TPS3870-Q1 Overvoltage Reset IC With Time Delay and Manual Reset

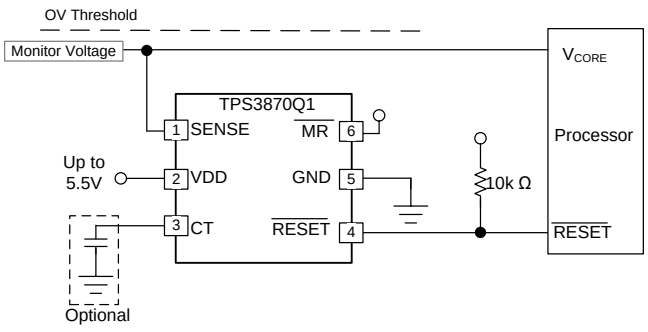
1 Features

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: –40°C to +125°C ambient operating temperature
  - Device HBM ESD classification level 2
  - Device CDM ESD classification level C7B
- Input voltage range: 1.7 V to 5.5 V
- Undervoltage lockout (UVLO): 1.7 V
- Low quiescent current: 7 µA (Max)
- High threshold accuracy:
  - ± 0.25% (typical)
  - ± 0.7% (–40°C to +125°C)
- Fixed threshold levels
  - 50-mV steps from 500 mV to 1.3 V
  - 1.5 V, 1.8 V, 2.5 V, 2.8 V, 2.9 V 3.3 V, 5 V
- User adjustable voltage threshold levels
- Internal glitch immunity and hysteresis
- Tolerance available from 3% to 7% in 1% steps
- Fixed time delay options: 50 µs, 1 ms, 5 ms, 10 ms, 20 ms, 100 ms, 200 ms
- Programmable time delay option with a single external capacitor
- Open-drain active low OV monitor
- $\overline{\text{RESET}}$ voltage latching output mode

2 Applications

- Advanced driver assistance system (ADAS)
- Camera
- Sensor fusion
- HEV/EV
- FPGA, ASIC and DSP based systems

Integrated Overvoltage Detection



3 Description

The TPS3870-Q1 device is an integrated overvoltage (OV) monitor or reset IC in industry's smallest 6-pin DSE package. This highly accurate voltage supervisor is ideal for systems that operate on low-voltage supply rails and have narrow margin supply tolerances. Low threshold hysteresis prevent false reset signals when the monitored voltage supply is in its normal range of operation. Internal glitch immunity and noise filters further eliminate false resets resulting from erroneous signals.

The TPS3870-Q1 does not require any external resistors for setting overvoltage reset thresholds, which further optimizes overall accuracy, cost, solution size, and improves reliability for safety systems. The Capacitor Time (CT) pin is used to select between the two available reset time delays designed into each device and also to adjust the reset time delay by connecting a capacitor. A separate SENSE input pin and VDD pin allow for the redundancy sought by high-reliability systems.

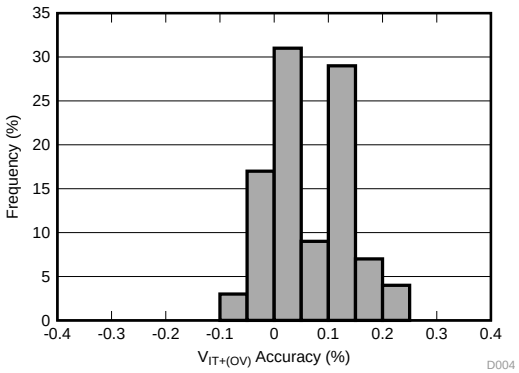
This device has a low typical quiescent current specification of 4.5 µA (typical). The TPS3870-Q1 is suitable for automotive applications and is qualified for AEC-Q100 Grade 1.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS3870-Q1	WSON (6)	1.50 mm × 1.50 mm

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

Typical Overvoltage Accuracy Distribution



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4 Revision History

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

Changes from Original (July 2019) to Revision A	Page
• Advance Information to Production Data release	1

5 Device Comparison Table

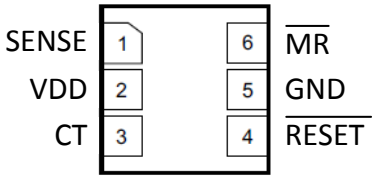
Table 1 shows the released versions of the TPS3870-Q1, including the nominal overvoltage thresholds. For all possible voltages, threshold tolerance, time delays, and threshold options, see Table 6. Contact TI sales representatives or on TI's E2E forum for details and availability of other options; minimum order quantities apply.

Table 1. Device Comparison Table

PART NUMBER	V_{MON}	TIME DELAY (ms)			THRESHOLD TOLERANCE
		CT Pin = Capacitor	CT Pin = Open	CT Pin = VDD	
TPS3870J4080DSERQ1	0.80 V	Programmable	10 ms	200 ms	4%
TPS3870J4330DSERQ1	3.30 V	Programmable	10 ms	200 ms	4%

6 Pin Configuration and Functions

DSE Package
6-Pin WSON
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	SENSE	I	Input for the monitored supply voltage rail. When the SENSE voltage goes above the overvoltage threshold, the $\overline{\text{RESET}}$ pin is driven low. Connect to VDD pin if monitoring VDD supply voltage.
2	VDD	I	Supply voltage input pin. Good analog design practice is to place a 0.1-µF ceramic capacitor close to this pin.
3	CT	I	Capacitor time delay pin. The CT pin offers two fixed time delays by connecting CT pin to VDD or leaving it floating. Delay time can be programmed by connecting an external capacitor reference to ground.
4	$\overline{\text{RESET}}$	O	Active-low, open-drain output. This pin goes low when the SENSE voltage rises above the internally overvoltage threshold (V_{IT+}). See the timing diagram in Figure 19 for more details. Connect this pin to a pull-up resistor terminated to the desired pull-up voltage.
5	GND	—	Ground
6	$\overline{\text{MR}}$	I	Manual reset (MR), pull this pin to a logic low ($V_{\overline{MR}\_L}$) to assert a reset signal . After the $\overline{\text{MR}}$ pin is deasserted the output goes high after the reset delay time(t_D) expires. $\overline{\text{MR}}$ can be left floating when not in use.

7 Specifications

7.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Voltage	V_{DD}	–0.3	6	V
Voltage	$V_{\overline{RESET}}$	–0.3	6	V
Voltage	V_{CT}	–0.3	6	V
Voltage	V_{SENSE}	–0.3	6	V
Voltage	$V_{\overline{MR}}$	–0.3	6	V
Current	$I_{\overline{RESET}}$		±40	mA
Temperature (2)	Continuous total power dissipation	See the Thermal Information		
	Operating junction temperature, T_J	-40	150	°C
	Operating free-air temperature, T_A	-40	150	°C
	Storage temperature, T_{stg}	-65	150	°C

(1) Stresses beyond values 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) As a result of the low dissipated power in this device, it is assumed that $T_J = T_A$.

7.2 ESD ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)		±2000	V
		Charged-device model (CDM), per AEC Q100-011	All pins	±500	
			Corner pins	±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

		MIN	NOM	MAX	UNIT
V_{DD}	Supply pin voltage	1.7		5.5	V
V_{SENSE}	Input pin voltage	0		5.5	V
V_{CT}	CT pin voltage (1) (2)			V_{DD}	V
$V_{\overline{RESET}}$	Output pin voltage	0		5.5	V
$V_{\overline{MR}}$	$\overline{MR}$ pin Voltage (3)	0		5.5	V
$I_{\overline{RESET}}$	Output pin current	0.3		10	mA
T_J	Junction temperature (free-air temperature)	-40		125	℃

(1) CT pin connected to VDD pin requires a pullup resistor; 10 kΩ is recommended.
(2) The maximum rating is V_{DD} or 5.5 V, whichever is smaller.
(3) If the logic signal driving $\overline{MR}$ is less than V_{DD}, then additional current flows into V_{DD} and out of $\overline{MR}$.

7.4 Thermal Information

THERMAL METRIC[1]		TPS3870-Q1 DSE (WSON) PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	184.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	30.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	86.4	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	13.4	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	86.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

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

7.5 Electrical Characteristics

At 1.7 V ≤ V_{DD} ≤ 5.5 V, CT = $\overline{MR}$ = Open, $\overline{RESET}$ Voltage ($V_{\overline{RESET}}$) = 10 kΩ to V_{DD}, $\overline{RESET}$ load = 10 pF, and over the operating free-air temperature range of – 40°C to 125°C, unless otherwise noted. Typical values are at T_J = 25°C, typical conditions at V_{DD} = 3.3 V.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{DD}	Supply Voltage		1.7		5.5	V
UVLO	Under Voltage Lockout[1]	V_{DD} falling below 1.7 V	1.2		1.7	V
V_{POR}	Power on reset voltage[2]	V_{OL}(max) = 0.25 V, I_{OUT} = 15 µA			1	V
$V_{IT+(OV)}$	Positive- going threshold accuracy		-0.7	±0.25	0.7	%
V_{HYS}	Hysteresis Voltage[3]		0.3	0.55	0.8	%
I_{DD}	Supply current	V_{DD} ≤ 5.5 V		4.5	7	µA
I_{SENSE}	Input current, SENSE pin	V_{SENSE} = 5 V		1	1.5	µA
V_{OL}	Low level output voltage	V_{DD} = 1.7 V, I_{OUT} = 0.4 mA			250	mV
		V_{DD} = 2 V, I_{OUT} = 3 mA			250	mV
		V_{DD} = 5 V, I_{OUT} = 5 mA			250	mV
I_{LKG}	Open drain output leakage current	V_{DD} = $V_{\overline{RESET}}$ = 5.5 V			300	nA
$V_{\overline{MR}\_L}$	$\overline{MR}$ logic low input				0.3	V
$V_{\overline{MR}\_H}$	$\overline{MR}$ logic high input		1.4			V
V_{CT_H}	High level CT pin voltage		1.4			V
$R_{\overline{MR}}$	Manual reset Internal pullup resistance			100		KΩ
I_{CT}	CT pin charge current		337	375	413	nA
V_{CT}	CT pin comparator threshold voltage[4]		1.133	1.15	1.167	V

(1) $\overline{RESET}$ pin is driven low when V_{DD} falls below UVLO.
(2) V_{POR} is the minimum V_{DD} voltage level for a controlled output state.
(3) Hysteresis is with respect of the trip point ($V_{IT+(OV)}$)
(4) V_{CT} voltage refers to the comparator threshold voltage that measures the voltage level of the external capacitor at CT pin.

7.6 Timing Requirements

At 1.7 V ≤ V_{DD} ≤ 5.5 V, CT = $\overline{MR}$ = Open, $\overline{RESET}$ Voltage ($V_{\overline{RESET}}$) = 10 kΩ to V_{DD}, $\overline{RESET}$ load = 10 pF, and over the operating free-air temperature range of – 40°C to 125°C, unless otherwise noted. Typical values are at T_J = 25°C, typical conditions at V_{DD} = 3.3 V.

			MIN	NOM	MAX	UNIT
t_D	Reset time delay, TPS3870J	CT = Open	7	10	13	ms
t_D	Reset time delay, TPS3870J	CT = 10 kΩ to V_{DD}	140	200	260	ms
t_D	Reset time delay, TPS3870K	CT = Open	0.7	1	1.3	ms
t_D	Reset time delay, TPS3870K	CT = 10 kΩ to V_{DD}	14	20	26	ms
t_D	Reset time delay, TPS3870L	CT = Open	3.5	5	6.5	ms
t_D	Reset time delay, TPS3870L	CT = 10 kΩ to V_{DD}	70	100	130	ms

Timing Requirements (continued)

At 1.7 V ≤ V_{DD} ≤ 5.5 V, CT = $\overline{MR}$ = Open, $\overline{RESET}$ Voltage ($V_{\overline{RESET}}$) = 10 kΩ to V_{DD}, $\overline{RESET}$ load = 10 pF, and over the operating free-air temperature range of – 40°C to 125°C, unless otherwise noted. Typical values are at T_J = 25°C, typical conditions at V_{DD} = 3.3 V.

			MIN	NOM	MAX	UNIT
t_D	Reset time delay, TPS3870M	CT = 10 kΩ to V_{DD} CT = Open		50		µs
t_{PD}	Propagation detect delay(1)(2)			15	30	µs
t_R	Output rise time(1)(3)			2.2		µs
t_F	Output fall time(1)(3)			0.2		µs
t_{SD}	Startup delay(4)			300		µs
$t_{GI\ (VIT+)}$	Glitch Immunity overvoltage $V_{IT+(OV)}$, 5% Overdrive(1)			3.5		µs
$t_{GI\ (\overline{MR})}$	Glitch Immunity $\overline{MR}$ pin				25	ns
$t_{PD\ (\overline{MR})}$	Propagation delay from $\overline{MR}$ low to assert $\overline{RESET}$			500		ns
$t_{\overline{MR}\_W}$	$\overline{MR}$ pin pulse width duration to assert $\overline{RESET}$		1			µs
$t_{D\ (\overline{MR})}$	$\overline{MR}$ reset time delay			t_D		ms

(1) 5% Overdrive from threshold. Overdrive % = [V_{SENSE} - $V_{IT+(OV)}$] / $V_{IT+(OV)}$
(2) t_{PD} measured from threshold trip point $V_{IT+(OV)}$ to $\overline{RESET}$ V_{OL} voltage
(3) Output transitions from V_{OL} to 90% for rise times and 90% to V_{OL} for fall times.
(4) During the power-on sequence, V_{DD} must be at or above $V_{DD\ (MIN)}$ for at least t_{SD} + t_D before the output is in the correct state.

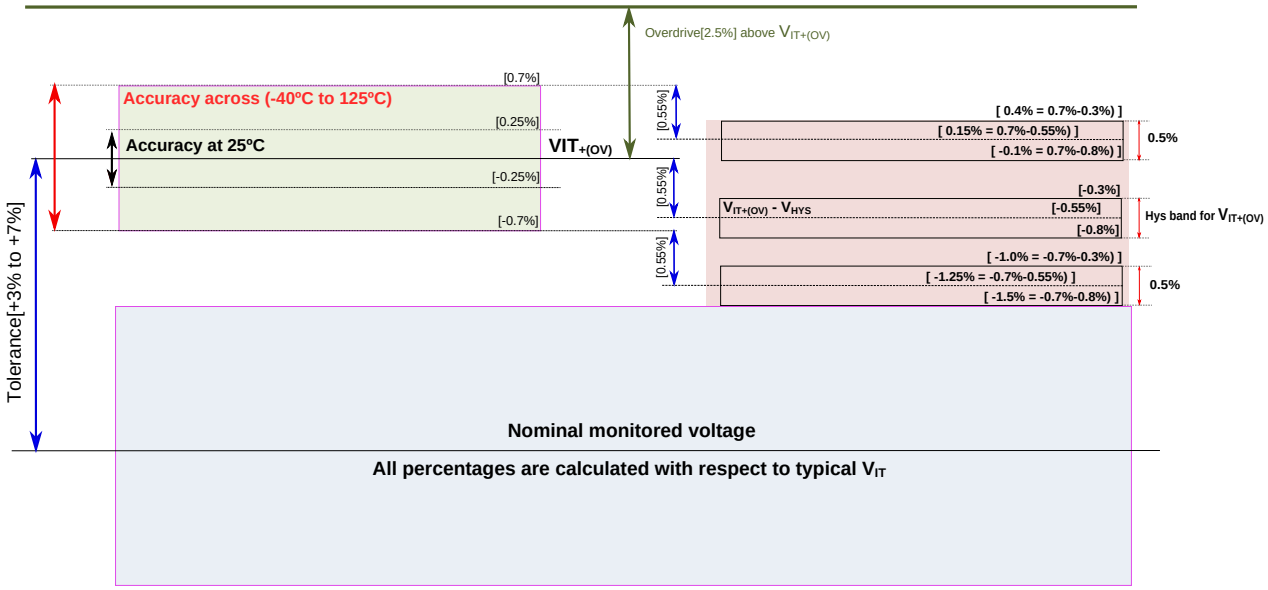
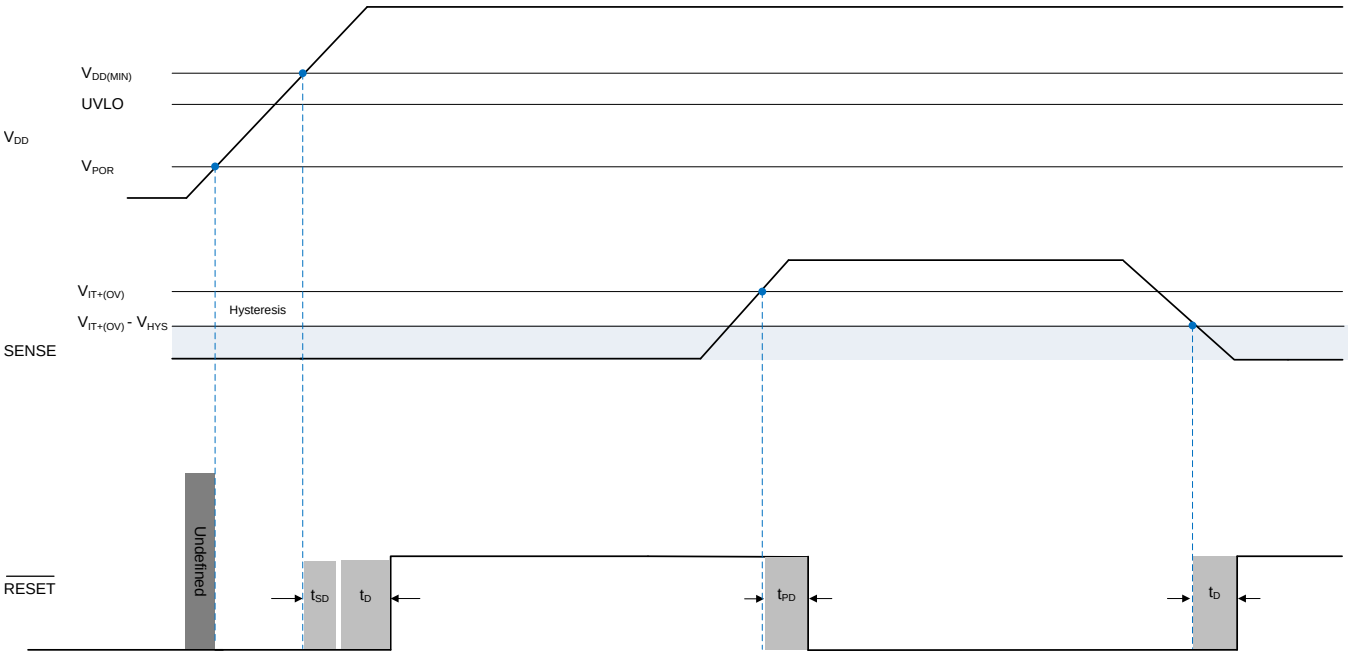


Figure 1. Voltage Threshold and Hysteresis Accuracy



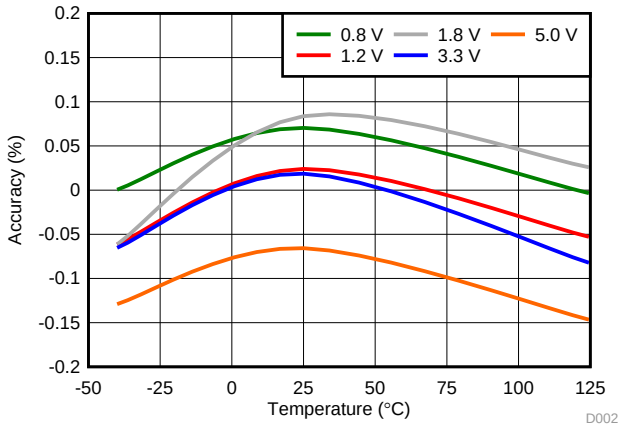
(1) V_{DD} = 2 V, R_{PU} = 10 kΩ to V_{DD}

(2) Variant M (time delay bypass) has a ~40 µs pulse at $\overline{RESET}$ pin during power up window, this is present only when the power cycle off time is longer than 10 seconds, this behavior will not occur if SENSE pin is within window of operation during V_{DD} power up.

Figure 2. SENSE Timing Diagram

7.7 Typical Characteristics

At T_J = 25°C, V_{DD} = 3.3 V, and R_{PU} = 10 kΩ, unless otherwise noted.



Tested across multiple voltage options

Figure 3. Overvoltage Accuracy vs Temperature

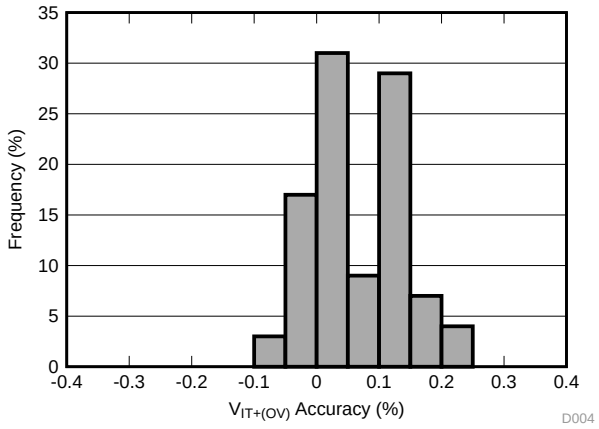
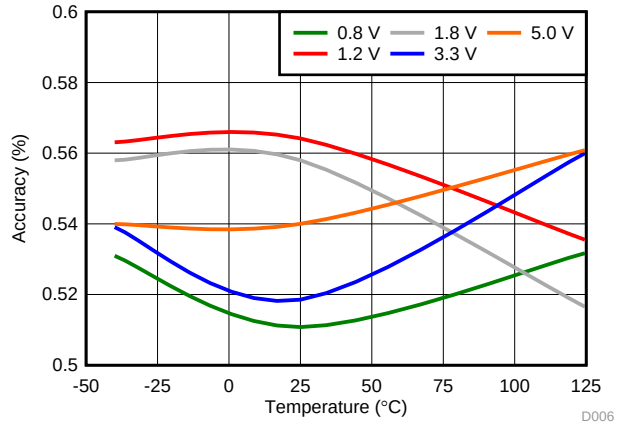
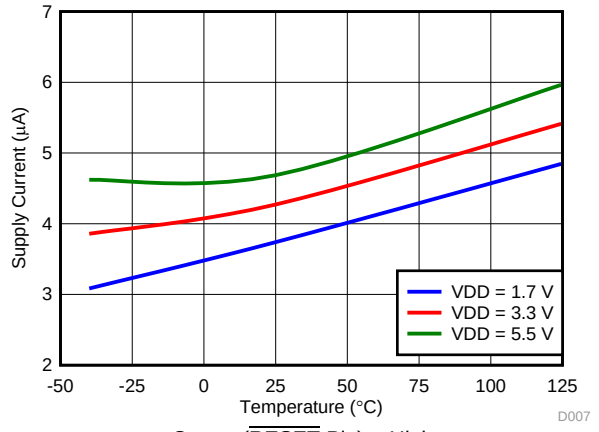


Figure 4. Overvoltage Accuracy Distribution



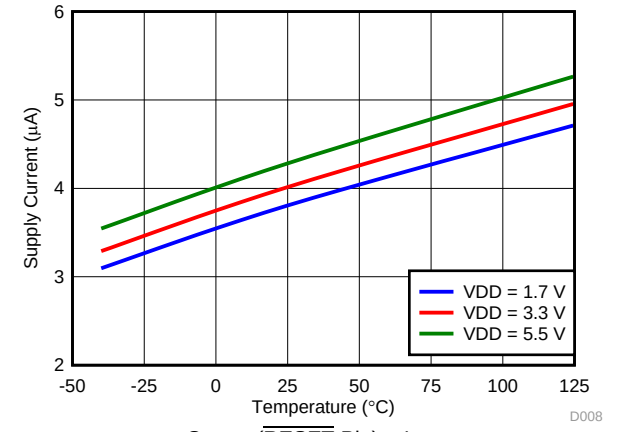
Tested across multiple voltage options

Figure 5. Overvoltage Hysteresis Voltage Accuracy vs Temperature



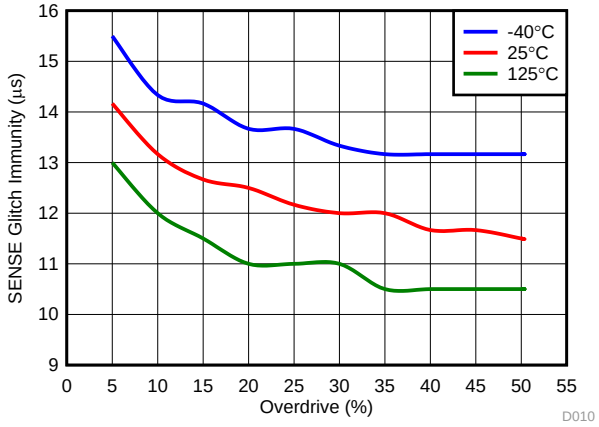
Output ($\overline{\text{RESET}}$ Pin) = High

Figure 6. Supply Current vs Temperature



Output ($\overline{\text{RESET}}$ Pin) = Low

Figure 7. Supply Current vs Temperature



VDD = 1.7 V

Figure 8. SENSE Glitch Immunity (VIT+) vs Overdrive

Typical Characteristics (continued)

At T_J = 25°C, V_{DD} = 3.3 V, and R_{PU} = 10 kΩ, unless otherwise noted.

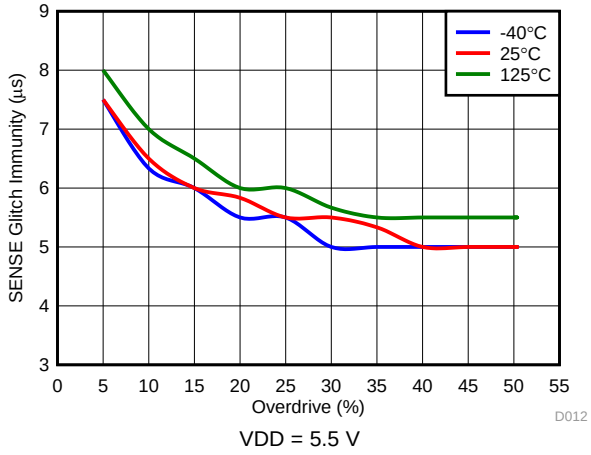


Figure 9. SENSE Glitch Immunity (VIT+) vs Overdrive

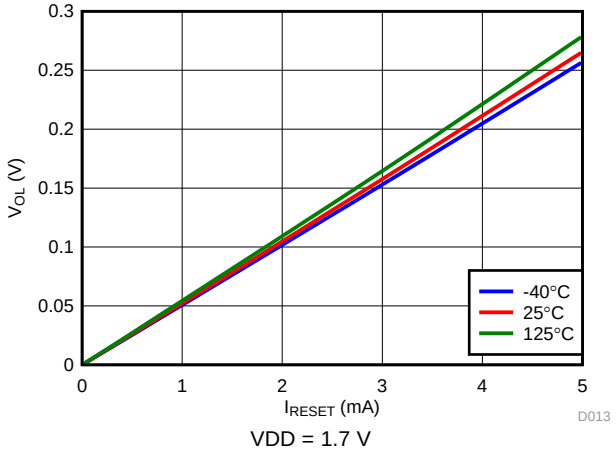


Figure 10. Low-Level Output Voltage vs RESET current

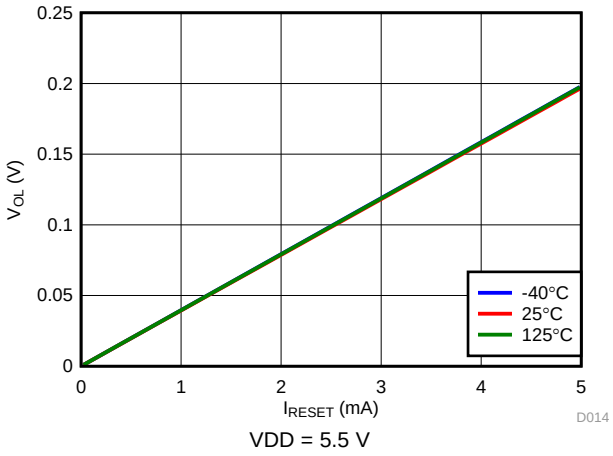


Figure 11. Low-Level Output Voltage vs RESET current

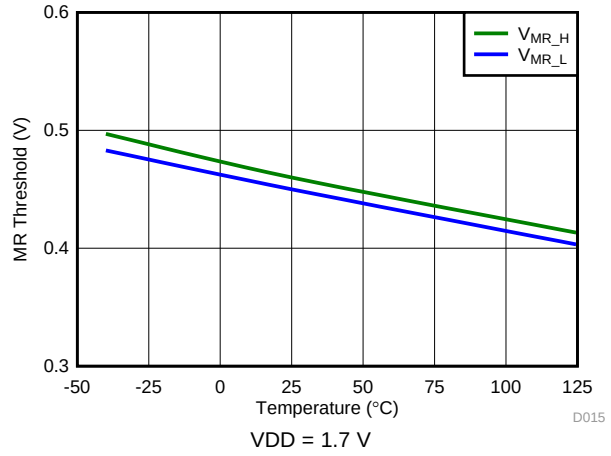


Figure 12. SET Threshold vs Temperature

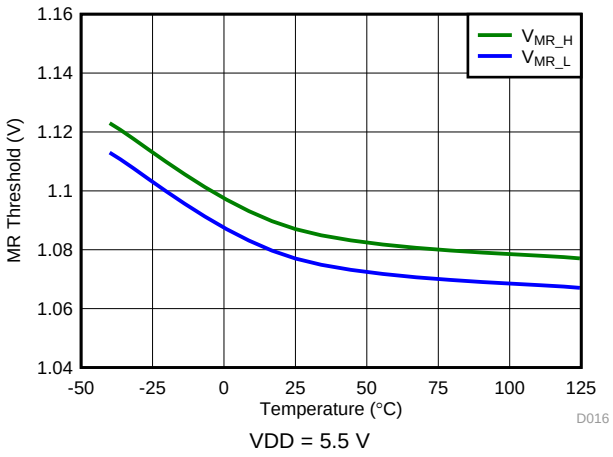


Figure 13. SET Threshold vs Temperature

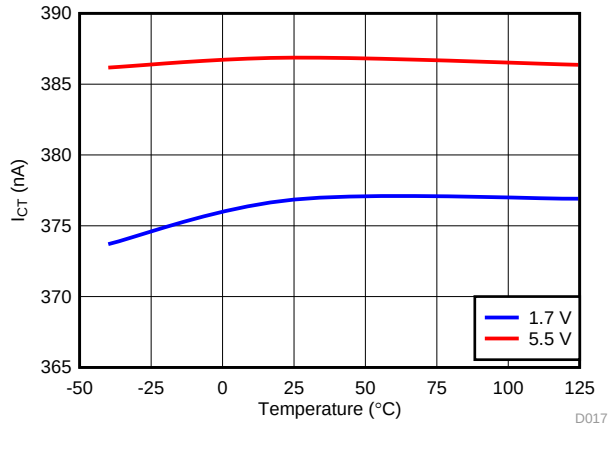


Figure 14. CT Current vs CT value

Typical Characteristics (continued)

At T_J = 25°C, V_{DD} = 3.3 V, and R_{PU} = 10 kΩ, unless otherwise noted.

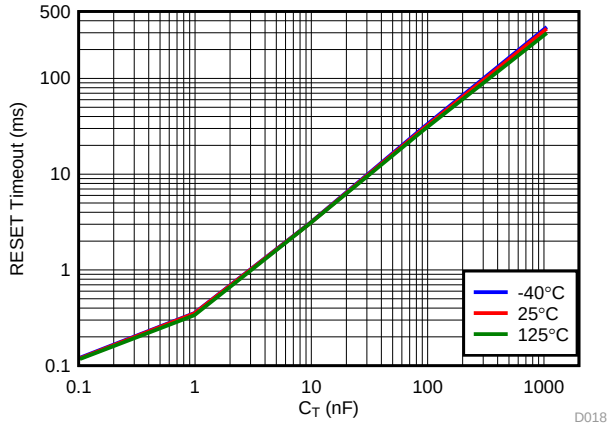


Figure 15. $\overline{\text{RESET}}$ Timeout vs CT Capacitor

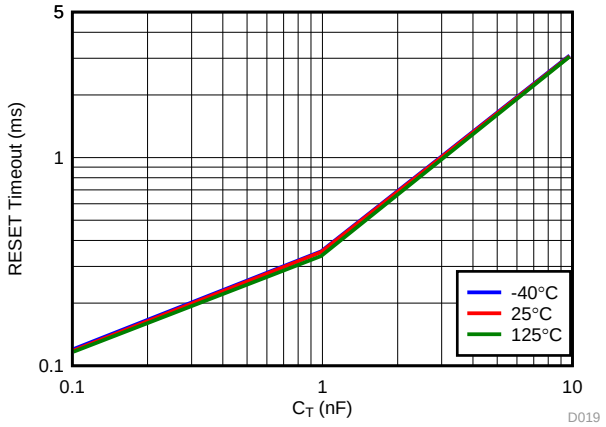


Figure 16. Timeout vs CT Capacitor (0.1 to 10 nF)

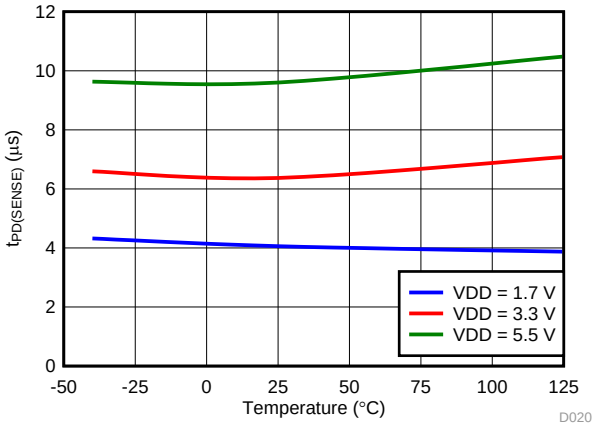


Figure 17. Detect Propagation Delay vs Temperature

8 Detailed Description

8.1 Overview

The TPS3870-Q1 family of devices uses a voltage comparator and a precision voltage reference for overvoltage detection. The TPS3870-Q1 features a highly accurate threshold voltage (±0.7% over temperature) and a variety of voltage threshold variants.

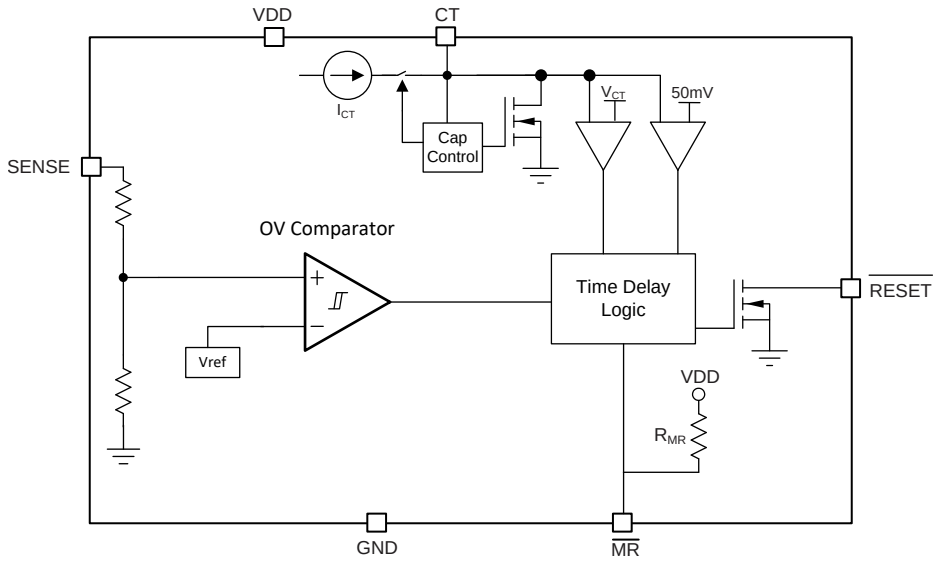
The TPS3870-Q1 includes the resistors used to set the overvoltage threshold internal to the device. These internal resistors allow for lower component counts and greatly simplifies the design because no additional margins are needed to account for the accuracy of external resistors.

TPS3870-Q1 versions J, K and L have three time delay settings, two fixed by connecting CT pin to VDD through a resistor and leaving CT floating and a programmable time delay setting that only requires a single capacitor connected from CT pin to ground.

Manual Reset ($\overline{MR}$) allows for sequencing or hard reset by driving the $\overline{MR}$ pin below $V_{\overline{MR}\_L}$.

The TPS3870-Q1 is designed to assert active low output signals when the monitored voltage is outside the safe window. The relationship between the monitored voltage and the states of the outputs is shown in Table 2.

8.2 Functional Block Diagram



*For all possible voltages, threshold tolerance, time delays, and threshold options, see Table 6.

8.3 Feature Description

8.3.1 VDD

The TPS3870-Q1 is designed to operate from an input voltage supply range between 1.7 V to 5.5 V. An input supply capacitor is not required for this device; however, if the input supply is noisy good analog practice is to place a 1-µF capacitor between the VDD pin and the GND pin.

V_{DD} needs to be at or above $V_{DD(MIN)}$ for at least the start-up delay (t_{SD}+ t_D) for the device to be fully functional.

8.3.2 SENSE

The TPS3870-Q1 uses a comparator with a precision reference voltage and a trimmed resistor divider. This configuration optimizes device accuracy because all resistor tolerances are accounted for in the accuracy and performance specifications. The comparator also includes built-in hysteresis that provides noise immunity and ensures stable operation.

Feature Description (continued)

Although not required in most cases, for noisy applications good analog design practice is to place a 1-nF to 10-nF bypass capacitor at the SENSE input in order to reduce sensitivity to transient voltages on the monitored signal.

When monitoring VDD supply voltage, the SENSE pin can be connected directly to VDD. The output ($\overline{\text{RESET}}$) is high impedance when voltage at the SENSE pin is lower than the upper boundary of the threshold.

8.3.3 $\overline{\text{RESET}}$

In a typical TPS3870-Q1 application, the $\overline{\text{RESET}}$ output is connected to a reset or enable input of a processor [such as a digital signal processor (DSP), application-specific integrated circuit (ASIC), or other processor type] or the enable input of a voltage regulator [such as a DC-DC converter or low-dropout regulator (LDO)].

The TPS3870-Q1 has an open drain active low output that requires a pull-up resistor to hold these lines high to the required voltage logic. Connect the pull-up resistor to the proper voltage rail to enable the output to be connected to other devices at the correct interface voltage levels. To ensure proper voltage levels, give some consideration when choosing the pull-up resistor values. The pull-up resistor value is determined by V_{OL}, output capacitive loading, and output leakage current. These values are specified in *Specifications*. The open drain output can be connected as a wired-OR logic with other open drain signals such as another TPS3870-Q1 $\overline{\text{RESET}}$ pin.

Table 2 describes the scenarios when the output ($\overline{\text{RESET}}$) is either asserted low or high impedance.

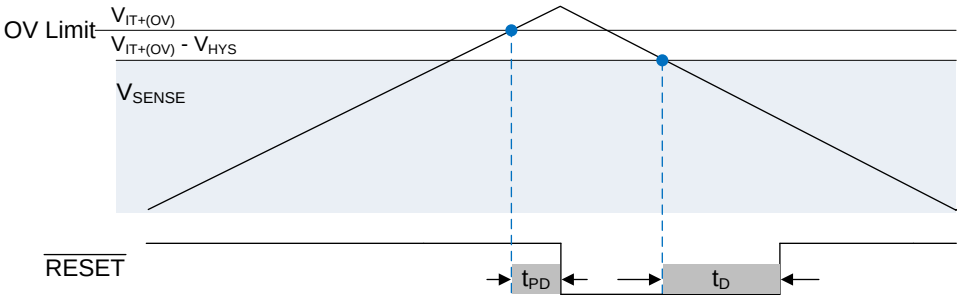


Figure 18. RESET output

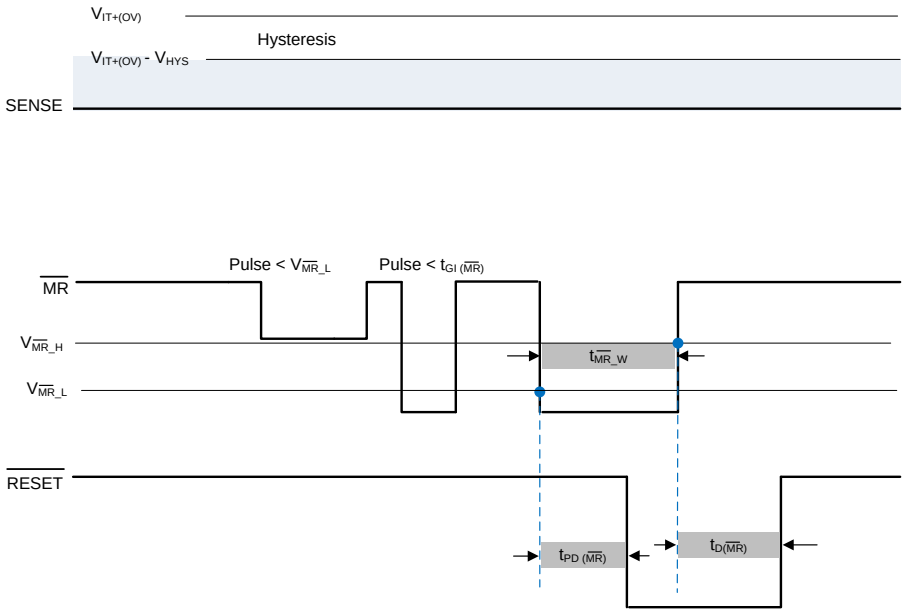
8.3.4 Capacitor Time (CT)

The CT pin provides the user the functionality of both high-precision, factory-programmed, reset delay timing options and user-programmable, reset delay timing. The CT pin can be pulled up to V_{DD} through a resistor, have an external capacitor to ground, or can be left unconnected. The configuration of the CT pin is re-evaluated by the device every time the voltage on the SENSE line enters the valid window ($V_{SENSE} < V_{IT+(OV)}$). The pin evaluation is controlled by an internal state machine that determines which option is connected to the CT pin. The sequence of events takes 450 µs to determine if the CT pin is left unconnected, pulled up through a resistor, or connected to a capacitor. If the CT pin is being pulled up to V_{DD}, then a pull-up resistor is required, 10 kΩ is recommended.

8.3.5 Manual Reset ($\overline{\text{MR}}$)

The manual reset ($\overline{\text{MR}}$) input allows a processor or other logic circuits to initiate a reset. A logic low on $\overline{\text{MR}}$ causes $\overline{\text{RESET}}$ to assert. After $\overline{\text{MR}}$ returns to a logic high and the SENSE pin voltage is within a valid condition ($V_{SENSE} < V_{IT+(OV)}$) , $\overline{\text{RESET}}$ is deasserted after the reset delay time (t_D). If $\overline{\text{MR}}$ is not controlled externally, then $\overline{\text{MR}}$ can either be connected to V_{DD} or left floating because the $\overline{\text{MR}}$ pin is internally pulled up to V_{DD}. Figure Figure 19 shows the relation between $\overline{\text{MR}}$ and $\overline{\text{RESET}}$.

Feature Description (continued)



(1) $\overline{RESET}$ pulls up to VDD with 10 kΩ.

(2) To initiate and continue time reset counter both conditions must be met $\overline{MR}$ pin above $V_{\overline{MR}\_H}$ or floating and V_{SENSE} below $V_{IT+(OV)}$ - V_{HYS}

(3) $\overline{MR}$ is ignored during output $\overline{RESET}$ low event

Figure 19. Manual Reset Timing Diagram

8.4 Device Functional Modes

Table 2. Functional Mode Truth Table

DESCRIPTION	CONDITION	$\overline{MR}$ PIN	VDD PIN	OUTPUT ($\overline{RESET}$ PIN)
Normal Operation	SENSE < $V_{IT+(OV)}$	Open or above $V_{\overline{MR}\_H}$	V_{DD} > $V_{DD(MIN)}$	High
Over Voltage detection	SENSE > $V_{IT+(OV)}$	Open or above $V_{\overline{MR}\_H}$	V_{DD} > $V_{DD(MIN)}$	Low
Manual reset	SENSE < $V_{IT+(OV)}$	Below $V_{\overline{MR}\_L}$	V_{DD} > $V_{DD(MIN)}$	Low
UVLO engaged	SENSE < $V_{IT+(OV)}$	Open or above $V_{\overline{MR}\_H}$	V_{POR} < V_{DD} < UVLO	Low

8.4.1 Normal Operation (V_{DD} > $V_{DD(MIN)}$)

When the voltage on V_{DD} is greater than $V_{DD(MIN)}$ for approximately (t_{SD}+ t_D), the $\overline{RESET}$ output state will correspond to the SENSE pin voltage with respect to the threshold limits, when SENSE voltage is outside of threshold limits the $\overline{RESET}$ voltage will be low (V_{OL}).

8.4.2 Undervoltage Lockout (V_{POR} < V_{DD} < UVLO)

When the voltage on V_{DD} is less than the device UVLO voltage but greater than the power-on reset voltage (V_{POR}), the $\overline{RESET}$ pin will be held low , regardless of the voltage on SENSE pin.

8.4.3 Power-On Reset (V_{DD} < V_{POR})

When the voltage on V_{DD} is lower than the required voltage (V_{POR}) to internally pull the asserted output to GND, $\overline{RESET}$ signal is undefined and is not to be relied upon for proper device function.

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 should validate and test their design implementation to confirm system functionality.

9.1 Application Information

9.1.1 Voltage Threshold Accuracy

Voltage monitoring requirements vary depending on the voltage supply tolerance of the device being powered. Due to the high precision of the TPS3870-Q1 (±0.7% Max), the device allows for a wider supply voltage margins and threshold headroom for tight tolerance applications.

For example, take a DC/DC regulator providing power to a core voltage rail of an MCU. The MCU has a tolerance of ±5% of the nominal output voltage of the DC/DC. The user sets an ideal voltage threshold of 4% which allows for ±1% of threshold accuracy. Since the TPS3870-Q1 threshold accuracy is higher than ±1%, the user has more supply voltage margin which can allow for a relaxed power supply design. This gives flexibility to the DC/DC to use a smaller output capacitor or inductor because of a larger voltage window for voltage ripple and transients. There is also headroom between the minimum system voltage and voltage tolerance of the MCU to ensure that the voltage supply will never be in the region of potential failure of malfunction without the TPS3870-Q1 asserting a reset signal.

Figure 20 illustrates the supply overvoltage margin and accuracy of the TPS3870-Q1 for the example explained above. Using a low accuracy supervisor will eat into the available budget for the power supply ripple and transient response. This gives less flexibility to the user and a more stringent DC/DC converter design.

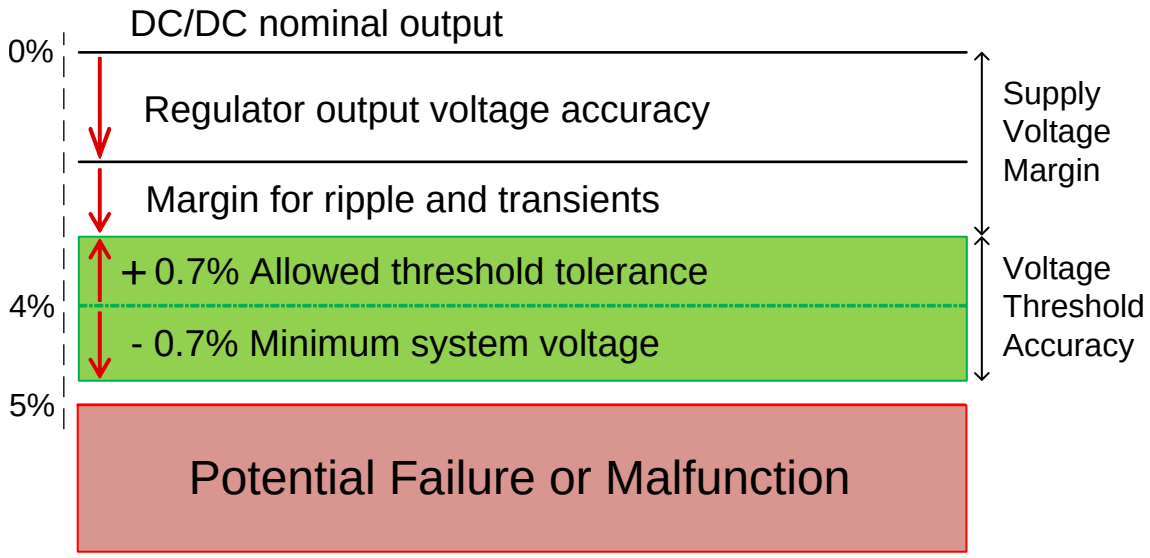


Figure 20. TPS3870-Q1 Voltage Threshold Accuracy

Application Information (continued)

9.1.2 CT Reset Time Delay

The TPS3870-Q1 features three options for setting the reset delay (t_D): connecting a capacitor to the CT pin, connecting a pull-up resistor to VDD, and leaving the CT pin unconnected. Figure 21 shows a schematic drawing of all three options. To determine which option is connected to the CT pin, an internal state machine controls the internal pulldown device and measures the pin voltage. This sequence of events takes 450 µs to determine which timing option is used. Every time the voltage on the SENSE line enters the valid window ($V_{SENSE} < V_{IT+(OV)} - V_{HYS}$, the state machine determines the CT option.

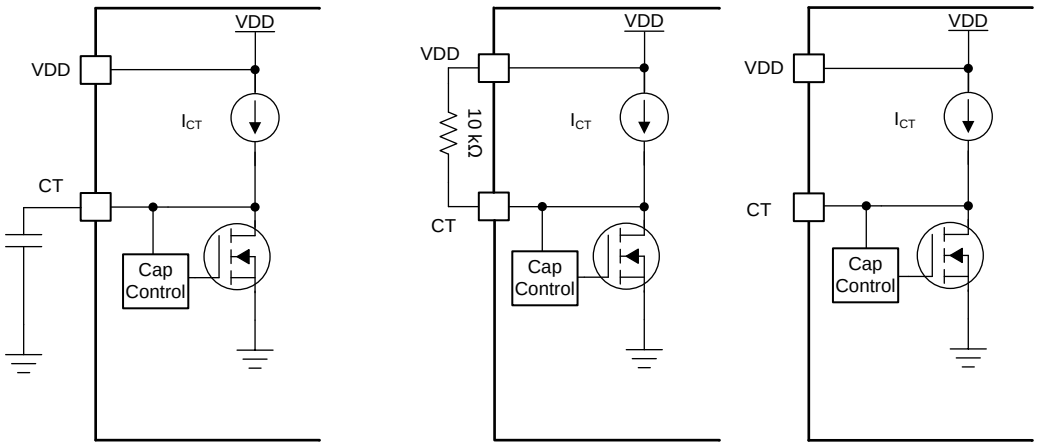


Figure 21. CT Charging Circuit

9.1.2.1 Factory-Programmed Reset Delay Timing

To use the factory-programmed timing options, the CT pin must either be left unconnected or pulled up to VDD through a 10 kΩ pull-up resistor. Using these options enables a high-precision reset delay timing, as shown in Table 3.

Table 3. Reset Delay Time for Factory-Programmed Reset Delay Timing

VARIANT	$\overline{\text{RESET}}$ DELAY TIME (t_D)			VALUE
	CT = Capacitor to GND	CT = Floating	CT = 10 kΩ to VDD	
TPS3870J	Programmable t_D	10	200	ms
TPS3870K	Programmable t_D	1	20	ms
TPS3870L	Programmable t_D	5	100	ms
TPS3870M	N/A	50	50	µs

9.1.2.2 Programmable Reset Delay-Timing

The TPS3870 reset time delay is based on internal current source (I_{CT}) to charge external capacitor (C_{CT}) and read capacitor voltage with the internal comparator. The minimum value capacitor is 250 pF. There is no limitation on maximum capacitor the only constrain is imposed by the initial voltage of the capacitor, if CT cap is zero or near to zero then ideally there is no other constraint on the max capacitor. The typical ideal capacitor value needed for a given delay time can be calculated using Equation 1, where C_{CT} is in nanofarads (nF) and t_D is in ms:

$$t_D = 3.066 \times C_{CT} + 0.5 \text{ ms} \quad (1)$$

To calculate the minimum and maximum-reset delay time use Equation 2 and Equation 3, respectively.

$$t_{D(min)} = 2.7427 \times C_{CT} + 0.3 \text{ ms} \quad (2)$$

$$t_{D(max)} = 3.4636 \times C_{CT} + 0.7 \text{ ms} \quad (3)$$

The slope of the equation is determined by the time the CT charging current (I_{CT}) takes to charge the external capacitor up to the CT comparator threshold voltage (V_{CT}). When $\overline{\text{RESET}}$ is asserted, the capacitor is discharged through the internal CT pulldown resistor. When the $\overline{\text{RESET}}$ conditions are cleared, the internal precision current source is enabled and begins to charge the external capacitor; when V_{CT} = 1.15 V, $\overline{\text{RESET}}$ is unasserted. Note that in order to minimize the difference between the calculated $\overline{\text{RESET}}$ delay time and the actual $\overline{\text{RESET}}$ delay time, use a use a high-quality ceramic dielectric COG, X5R, or X7R capacitor and minimize parasitic board capacitance around this pin. Table 4 lists the reset delay time ideal capacitor values for C_{CT}.

Table 4. Reset Delay Time for Ideal Capacitor Values

C_{CT}	$\overline{\text{RESET}}$ DELAY TIME (t_D), TYPICAL
250 pF	1.27 ms
1 nF	3.57 ms
3.26 nF	10.5 ms
32.6 nF	100.45 ms
65.2 nF	200.40 ms
1uF	3066.50 ms

9.1.3 $\overline{\text{RESET}}$ Latch Mode

The TPS3870-Q1 features a voltage latch mode on the $\overline{\text{RESET}}$ pin when connecting the CT pin to common ground . A pull-down resistor is recommended to limit current consumption of the system. In latch mode, if the $\overline{\text{RESET}}$ pin is low or triggers low, the pin will stay low regardless if V_{SENSE} is within the acceptable voltage boundaries (V_{SENSE} < $V_{IT+(OV)}$). To unlatch the device provide a voltage to the CT pin that is greater than the CT pin comparator threshold voltage, V_{CT}. The $\overline{\text{RESET}}$ pin will trigger high instantaneously without any reset delay. A voltage greater than 1.2 V to recommended to ensure a proper unlatch. Use a series resistance to limit current when an unlatch voltage is applied. For more information, Design 1: $\overline{\text{RESET}}$ Latch Mode gives an example of a typical latch application.

NOTE

At power up, the TPS3870-Q1 will be latched when CT is connected to GND. To ensure correct power up when using $\overline{\text{RESET}}$ latch mode, send a pulse to the CT pin greater than 1.2 V after t_{SD} and SENSE is within the correct window of operation.

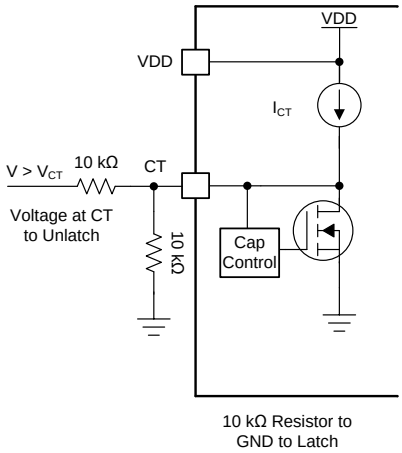


Figure 22. $\overline{\text{RESET}}$ Latch Circuit

9.1.4 Adjustable Voltage Thresholds

The TPS3870-Q1 0.7% maximum accuracy allows for adjustable voltage thresholds using external resistors without adding major inaccuracies to the device. In case that the desired monitored voltage is not available, external resistor dividers can be used to set the desired voltage thresholds. Figure 23 illustrates an example of how to adjust the voltage threshold with external resistor dividers. The resistors can be calculated depending on the desired voltage threshold and device part number. TI recommends using the 0.8V voltage threshold device such as the TPS3870J4080 because of the bypass mode of internal resistor ladder.

For example, consider a 2.0 V rail being monitored (V_{MON}) using the TPS3870J4080 variant. Using Equation 4, R1 = 15 kΩ given that R2 = 10 kΩ, V_{MON} = 2 V , and V_{SENSE} = 0.8 V. This device is typically meant to monitor a 0.8 V rail with a +4% voltage threshold. This means that the device overvoltage threshold ($V_{IT+(OV)}$) is 0.832 V. Using Equation 4, the monitored overvoltage threshold (V_{MON+}) = 2.08 V when V_{SENSE} = $V_{IT+(OV)}$. If a wider tolerance threshold is desired, use a device variant shown on Table 6 to determine what device part number matches your application.

$$V_{SENSE} = V_{MON} \times (R_2 \div (R_1 + R_2)) \quad (4)$$

There are inaccuracies that must be taken into consideration while adjusting voltage thresholds. Aside from the tolerance of the resistor divider, there is an internal resistance of the SENSE pin that may affect the accuracy of the resistor divider. Although expected to be very high impedance, users are recommended to calculate the values for design specifications. The internal sense resistance (R_{SENSE}) can be calculated by the sense voltage (V_{SENSE}) divided by the sense current (I_{SENSE}) as shown in Equation 6. V_{SENSE} can be calculated using Equation 4 depending on the resistor divider and monitored voltage. I_{SENSE} can be calculated using Equation 5.

$$I_{SENSE} = (V_{MON} - V_{SENSE}) \div R_1 - (V_{SENSE} \div R_2) \quad (5)$$

$$R_{SENSE} = V_{SENSE} \div I_{SENSE} \quad (6)$$

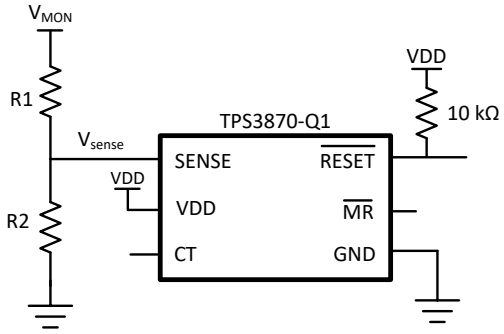


Figure 23. Adjustable Voltage Threshold with External Resistor Dividers

Although Equation 4 solves for V_{SENSE}, inaccuracies for leakage need to be taken into consideration when understanding the overall threshold accuracy of the device. To calculate the threshold with this inaccuracy taken into account, use Equation 7

$$V_{IT\_Actual} = V_{SENSE} + R_1 \times ((V_{SENSE} \div R_2) + I_{SENSE}) \quad (7)$$

To calculate the worst case values through the resistor divider, I_{SENSE} should be taken from the Electrical Characteristics table. While these equations provide a summary of what you need to correctly account for factors that go into determining your resistor divider with inaccuracy, you should use the Application Report Optimizing Resistor Dividers at a Comparator Input to further understand this and to design your implementation. This report explains how to optimize the resistor divider at the SENSE input for an adjustable voltage threshold version of the device. You should follow this Application Report using 0.8 V as the V_{REF} value for the TPS3870-Q1.

9.1.5 Immunity to SENSE Pin Voltage Transients

The TPS3870-Q1 is immune to short voltage transient spikes on the input pins. Sensitivity to transients depends on both transient duration and overdrive (amplitude) of the transient.

Overdrive is defined by how much the V_{SENSE} exceeds the specified threshold, and is important to know because the smaller the overdrive, the slower the response of the outputs ($\overline{RESET}$). Threshold overdrive is calculated as a percent of the threshold in question, as shown in Equation 8:

$$\text{Overdrive \%} = | (V_{SENSE} - (V_{IT+(OV)})) / V_{IT} \text{ (Nominal)} \times 100\% | \quad (8)$$

where:

- V_{SENSE} is the voltage at the SENSE pin
- V_{IT} (Nominal) is the nominal threshold voltage
- $V_{IT+(OV)}$ represents the actual overvoltage tripping voltage

9.1.5.1 Hysteresis

The overvoltage comparator includes built-in hysteresis that provides noise immunity and ensures stable operation. For example if the voltage on the SENSE pin goes above $V_{IT+(OV)}$ and $\overline{RESET}$ is asserted (driven low), then when the voltage on the SENSE pin is below the positive threshold voltage, $\overline{RESET}$ deasserts after the user-defined $\overline{RESET}$ delay time. Figure Figure 24 shows the relation between $V_{IT+(OV)}$ and hysteresis voltage (V_{HYS}).

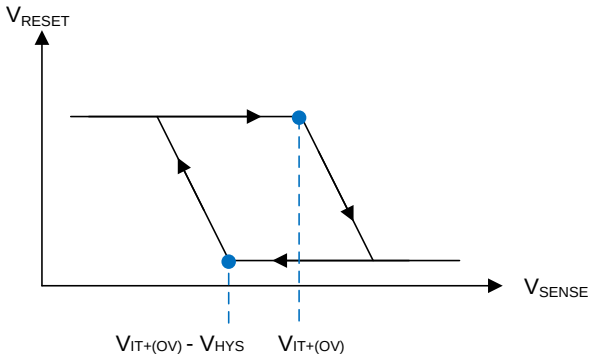


Figure 24. SENSE Pin Hysteresis

9.2 Typical Application

9.2.1 Design 1: $\overline{\text{RESET}}$ Latch Mode

Another typical application for the TPS3870-Q1 is shown in Figure 25. The TPS3870-Q1 is used in a $\overline{\text{RESET}}$ latch output mode. In latch mode, once $\overline{\text{RESET}}$ driven logic low, it will stay low regardless of the sense voltage. If the $\overline{\text{RESET}}$ pin is low on start up, it will also stay low regardless of sense voltage.

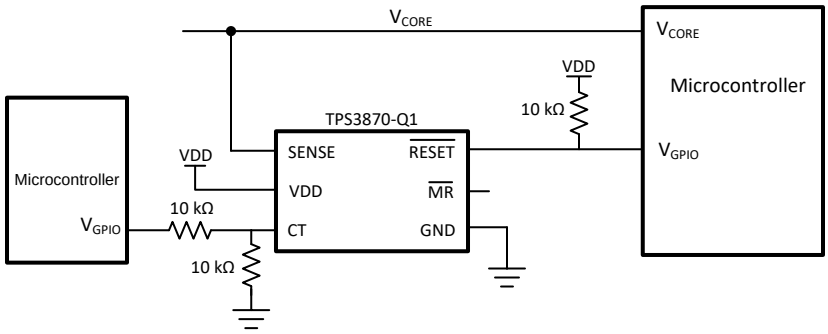


Figure 25. Window Voltage Monitoring with $\overline{\text{RESET}}$ Latch

9.2.1.1 Design Requirements

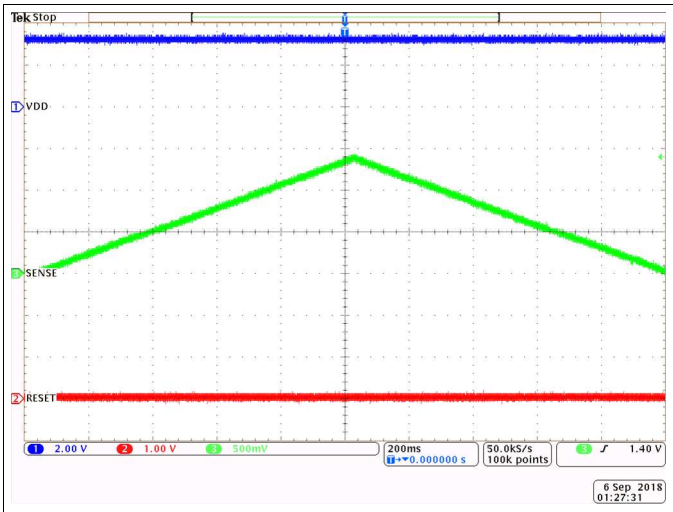
Table 5. Design Parameters

PARAMETER	DESIGN REQUIREMENT	DESIGN RESULT
Monitored Rail	1.2-V_{CORE} nominal, with alerts if outside of 5% of 1.2 V (including device accuracy), Latch when $\overline{\text{RESET}}$ is low, until voltage is applied on CT pin.	Worst case $V_{IT+(OV)}$ = 1.256 V (4.7%),
Output logic voltage	5-V CMOS	5-V CMOS
Maximum device current consumption	15 µA	4.5 µA (Typ), 7 µA (Max)

9.2.1.2 Detailed Design Procedure

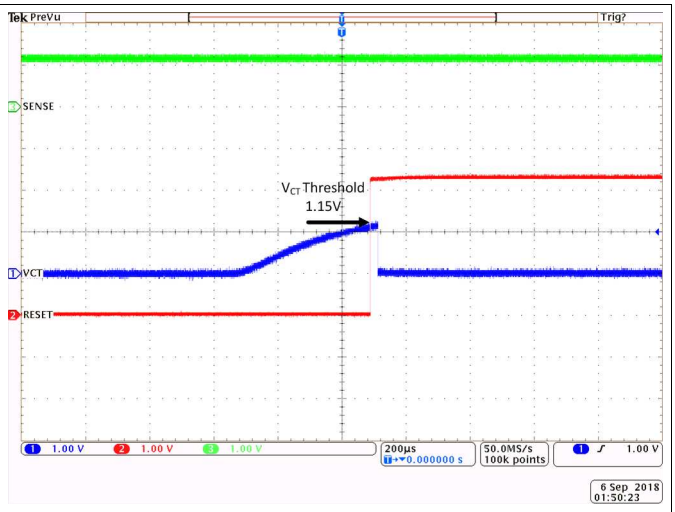
The $\overline{\text{RESET}}$ pin can be latched when the CT pin is connected to a common ground with a pull-down resistor. A 10 kΩ resistors is recommended to limit current consumption. To unlatch the device provide a voltage to the CT pin that is greater than the CT pin comparator threshold voltage, V_{CT}. A voltage greater than 1.15 V to recommended to ensure a proper unlatch. Use a series resistance to limit current when an unlatch voltage is applied. To go back into latch operation, disconnect the voltage on the CT pin. The $\overline{\text{RESET}}$ pin will trigger high instantaneously without any reset delay.

9.2.1.3 Application Curves



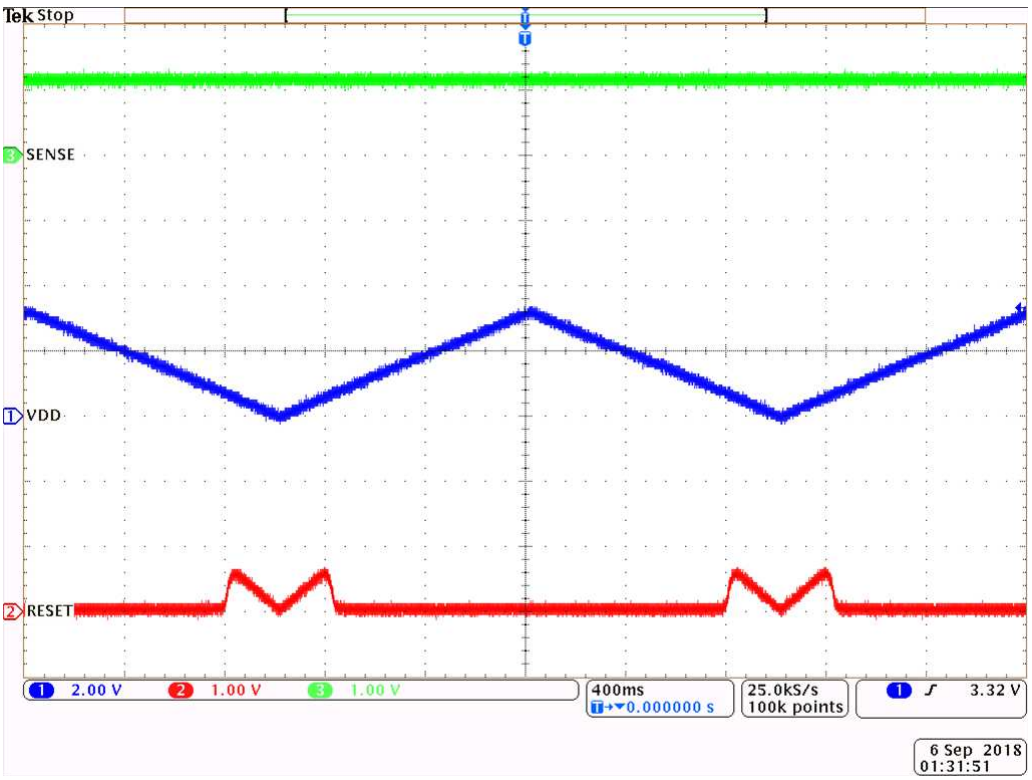
V_{SENSE} ramp from 0 V to 1.4V, V_{DD} = 3.3 V, V_{CT} = 0 V
$V_{\overline{RESET}}$ = VDD = 3.3 V

Figure 26. TPS3870-Q1 SENSE Ramp Latch Function



V_{CT} biased at least to 1.15 V , V_{SENSE} = 1.2 V
$V_{\overline{RESET}}$ = VDD = 3.3 V

Figure 27. TPS3870-Q1 CT Bias Unlatch Function



V_{DD} ramp up from 0 V to 3.3 V , V_{SENSE} = 1.2 V, CT = 0 V
$V_{\overline{RESET}}$ = VDD = 3.3 V

Figure 28. TPS3870-Q1 VDD Ramp Latch Function

10 Power Supply Recommendations

10.1 Power Supply Guidelines

This device is designed to operate from an input supply with a voltage range between 1.7 V to 5.5 V. It has a 6-V absolute maximum rating on the VDD pin. It is good analog practice to place a 0.1-µF to 1-µF capacitor between the VDD pin and the GND pin depending on the input voltage supply noise. If the voltage supply providing power to VDD is susceptible to any large voltage transient that exceed maximum specifications, additional precautions must be taken. See SNVA849 for more information.

11 Layout

11.1 Layout Guidelines

- Place the external components as close to the device as possible. This configuration prevents parasitic errors from occurring.
- Avoid using long traces for the VDD supply node. The VDD capacitor, along with parasitic inductance from the supply to the capacitor, can form an LC circuit and create ringing with peak voltages above the maximum VDD voltage.
- Avoid using long traces of voltage to the sense pin. Long traces increase parasitic inductance and cause inaccurate monitoring and diagnostics.
- Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible, and only make perpendicular crossings when absolutely necessary.

11.2 Layout Example

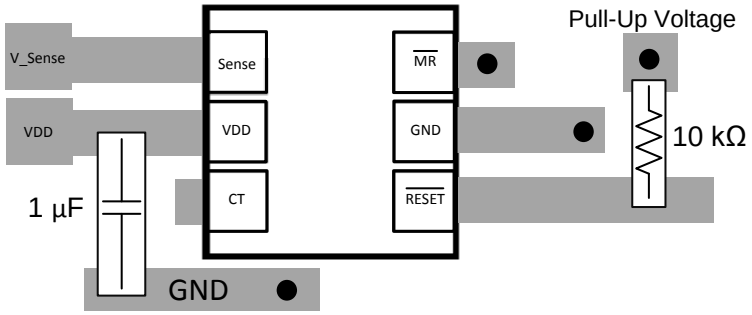


Figure 29. Recommended Layout

12 Device and Documentation Support

12.1 Device Nomenclature

Table 6 shows how to decode the function of the device based on its part number.

Table 6. Device Naming Convention

DESCRIPTION		NOMENCLATURE	VALUE
		TPS3870	TPS3870
Time delay options: Every part has two fixed time delay and adjustable delay option via external capacitor Part number	OV Only	J	CT pin open = 10 ms, CT pin tied to VDD = 200 ms CT programable with external capacitor
		K	CT pin open = 1 ms, CT pin tied to VDD = 20 ms CT programable with external capacitor
		L	CT pin open = 5 ms, CT pin tied to VDD = 100 ms CT programable with external capacitor
		M	CT pin open = 50 µs, CT pin tied to VDD = 50 µs CT not programable
Tolerance options: Trigger or threshold voltage as a percentage of the monitored threshold voltage		3	Overvoltage threshold from nominal value = OV : 3%
		4	Overvoltage threshold from nominal value = OV : 4%
		5	Overvoltage threshold from nominal value = OV : 5%
		6	Overvoltage threshold from nominal value = OV : 6%
		7	Overvoltage threshold from nominal value = OV : 7%
Nominal monitor threshold voltage option		050	0.50 V
		055	0.55 V
		060	0.60 V
		065	0.65 V
		070	0.70 V
		075	0.75 V
		080	0.80 V
		085	0.85 V
		090	0.90 V
		095	0.95 V
		100	1.00 V
		105	1.05 V
		110	1.10 V
		115	1.15 V
		120	1.20 V
		125	1.25 V
		130	1.30 V
		150	1.50 V
		180	1.80 V
		250	2.50 V
		280	2.80 V
		290	2.90 V
		330	3.30 V
		500	5.00 V
Package		DSE	WSON - 6 pin (1.5 mm × 1.5 mm)
Reel		R	Large reel
Automotive version		Q1	Q100 AEC

12.2 Documentation Support

12.2.1 Evaluation Module

An evaluation module (EVM) is available to assist in the initial circuit performance evaluation using the TPS3870-Q1. The EVM for the TPS3703-Q1 can be used to evaluate the TPS3870-Q1 for just overvoltage only. The *TPS3703-Q1 evaluation module* (and *related user guide*) can be requested at the Texas Instruments website through the product folders or purchased directly from the TI eStore .

12.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

12.4 Support Resources

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

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

12.5 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.6 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.

12.7 Glossary

SLYZ022 — *TI Glossary*.

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

13 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.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS3870J4080DSERQ1	ACTIVE	WSON	DSE	6	3000	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	H5	Samples
TPS3870J4330DSERQ1	ACTIVE	WSON	DSE	6	3000	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	H4	Samples

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

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

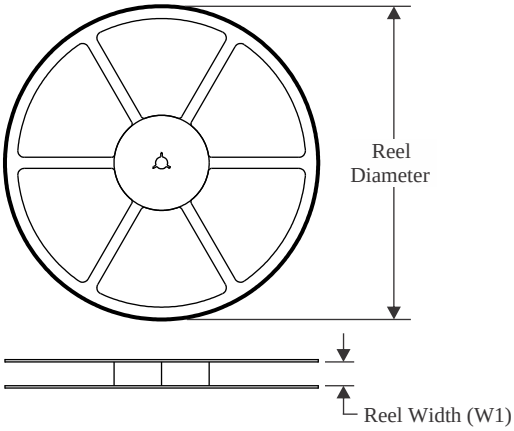
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

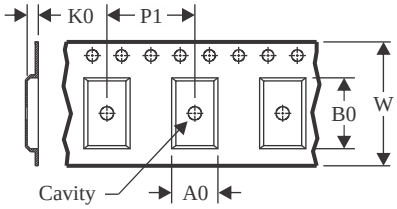
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

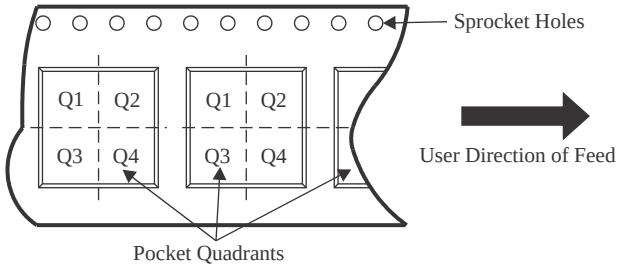


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

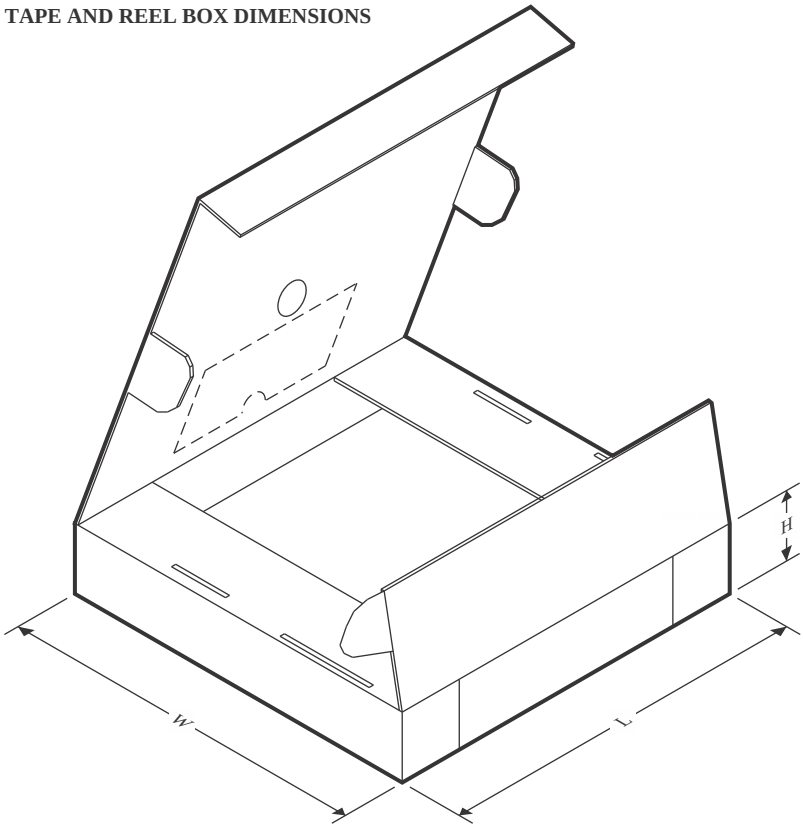
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS3870J4080DSERQ1	WSON	DSE	6	3000	178.0	8.4	1.7	1.7	0.95	4.0	8.0	Q2
TPS3870J4330DSERQ1	WSON	DSE	6	3000	178.0	8.4	1.7	1.7	0.95	4.0	8.0	Q2

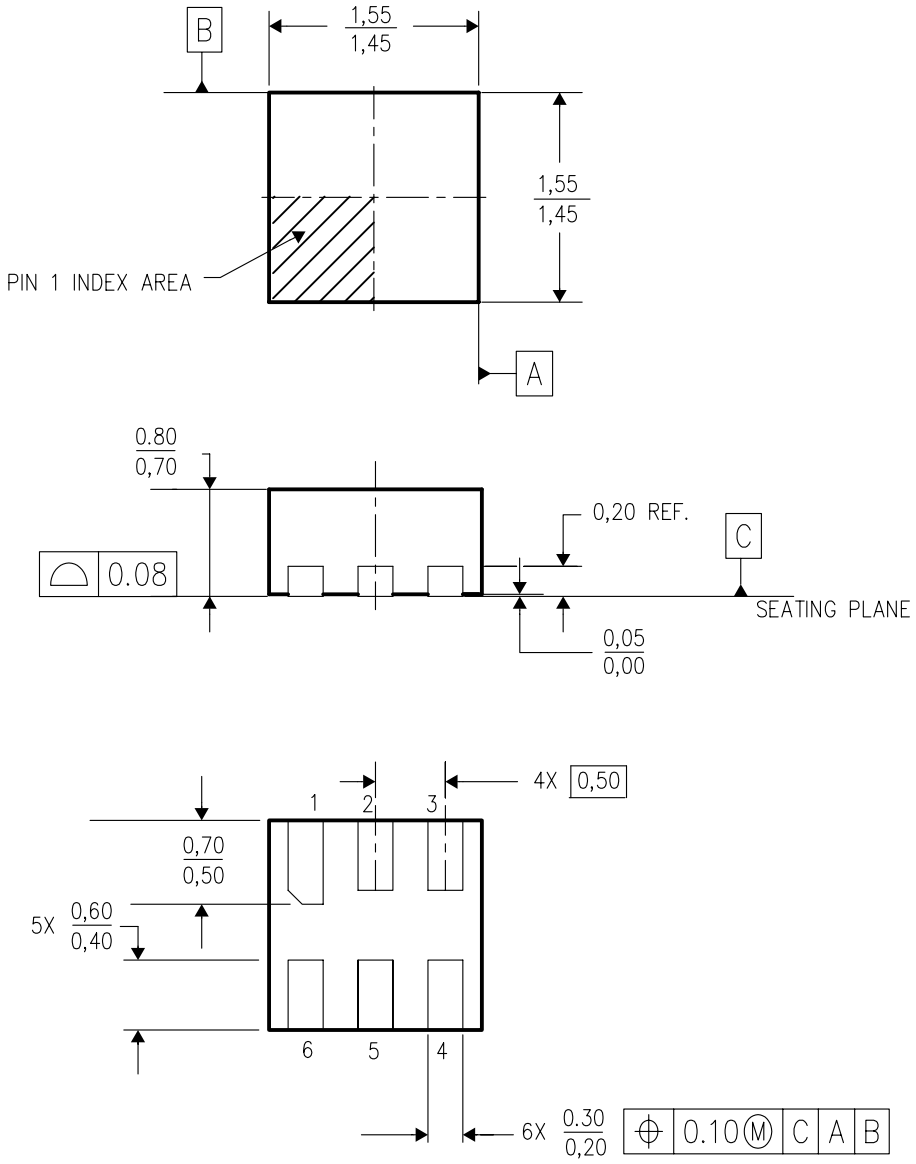
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS3870J4080DSERQ1	WSON	DSE	6	3000	205.0	200.0	33.0
TPS3870J4330DSERQ1	WSON	DSE	6	3000	205.0	200.0	33.0

DSE (S–PDSO–N6) PLASTIC SMALL OUTLINE



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NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Small Outline No–Lead (SON) package configuration.
D. This package is lead–free.

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