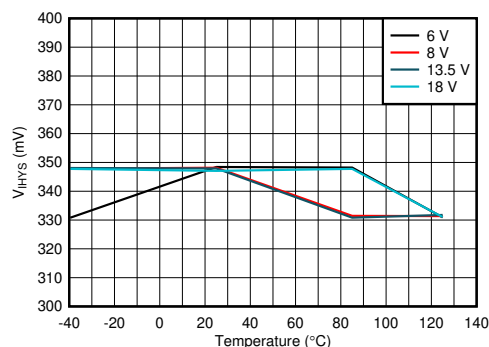
Figure 6-18. V_{IL} vs Temperature

6.8 Typical Characteristics (continued)



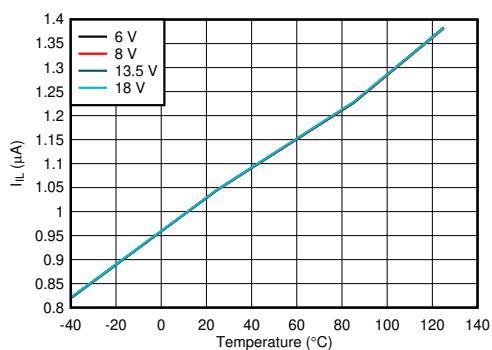
$V_{EN} = 0V \text{ to } 3.3V$ $V_{OUT} = 0V$ $V_{DIAG_EN} = 0V$
 $R_{OUT} = 1k\Omega$

Figure 6-19. V_{IH} vs Temperature



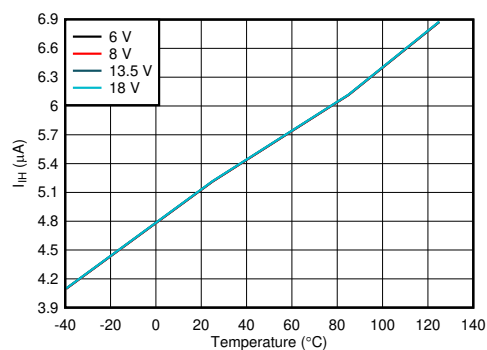
$V_{EN} = 0V \text{ to } 3.3V$ $V_{OUT} = 0V$ $V_{DIAG_EN} = 0V$
and 3.3V to 0V
 $R_{OUT} = 1k\Omega$

Figure 6-20. V_{IHYS} vs Temperature



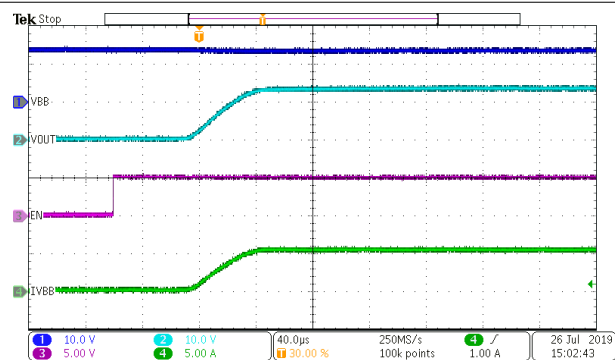
$V_{EN} = 0.8V$ $V_{OUT} = 0V$ $V_{DIAG_EN} = 0V$
 $R_{OUT} = 1k\Omega$

Figure 6-21. I_{IL} vs Temperature



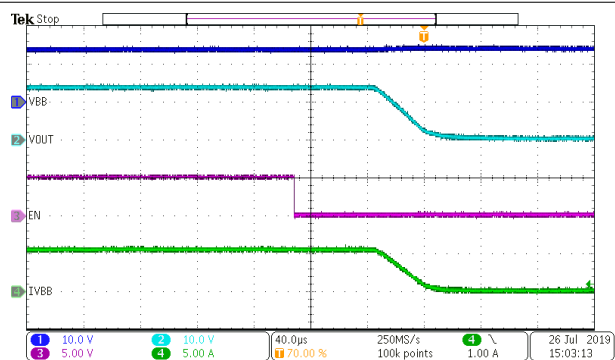
$V_{EN} = 5V$ $V_{OUT} = 0V$ $V_{DIAG_EN} = 0V$
 $R_{OUT} = 1k\Omega$

Figure 6-22. I_{IH} vs Temperature



$R_{OUT1} = 2.6\Omega$ $R_{SNS} = 1k\Omega$ $V_{DIA_EN} = 5V$
 $V_{SEL} = 0V$

Figure 6-23. Turn-on Time (t_{ON})



$R_{OUT1} = 2.6\Omega$ $R_{SNS} = 1k\Omega$ $V_{DIA_EN} = 5V$
 $V_{SEL} = 0V$

Figure 6-24. Turn-off Time (t_{OFF})

6.8 Typical Characteristics (continued)

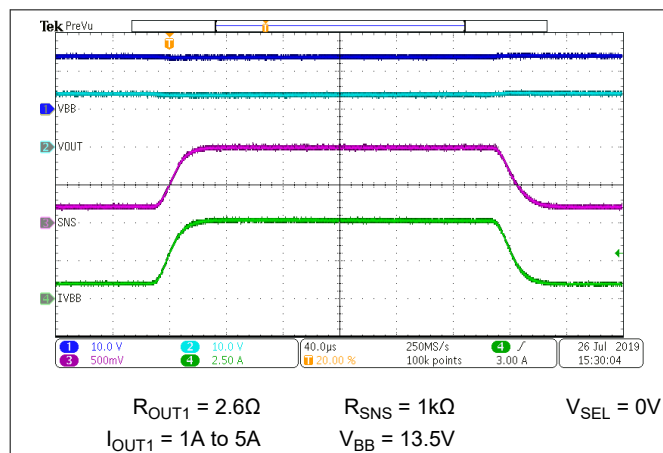


Figure 6-25. I_{SNS} Settling time ($t_{SNSION1}$) on Load Step

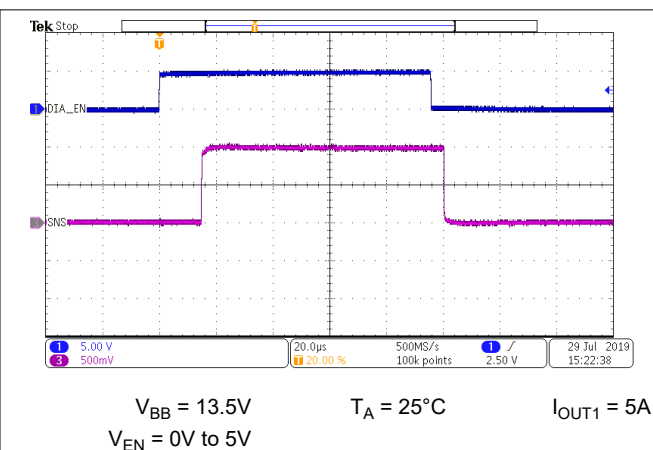


Figure 6-26. SNS Output Current Measurement Enable on DIAG_EN PWM

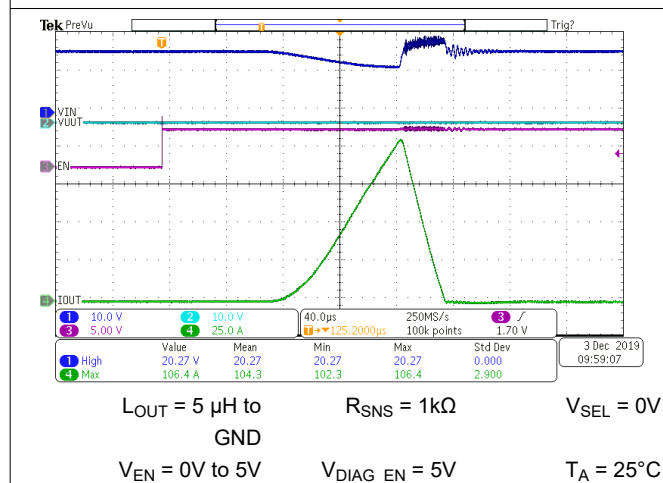


Figure 6-27. Device Version F Short Circuit Event

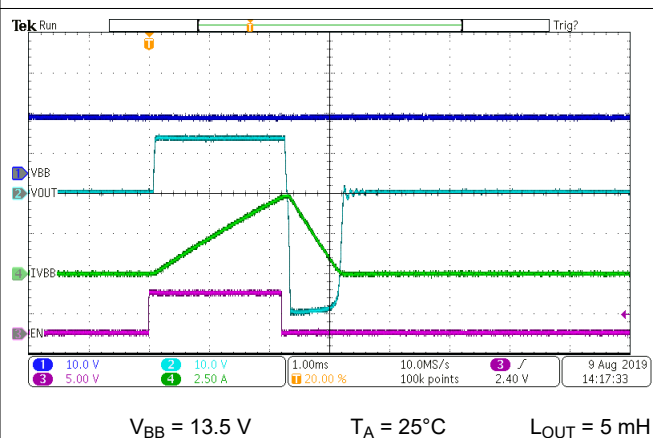


Figure 6-28. 5mH Inductive Load Demagnetization

7 Parameter Measurement Information

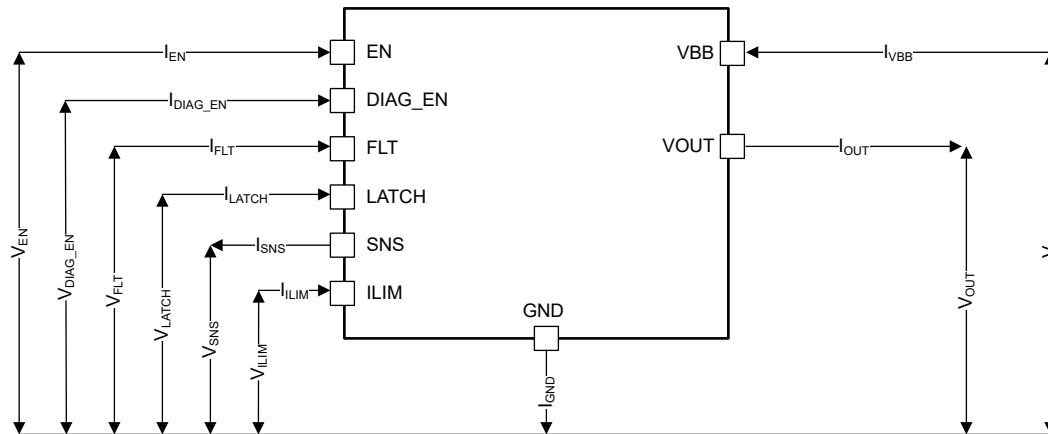


Figure 7-1. Parameter Definitions

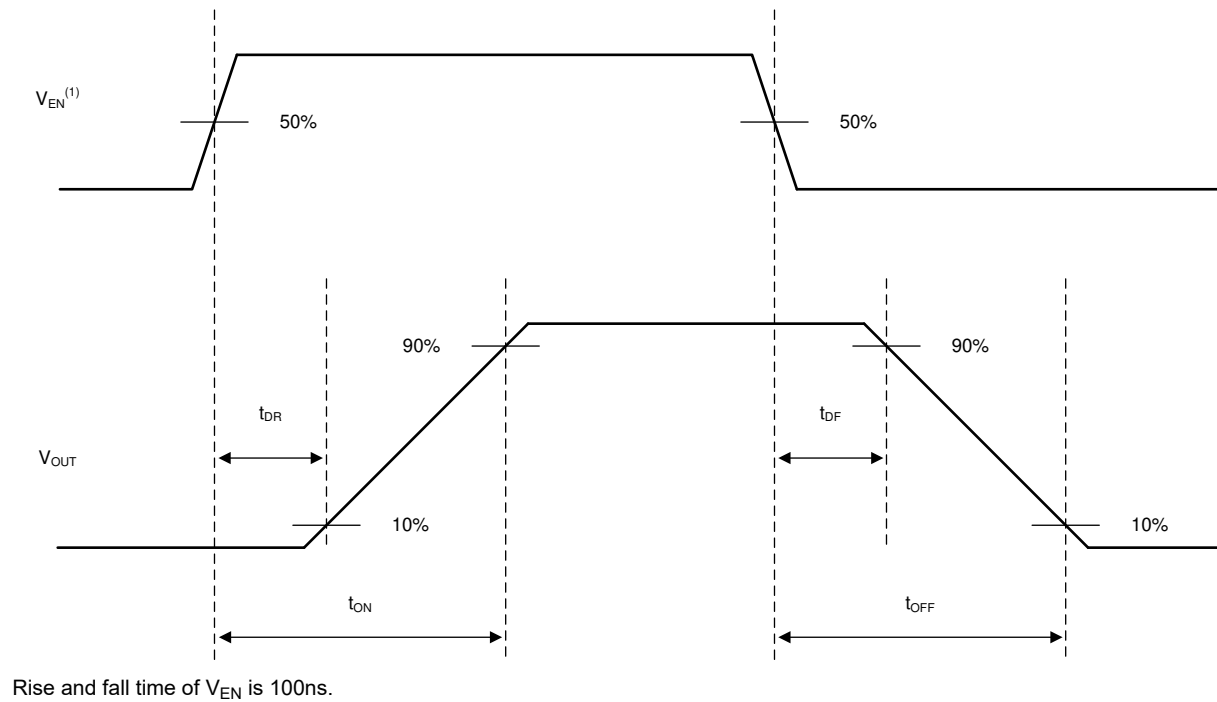
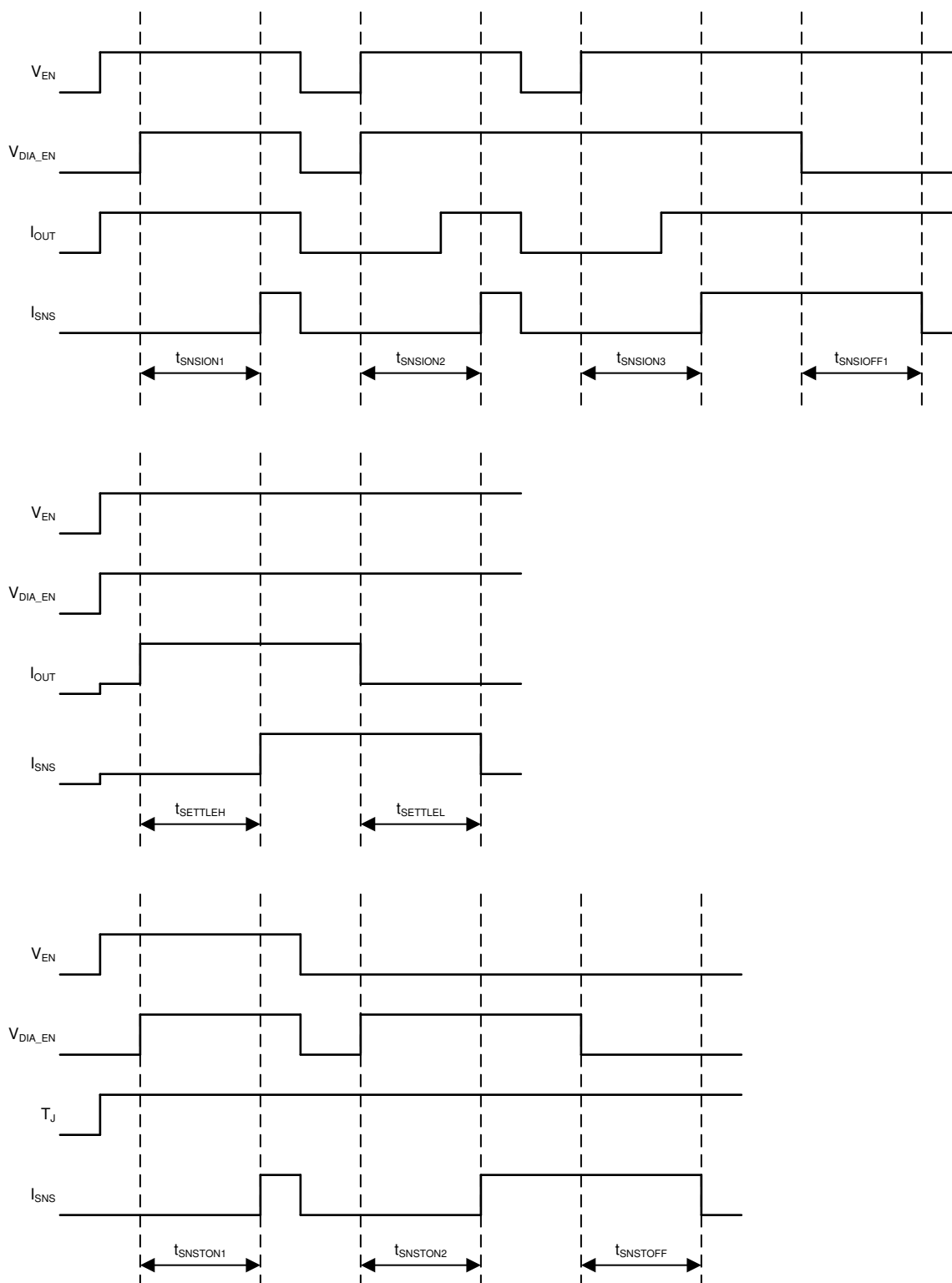


Figure 7-2. Switching Characteristics Definitions



Rise and fall times of control signals are 100ns. Control signals include: EN, DIA_EN.

Figure 7-3. SNS Timing Characteristics Definitions

8 Detailed Description

8.1 Overview

The TPS1HB08-Q1 device is a single-channel smart high-side switch intended for use with 12V automotive batteries. Many protection and diagnostic features are integrated in the device.

Diagnostics features include the analog SNS output that can provide a signal that is proportional to load current or device temperature. The high-accuracy load current sense allows for diagnostics of complex loads. Version F of the device includes an open drain $\overline{\text{FLT}}$ pin that indicates device fault states.

This device includes protection through thermal shutdown, current limiting, 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.

The TPS1HB08-Q1 is one device in a family of TI high side switches. For each device, the part number indicates elements of the device behavior. [Figure 8-1](#) gives an example of the device nomenclature.

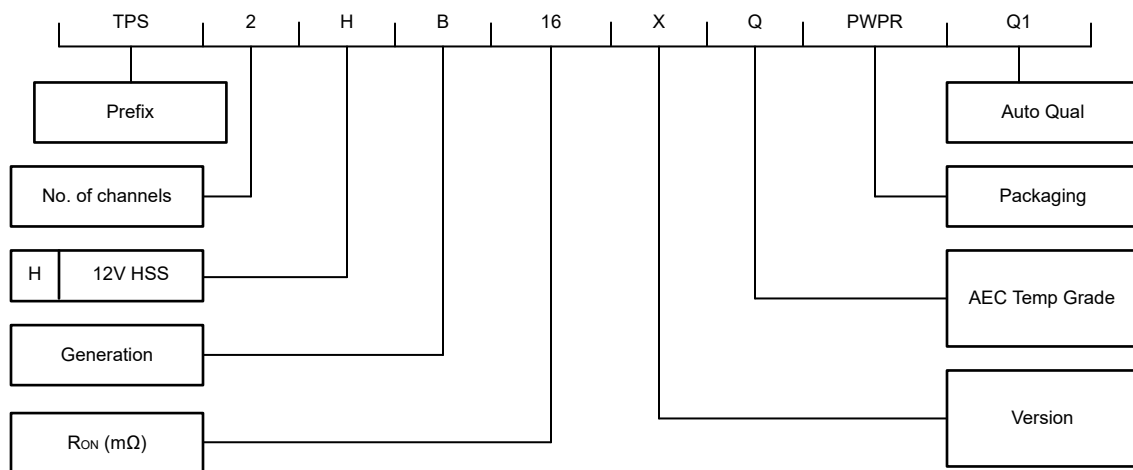
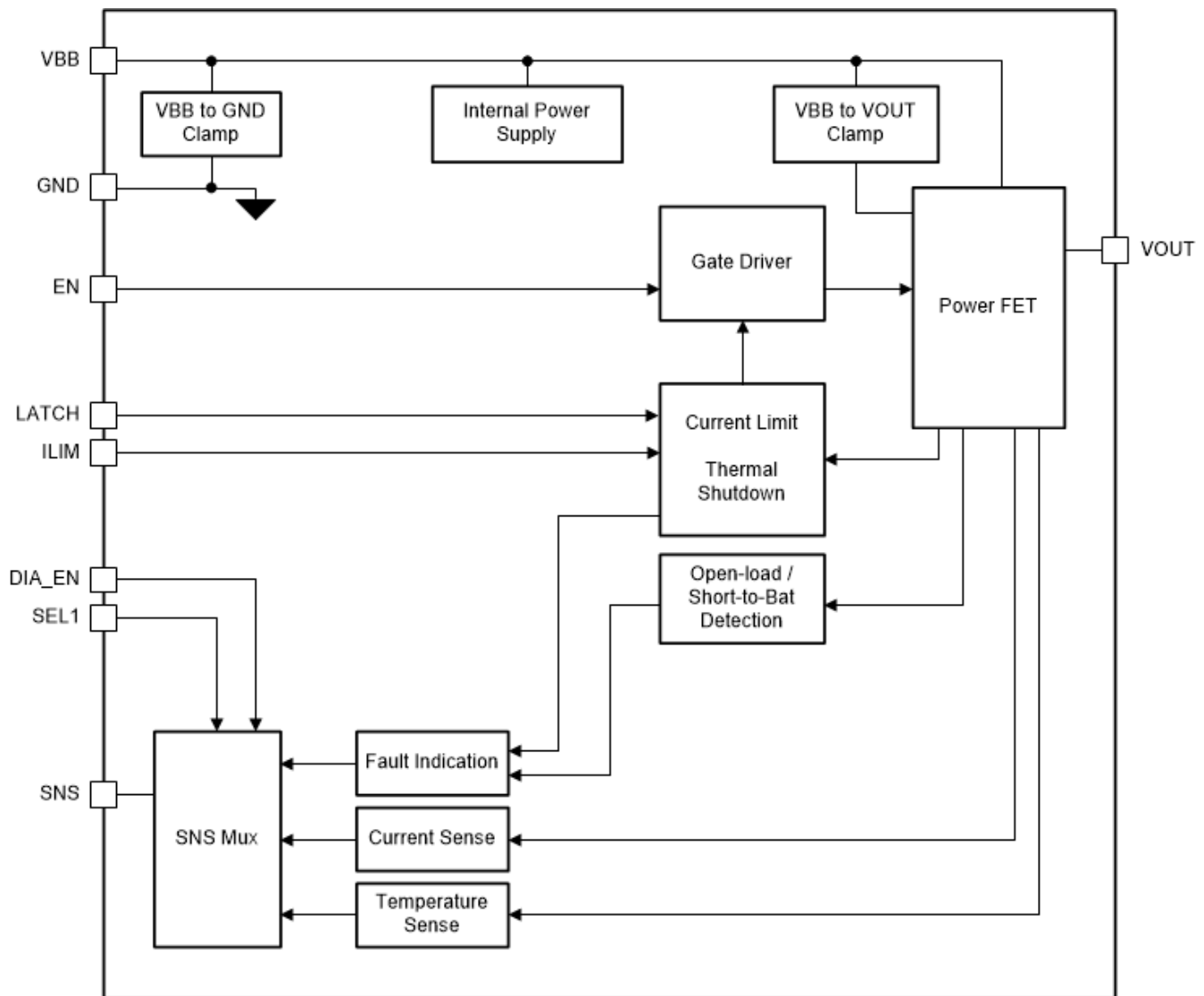


Figure 8-1. Naming Convention

8.2 Functional Block Diagram

The functional block diagram shown is for device versions A, B. For version F, the ILIM pin is replaced by open drain output $\overline{\text{FLT}}$.



8.3 Feature Description

8.3.1 Protection Mechanisms

The TPS1HB08-Q1 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 two protection features which, if triggered, causes the switch to automatically disable:

- Thermal Shutdown
- Current Limit

When any of these protections are triggered, the device enters the FAULT state. In the FAULT state, the fault indication is available on the SNS pin (see the [Diagnostic Mechanisms](#) section of the datasheet for more details). For version F of the device, the fault will also be indicated on the $\overline{\text{FLT}}$ pin.

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)

8.3.1.1 Thermal Shutdown

The TPS1HB08-Q1 includes a temperature sensor on the power FET and also within the controller portion of the device. There are two cases that the device considers to be a thermal shutdown fault:

- $T_{J,FET} > T_{ABS}$
- $(T_{J,FET} - T_{J,controller}) > T_{REL}$

After the fault is detected, the switch turns off. If $T_{J,FET}$ passes T_{ABS} , the fault is cleared when the switch temperature decreases by the hysteresis value, T_{HYS} . If instead the T_{REL} threshold is exceeded, the fault is cleared after T_{RETRY} passes.

8.3.1.2 Current Limit

When I_{OUT} reaches the current limit threshold, I_{CL} , the channel switches off immediately. The I_{CL} value varies with slew rate and a fast current increase that occurs during a powered-on short circuit can temporarily go above the specified I_{CL} value. When the switch is in the FAULT state, it outputs an output current I_{SNSFH} on the SNS pin and on version F of the device, the fault will also be indicated on the corresponding $\overline{FLT}$ pin.

During a short-circuit event, the device hits the I_{CL} value that is listed in the Electrical Characteristics table (for the given device version and R_{ILIM}) and then turn the output off to protect the device. The device registers a short-circuit event when the output current exceeds I_{CL} , however, the measured maximum current can exceed the I_{CL} value due to the TPS1HB08-Q1 deglitch filter and turn-off time. This deglitch time is defined at 3 μ s, so use the test setup described in the [TPS1HB08-Q1 AEC-Q100-012 Short Circuit Reliability](#) section, and take 3 μ s before the peak value as the I_{CL} . The device is assured to protect itself during a short-circuit event over the nominal supply voltage range (as defined in the Electrical Characteristics table) at 125°C.

On version F of the device, the current limit set point of the device is flat from -40°C to 60°C, and then will linearly decrease until 150°C. This decrease of the current limit is designed to protect the part in even hot temperatures where a short-circuit event causes more damage.

8.3.1.2.1 Current Limit Foldback

Version B and F of the TPS1HB08-Q1 implement a current limit fold-back feature that is designed to protect the device in the case of a long-term fault condition. If the device undergoes fault shutdown events (either of thermal shutdown or current limit) seven consecutive times, the current limit reduces to half of the original value. The device reverts to the original current limit threshold if either of the following occurs:

- The device goes to standby mode.
- The switch turns on and turns off without any fault occurring.

Version A do not implement the current limit foldback due to the lower current limit causing less harm during repetitive long-term faults.

8.3.1.2.2 Programmable Current Limit

All versions except F of the TPS1HB08-Q1 include an adjustable current limit. Some applications (for example, incandescent bulbs) will require a high current limit while other applications can benefit from a lower current limit threshold. In general, wherever possible a lower current limit is recommended due to allowing system advantages through:

- Reduced size and cost in current carrying components such as PCB traces and module connectors
- Less disturbance at the power supply (V_{BB} pin) during a short-circuit event
- Improved protection of the downstream load

To set the current limit threshold, connect a resistor from I_{LIM} to V_{BB} . The current limit threshold is determined by [Equation 1](#) (R_{ILIM} in k Ω):

$$I_{CL} = K_{CL} / R_{ILIM} \quad (1)$$

The R_{ILIM} range is between 5k Ω and 25 k Ω . An R_{ILIM} resistor is required, however in the fault case where the pin is floating, grounded, or outside of this range the current limit defaults to an internal level that is defined in the [Specifications](#) section of this document. If R_{ILIM} is out of this range, the device cannot assure complete short-circuit protection.

Note

Capacitance on the I_{LIM} pin can cause I_{LIM} to go out of range during short-circuit events. For accurate current limiting, place R_{ILIM} near to the device with short traces to ensure < 5pF capacitance to GND on the I_{LIM} pin.

For device version F, there is no I_{LIM} pin and the current limit is not adjustable. In this case, the device will current limit at the internal threshold I_{CL} as defined in the [Electrical Characteristics](#) section.

8.3.1.2.3 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 0V at a ramp rate slower than 1V/ms, V_{EN} pin must 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, confirm that V_{BB} has risen above UVLO before setting the V_{EN} pin to high.

8.3.1.2.4 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 decrease is caused by the sudden increase in current flowing through the wiring harness cables. To achieve peak system behavior, TI recommends that the module maintain $V_{BB} > 3V$ (above the maximum V_{UVLOF}) during V_{OUT} short-to-ground. This maintenance is typically accomplished by placing bulk capacitance on the power supply node.

8.3.1.3 Voltage Transients

The TPS1HB08-Q1 device contains two types of voltage clamps which protect the FET against system-level voltage transients. The two different clamps are shown in [Figure 8-2](#).

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. If the voltage potential from V_{BB} to GND exceeds the V_{BB} clamp level, the clamp allows current to flow through the device from V_{BB} to GND (path 2). If the voltage potential from V_{BB} to V_{OUT} exceeds the clamping voltage, the power FET allows current to flow from V_{BB} to V_{OUT} (path 3). Additional capacitance from V_{BB} to GND can increase the reliability of the system during ISO 7637 pulse 2A testing.

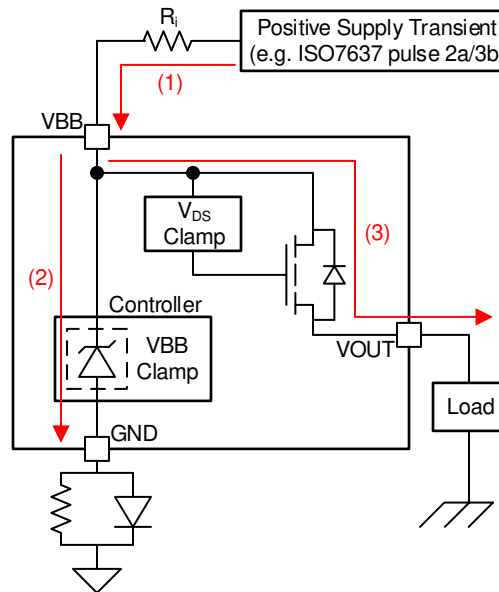


Figure 8-2. Current Path During Supply Voltage Transient

8.3.1.3.1 Load Dump

The TPS1HB08-Q1 device is tested according to ISO 16750-2:2010(E) suppressed load dump pulse. The device supports up to 40V load dump transient and maintains normal operation during the load dump pulse. If the switch is enabled, it stays enabled and if the switch is disabled, it stays disabled.

8.3.1.3.2 Driving Inductive Loads

When switching off an inductive load, the inductor can impose a negative voltage on the output of the switch. The TPS1HB08-Q1 includes a voltage clamp to limit voltage across the FET. The maximum acceptable load inductance is a function of the device robustness. With a 5mH load, the device can withstand one pulse of 95 mJ inductive dissipation at 125°C and can withstand 56 mJ of one million inductive repetitive pulses with a 10Hz 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.

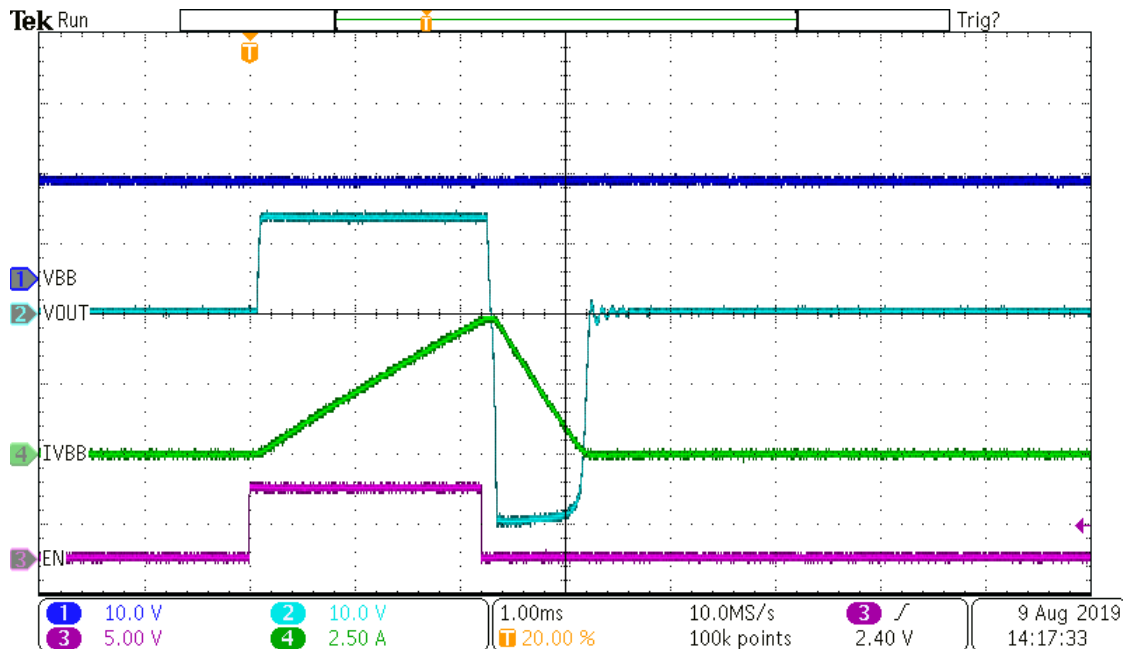


Figure 8-3. TPS1HB08-Q1 Inductive Discharge (5mH)

For more information on driving inductive loads, refer to TI's [How To Drive Inductive, Capacitive, and Lighting Loads With Smart High Side Switches](#) application note.

8.3.1.4 Reverse Battery

In the reverse battery condition, the switch automatically enables regardless of the state of EN to prevent excess power dissipation inside the MOSFET body diode. In many applications (for example, resistive loads), the full load current can be present during reverse battery. To activate the automatic switch on feature, SEL must have a path to ground from either from the MCU or it must be tied to ground through R_{PROT} if unused.

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

Path 1 shown in [Figure 8-4](#) is blocked inside of the device.

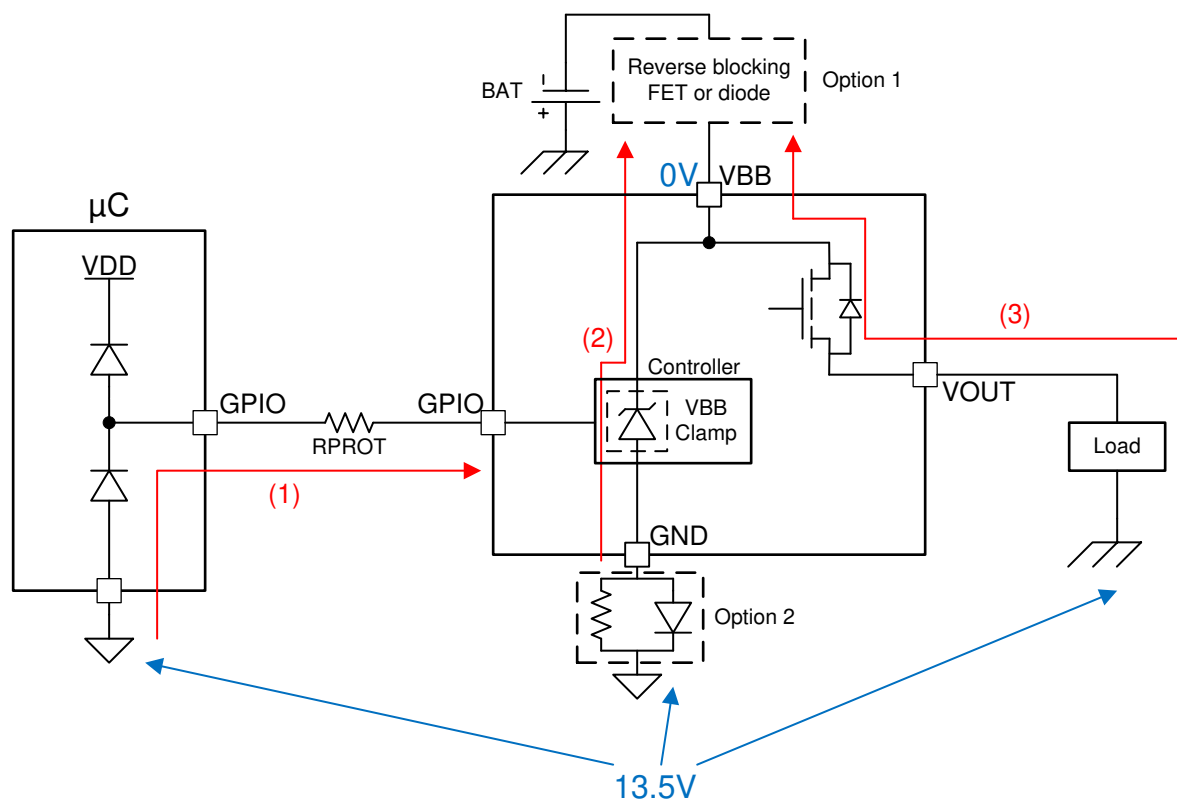


Figure 8-4. Current Path During Reverse Battery

For more information on reverse battery protection, refer to TI's [Reverse Battery Protection for High Side Switches](#) application note.

8.3.1.5 Fault Event – Timing Diagrams - Version A and B

Note

All timing diagrams assume that the SEL1 pin is low.

The LATCH, DIA_EN, and EN pins are controlled by the user. The timing diagrams represent a possible use case.

Figure 8-5 shows the immediate current limit switch off behavior. The diagram also shows the retry behavior. As shown, the switch remains latched off until the LATCH pin is low.

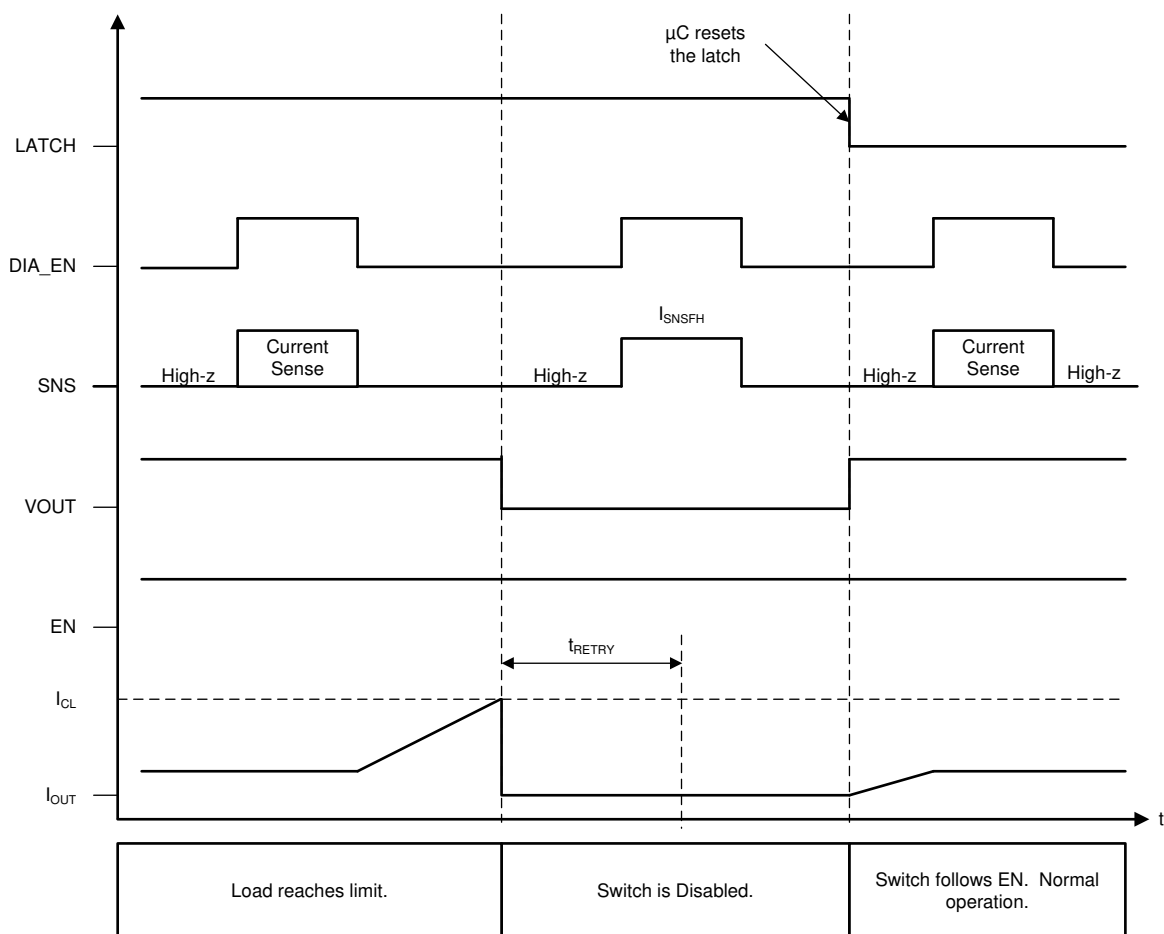


Figure 8-5. Current Limit – Version A and B - Latched Behavior

Figure 8-6 shows the immediate current limit switch off behavior. In this example, LATCH is tied to GND; hence, the switch retries after the fault is cleared and t_{RETRY} has expired.

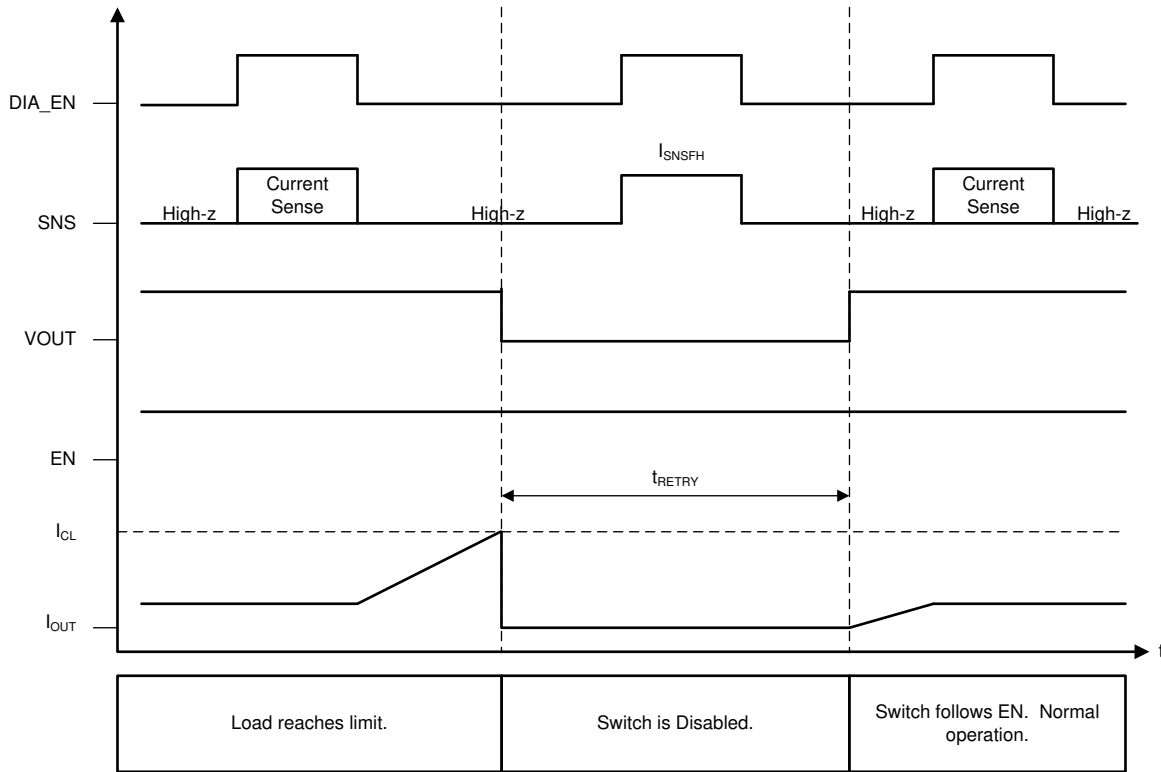


Figure 8-6. Current Limit - Version A and B - LATCH = 0

When the switch retries after a shutdown event, the SNS fault indication remains until V_{OUT} has risen to $V_{BB} - 1.8V$. After V_{OUT} has risen, the SNS fault indication is reset and current sensing is available. If there is a short-to-ground and V_{OUT} is not able to rise, the SNS fault indication remains indefinitely. Figure 8-7 shows auto-retry behavior and provides a zoomed-in view of the fault indication during retry.

Note

Figure 8-7 assumes that t_{RETRY} has expired by the time that T_J reaches the hysteresis threshold.

LATCH = 0V and DIA_EN = 5V

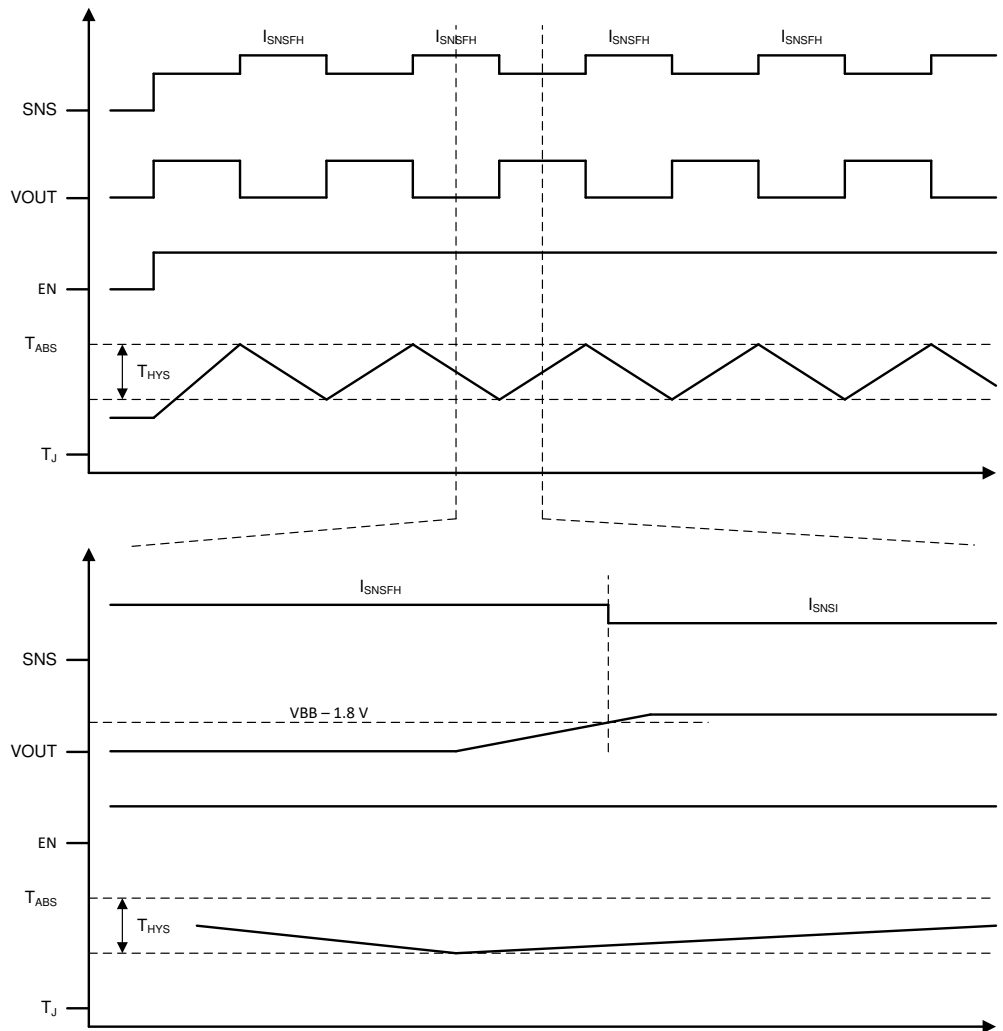


Figure 8-7. Fault Indication During Retry

8.3.1.6 Fault Event – Timing Diagrams - Version F

TPS1HB08-Q1 device version F follows the same timing and fault diagrams as described in [Section 8.3.1.5](#), with the only difference being the behavior of the $\overline{\text{FLT}}$ pin. For each diagram, if version F is used, it indicates fault in the same cases as the SNS pin. In every diagram, when the SNS pin outputs I_{SNSFH} , the $\overline{\text{FLT}}$ pin goes to an open-drain state to indicate fault as well.

8.3.2 Diagnostic Mechanisms

8.3.2.1 VOUT Short-to-Battery and Open-Load

The TPS1HB08-Q1 can detect short-to-battery and open-load events regardless of whether the switch is turned on or off, however the two conditions use different methods.

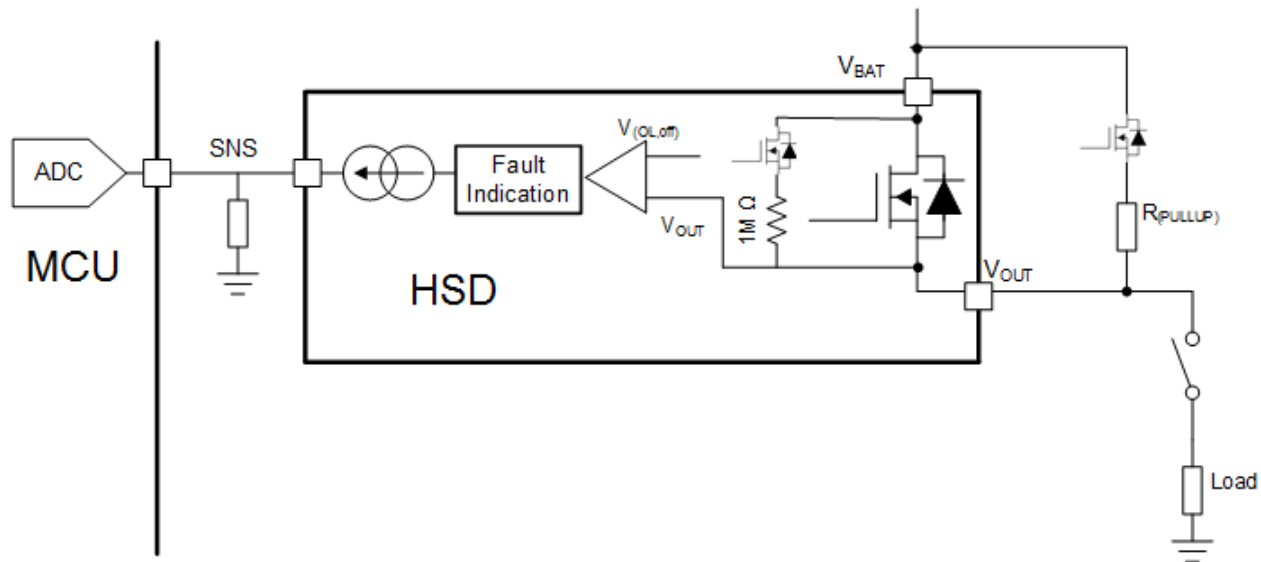
8.3.2.1.1 Detection With Switch Enabled

When the switch is enabled, the VOUT short-to-battery and open-load conditions can be detected by the current sense feature. In both cases, the load current is measured through the SNS pin as below the expected value.

8.3.2.1.2 Detection With Switch Disabled

While the switch is disabled, if DIA_EN is high, an internal comparator detects the condition of V_{OUT} . If the load is disconnected (open load condition) or there is a short to battery the V_{OUT} voltage is higher than the open load threshold ($V_{\text{OL,off}}$) and a fault is indicated on the SNS pin and the $\overline{\text{FLT}}$ pin on version F. An internal pull-up of

1M Ω is in series with an internal MOSFET switch, so no external component is required if a completely open load must 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.



This figure assumes that the device ground and the load ground are at the same potential. In a real system, there can be a ground shift voltage from 1V to 2V.

Figure 8-8. 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 goes to the fault level, but if $V_{OUT} < V_{OL}$ there is no fault indication. The fault indication will only occur if the SEL1 pin is low.

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 greater than V_{OL} to less than 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.

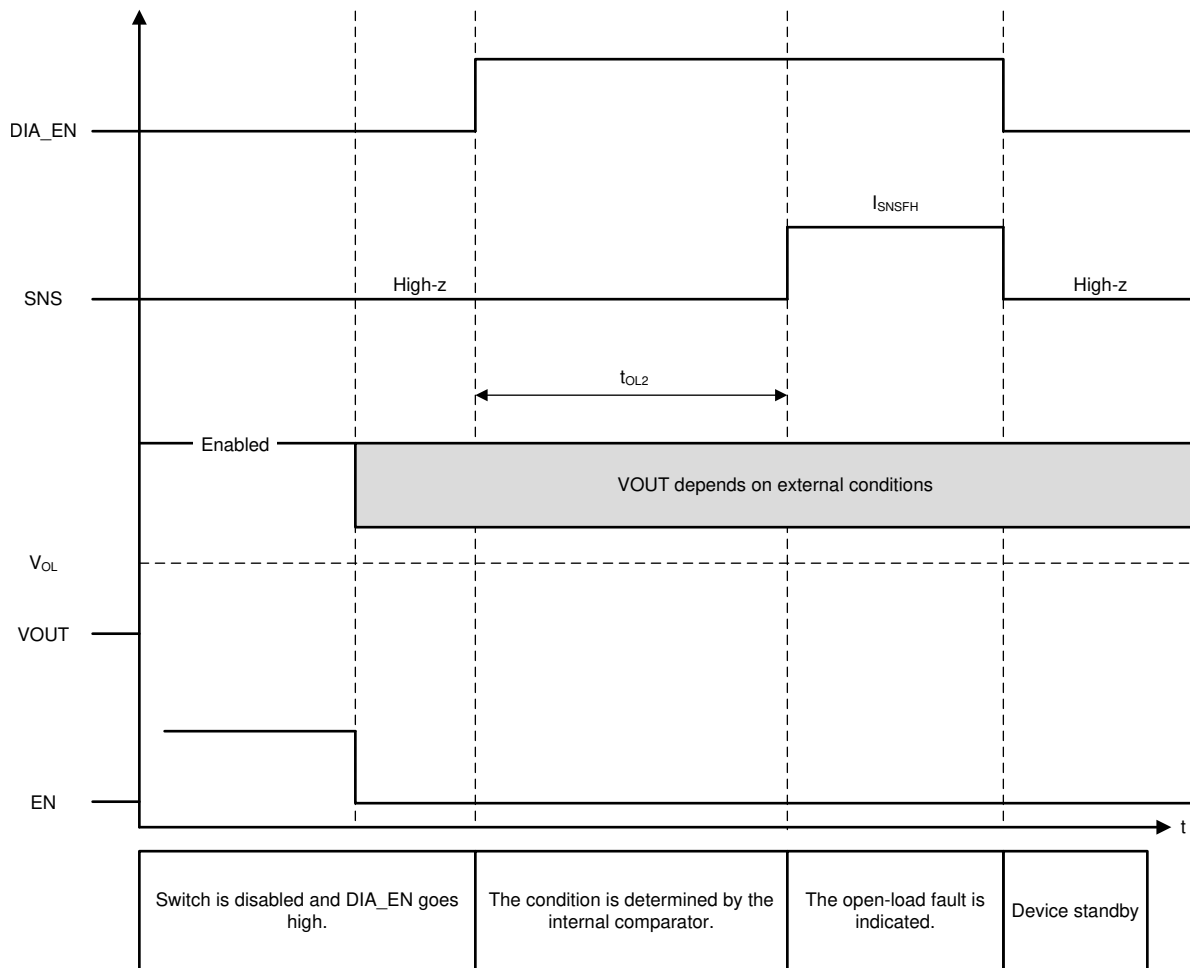


Figure 8-9. Open Load

8.3.2.2 SNS Output

The SNS output can be used to sense the load current if the SEL1 pin is low and there is no fault or device temperature if the SEL1 pin is high and there is no fault. The sense circuit provides a current that is proportional to the selected parameter. This current is sourced into an external resistor to create a voltage that is proportional to the selected parameter. This voltage can be measured by an ADC or comparator. In addition, the SNS pin can be used to measure the FET temperature.

To confirm accurate sensing measurement, the sensing resistor must connect to the same ground potential as the μ C ADC.

Table 8-1. Analog Sense Transfer Function

PARAMETER	TRANSFER FUNCTION
Load current	$I_{SNSI} = I_{OUT} / K_{SNS} = I_{OUT} / 5000$
Device temperature	$I_{SNSST} = (T_J - 25^{\circ}\text{C}) \times dI_{SNSST} / dT + 0.85$

The SNS output will also be used to indicate system faults. I_{SNS} goes to the predefined level, I_{SNSFH} , when there is a fault. I_{SNSFH} , dI_{SNSST}/dT , and K_{SNS} are defined in the [Specifications](#) section.

Device version F does not have the capability to measure device temperature, so can only measure load current.

8.3.2.2.1 R_{SNS} Value

Consider the following factors when selecting the R_{SNS} value:

- Current sense ratio (K_{SNS})
- Largest and smallest diagnosable load current required for application operation
- Full-scale voltage of the ADC
- Resolution of the ADC

For an example of selecting R_{SNS} value, reference [R_{ILIM} Calculation](#) in the applications section of this datasheet.

8.3.2.2.1.1 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 (BCM) must be compatible with both incandescent bulbs and also LED modules. The bulb can be relatively simple to diagnose. However, the LED module consumes less current and also can include multiple LED strings in parallel. The same BCM is used in both cases, so the high-side switch can 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.

8.3.2.2.1.2 SNS Output Filter

To achieve the most accurate current sense value, TI recommends to filter the SNS output. There are two methods of filtering:

- Low-Pass RC filter between the SNS pin and the ADC input. This filter is shown in [Figure 10-1](#) with typical values for the resistor and capacitor. The designer must select a C_{SNS} capacitor value based on system requirements. A larger value provides improved filtering but a smaller value allows for faster transient response.
- The ADC and microcontroller can also be used for filtering. TI recommends that the ADC collects several measurements of the SNS output. The median value of this data set must be considered as the most accurate result. By performing this median calculation, the microcontroller can filter out any noise or outlier data.

8.3.2.3 Fault Indication and SNS Mux

The following faults are communicated through the SNS output:

- Switch shutdown, due to:
 - Thermal shutdown
 - Current limit
- Open-Load and V_{OUT} shorted-to-battery

Open-load and Short-to-battery are not indicated while the switch is enabled, although these conditions can still be detected through the sense current. Hence, if there is a fault indication while the channel is enabled, then it must be either due to an overcurrent or overtemperature event.

The SNS pin will only indicate the fault if the SEL1 pins is low. When the SEL1 pin is high and the device is set to measure temperature, the pin is measuring the channel FET temperature.

For device version F, the $\overline{FLT}$ pin pulls low when the device is in any of these fault states.

Table 8-2. Device Version A/B SNS Mux

INPUTS			OUTPUTS
DIA_EN	SEL1	FAULT DETECT ⁽¹⁾	SNS
0	X	X	High-z
1	0	0	Output current
1	1	0	Device temperature
1	0	1	I _{SNSFH}
1	1	1	Device temperature

(1) Fault Detect encompasses multiple conditions:

- Switch shutdown and waiting for retry
- Open Load and Short To Battery

For device version F, the SEL1 pin has no functionality so the device cannot output a temperature sense current. In this case, SEL1 must be connected to ground through an R_{PROT} resistor and the SNS behavior follows the table below.

Table 8-3. Device Version F SNS Mux

INPUTS			OUTPUTS	
DIA_EN	SEL1	FAULT DETECT ⁽¹⁾	SNS	FLT ⁽²⁾
0	X	X	High-z	High-z
1	X	0	Output current	High-z
1	X	1	I _{SNSFH}	Open-drain

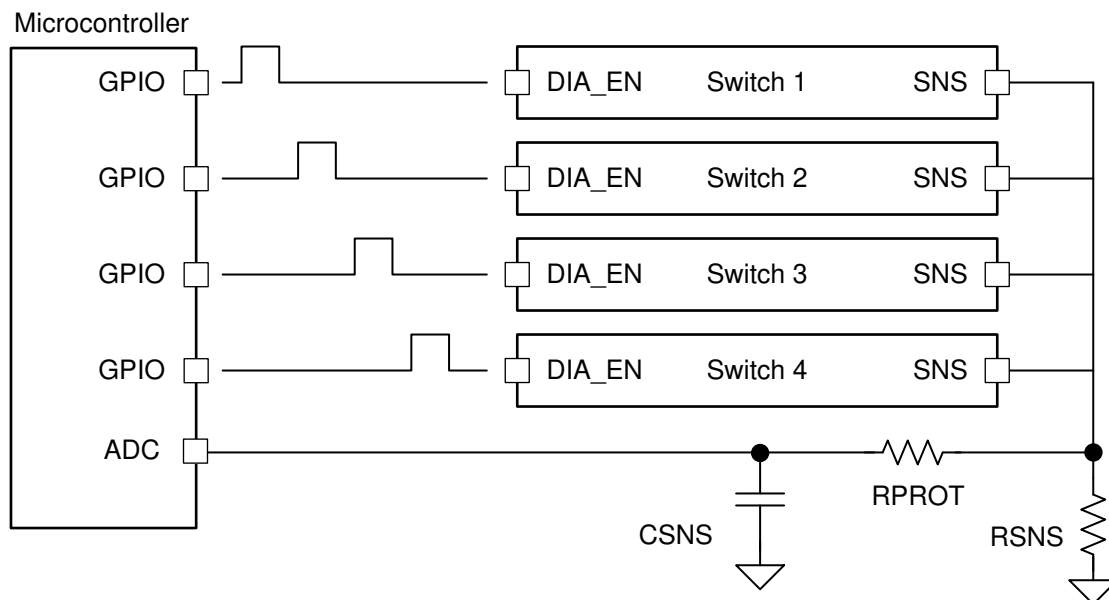
(1) Fault Detect encompasses multiple conditions:

- Switch shutdown and waiting for retry
- Open Load / Short To Battery

(2) Version F Only

8.3.2.4 Resistor Sharing

Multiple high-side devices can use the same SNS resistor as shown in Figure 8-10. This action reduces the total number of passive components in the system and the number of ADC terminals that are required of the microcontroller.

**Figure 8-10. Sharing R_{SNS} Among Multiple Devices**

8.3.2.5 High-Frequency, Low Duty-Cycle Current Sensing

Some applications operate with a high-frequency, low duty-cycle PWM or require fast settling of the SNS output. For example, a 250Hz, 5% duty-cycle PWM has an on-time of only 200µs that must be accommodated. The microcontroller ADC can sample the SNS signal after the defined settling time $t_{SNSION3}$.

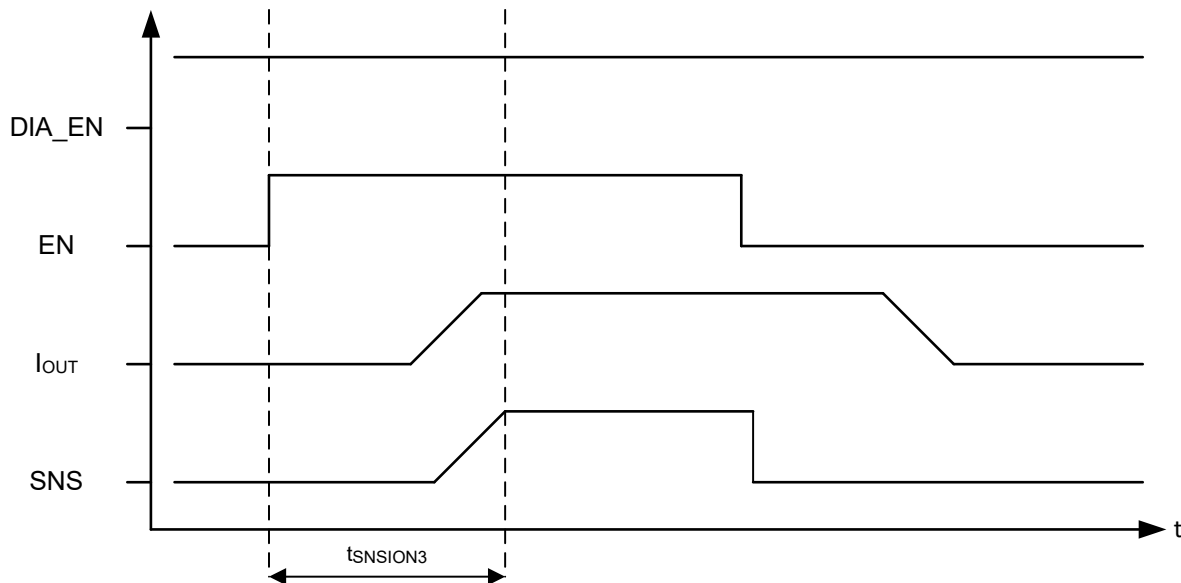


Figure 8-11. Current Sensing in Low-Duty Cycle Applications

8.4 Device Functional Modes

During typical operation, the TPS1HB08-Q1 can operate in several states that are described below and shown as a state diagram in [Figure 8-12](#).

8.4.1 Off

Off state occurs when the device is not powered.

8.4.2 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.

8.4.3 Diagnostic

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

8.4.4 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 goes to Standby State.

8.4.5 Active

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

8.4.6 Fault

The Fault state is entered if a fault shutdown occurs (thermal shutdown or current limit). After all faults are cleared, the LATCH pin is low, and the retry timer has expired, the device transitions out of Fault state. If the EN pin is high, the switch re-enables. If the EN pin is low, the switch remains off.

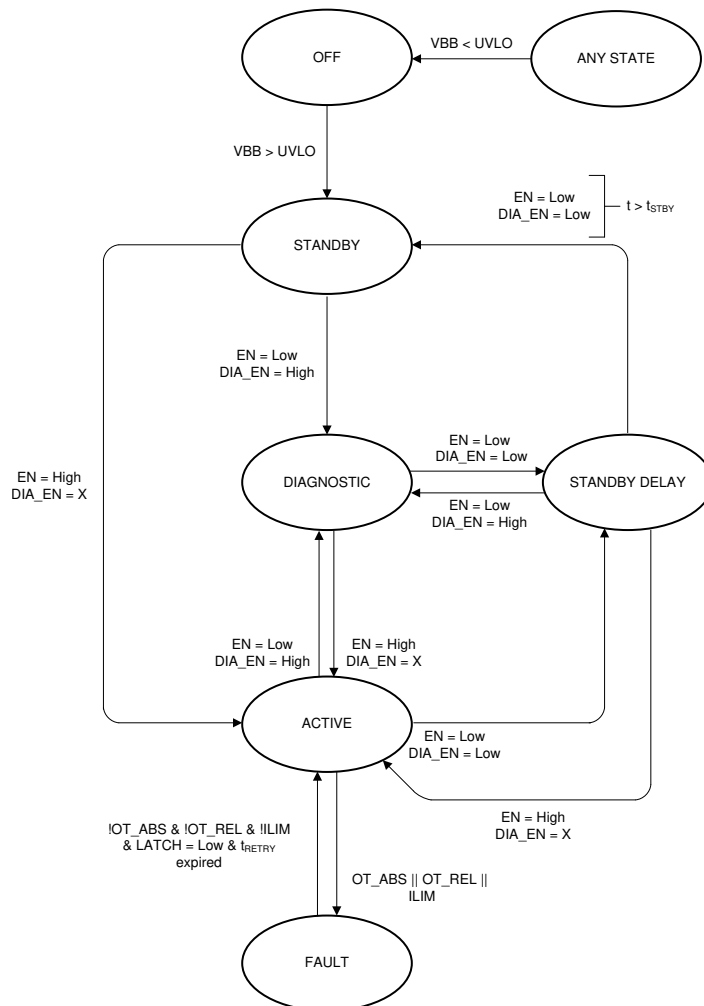


Figure 8-12. State Diagram

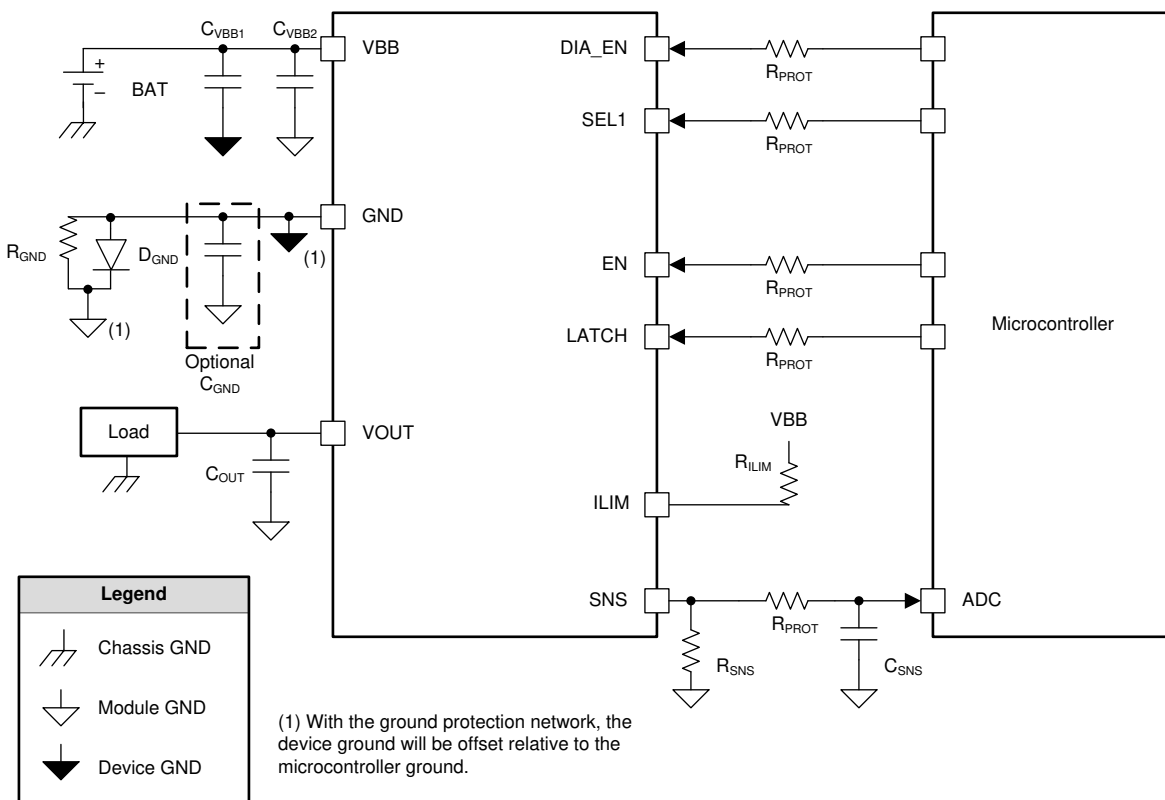
9 Application and Implementation

Note

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

9.1 Application Information

Figure 9-1 shows the schematic of a typical application for version A or B of the TPS1HB08-Q1. It includes all standard external components. This section of the datasheet describes the considerations in implementing commonly required application functionality. Version F of the device replaces the ILIM pin with the open-drain FLT pin. In this case, the FLT pin must connect to a 5V rail through a 10kΩ pullup resistor.



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

Figure 9-1. System Diagram

Table 9-1. Recommended External Components

COMPONENT	TYPICAL VALUE	PURPOSE
R _{PROT}	15kΩ	Protect microcontroller and device I/O pins.
R _{SNS}	1kΩ	Translate the sense current into sense voltage.
C _{SNS}	100pF – 10nF	Low-pass filter for the ADC input.
R _{GND}	4.7kΩ	Stabilize GND potential during turn-off of inductive load.
D _{GND}	BAS21 Diode	Protects device during reverse battery.
R _{ILIM}	5kΩ – 25kΩ	Set current limit threshold.

Table 9-1. Recommended External Components (continued)

COMPONENT	TYPICAL VALUE	PURPOSE
C _{VBB1}	4.7nF to Device GND	Filtering of voltage transients (for example, ESD, ISO7637-2) and improved emissions.
C _{VBB2}	220nF to Module GND	Stabilize the input supply and filter out low-frequency noise.
C _{OUT}	220nF	Filtering of voltage transients (for example, ESD, ISO7637-2).

9.1.1 Ground Protection Network

As discussed in the [Reverse Battery](#) section, D_{GND} can 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}) can be shared amongst multiple high-side switches.

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

$$R_{GND} \geq V_{BB} / I_{GND} \quad (2)$$

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

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

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

$$P_{RGND} = V_{BB}^2 / R_{GND} \quad (3)$$

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

In practice, R_{GND} cannot be rated for such a high power. In this case, a larger resistor value must be selected.

9.1.2 Interface With Microcontroller

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

Logic pin voltage is 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}.

The sense resistor, R_{SNS}, must 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.

9.1.3 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. The SNS pin voltage can exceed the ADC input pin maximum voltage if the fault or saturation current causes a high enough voltage drop across the sense resistor. If that can occur in the design (for example, by switching to a high value R_{SNS} to improve ADC input level), then an appropriate external clamp has to be designed to prevent a high voltage at the SNS output and the ADC input.

9.1.4 Inverse Current

Inverse current occurs when 0V < V_{BB} < V_{OUT}. In this case, current can 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} can be greater than V_{BB}.

The TPS1HB08-Q1 does not detect inverse current. When the switch is enabled, inverse current passes through the switch. When the switch is disabled, inverse current can pass through the MOSFET body diode. The device continues operating in the normal manner during an inverse current event.

9.1.5 Loss of GND

The ground connection can be lost either on the device level or on the module level. If the ground connection is lost, the switch is disabled. If the switch is already disabled when the ground connection is lost, the switch remains disabled. When the ground is reconnected, normal operation resumes.

9.1.6 Automotive Standards

The TPS1HB08-Q1 is designed to be protected against all relevant automotive standards to establish reliable operations when connected to a 12V automotive battery.

9.1.6.1 ISO7637-2

The TPS1HB08-Q1 is tested according to the ISO7637-2:2011 (E) standard. The test pulses are applied both with the switch 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”. See [Table 9-2](#) for ISO7637-2:2011 (E) expected results.

Table 9-2. 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		MINIMUM	MAXIMUM
1	III	–112V	500 pulses	0.5s	—
2a ⁽¹⁾	III	+55V	500 pulses	0.20	5s
2b	IV	+10V	10 pulses	0.5s	5s
3a	IV	–220V	1 hour	90ms	100ms
3b	IV	+150V	1 hour	90ms	100ms

(1) 1 μ F capacitance on C_{VBB} is required for passing level 3 ISO7637 pulse 2A.

9.1.6.2 TPS1HB08-Q1 AEC-Q100-012 Short-Circuit Reliability

The TPS1HB08-Q1 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 conditions and test procedures are summarized in [Table 9-3](#). For further details, refer to the AEC-Q100-012 standard document.

Test conditions:

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

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
- Functional testing is performed on each unit post-stress to verify that the part still operates as expected

The cold repetitive test is run at 85°C which is the worst-case condition for the device to sustain a short circuit. The cold repetitive test refers to the device being given time to cool down between pulses, rather than being run at a cold temperature. The load short circuit is the worst-case situation, because the energy stored in the cable inductance can cause additional harm. The fast response of the device establishes current limiting occurs quickly and at a current close to the load short condition. In addition, the hot repetitive test is performed as well.

Table 9-3. AEC-Q100-012 Test Results

TEST	LOCATION OF SHORT	DEVICE VERSION	NO. OF CYCLES, DURATION	NO. OF UNITS	NO. OF FAILS
Cold Repetitive - Long Pulse	Load Short Circuit, $L_{\text{short}} = 5\mu\text{H}$, $R_{\text{short}} = 50\text{m}\Omega$, $T_A = -40^\circ\text{C}$	F	100k cycles	30	0
Cold Repetitive - Long Pulse - Load Short ⁽¹⁾	Load Short Circuit, $L_{\text{short}} = 5\mu\text{H}$, $R_{\text{short}} = 200\text{m}\Omega$, $T_A = 85^\circ\text{C}$	F	100k cycles	30	0
Cold Repetitive - Long Pulse - Load Short ⁽¹⁾	Load Short Circuit, $L_{\text{short}} = 5\mu\text{H}$, $R_{\text{short}} = 200\text{m}\Omega$, $T_A = -40^\circ\text{C}$	F	100k cycles	30	0
Cold Repetitive - Long Pulse - Terminal Short	Load Short Circuit, $L_{\text{short}} < 1\mu\text{H}$, $R_{\text{short}} < 20\text{m}\Omega$, $T_A = 85^\circ\text{C}$	F	100k cycles	30	0
Hot Repetitive - Long Pulse	Load Short Circuit, $L_{\text{short}} = 5\mu\text{H}$, $R_{\text{short}} = 100\text{m}\Omega$, $T_A = 25^\circ\text{C}$	F	100 hours	30	0

(1) For Cold Repetitive short, 200mΩ R_{short} is used so that the device is at a higher junction temperature before the short-circuit event, increasing the harshness of the test.

9.1.7 Interference on Device Pins

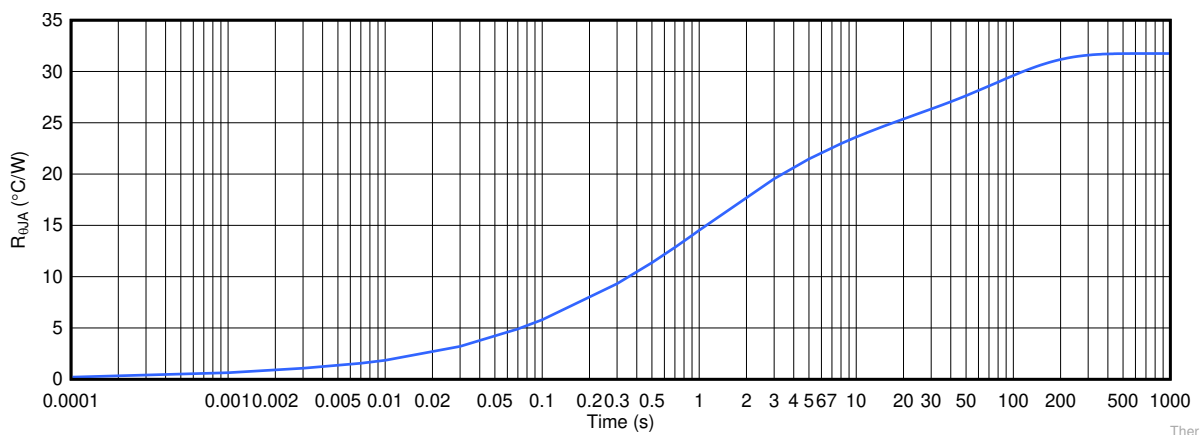
As described in [Section 8.3.1.3.1](#) and [Section 9.1.6](#), the TPS1HB08-Q1 is qualified against standard automotive transient conditions including ISO 7637-2 conducted transient pulses and ISO 16750-2 suppressed load dump. Device behavior under a variety of conditions is documented in the relevant sections.

Beyond the qualified conditions, this device requires stable voltages on all pins unless otherwise specified. Voltage transients, AC noise, or injected RF currents exceeding the levels defined by the above automotive standards — or present on pins not covered by automotive standards — can cause deviation from specified operating parameters or device malfunction, even if the DC voltage level remains within the specified operating range.

During design validation, the board designer must verify that all device pins receive voltages within the specified operating conditions, free from excessive noise or transients beyond the conditions covered by the device specification. If supply noise or injected signals are observed, the board design must be modified to mitigate these effects before production release. Recommended mitigation includes board-level filtering, proper decoupling capacitor placement, and PCB layout techniques to minimize conducted noise between ICs sharing common supply rails.

9.1.8 Thermal Information

When outputting current, the TPS1HB08-Q1 heats up due to the power dissipation. The transient thermal impedance curve can be used to determine the device temperature during a pulse of a given length. This $Z_{\theta JA}$ value corresponds to a JEDEC standard 2s2p thermal test PCB with thermal vias.

**Figure 9-2. TPS1HB08-Q1 Transient Thermal Impedance**

9.2 Typical Application: Resistive Heater Loads

This application example demonstrates how the TPS1HB08-Q1 device can be used to power resistive heater loads in automotive seats. This example considers a heater load that is powered by the device. This is just one example of the many applications where this device can fit.

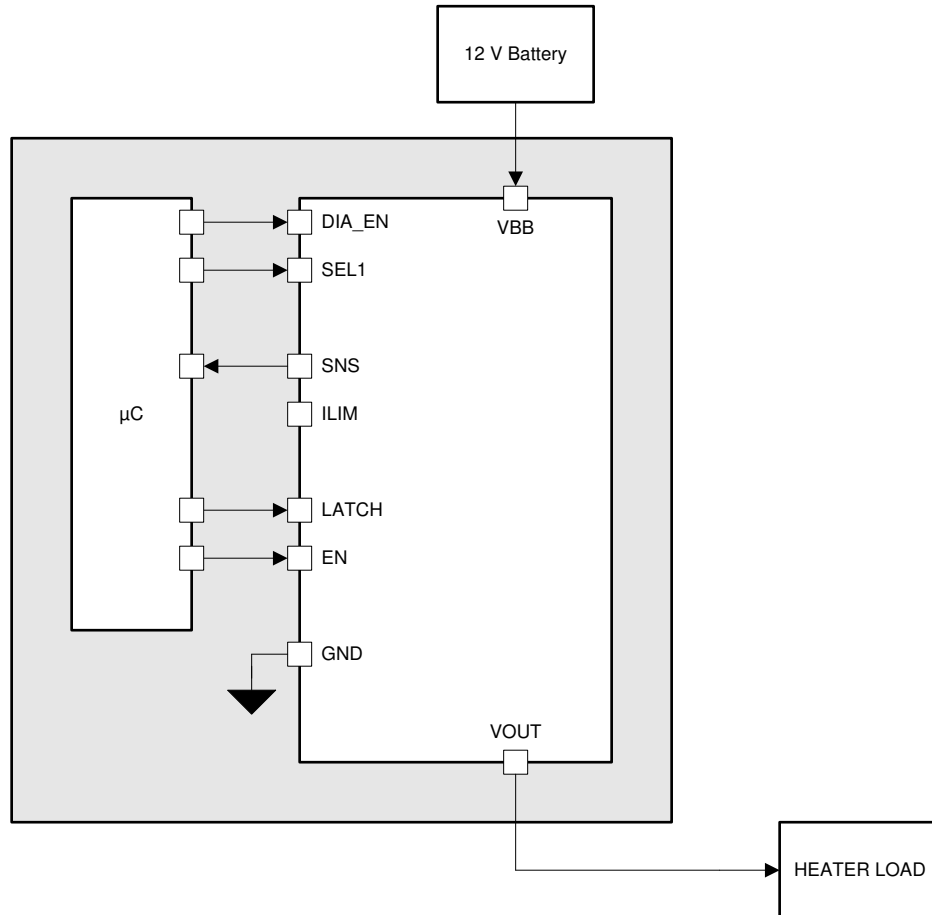


Figure 9-3. Block Diagram for Powering Heater Load

9.2.1 Design Requirements

For this design example, use the input parameters shown in [Table 9-4](#).

Table 9-4. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V _{BB}	13.5V
Load - Heater	130W maximum
Load current sense	100mA to 20A
I _{LIM}	12A
Ambient temperature	70°C
R _{θJA}	32.6°C/W (depending on PCB)
Device version	A

9.2.2 Detailed Design Procedure

9.2.2.1 Thermal Considerations

The 130 W heater load causes a DC current in the channel under maximum load power condition of around 9.6 A. Therefore, this current at 13.5V assumes worst-case heating.

Power dissipation in the switch is calculated in Equation 4. R_{ON} is assumed to be 16 m Ω because this is the maximum specification at high temperature. In practice, R_{ON} is almost always lower.

$$P_{FET} = I^2 \times R_{ON} \quad (4)$$

$$P_{FET} = (9.6A)^2 \times 16m\Omega = 1.47W \quad (5)$$

This means that the maximum FET power dissipation is 1.47 W. The junction temperature of the device can be calculated using Equation 6 and the $R_{\theta JA}$ value from the [Specifications](#) section.

$$T_J = T_A + R_{\theta JA} \times P_{FET} \quad (6)$$

$$T_J = 70^\circ C + 32.6^\circ C/W \times 1.47W = 117.9^\circ C$$

The maximum junction temperature rating for the TPS1HB08-Q1 is $T_J = 150^\circ C$. Based on the above example calculation, the device temperature stays below the maximum rating even at this high level of current.

9.2.2.2 R_{ILIM} Calculation

In this application, the TPS1HB08-Q1 must allow for the maximum DC current with margin but minimize the energy in the switch during a fault condition by minimizing the current limit. For this application, the best I_{LIM} set point is approximately 12A. Equation 7 allows the user to calculate the R_{ILIM} value that is placed from the I_{LIM} pins to V_{BB} . R_{ILIM} is calculated in k Ω .

$$R_{ILIM} = K_{CL} / I_{CL} \quad (7)$$

Because this device is version A, the K_{CL} value in the [Specifications](#) section is 160 A $\times$ k Ω .

$$R_{ILIM} = 160 (A \times k\Omega) / 12A = 13.3k\Omega \quad (8)$$

For a I_{LIM} of 12A, set the R_{ILIM} value at around 13.3k Ω .

9.2.2.3 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 with the current sense feature of the TPS1HB08-Q1 device. Under open load condition, the current in the SNS pin is the fault current and the can be detected from the sense voltage measurement.

9.2.2.3.1 Selecting the R_{SNS} Value

Table 9-5 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.

Table 9-5. R_{SNS} Calculation Parameters

PARAMETER	EXAMPLE VALUE
Current Sense Ratio (K_{SNS})	5000
Largest diagnosable load current	20A
Smallest diagnosable load current	100mA
Full-scale ADC voltage	5V
ADC resolution	10 bit

The load current measurement requirements of 20A confirms that even in the event of a overcurrent surpassing the set current limit, the MCU can register and react by shutting down the TPS1HB08-Q1, while the low level of 100mA allows for accurate measurement of low load currents.

The R_{SNS} resistor value must be selected such that the largest diagnosable load current puts V_{SNS} at about 95% of the ADC full-scale. With this design, any ADC value above 95% can be considered a fault. Additionally, the R_{SNS} resistor value must establish that the smallest diagnosable load current does not cause V_{SNS} to fall below 1LSB of the ADC. With the given example values, a 1.2k Ω sense resistor satisfies both requirements shown in Table 9-6.

Table 9-6. V_{SNS} Calculation

LOAD (A)	SENSE RATIO	I_{SNS} (mA)	R_{SNS} (Ω)	V_{SNS} (V)	% of 5V ADC
0.1	5000	0.02	1200	0.024	0.5%
20	5000	4	1200	4.800	96.0%

9.3 Typical Application: Headlight Bulb Loads

This application example demonstrates how the TPS1HB08-Q1 device can be used to power bulb loads in automotive headlights. In this example, consider a 65W bulb that is powered by the device. This example is just one example of the many applications where this device can fit.

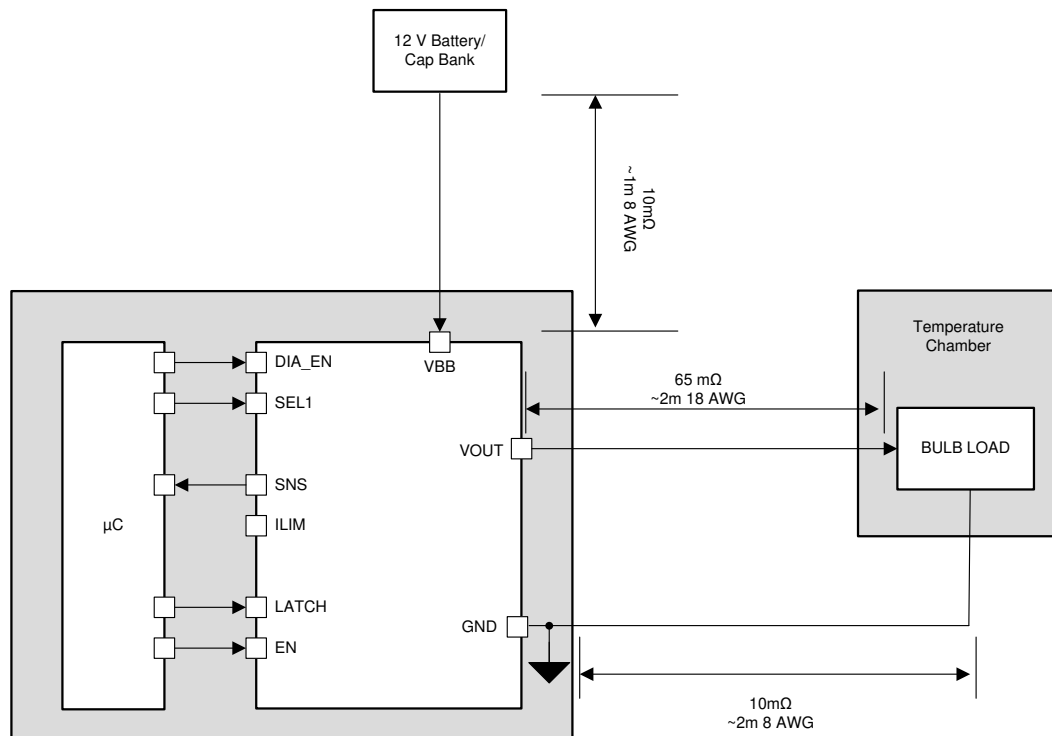


Figure 9-4. Block Diagram for Driving Bulb Load

9.3.1 Design Requirements

For this design example, use the input parameters shown in Table 9-7.

Table 9-7. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{BB}	16V
Load - Bulb	65W maximum
Fixed I_{LIM}	94 A

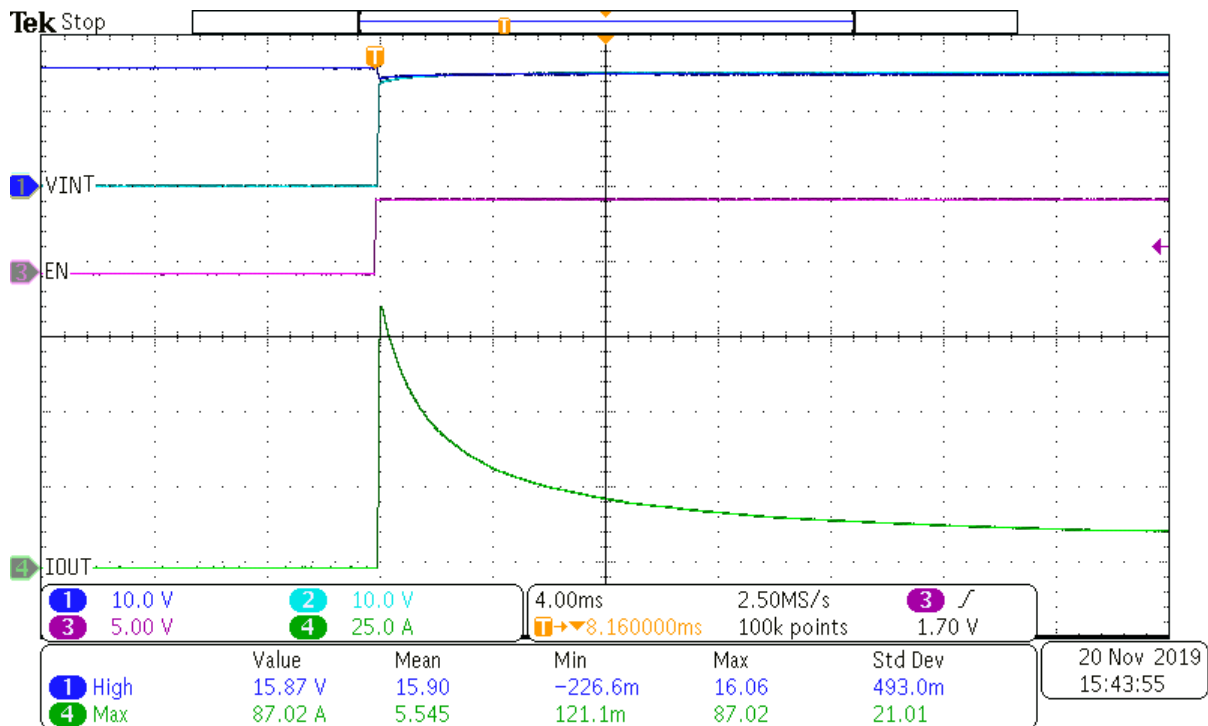
Table 9-7. Design Parameters (continued)

DESIGN PARAMETER	EXAMPLE VALUE
Ambient temperature	25°C
Bulb temperature in chamber	–40°C
Cable impedance from device to bulb	65mΩ
Device version	F

9.3.2 Detailed Design Procedure

The typical bulb test setup is where the device is at 25°C and the bulb is in a temperature chamber at –40°C. The bulb must be kept at –40°C so that the impedance is very low and the inrush current is the highest. The impedance of the cables is important because it changes the inrush current of the bulb as well. The F version of the TPS1HB08-Q1 has a very high fixed current limit so that the inrush current of the bulb can be passed without limitation.

9.3.3 Application Curves

**Figure 9-5. TPS1HB08-Q1 Version F 65W Bulb Inrush Current**

9.4 Power Supply Recommendations

The TPS1HB08-Q1 device is designed to operate in a 12V automotive system. The nominal supply voltage range is from 6V to 18V as measured at the V_{BB} pin with respect to the GND pin of the device. In this range the device meets full parametric specifications as listed in the [Electrical Characteristics](#) table. The device is also designed to withstand voltage transients beyond this range. When operating outside of the nominal voltage range but within the operating voltage range, the device exhibits normal functional behavior. However, parametric specifications cannot be specified outside the nominal supply voltage range.

Table 9-8. Operating Voltage Range

V_{BB} VOLTAGE RANGE	NOTE
3V to 6V	Transients such as cold crank and start-stop, functional operation are specified but some parametric specifications cannot apply. The device is completely short-circuit protected up to 125°C.

Table 9-8. Operating Voltage Range (continued)

V _{BB} VOLTAGE RANGE	NOTE
6V to 18V	Nominal supply voltage, all parametric specifications apply. The device is completely short-circuit protected up to 125°C.
18V to 40V	Transients such as jump start and load-dump, functional operation specified but some parametric specifications cannot apply.

9.5 Layout

9.5.1 Layout Guidelines

To achieve peak thermal performance, connect the exposed pad to a large copper pour. On the top PCB layer, the pour can extend beyond the package dimensions as shown in the example below. In addition to this, TI recommends to also have a V_{BB} plane either on one of the internal PCB layers or on the bottom layer.

Vias must connect this plane to the top V_{BB} pour.

Confirm that all external components are placed close to the pins. Device current limiting performance can be harmed if the R_{ILIM} is far from the pins and extra parasitics are introduced.

9.5.2 Layout Example

The layout example is for device versions A/B. For device version F, the ILIM pin is replaced by the FLT pin.

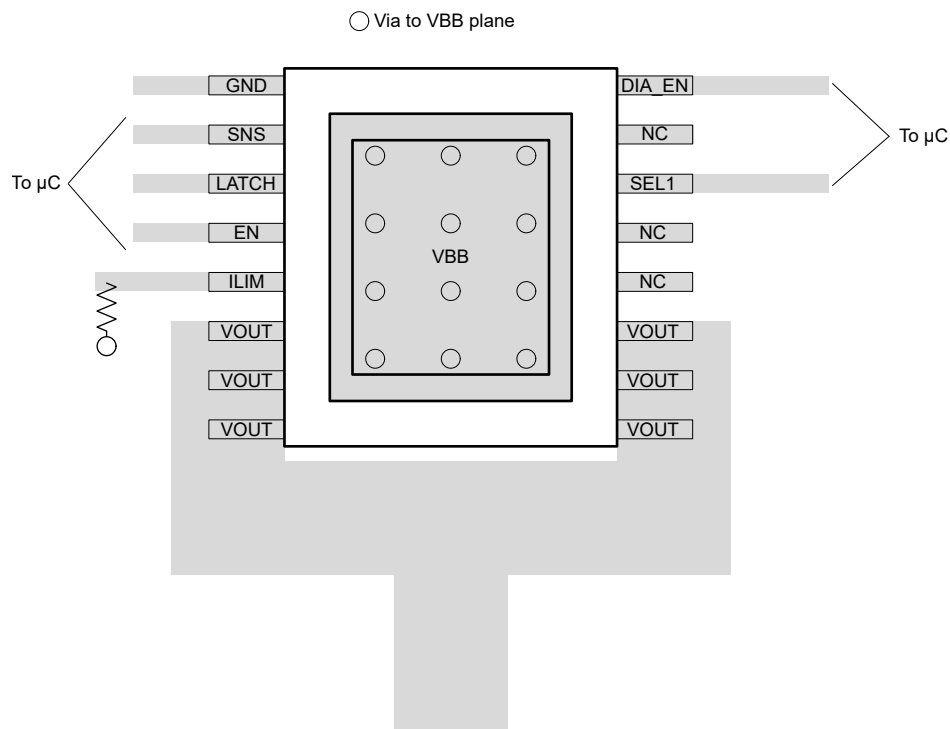


Figure 9-6. 16-PWP Layout Example

10 Device and Documentation Support

10.1 Documentation Support

10.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [How To Drive Inductive, Capacitive, and Lighting Loads with Smart High Side Switches application note](#)
- Texas Instruments, [Short-Circuit Reliability Test for Smart Power Switch application note](#)
- Texas Instruments, [Reverse Battery Protection for High Side Switches application note](#)
- Texas Instruments, [Adjustable Current Limit of Smart Power Switches application note](#)

10.2 Receiving Notification of Documentation Updates

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

10.3 Support Resources

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

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10.4 Trademarks

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10.5 Electrostatic Discharge Caution



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

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

10.6 Glossary

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

11 Revision History

Changes from Revision C (January 2020) to Revision D (August 2026)	Page
• Updated the numbering format for tables, figures and cross-references throughout the document.....	1
• Updated the title to include Automotive wording.....	1
• Updated Recommended Operating Conditions to separate V_{BB} extended lower and higher supply voltage....	6
• Updated Electrical Characteristics.....	7
• Updated Figure 7-1	17
• Updated note below Figure 7-3	17
• Added note to Table 8-2 and Table 8-3	31
• Added Interference on Device Pins section.....	38
• Updated Typical Applications section title to specify Resistive Heater Loads.....	39
• Updated Typical Applications title to specify Headlight Bulb Loads.....	41

Changes from Revision B (December 2019) to Revision C (January 2020)

Page

- Deleted table note from the [Device Comparison Table](#) to remove product preview from Versions A and B.....**3**
-

12 Mechanical, Packaging, and Orderable Information

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

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